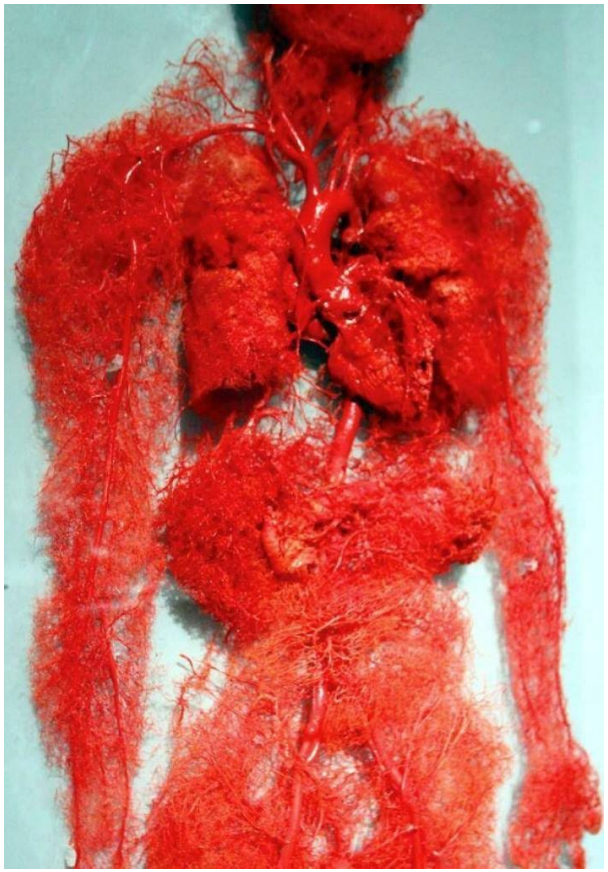
Chapter 20.1

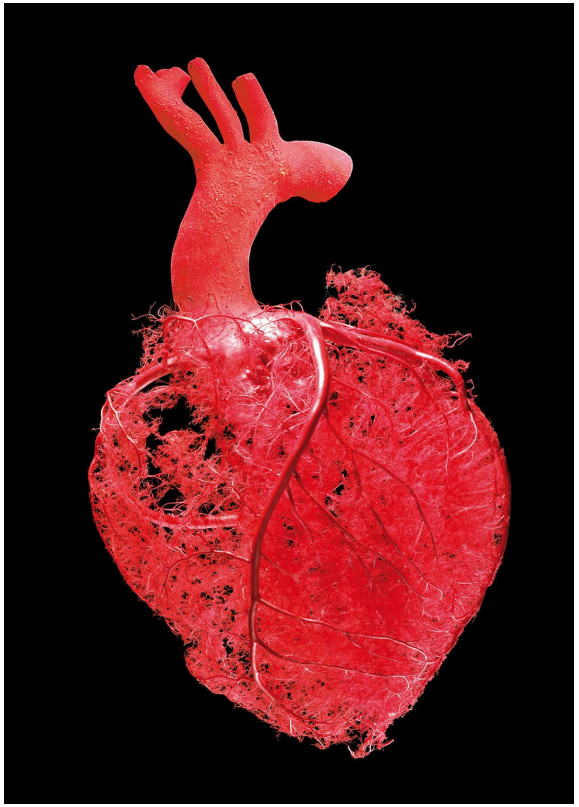
Blood Vessels and Blood Circulation

The human body has 60,000 miles of blood vessels.

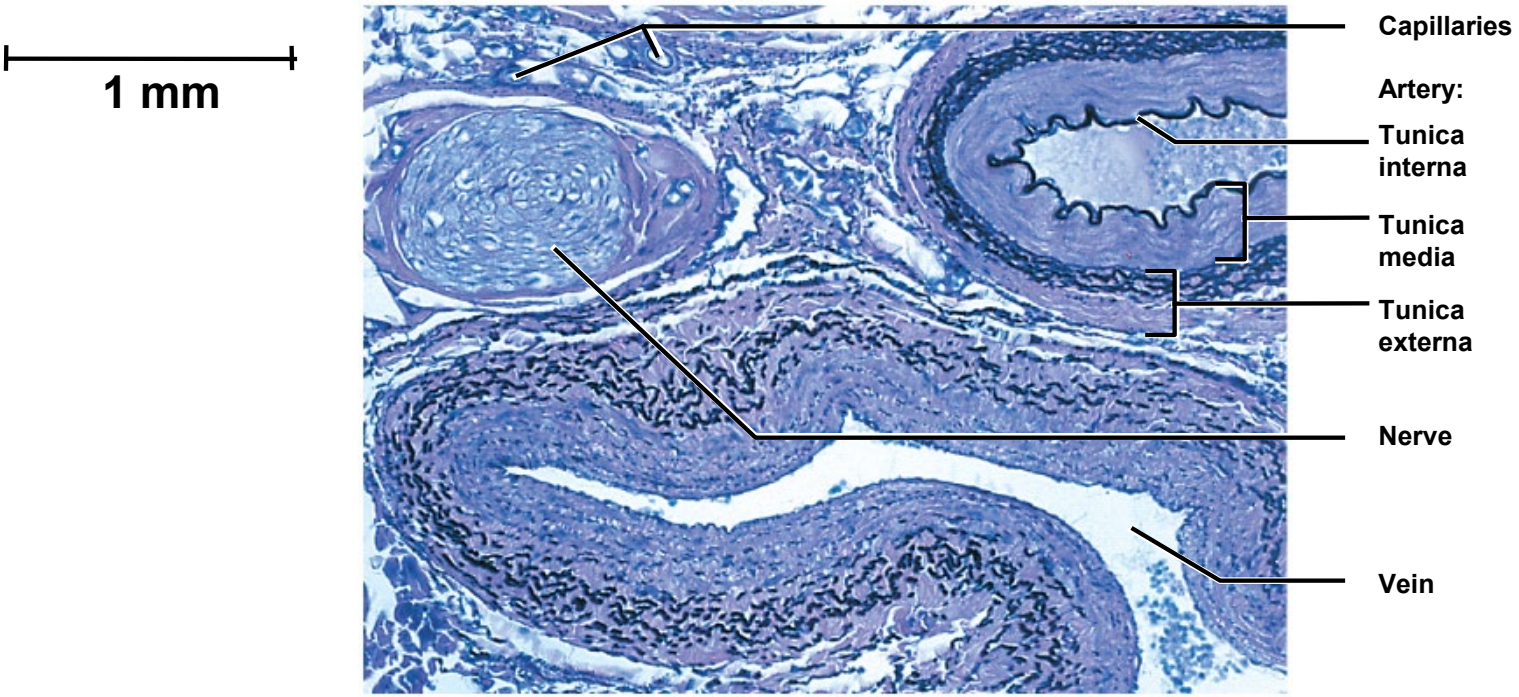
This is nearly enough blood vessels to circle the earth 2 ½ times.

When you gain one pound of fat, you add another mile of blood vessels.





Blood Vessels



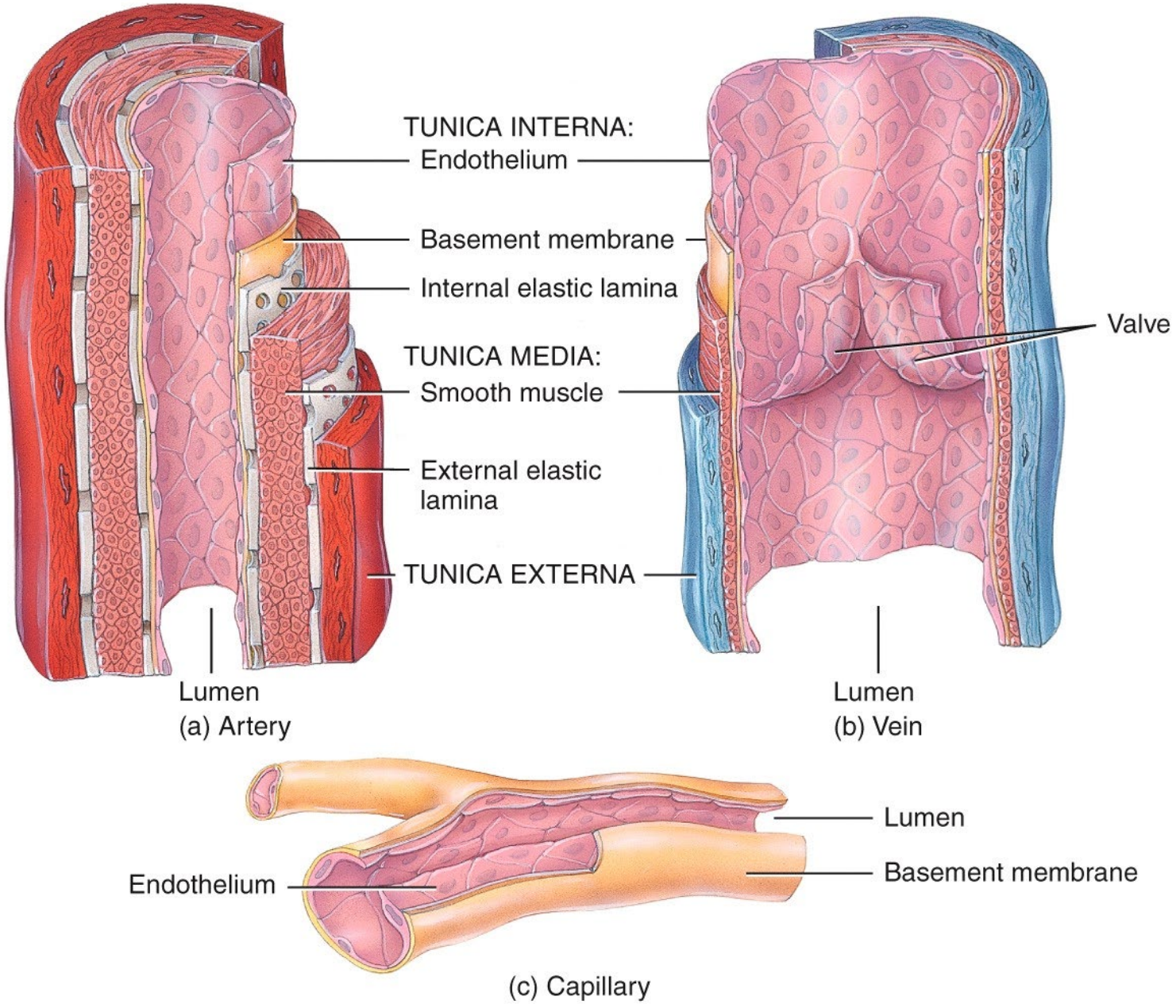
Arteries - carry blood away from heart

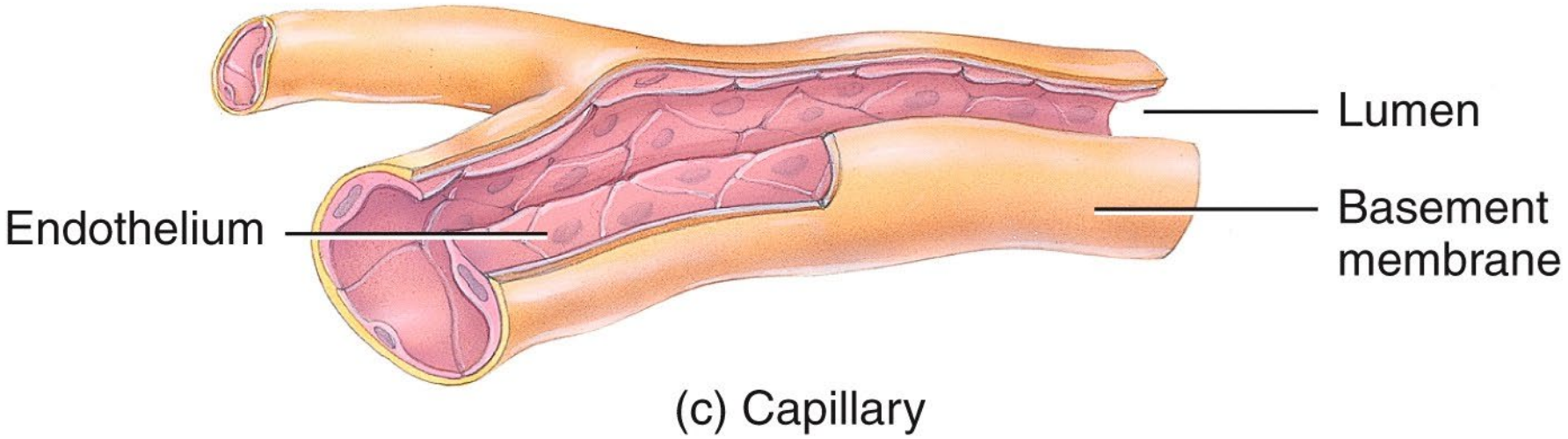
Veins - carry blood back to heart

Capillaries - connect smallest arteries to smallest veins

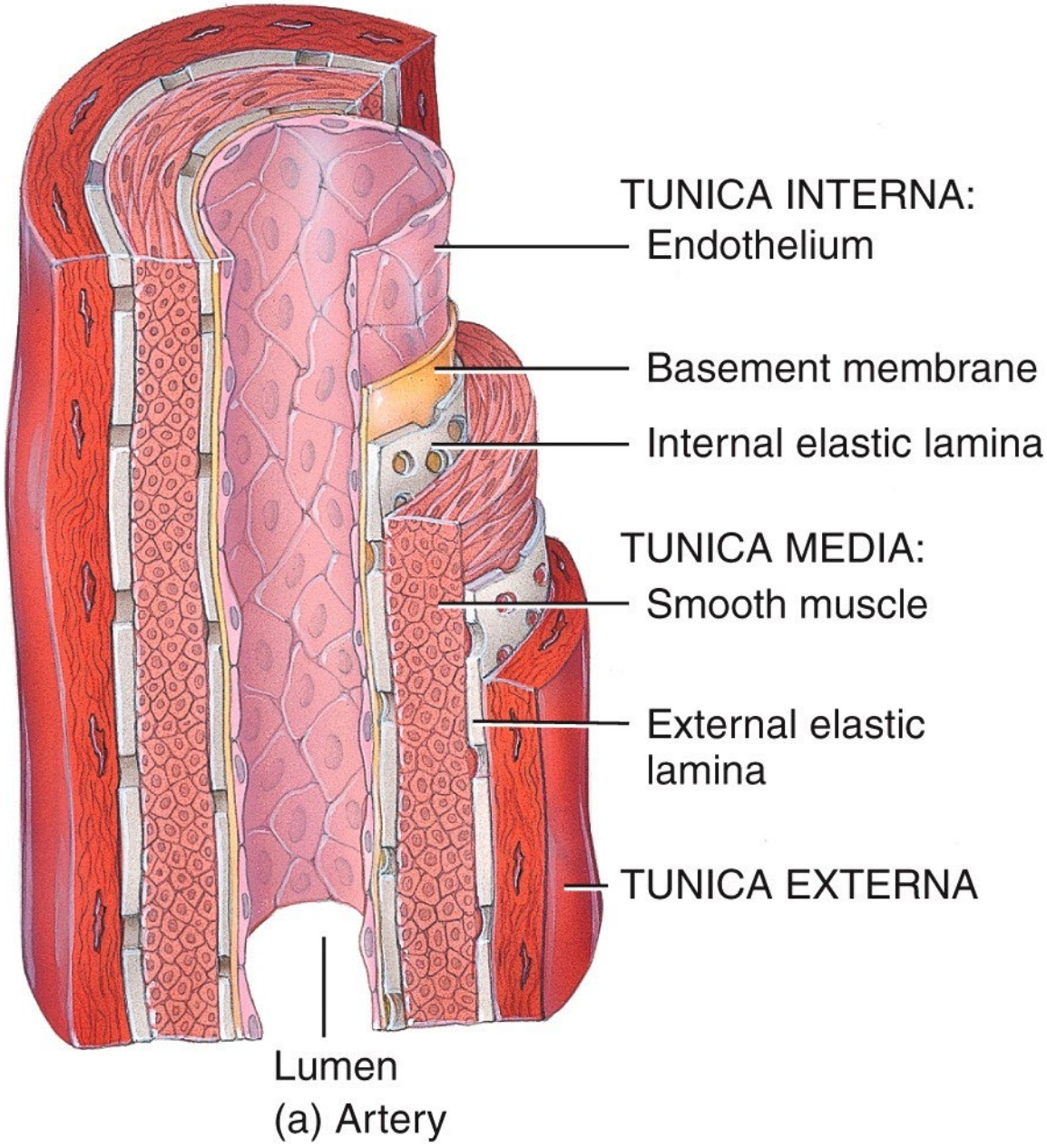
Capillaries are “semi-permeable membranes” to allow for the exchange of fluid, ions, & small molecules between the blood and the intersticial space

Arteries and veins have three tunics (layers)


TUNICA INTERNA:
Endothelium
Basement membrane
Internal elastic lamina
TUNICA MEDIA:
Smooth muscle
External elastic lamina
TUNICA EXTERNA
Lumen
(a) Artery
Valve
Lumen
(b) Vein
Lumen
Basement membrane
Endothelium
(c) Capillary



The endothelium are epithelial cell which are always attached to a basement membrane and have an apical and basal side.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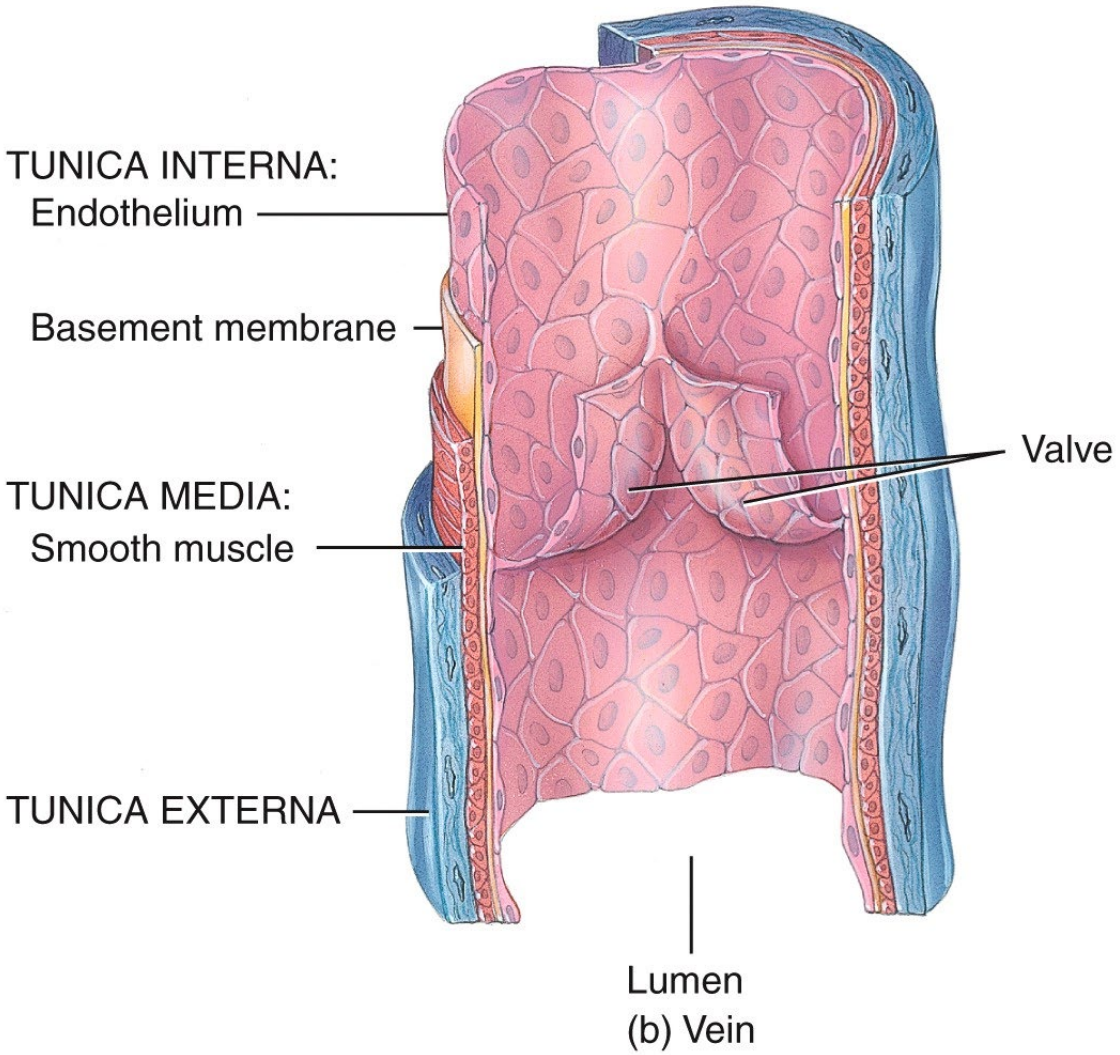
(a) Artery



Veins have some elasticity, but they are significantly less elastic and more compliant (stretchable) than arteries. Veins have thinner walls with less elastic and smooth muscle tissue, which allows them to hold a large volume of blood at low pressure, unlike arteries, which are built to withstand high pressure and recoil.

Tunica Interna (tunica intima)

Endothelium **are c**ells that lines the inside of blood vessel

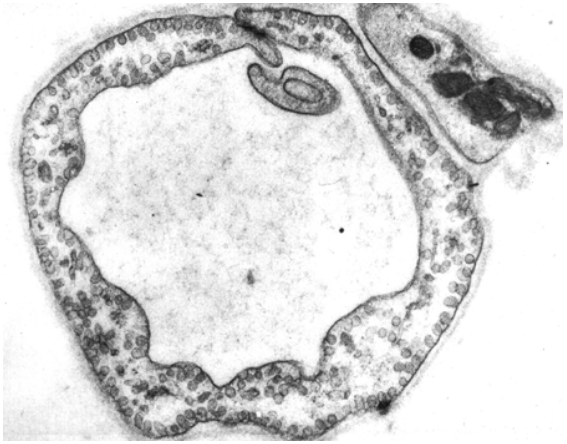
Simple squamous epithelium with basal surface attached to a basement membrane

It is a **selectively permeable** barrier (semi-permeable membrane)

Normally **repels blood cells and platelets** /// endothelium secrete prostacyclin – make surface "slippery" so platelets don't stick to the endothelium

When tissue around vessel is inflamed, the endothelial cells produce cell-adhesion molecules that induce leukocytes to adhere to the surface

Allows leukocytes to congregate in tissues where their defensive actions are needed



Tunica Media

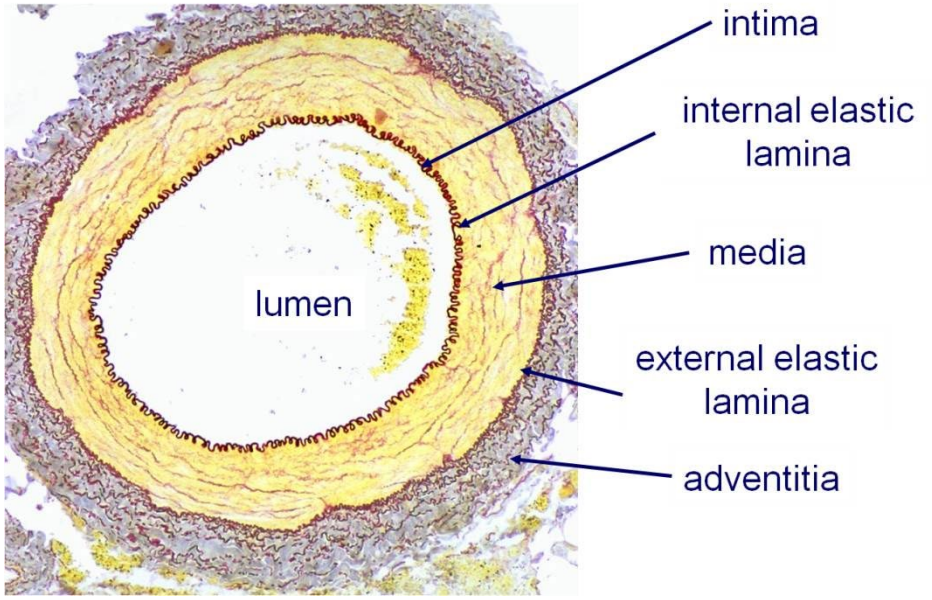
The middle layer

Consists of smooth muscle and connective tissue with collagen and elastic fibers

Strengthens vessel and prevents blood pressure from rupturing vessels

Arteries have elastic tissue on both sides of the tunica media and veins do not have any elastic tissue.

Vasomotion – changes in diameter of the blood vessel brought about by smooth muscle action /// regulated by vasomotion center in medula oblongata



Note: at end of arterial system are small diameter vessels called arterioles // the vasomotor center can control blood pressure by regulating smooth muscle contraction --- this is known as peripheral resistance.

The volume of blood on the arterial side also contributes to the blood pressure.

Tunica Externa

Outermost layer

Consists of loose connective tissue

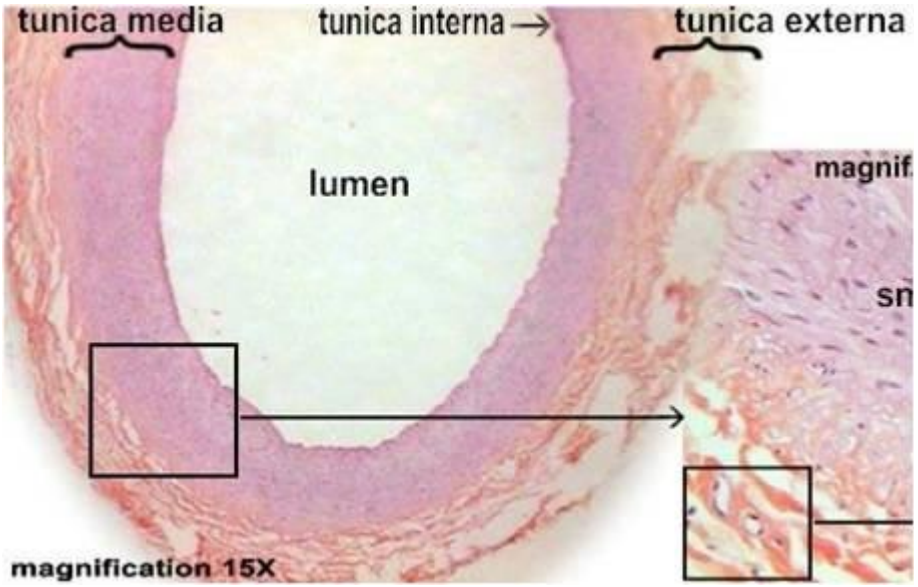
Merges with that of neighboring blood vessels, nerves, or other organs

Anchors the vessel to surrounding tissues

Provides passage for small nerves, lymphatic vessels

Vasa vasorum – small vessels that supply blood to the outer half of the blood vessel's wall

Blood from the lumen is thought to nourish the inner half of the blood vessel's wall by diffusion



Arteries

Carry blood away from the heart

Maybe classified by their function

Elastic arteries (largest – garden hose size /// also function as a pressure reservoirs – e.g. aorta)

Distributing arteries (also called conduction arteries) // medium size sometimes referred to as muscular / pencil to string size / e.g. renal artery

Resistance arterioles (small arteries – able to regulate blood flow into capillary beds and change blood pressure / regulated by vaso motor center)

Distributing Arteries

Distributing arteries are also called conducting arteries

- **These are "named arteries"**
- Arteries distal to pulmonary truck and aorta // e.g. renal, common carotid, subclavian,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 – helps to maintain downstream pressure // this lessens fluctuations in blood pressure

Elastic Arteries

Walls stretched as blood received by pulmonary truck and aorta

Stretching vessel walls “stores energy” because of elastic component of the vessel wall

Elastic recoil in pulmonary truck and aorta keep blood flowing while ventricles are in diastole

Resistance Arteries

Why are arteries called resistance vessels?

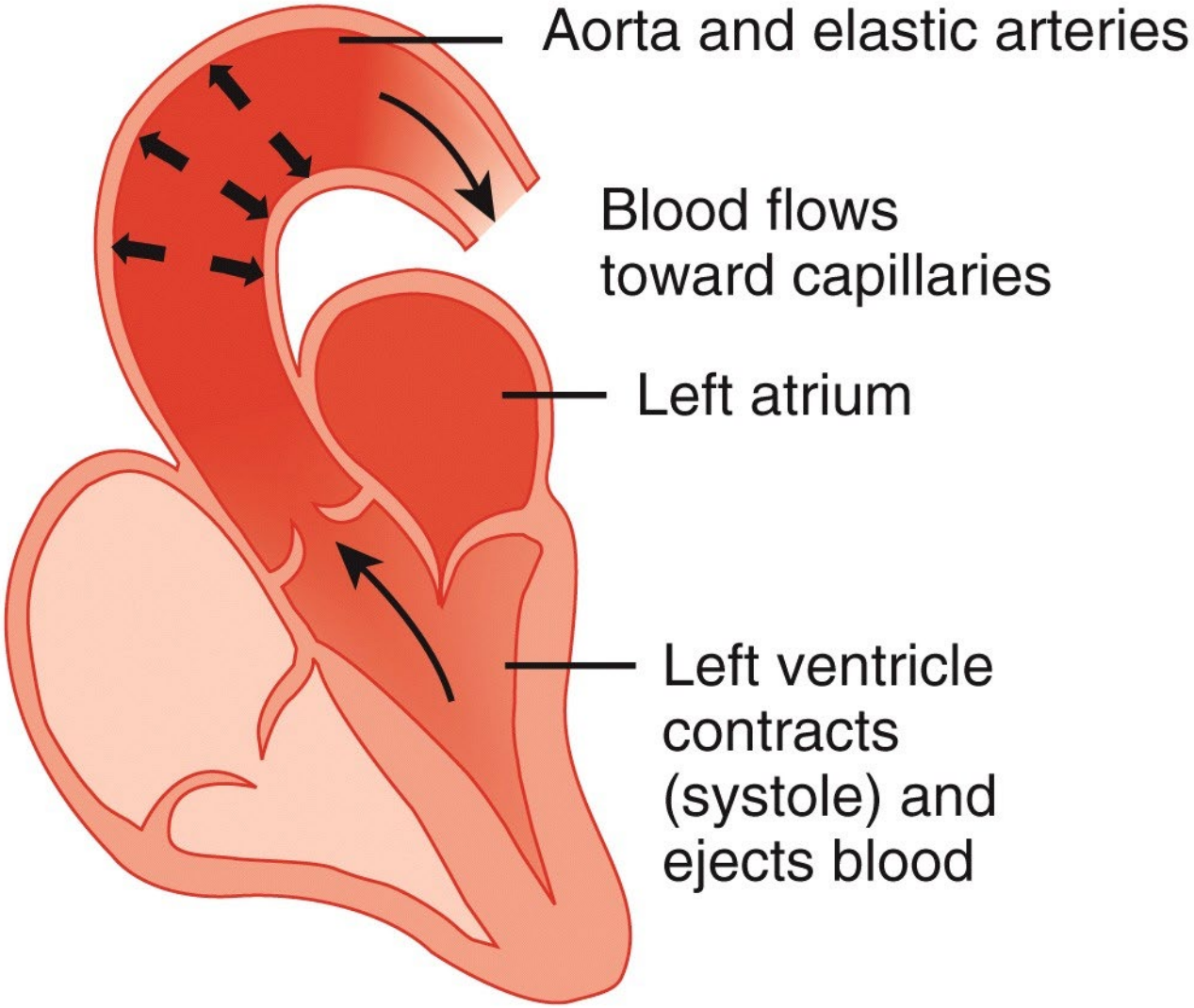
Because they have thick smooth muscle walls

Resilient wall structure that can resists dilation due to high blood pressure

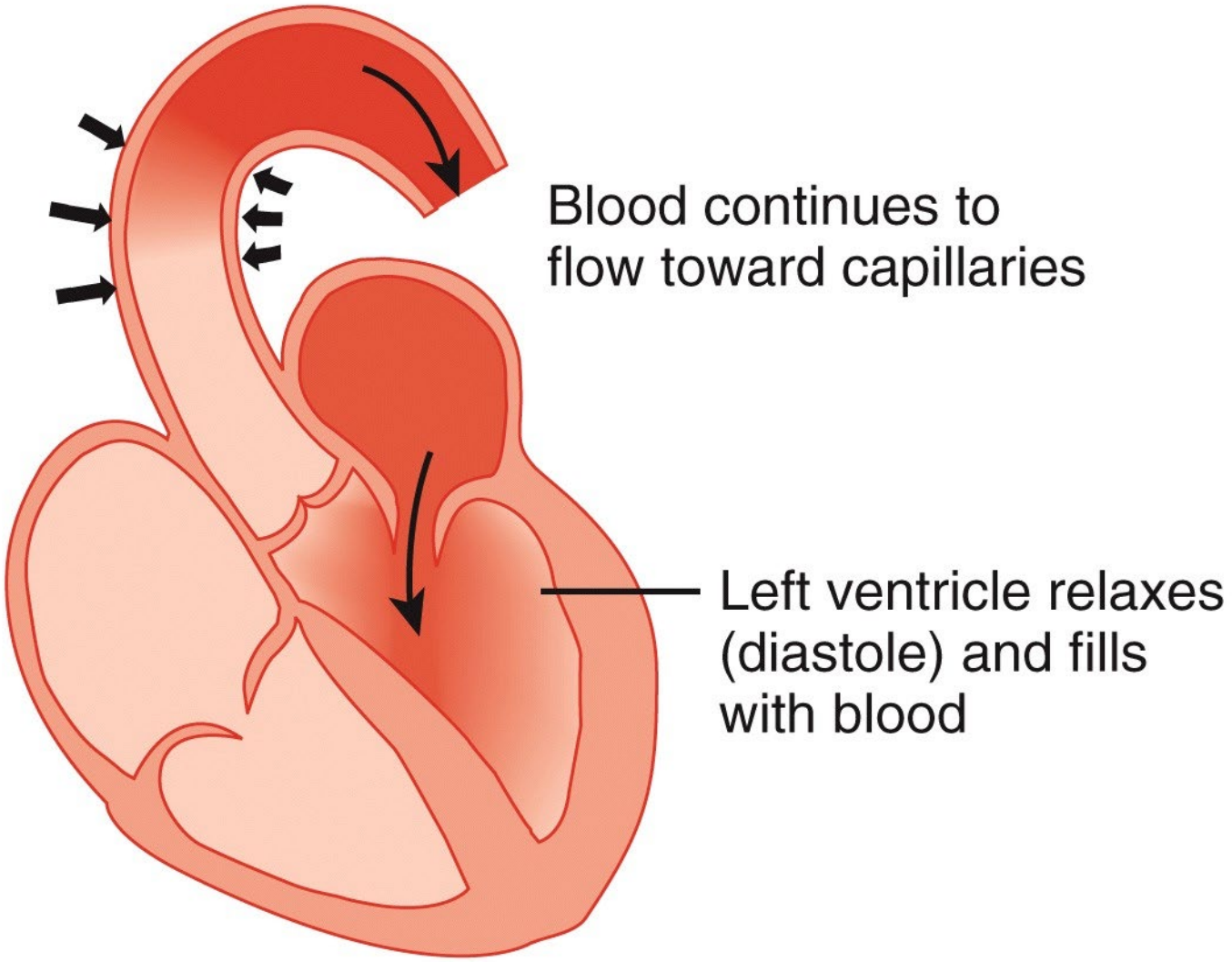
Arterioles (smallest of the arteries) just before capillaries are "regulated" by the vasomotor center

Two functions of the vasomotor center (located in medulla oblongata)

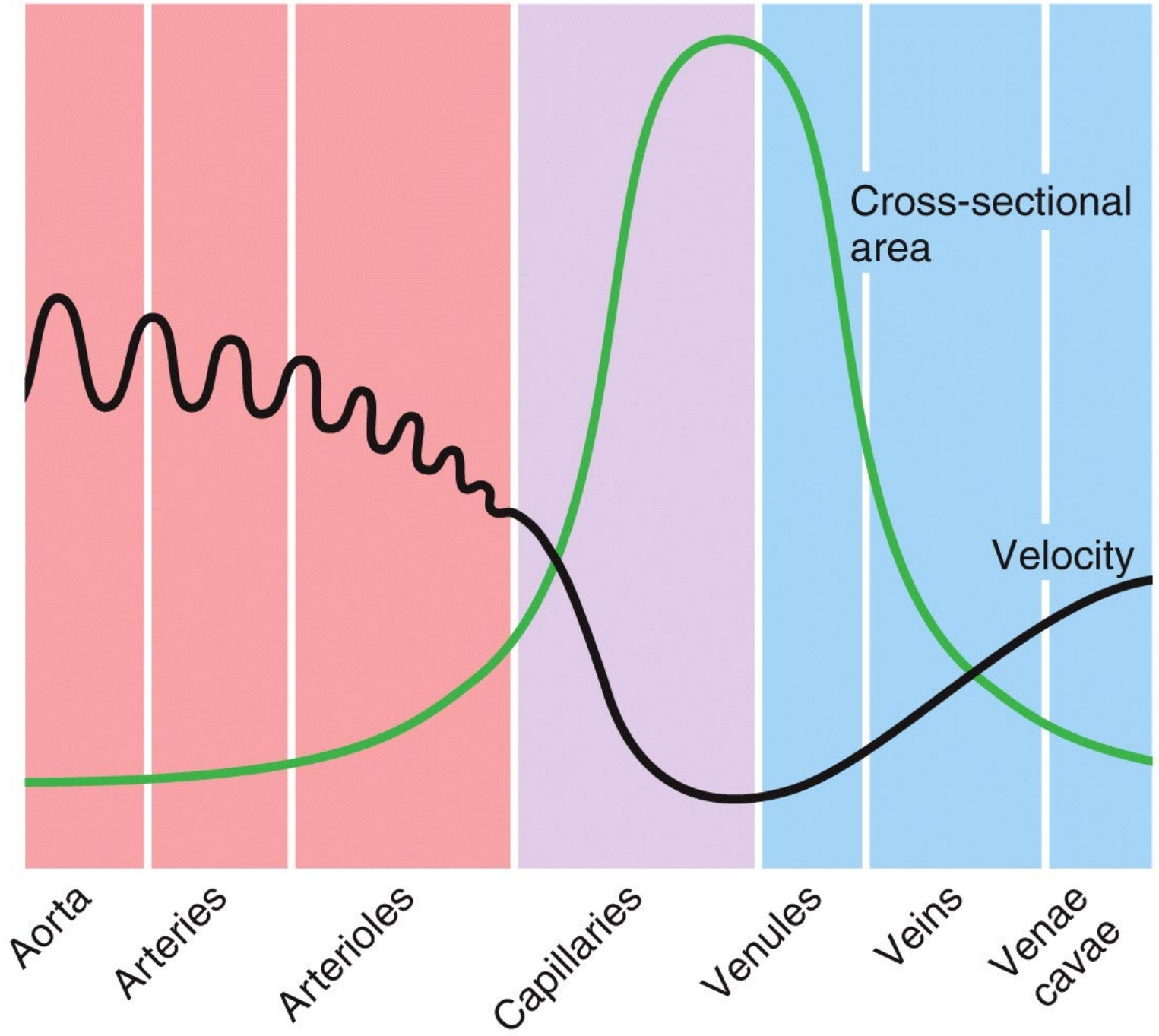
- Regulate blood pressure
- Regulate blood distribution



(a) Elastic aorta and arteries stretch during ventricular contraction



(b) Elastic aorta and arteries recoil during ventricular relaxation


Cross-sectional area
Velocity
Aorta
Arteries
Arterioles
Capillaries
Venules
Veins
Venae cavae

Arterial Sense Organs

Sensory structures in the walls of the aorta and carotid arteries monitor blood pressure and blood chemistry

Transmit information to brain stem to regulate

- *1) heart rate **
- *2) vasomotion (vasomotor center) **
- *3) respiration*

Location of sense organs

- *carotid baroreceptor (also called carotid sinus)*
- *aortic barorecptor (also called aortic sinus)*
- *carotid chemoreceptor*
- *aortic chemoreceptor*

*** Please Note: the chemorecptors are more important in regulating respiration.*

Arterial Sense Organs

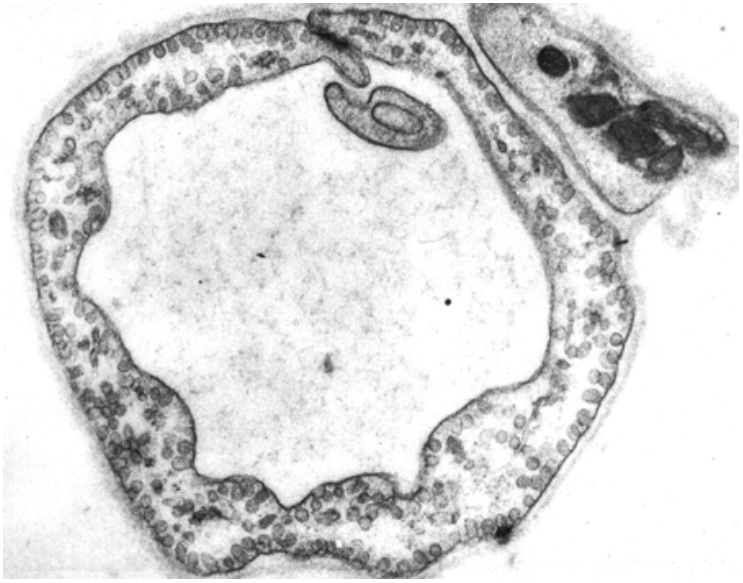
Aortic & carotid sinuses // baroreceptors (pressure sensors)

- most important in regulation of heart
- in walls of internal carotid artery & aortic arch
- monitors blood pressure – signaling brainstem
- decreased heart rate and vessels dilation in response to high blood pressure

Aortic & 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
- one to three in walls of aortic arch
- same function as carotid bodies

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**

Capillaries are absent or scarce in tendons, ligaments, epithelia, cornea and lens of the eye

Three Types of Capillaries

- Continuous Capillaries
- Fenestrated Capillaries
- Sinusoid Capillaries

Distinguished by ease with which substances pass through their walls

Structural differences that account for their greater or lesser permeability

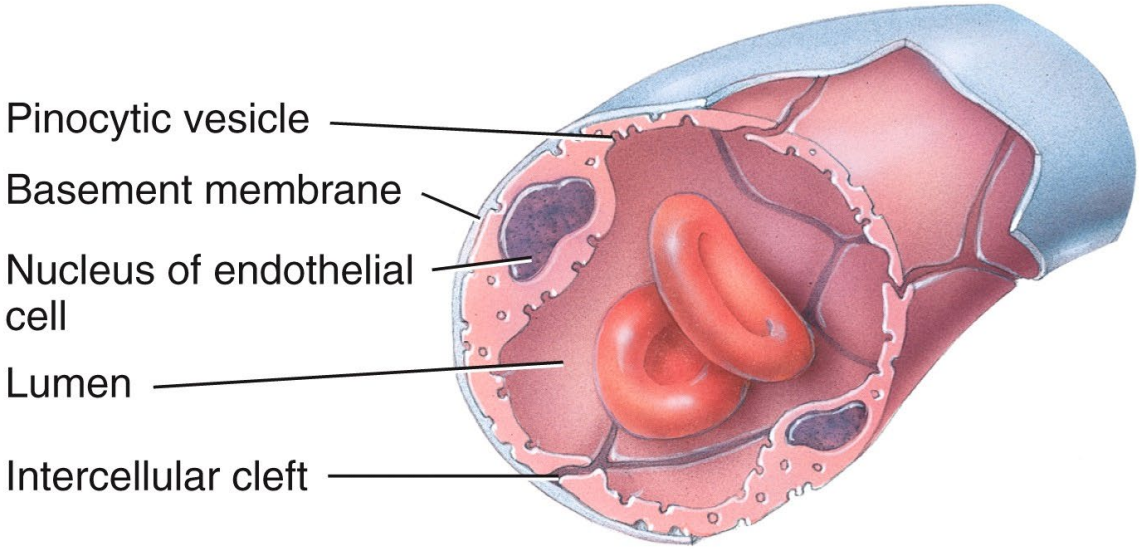
Continuous Capillaries

Most common, occur in most tissues

Endothelial cells have **tight junctions** forming a continuous tube with **intercellular clefts**

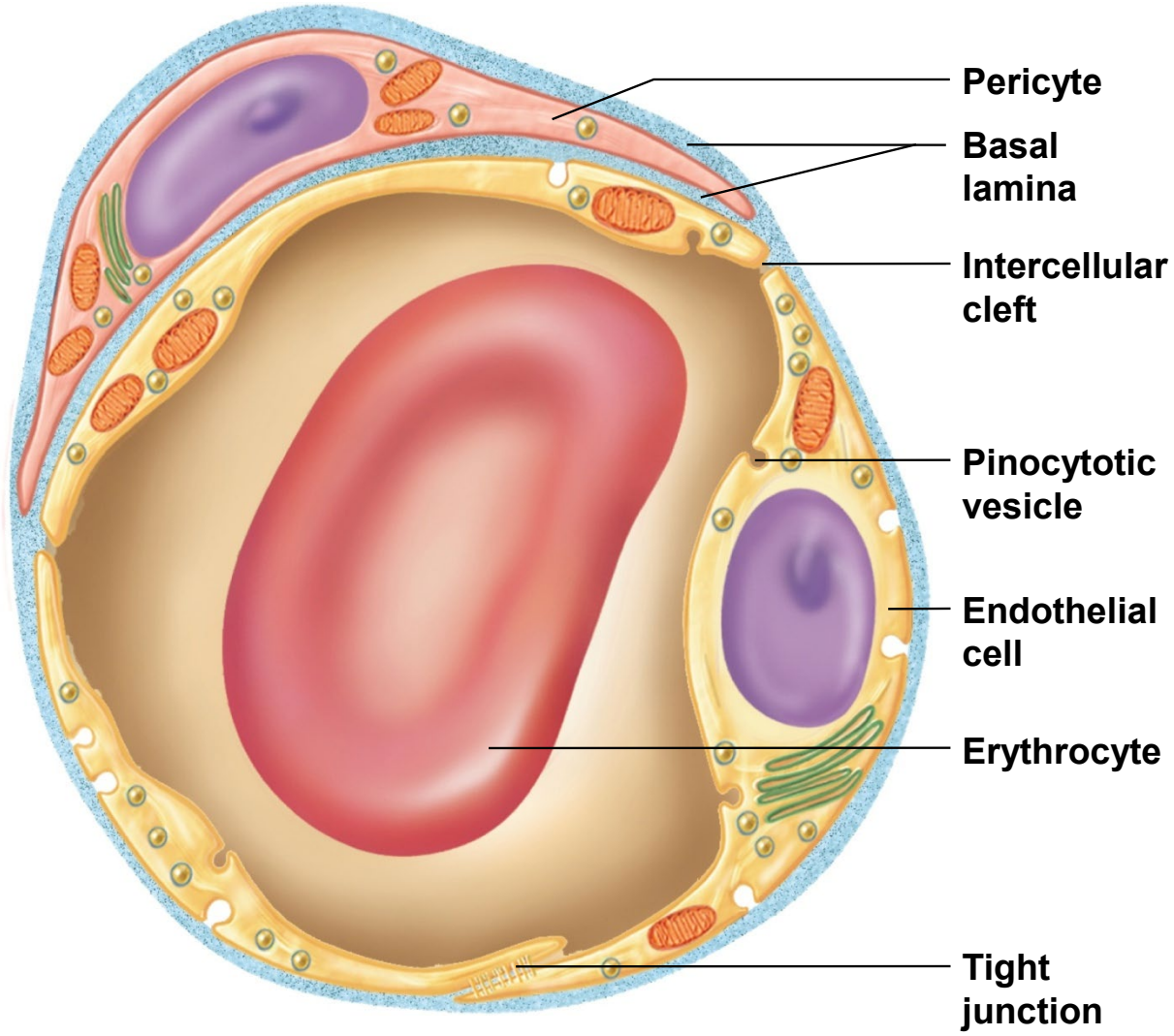
•**A**llow passage of solutes such as glucose

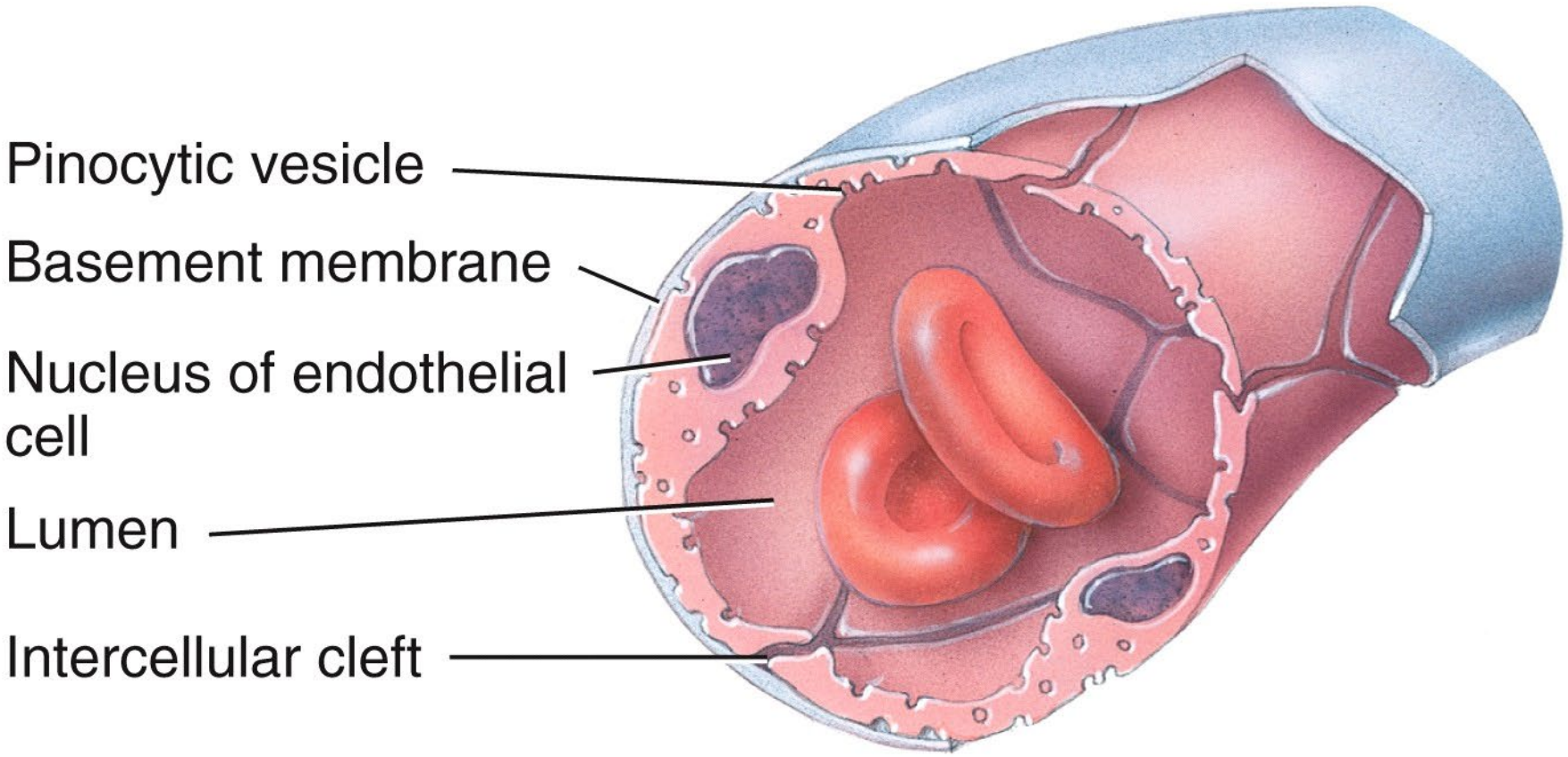
Pericytes wrap around the capillaries and contain the same contractile protein as muscle // contract but minimum ability to regulate blood flow



(a) Continuous capillary formed by endothelial cells

Continuous Capillary





(a) Continuous capillary formed by endothelial cells

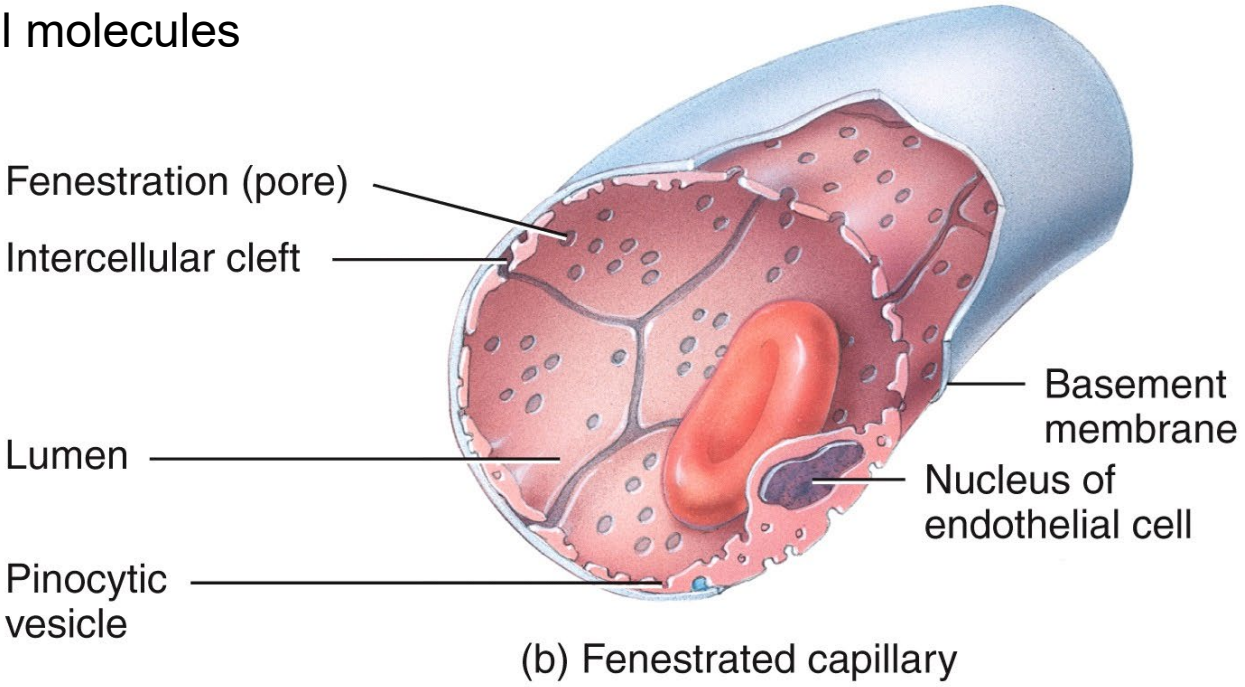
Fenestrated Capillaries

Common in kidneys and small intestine // organs that require rapid absorption or filtration

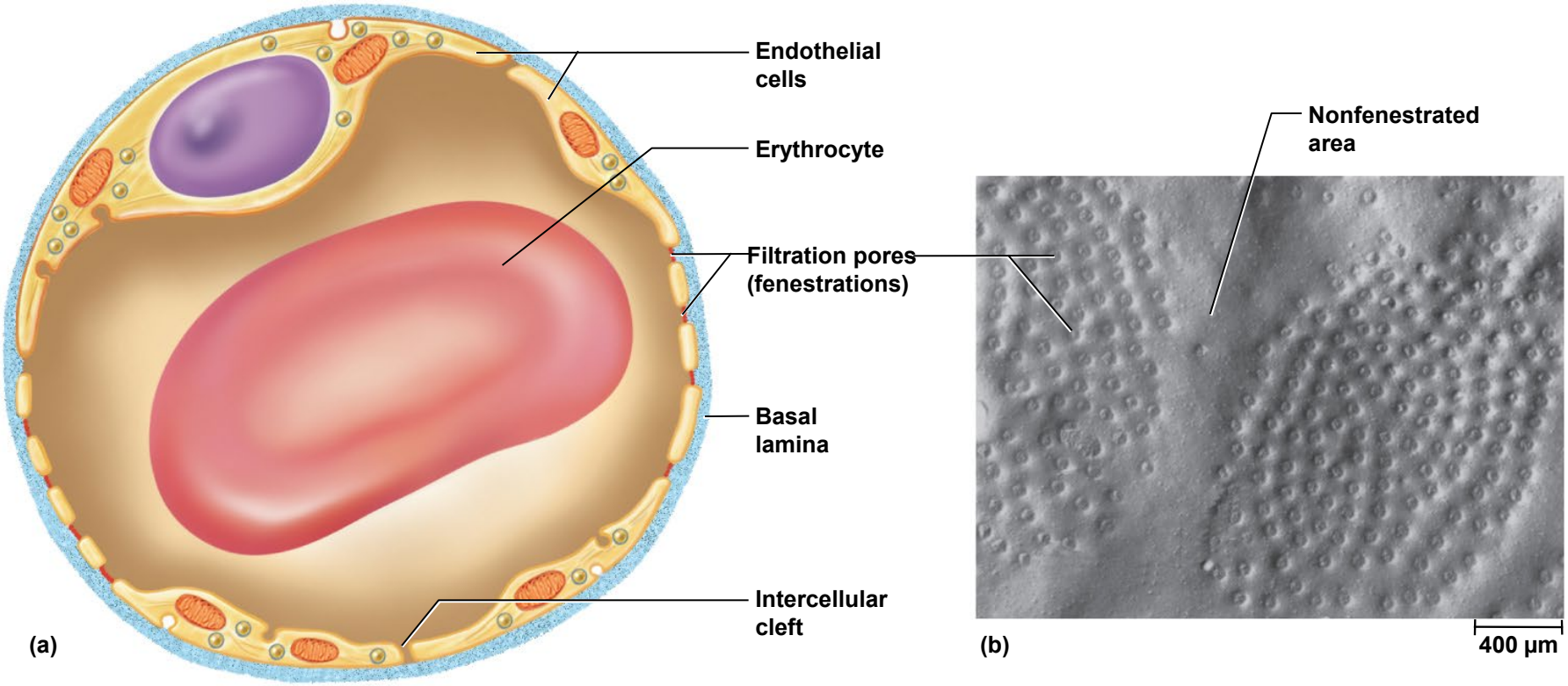
Endothelial cells riddled with holes called **filtration pores** **(fenestrations)**

Spanned by very thin glycoprotein layer

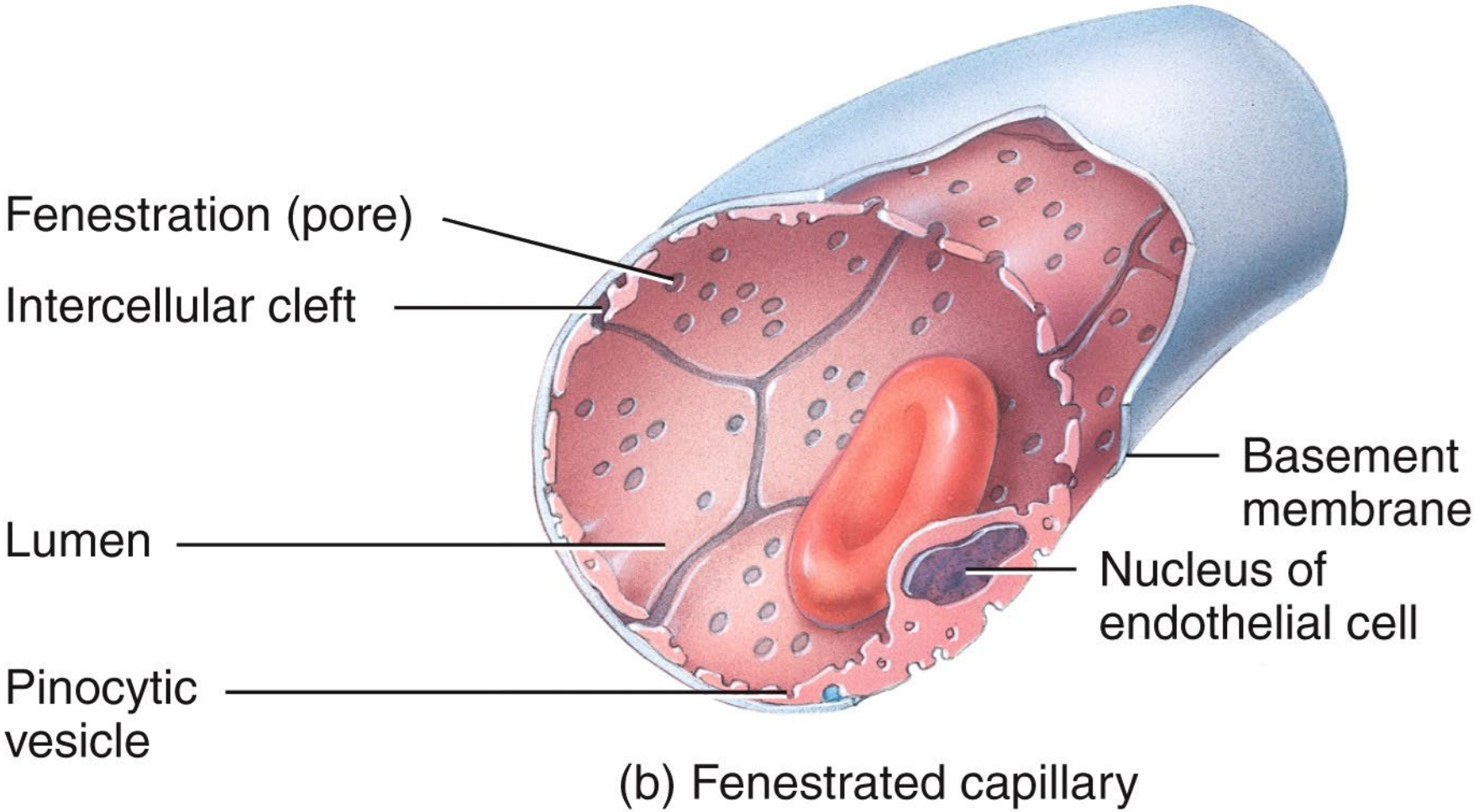
Allows passage for small molecules



Fenestrated Capillary



b: Courtesy of S. McNutt



(b) Fenestrated capillary

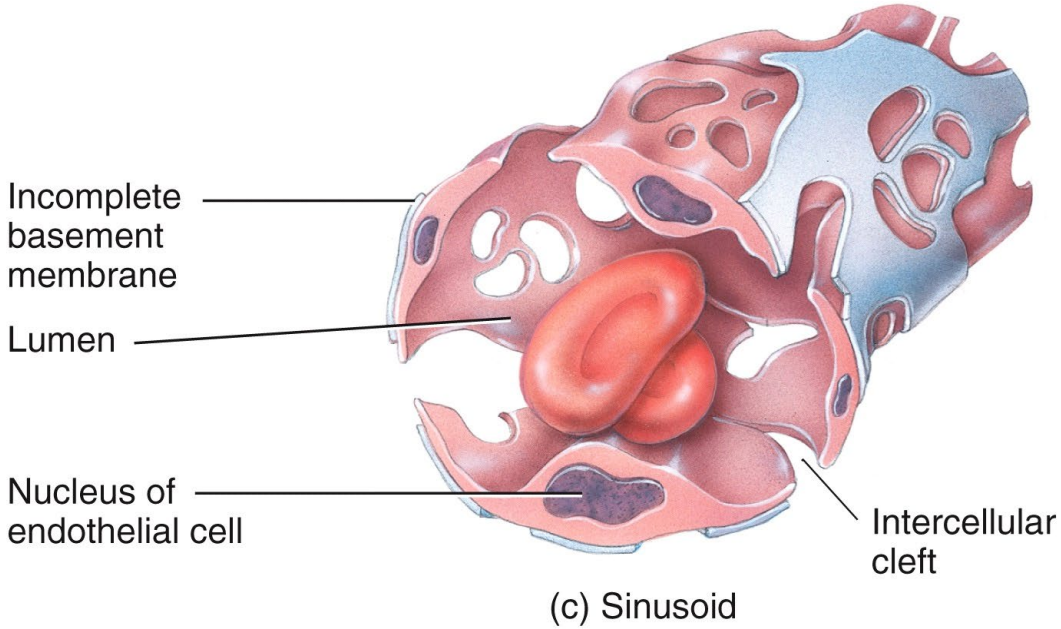
Sinusoids

–Discontinuous capillaries

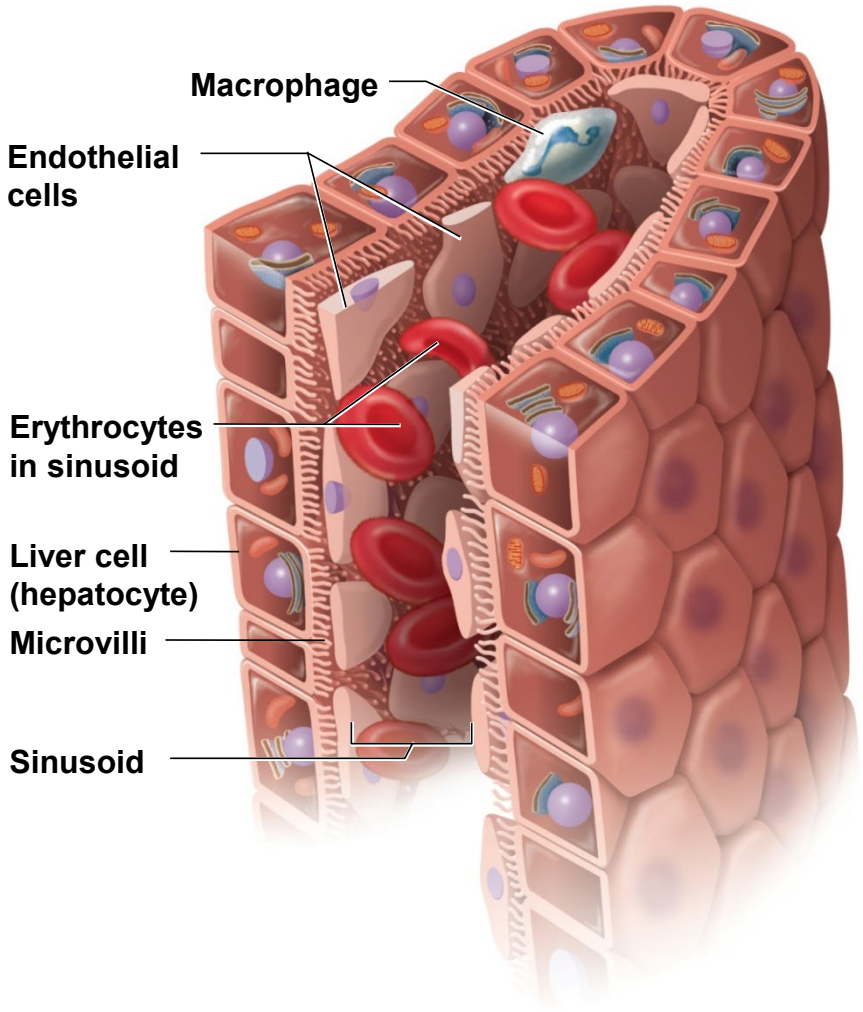
Liver, bone marrow, spleen // these tissues make large proteins and/or cells which must enter blood vessels.

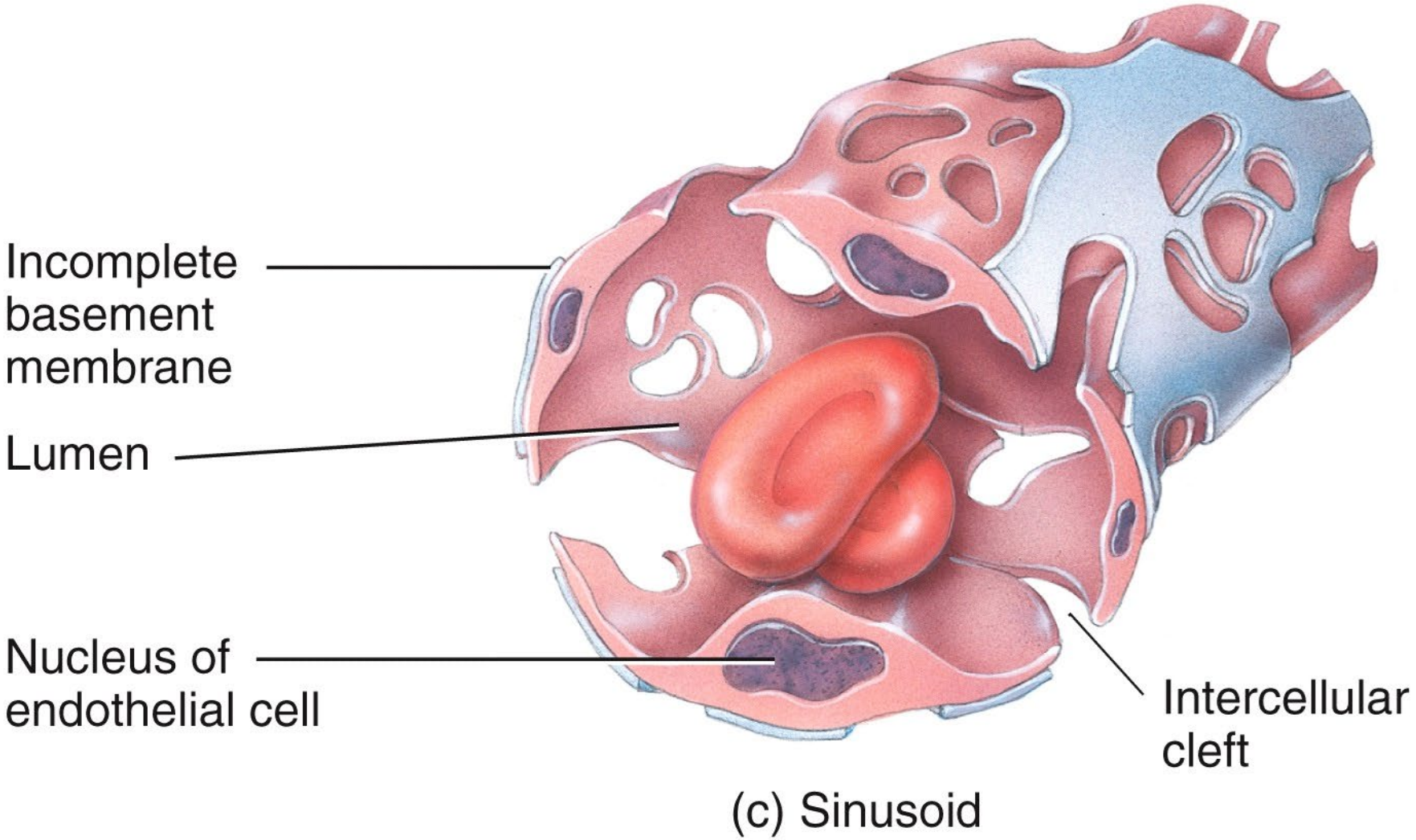
Irregular blood-filled spaces with large fenestrations

Allow proteins (albumin), clotting factors, and new blood cells to enter the circulation



Sinusoid in Liver




Incomplete basement membrane
Lumen
Nucleus of endothelial cell
Intercellular cleft

(c) Sinusoid

Capillary Beds

•Capillaries organized into networks called **capillary beds**

•Situated between an arteriole and venule

•A passageway connects the arteriole to the venule // two segments

–**Metarteriole** – proximal to arteriole / no smooth muscle but smooth muscle at junction between metarteriole and capillary

•**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 and flows through thoroughfare channel to venule

–**Thoroughfare channel** – point beyond the metarteriole that continues through capillary bed to venule

Arterioles and Metarterioles

Arterioles

Responsible for "peripheral resistance"

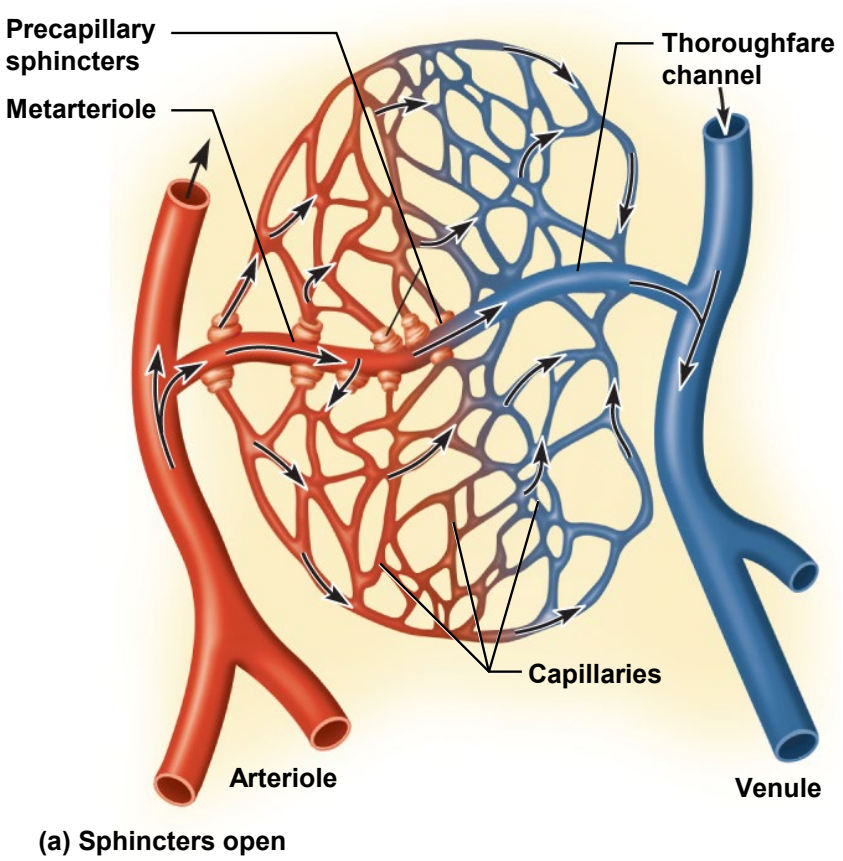
The smallest arteries with two functions.

Control amount of blood flowing into various organs

Create "peripheral resistance" to regulate blood pressure.

Thicker tunica media in proportion to their lumen than large arteries

Little tunica externa



(a) Sphincters open

Arterioles to Metarterioles

Metarterioles

Short vessels that link arterioles to capillaries

Smooth muscle cells form **precapillary sphincter** at entrance to capillary bed

Constriction of these sphincters reduces or shuts off blood flow into capillaries

Relax sphincter muscles allow blood to flow into capillary bed.

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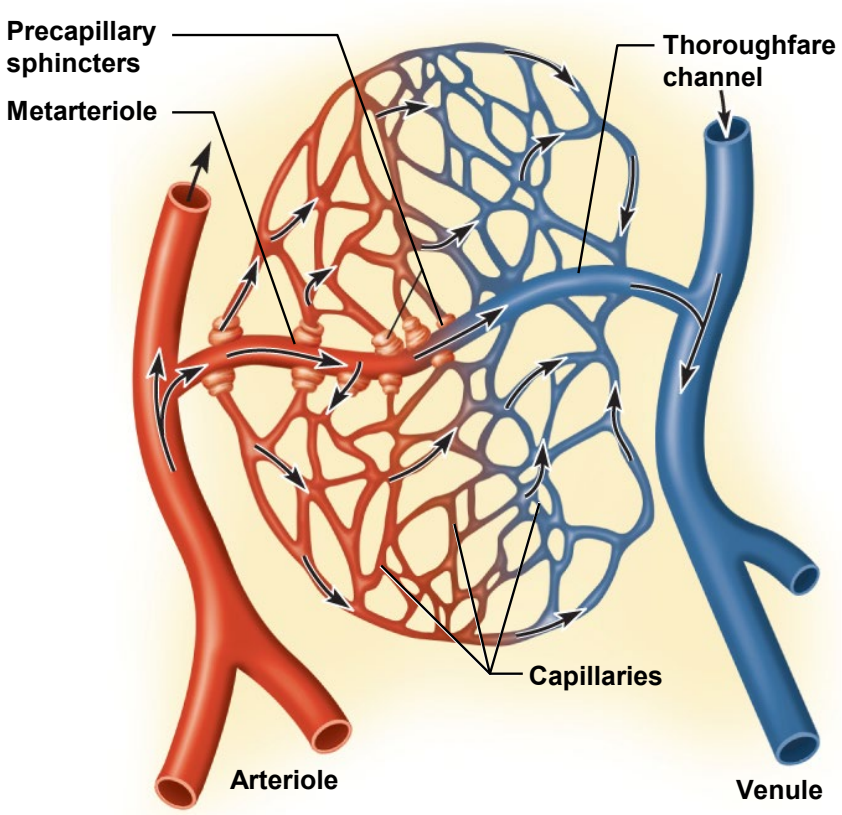
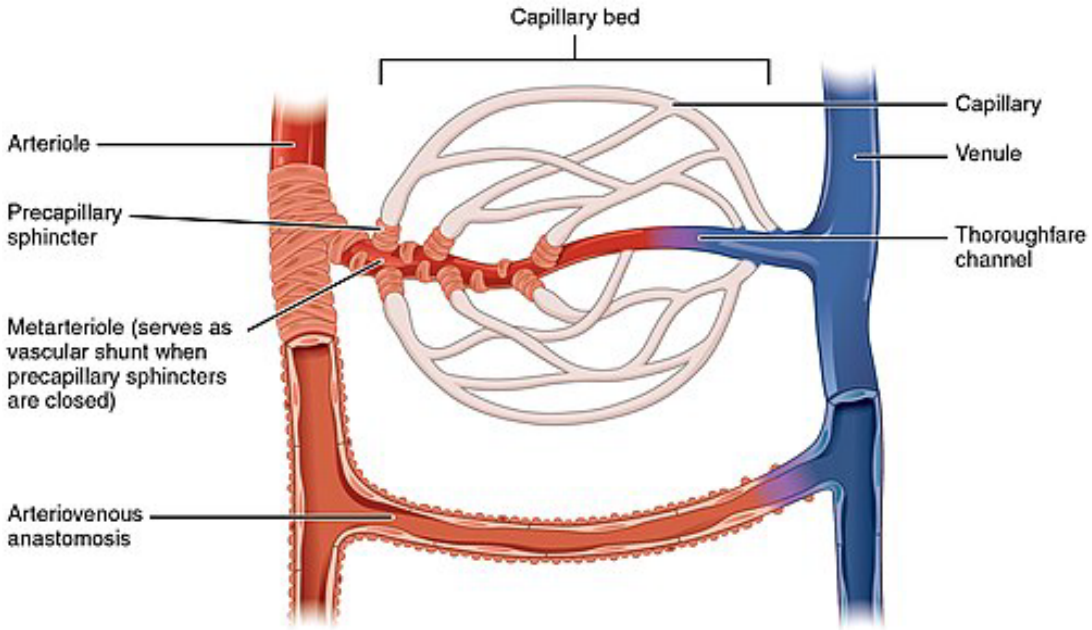
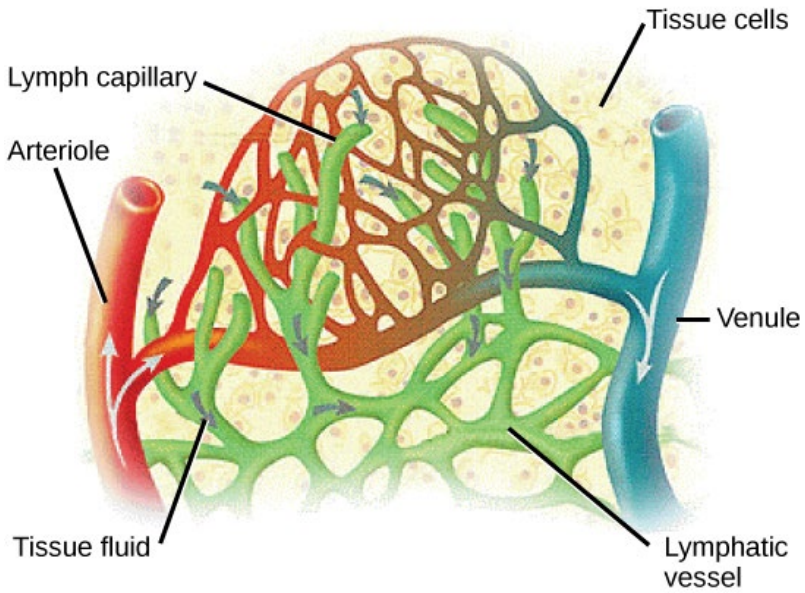


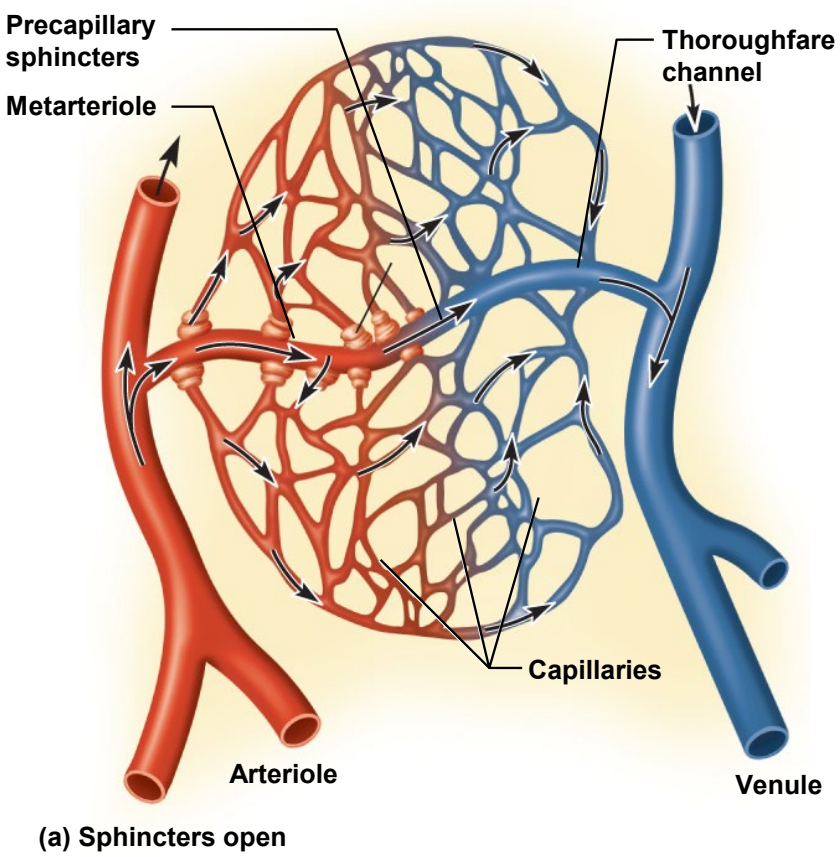
(a) Sphincters open



Lymph Capillaries in the Tissue Spaces



Sphincters Open Blood Flow Into Capillary Bed



(a) Sphincters open

approximately one billion capillaries

no cell more than 40 to 80 micrometers from capillary

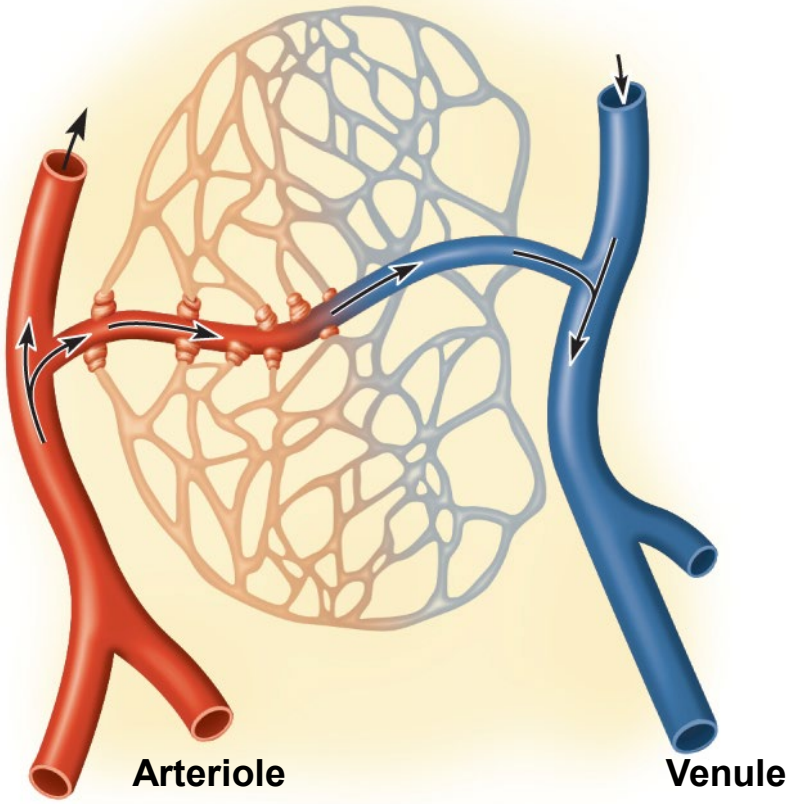
four to six cell widths

Pre-capillary sphincters are not controlled by vasomotor center

Pre-capillary sphincters regulated by “local regulation”

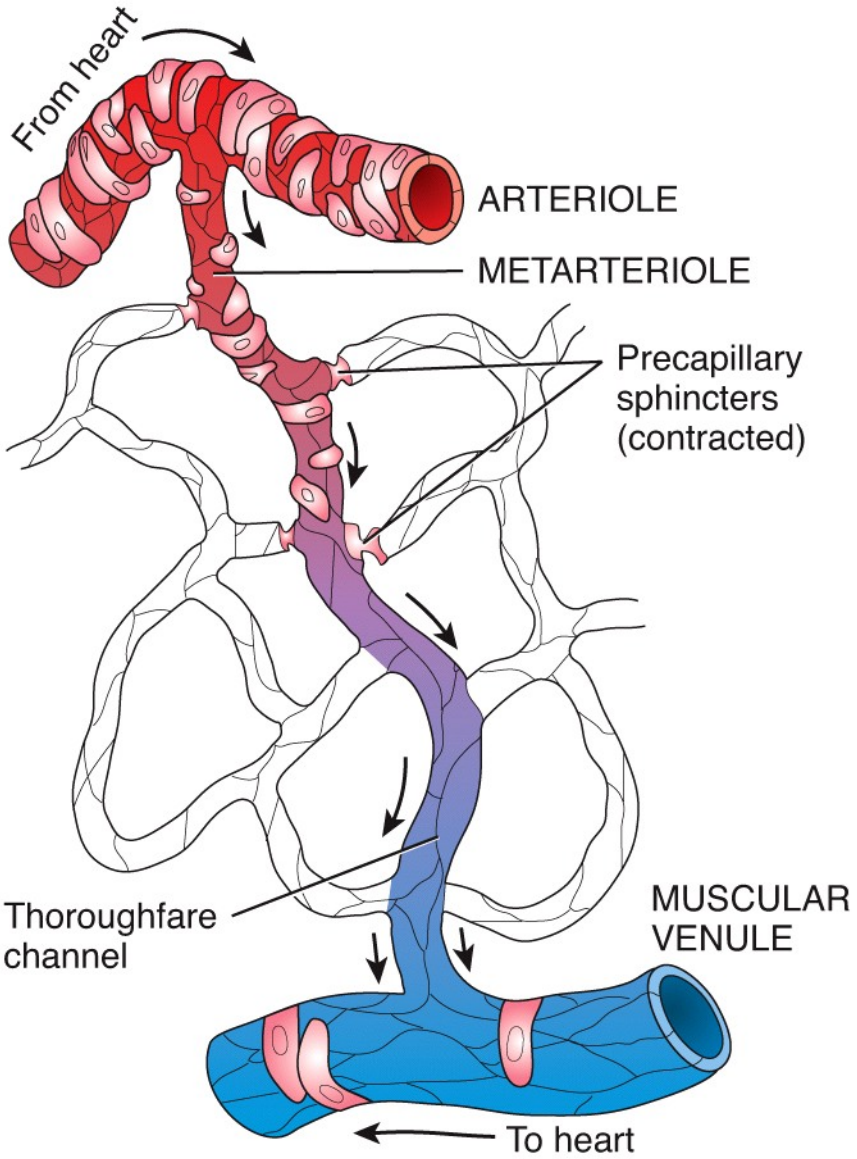
When sphincters are open, the capillaries are well perfused ///
75% of the capillaries are normally shut down

Sphincters Closed Blood Flows Directly to Venule

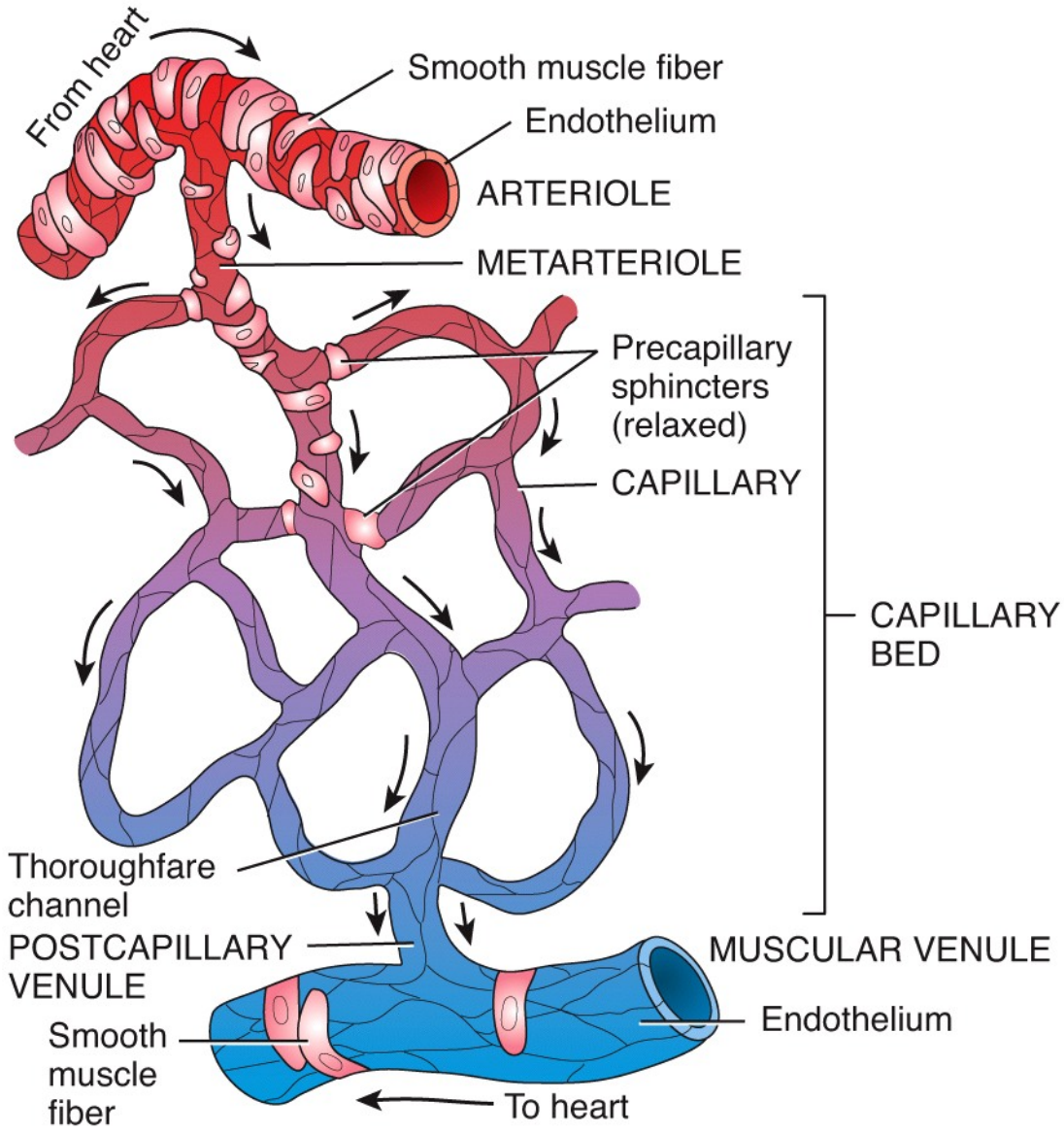


(b) Sphincters closed

When the sphincters are closed, little to no blood flow into capillary bed (e.g. when skeletal muscles at rest)



(b) Sphincters contracted: blood flowing through thoroughfare channel



(a) Sphincters relaxed: blood flowing through capillaries

Metabolic Theory of Auto-Regulation

Autoregulation = Local Control = the ability of the tissues to regulate its own blood supply

This principle applies to the capillary beds

If tissue is not adequately perfused with blood, then *carbon dioxide accumulate* and stimulates vasodilation // increases perfusion

Bloodstream delivers oxygen and removes carbon dioxide

When carbon dioxide levels drop then smooth muscle constricts

Why does this make sense? Explain.

Capillary Filtration and Reabsorption

Capillary filtration occurs at arterial end

Capillary reabsorption (osmosis) occurs at venous end

Variations occurs within different organ types

Location:

Glomeruli of kidney // devoted to filtration

Alveolar capillary of lungs // devoted to absorption

Activity or trauma also increases filtration

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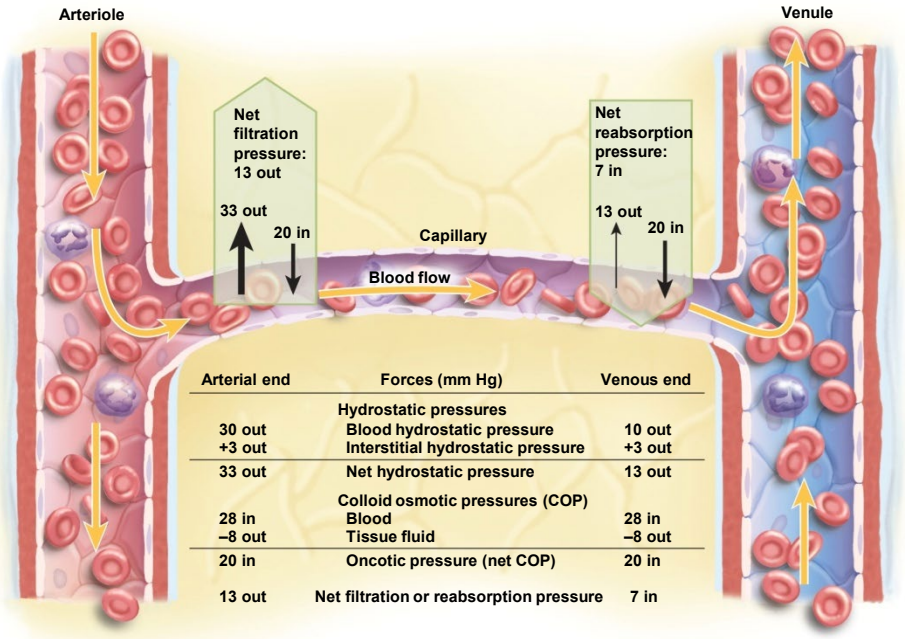
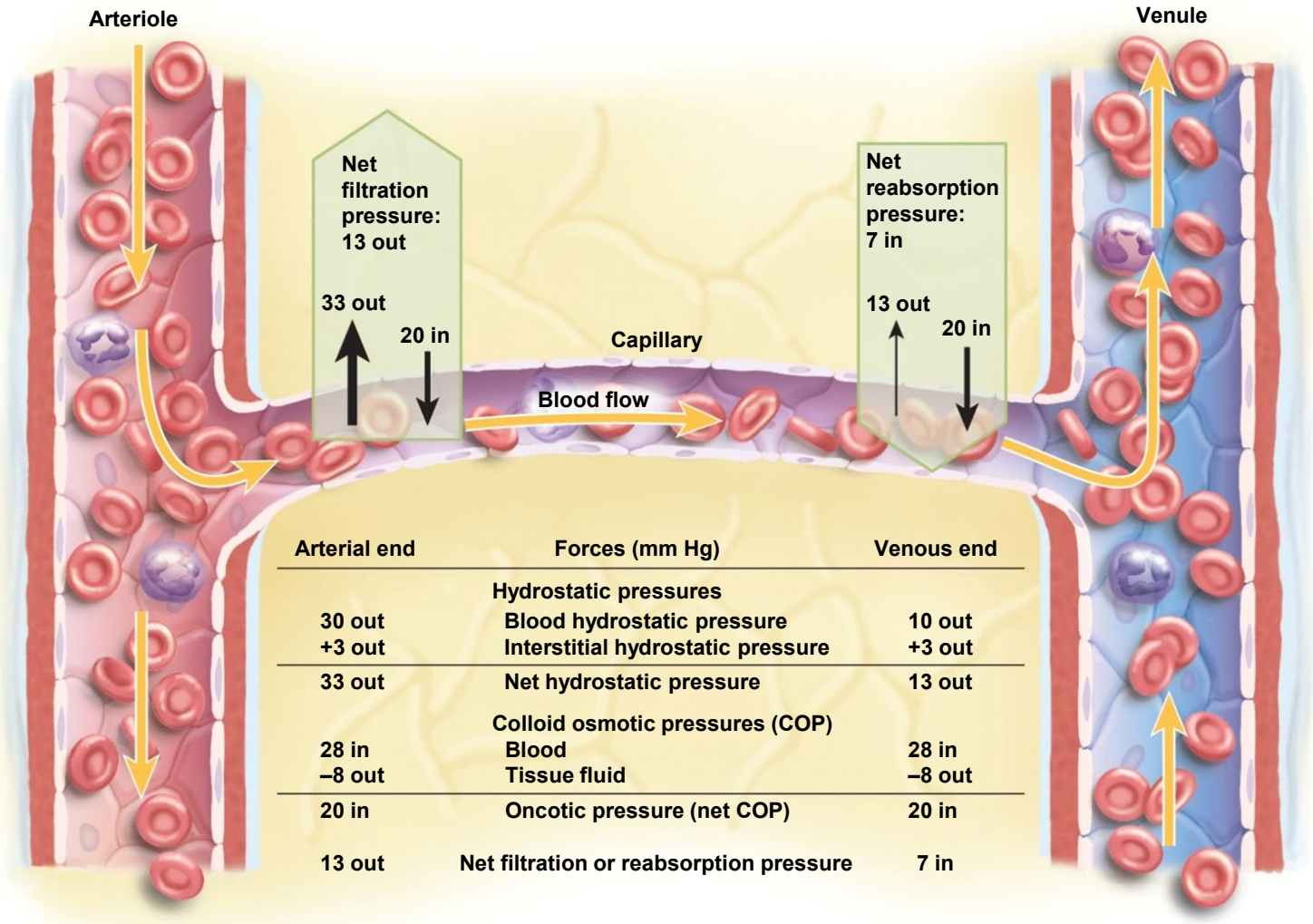


Arterial end	Forces (mm Hg)	Venous end
	Hydrostatic pressures	
30 out	Blood hydrostatic pressure	10 out
+3 out	Interstitial hydrostatic pressure	+3 out
33 out	Net hydrostatic pressure	13 out
	Colloid osmotic pressures (COP)	
28 in	Blood	28 in
–8 out	Tissue fluid	–8 out
20 in	Oncotic pressure (net COP)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

Capillary Filtration and Reabsorption



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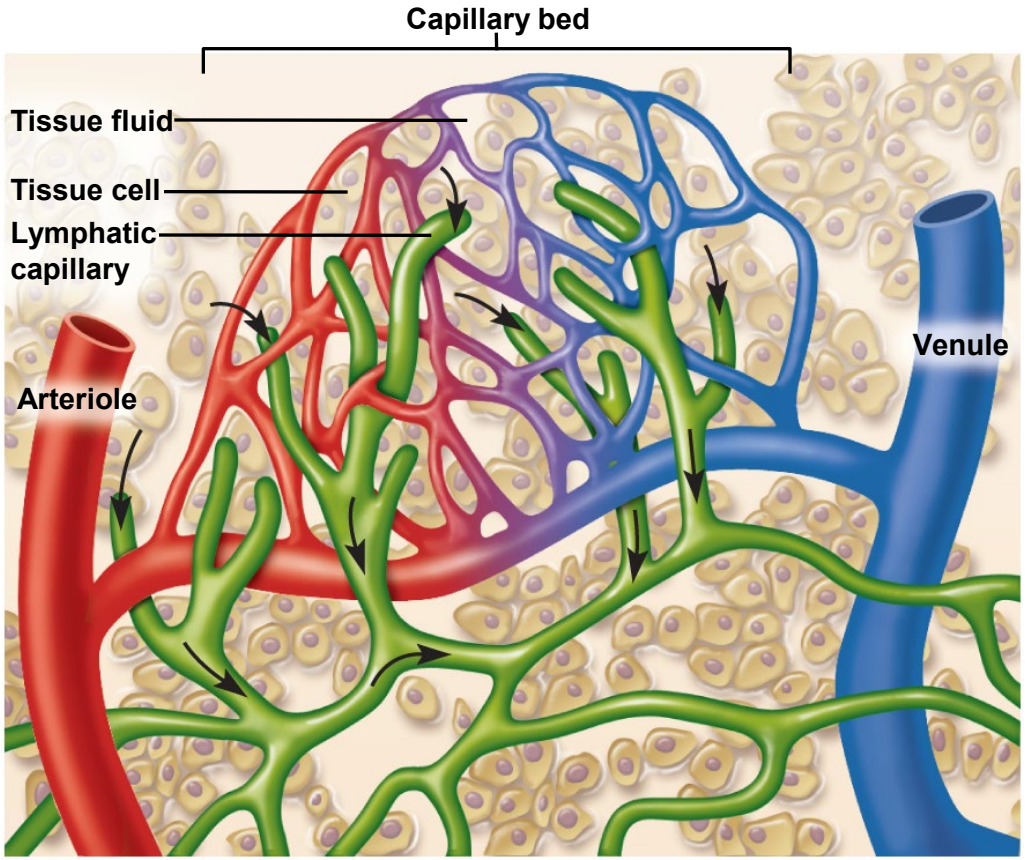
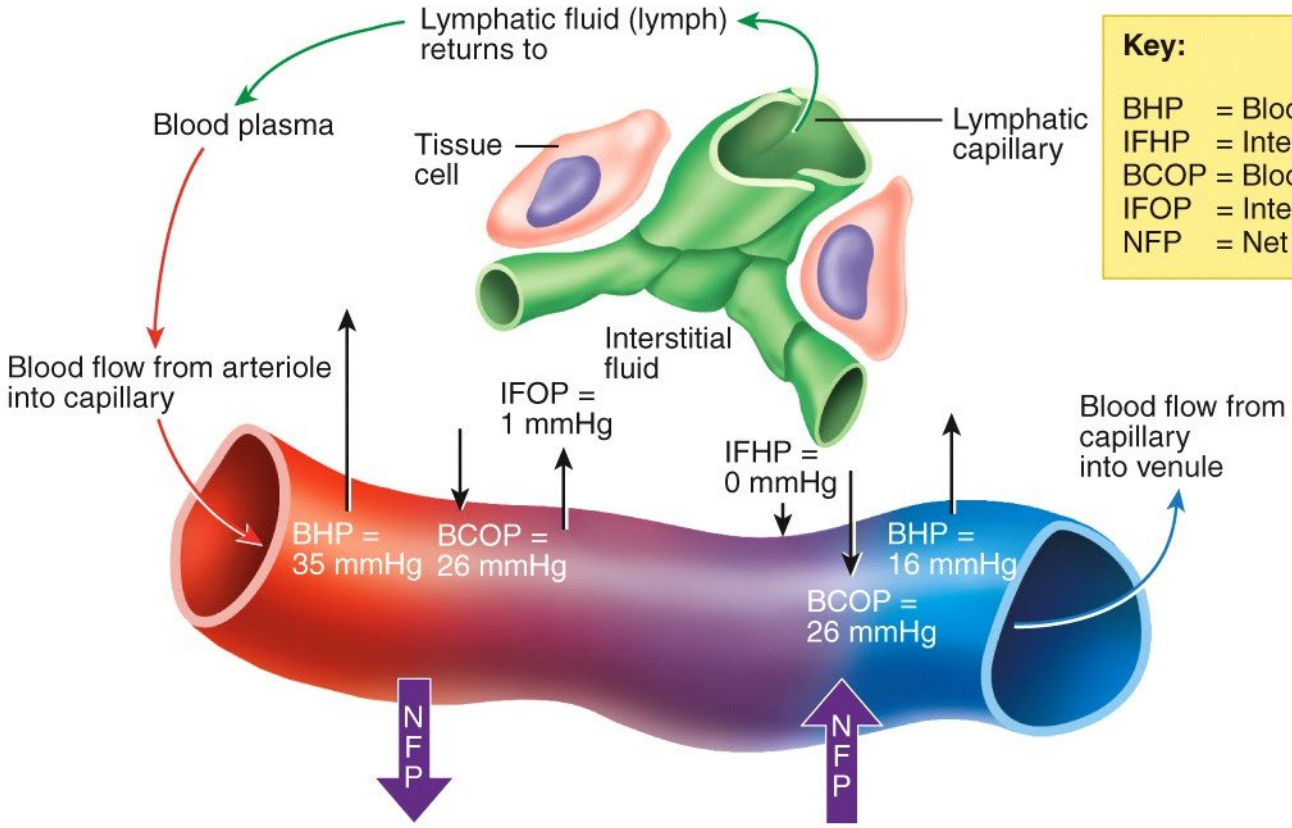
28 in	Blood	28 in
–8 out	Tissue fluid	–8 out
20 in	Oncotic pressure (net COP)	20 in
13 out	Net filtration or reabsorption pressure	7 in

Net “6 mm Hg” out. Reabsorb only 85% // Where does the fluid go?

Structure of a Capillary Bed with Lymphatic Capillaries and Their Afferent Vessels



How much fluid is not recovered at the end of the capillary bed?



Key:

BHP = Blood hydrostatic pressure
IFHP = Interstitial fluid hydrostatic pressure
BCOP = Blood colloid osmotic pressure
IFOP = Interstitial fluid osmotic pressure
NFP = Net filtration pressure

Net filtration at arterial end of capillaries (20 liters per day)

Net reabsorption at venous end of capillaries (17 liters per day)

Net filtration pressure (NFP) = (BHP + IFOP) − (BCOP + IFHP)

Pressures promoting filtration

Pressures promoting reabsorption

	Arterial end	Venous end
	NFP = (35 + 1) − (26 + 0) = 10 mmHg	**NFP** = (16 + 1) − (26 + 0) = −9 mmHg
Result	Net filtration	Net reabsorption

Veins (Capacitance Vessels)

Greater capacity (volume) for blood containment than arteries (54% vs 11%)

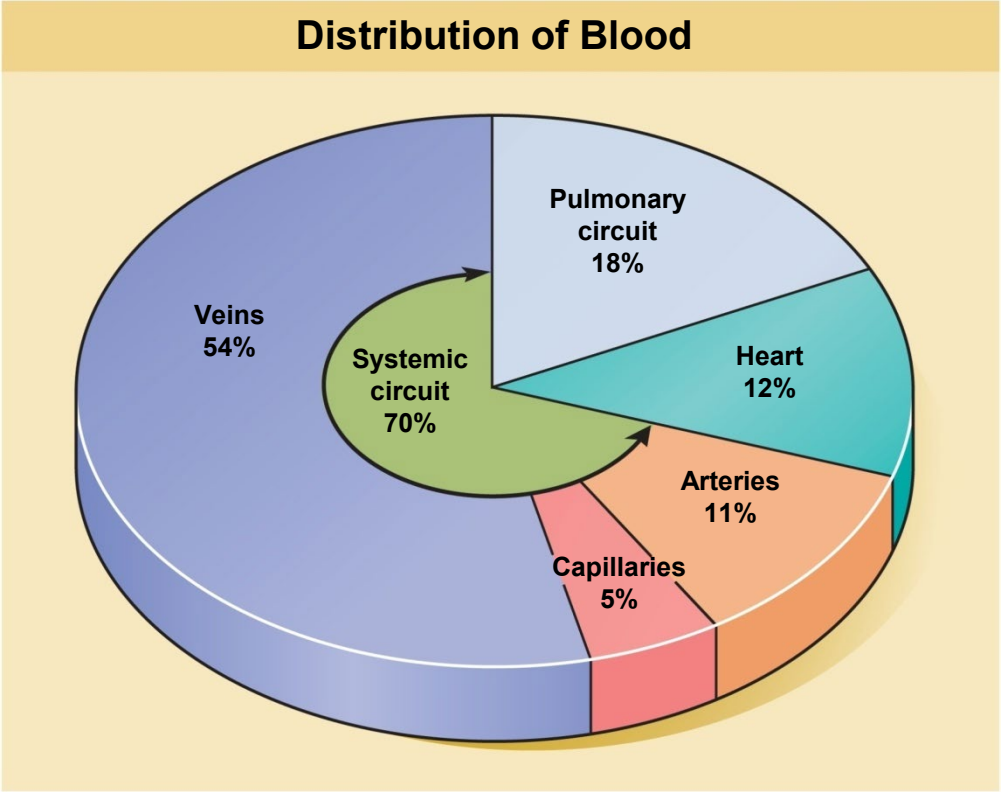
Thinner walls, flaccid, less muscular and elastic tissue

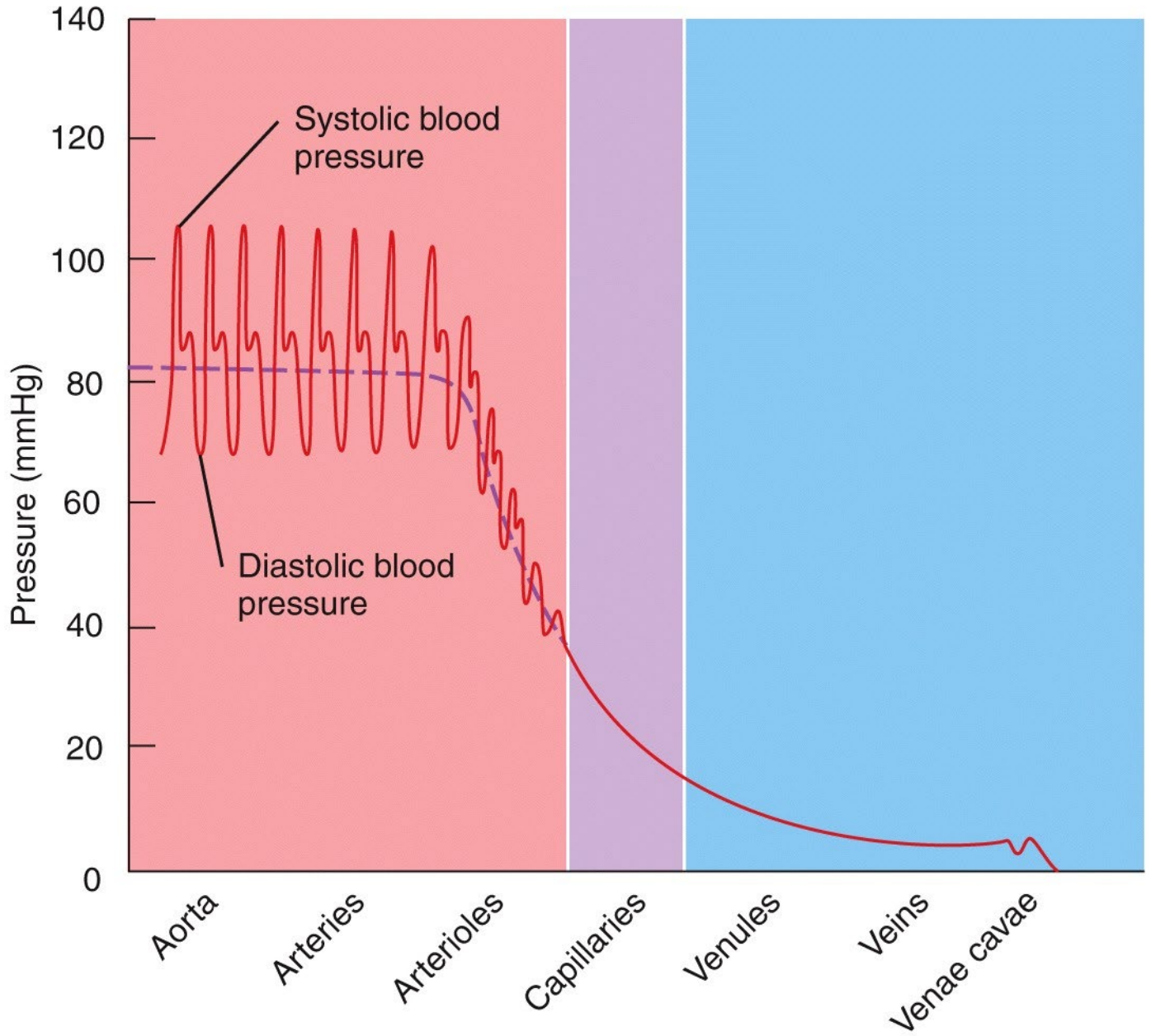
Collapse when empty, expand easily

Have steady blood flow

Merge to form larger veins

Subjected to relatively low blood pressure /// remains 10 mm Hg with little fluctuation




140
120
100
80
60
40
20
0
Pressure (mmHg)
Systolic blood pressure
Diastolic blood pressure
Aorta
Arteries
Arterioles
Capillaries
Venules
Veins
Venae cavae

Venules

Venules – smallest veins, occur just past the capillary bed

Even more porous than capillaries // 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 and Large Veins

Medium veins – up to 10 mm in diameter

Thin tunica media and thick tunica externa

Tunica interna in this area forms **venous valves**

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

Examples /// venae cavae, pulmonary veins, internal jugular veins, and renal veins

Sinuses

Venous sinuses

Veins with extremely thin walls

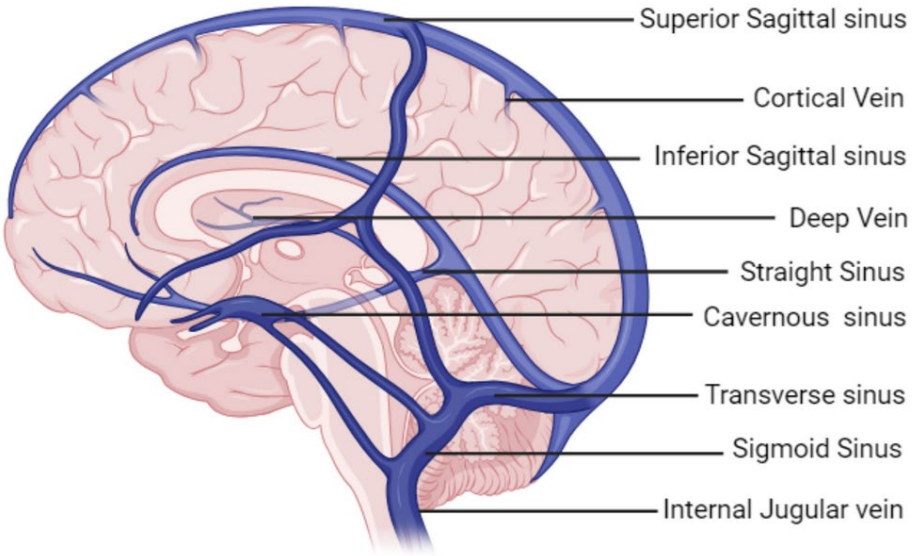
Large lumen, and no smooth muscle

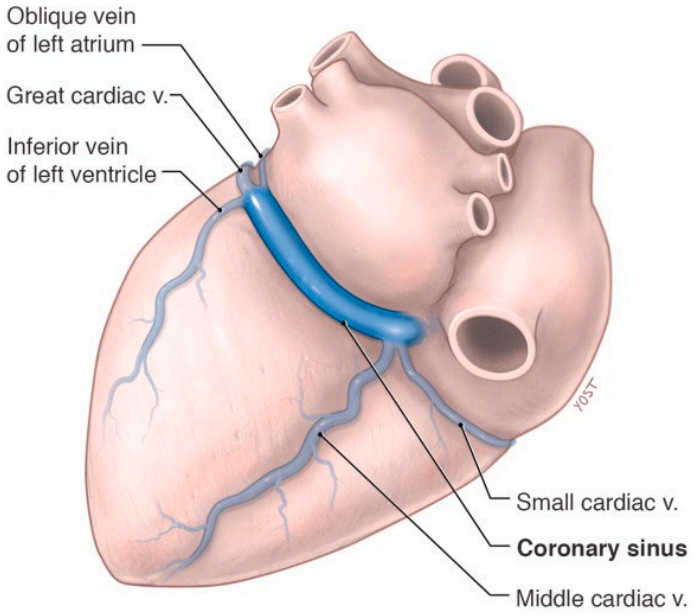
Dural venous sinus in the brain

Coronary sinus in the heart

These vessels are not capable of vasomotion

Function as blood reservoirs





Mechanisms of Venous Return

Venous return – the flow of blood back to the heart occurs at low pressure gradient

blood pressure is the most important force in venous return

7-13 mm Hg venous pressure towards heart

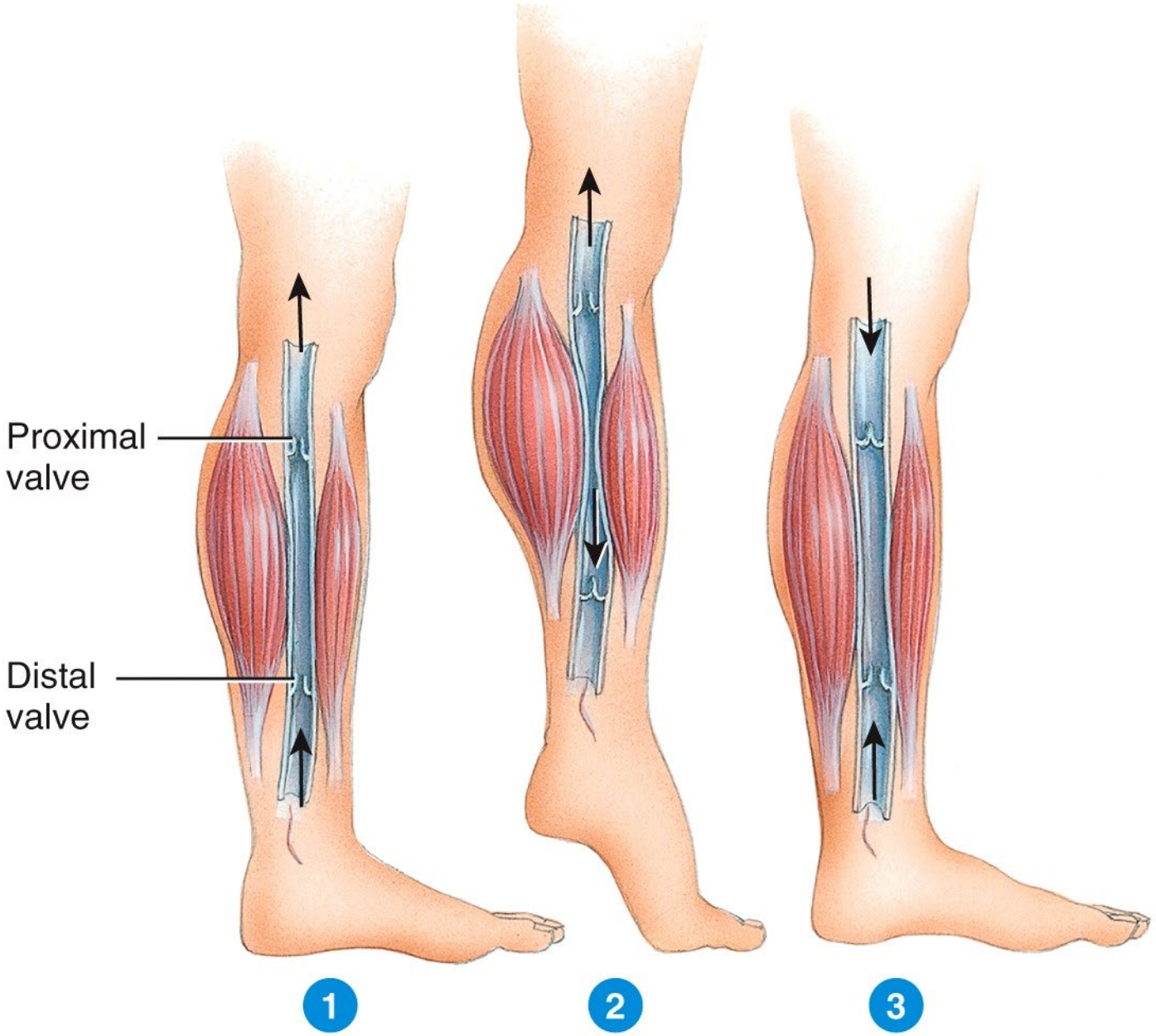
venules (12-18 mm Hg) to **central venous pressure –** point where the venae cavae enter the heart (~5 mm Hg)

Skeletal muscle pump **–** occurs in the limbs

contracting muscle compressed vein between muscles to move blood towards heart

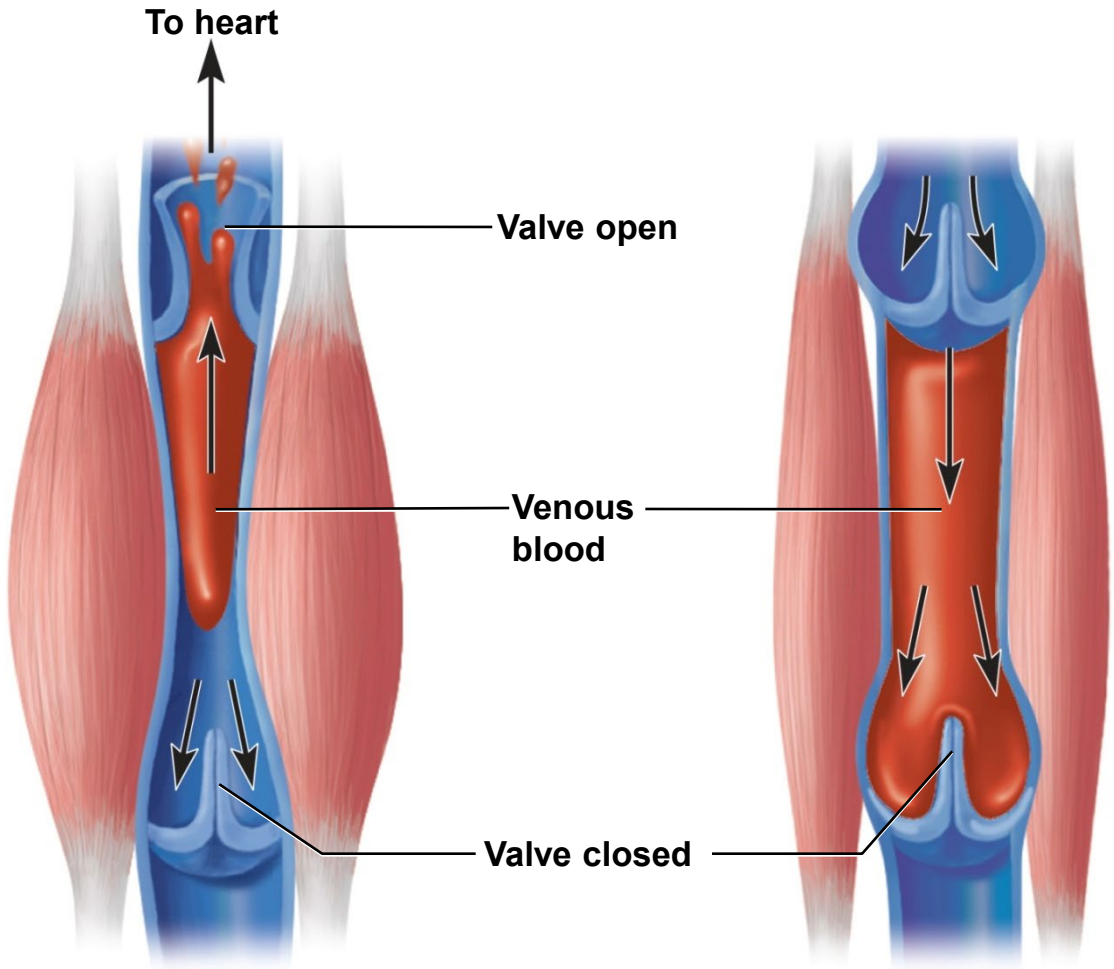
deep veins in legs have one way valves

veins in arm also have valves, but fewer than in legs


Proximal valve
Distal valve
1
2
3

Skeletal Muscle Pump

Propels venous blood back toward the heart



Other Mechanisms of Venous Return

Gravity - drains blood from head and neck

Thoracic (respiratory) pump // as you inhale the 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 - caused by expanding atria

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

Venous pooling occurs with inactivity

venous pressure not great enough to force blood upward

with prolonged standing, may be low enough to cause dizziness or fainting

prevented by tensing leg muscles to activate skeletal muscle pump

jet pilots wear pressure suits

Varicose Veins

Blood pools in the lower legs in people who stand for long periods and causes stretching of the veins

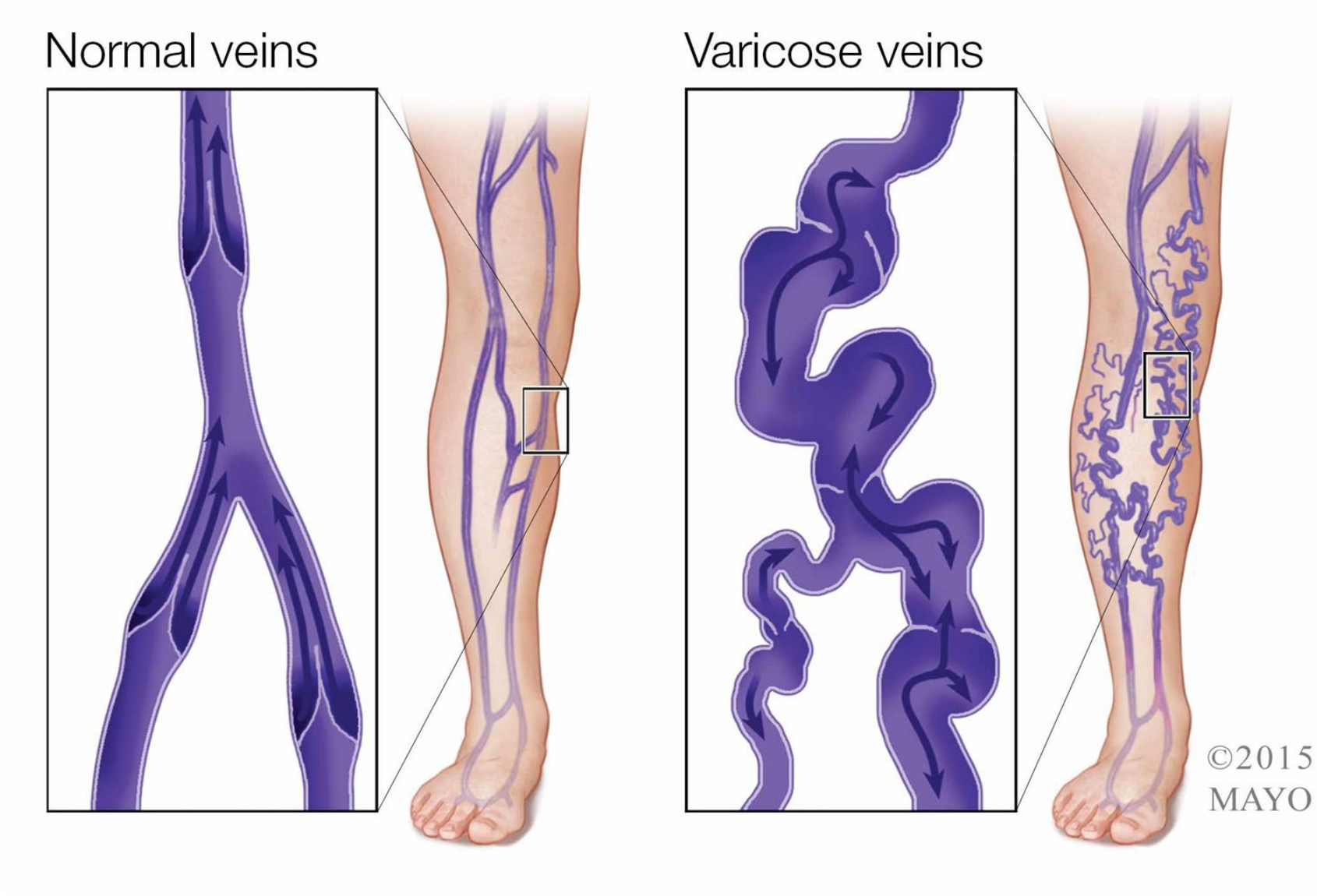
Cusps of the valves pull apart in enlarged superficial veins further weakening vessels

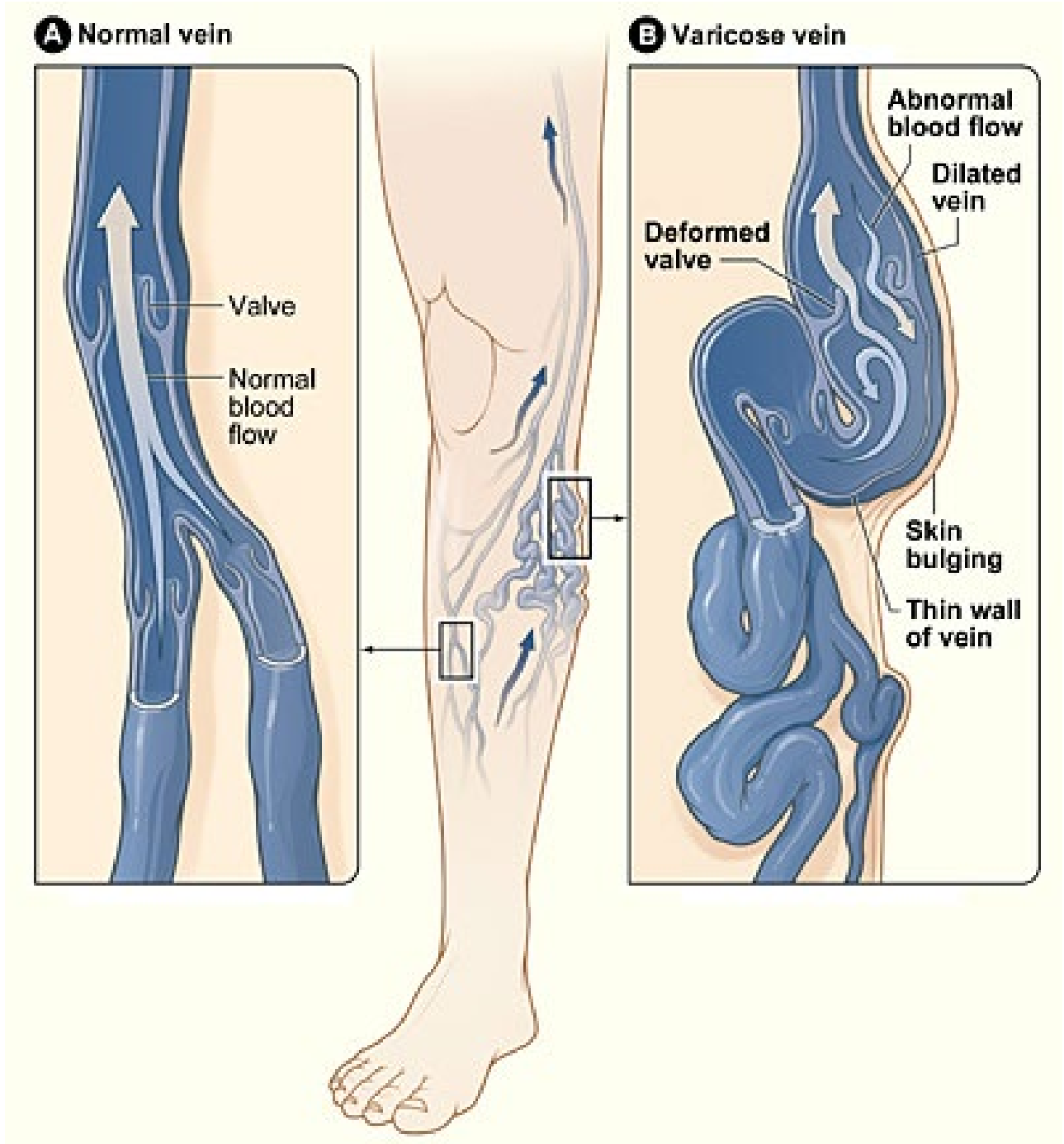
Blood backflows and further distends the vessels, their walls grow weak and develop into varicose veins

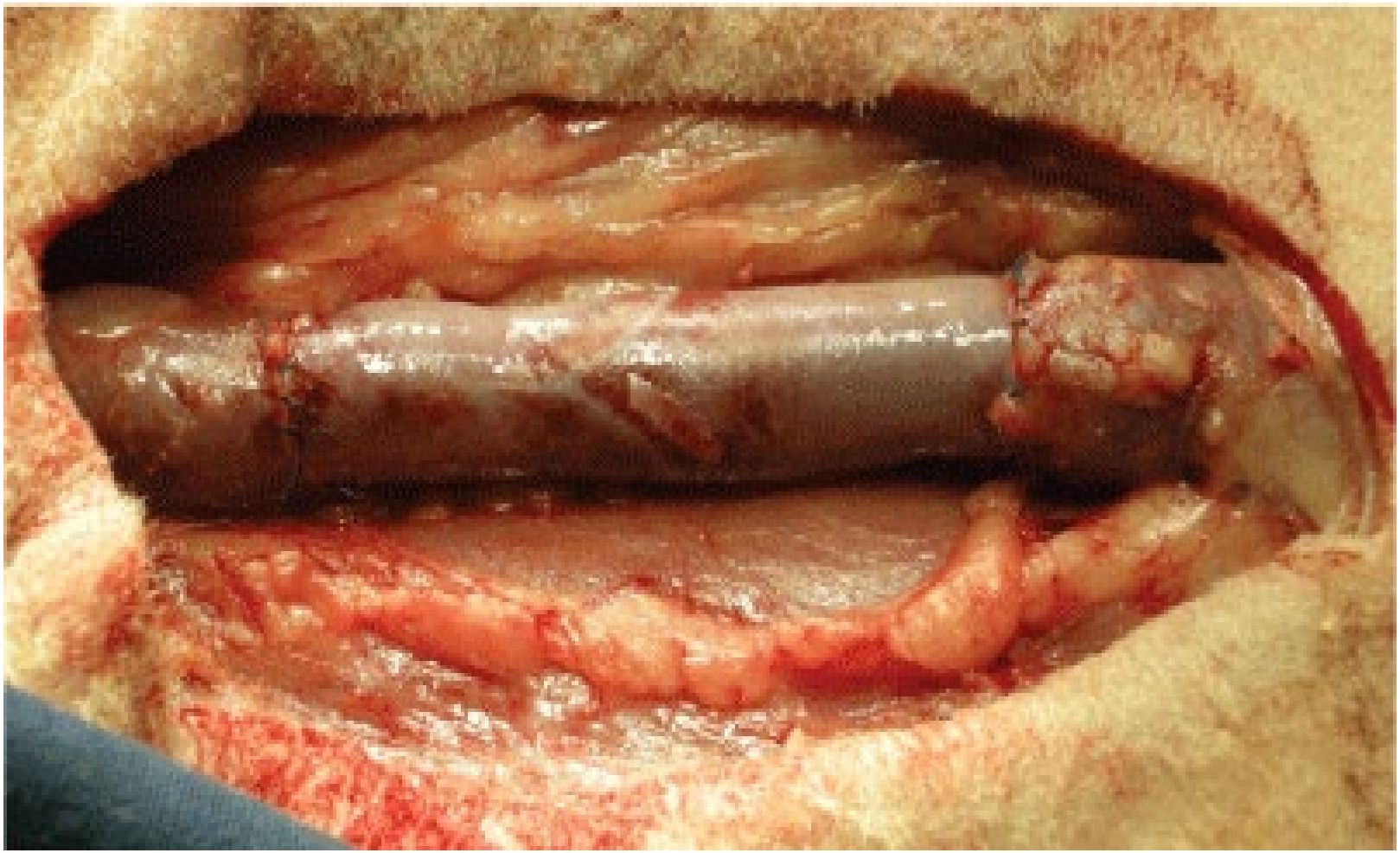
Hereditary weakness, obesity, and pregnancy also promote problems

Hemorrhoids are varicose veins of the anal canal

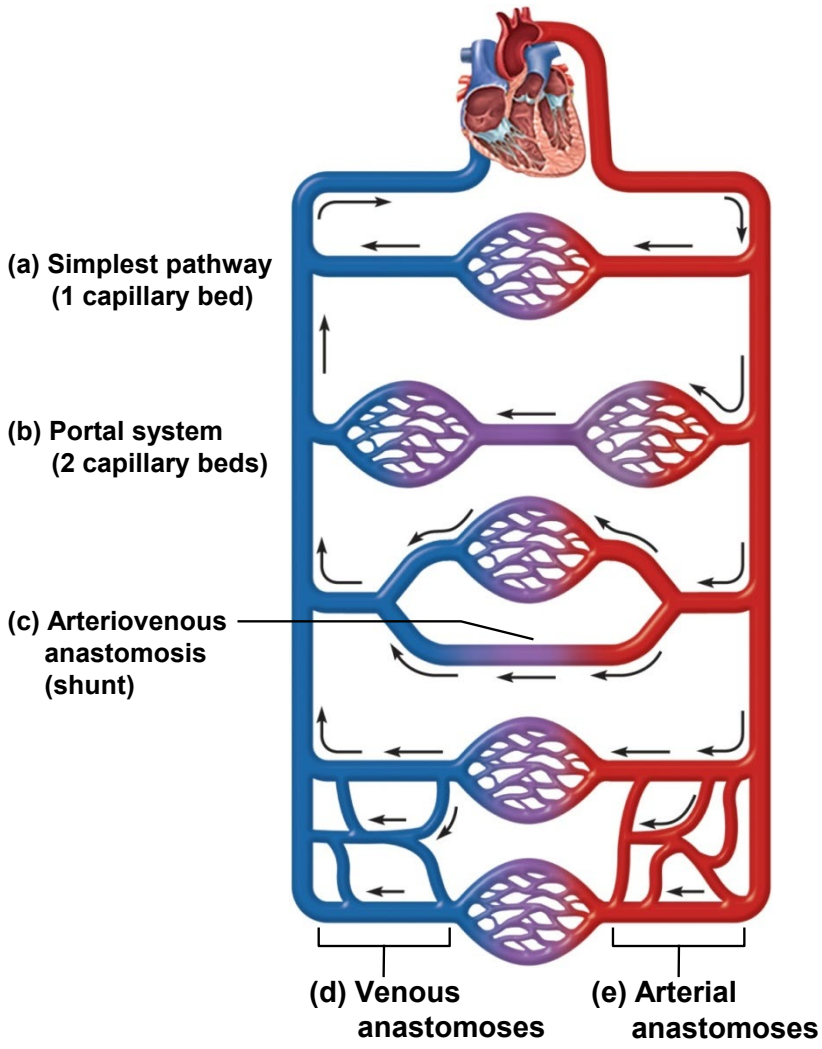
Normal and Varicose Veins




A Normal vein
Valve
Normal blood flow
B Varicose vein
Abnormal blood flow
Dilated vein
Deformed valve
Skin bulging
Thin wall of vein



Circulatory Routes



Most common route = heart → arteries → arterioles → capillaries → venules → veins

In most cases, 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 capillary** networks before returning to heart

artery → capillary → portal vein → capillary → vein

Three locations:

1) between hypothalamus and anterior pituitary
2) kidneys (peritubular capillaries)
3) between intestines and liver

Anastomosis – the point where two blood vessels merge

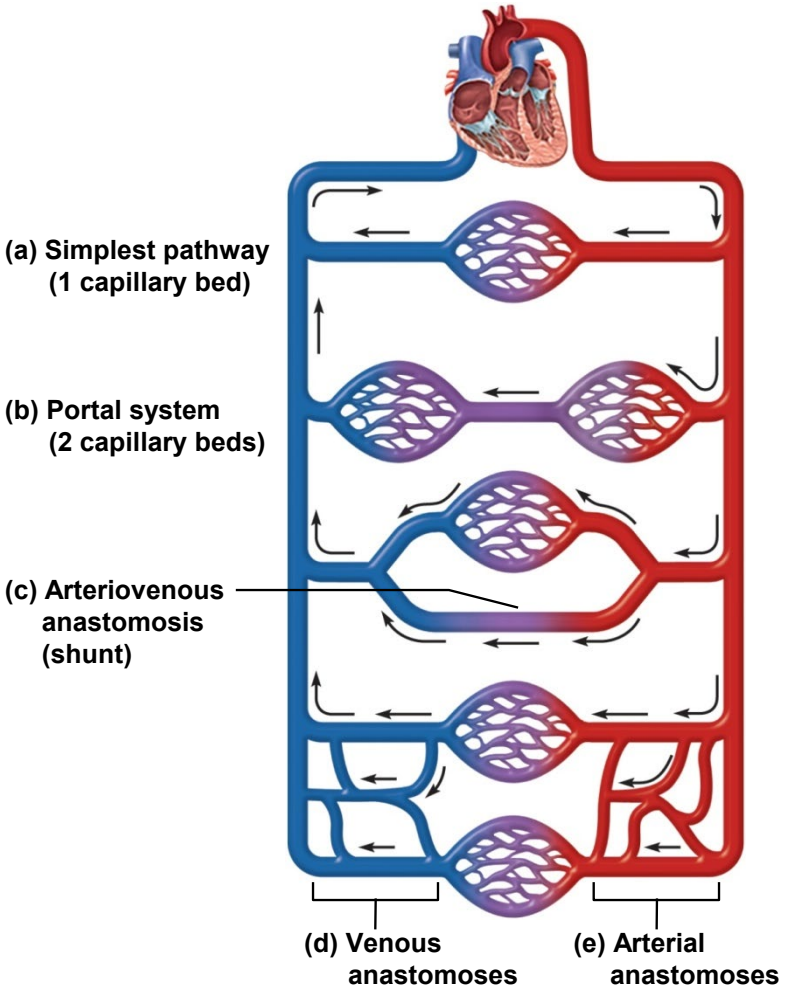
Arteriovenous anastomosis (shunt) // artery flows directly into vein bypassing capillaries

Venous anastomosis

– most common
– one vein empties directly into another
– vein blockage less serious
– arterial blockage more dangerous

Arterial anastomosis

– two arteries merge
– provides collateral (alternative) routes
– coronary circulation and around joints



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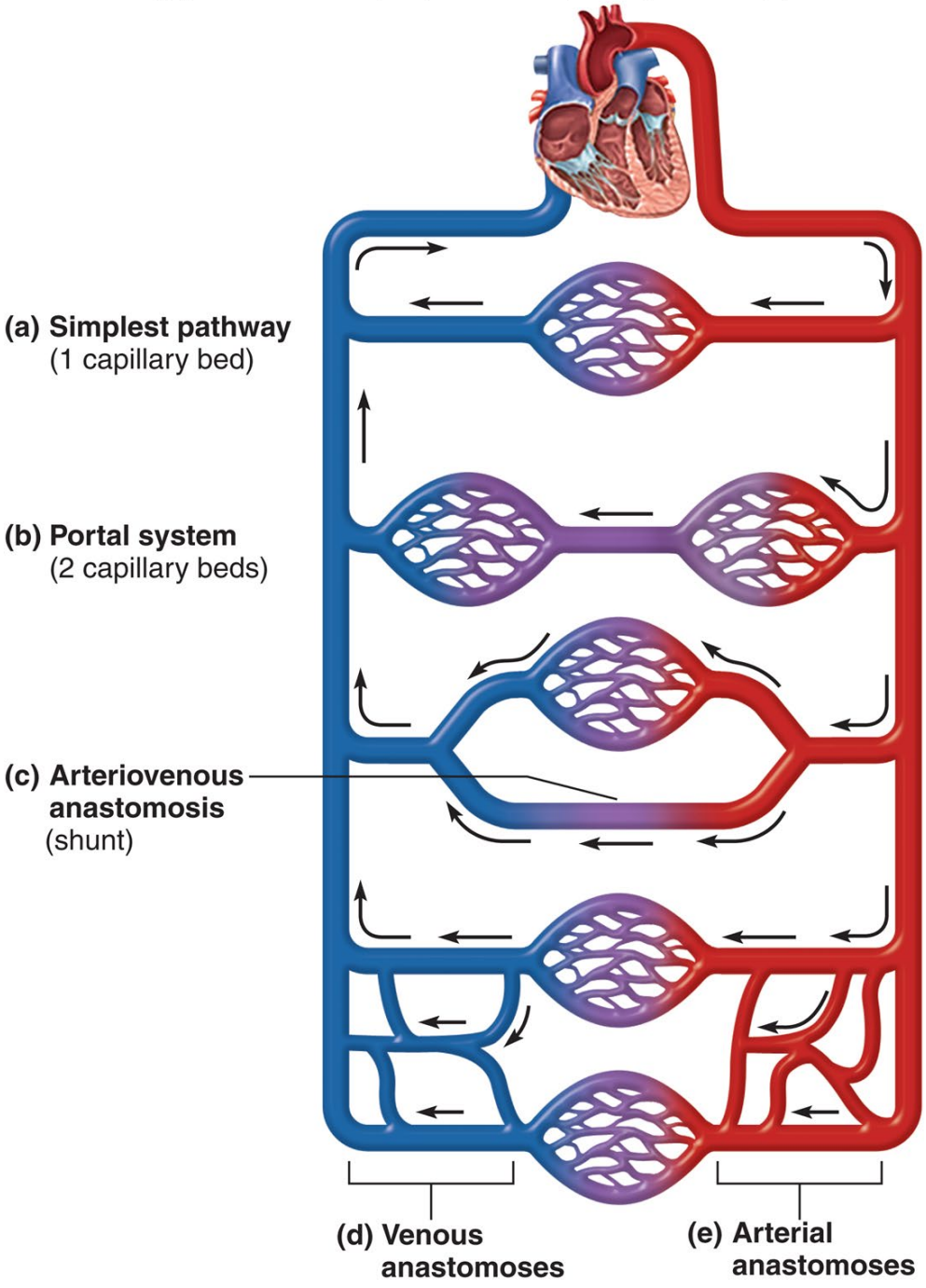


Aneurysm

Weak point in a wall of an artery

Forms a thin-walled, bulging sac that pulsates with each heartbeat and may rupture at any time

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

Most common sites // abdominal aorta, renal arteries, and arterial circle at the base of the brain

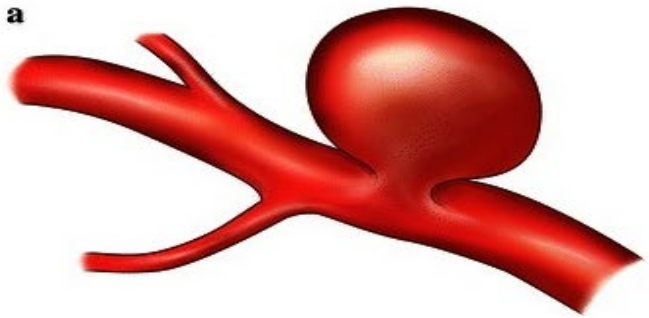
Can cause pain by putting pressure on other structures

Can rupture causing hemorrhage

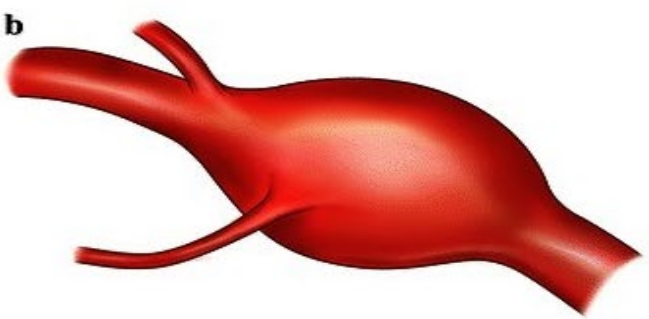
Result from congenital weakness of the blood vessels or result of trauma or bacterial infections such as syphilis

Most common cause is atherosclerosis and hypertension

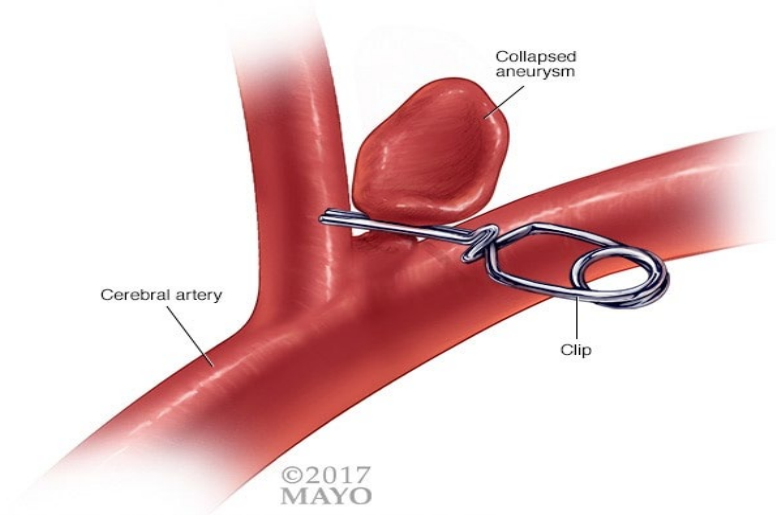
Aneurysm



Saccular Aneurysm



Fusiform Aneurysm



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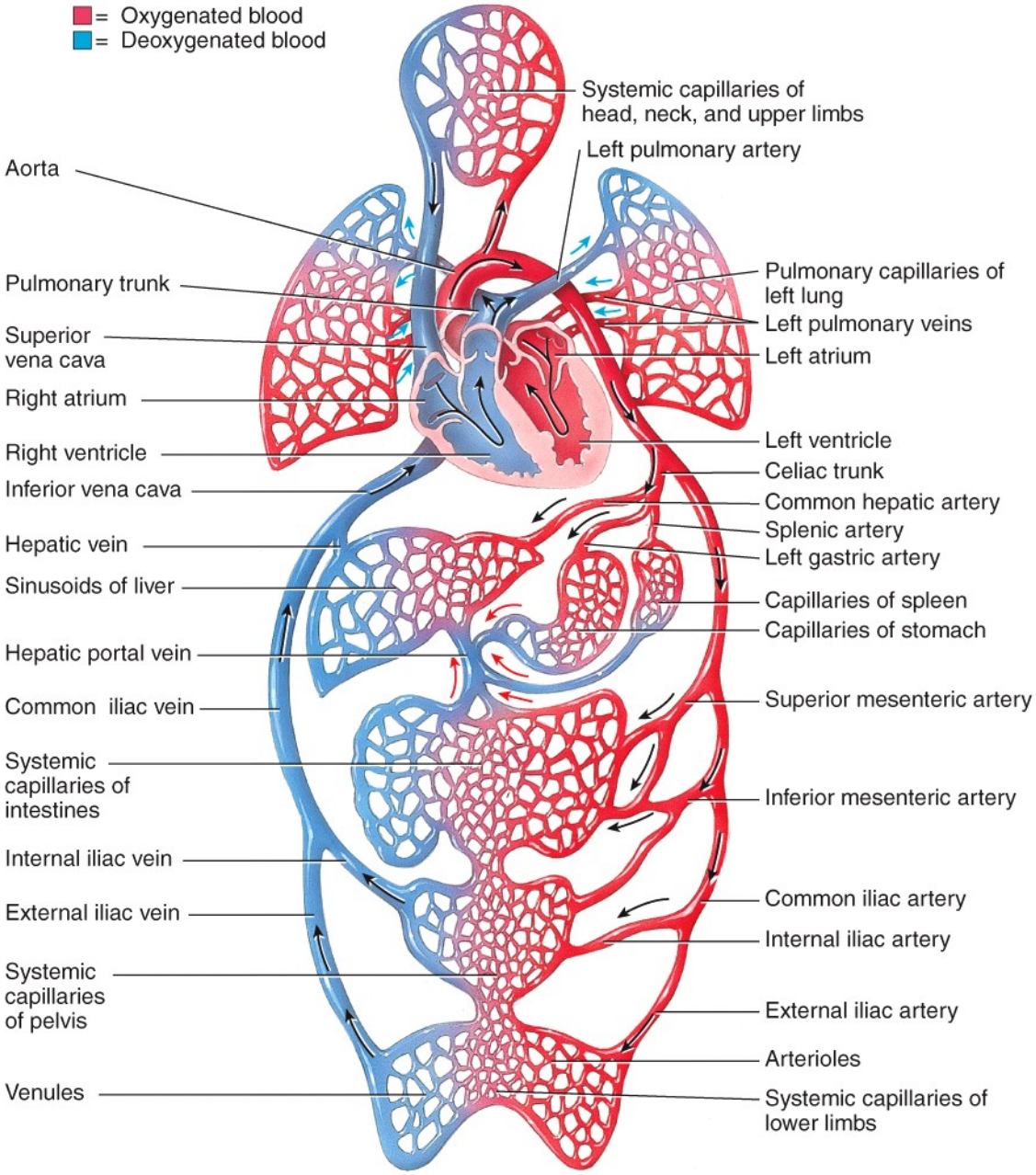
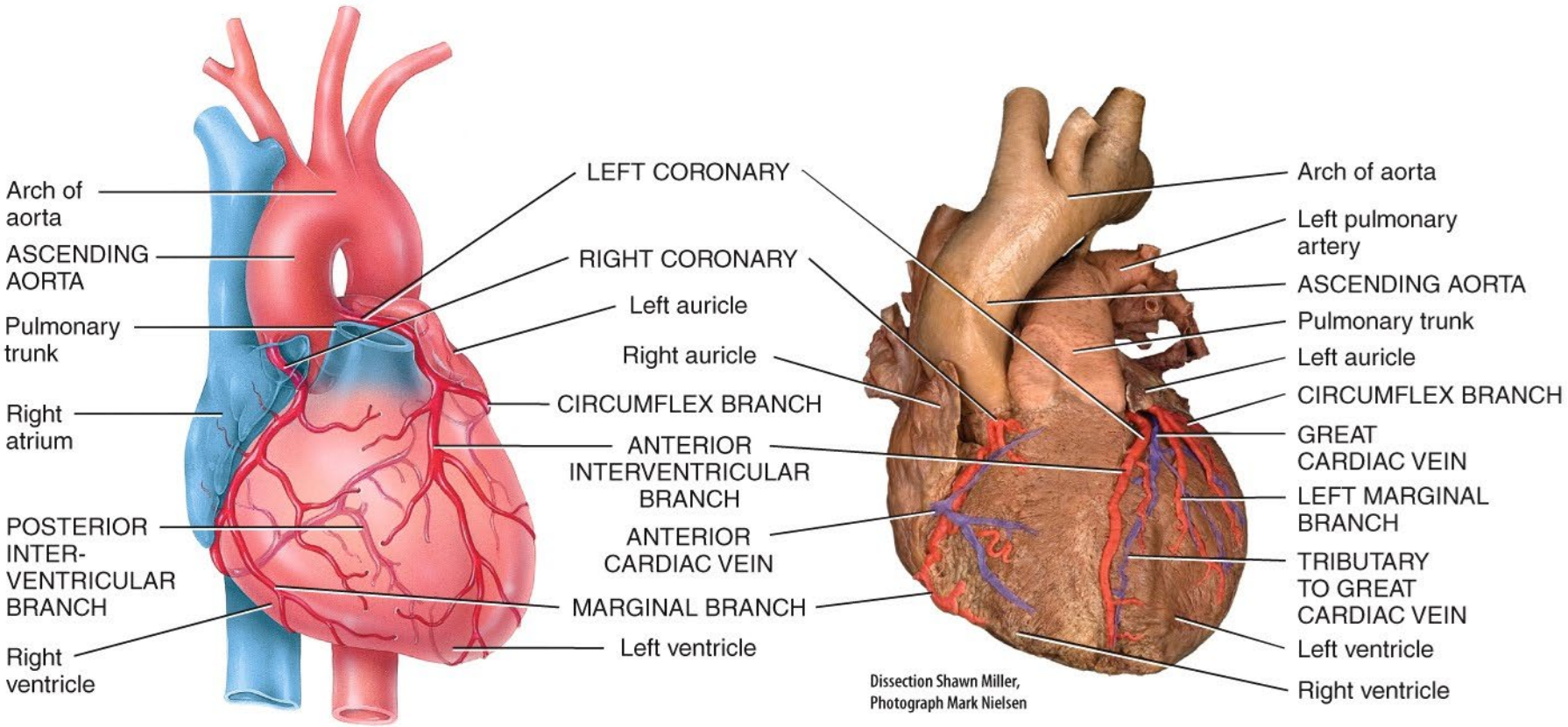
Lecture Objectives Stop

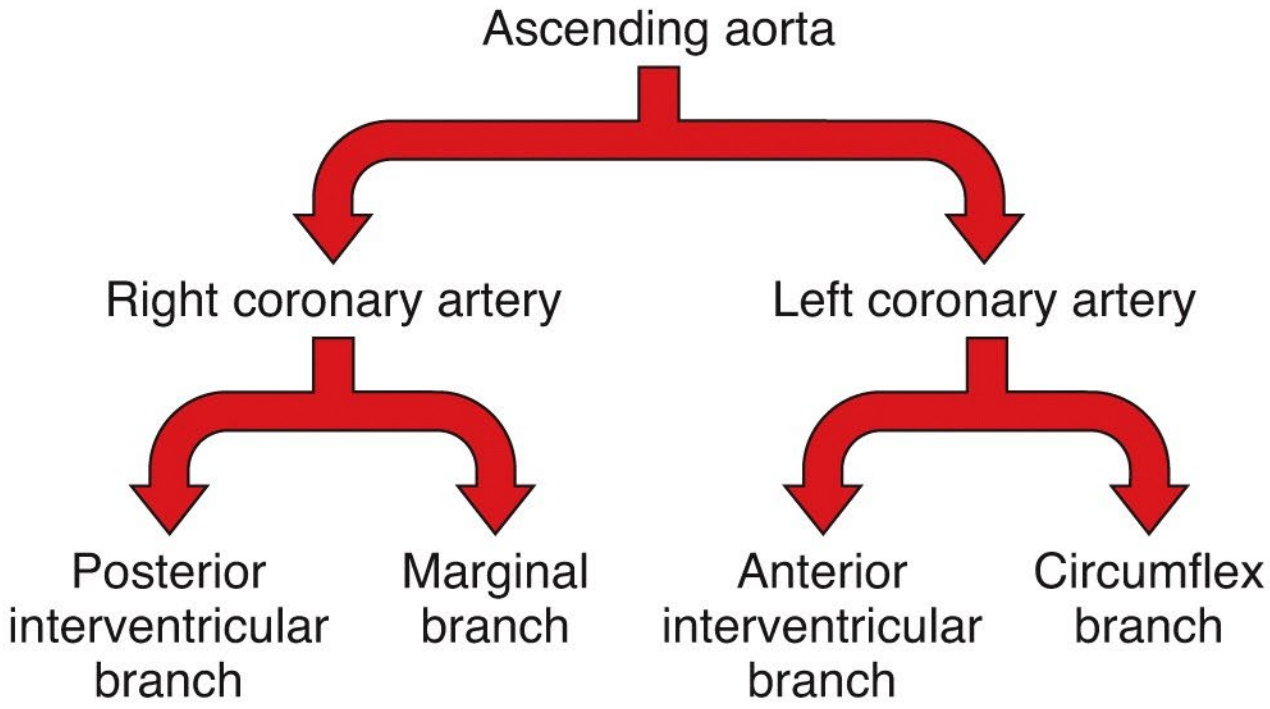
Review of Blood Vessels

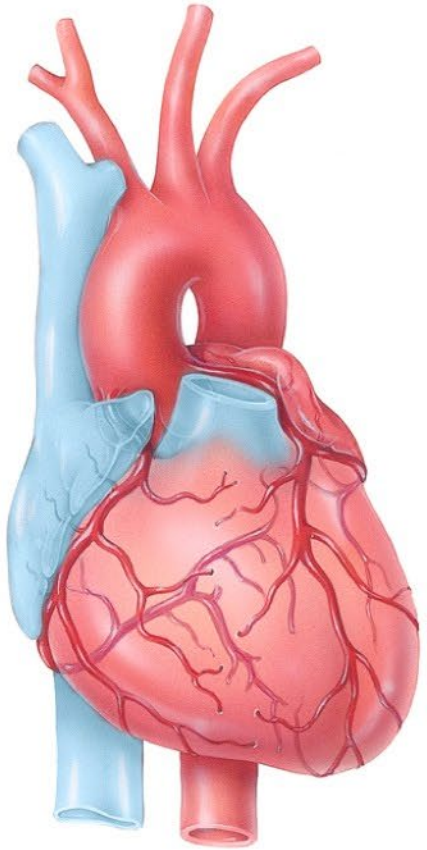

= Oxygenated blood
= Deoxygenated blood
Systemic capillaries of head, neck, and upper limbs
Left pulmonary artery
Aorta
Pulmonary trunk
Superior vena cava
Right atrium
Right ventricle
Inferior vena cava
Hepatic vein
Sinusoids of liver
Hepatic portal vein
Common iliac vein
Systemic capillaries of intestines
Internal iliac vein
External iliac vein
Systemic capillaries of pelvis
Venules
Pulmonary capillaries of left lung
Left pulmonary veins
Left atrium
Left ventricle
Celiac trunk
Common hepatic artery
Splenic artery
Left gastric artery
Capillaries of spleen
Capillaries of stomach
Superior mesenteric artery
Inferior mesenteric artery
Common iliac artery
Internal iliac artery
External iliac artery
Arterioles
Systemic capillaries of lower limbs

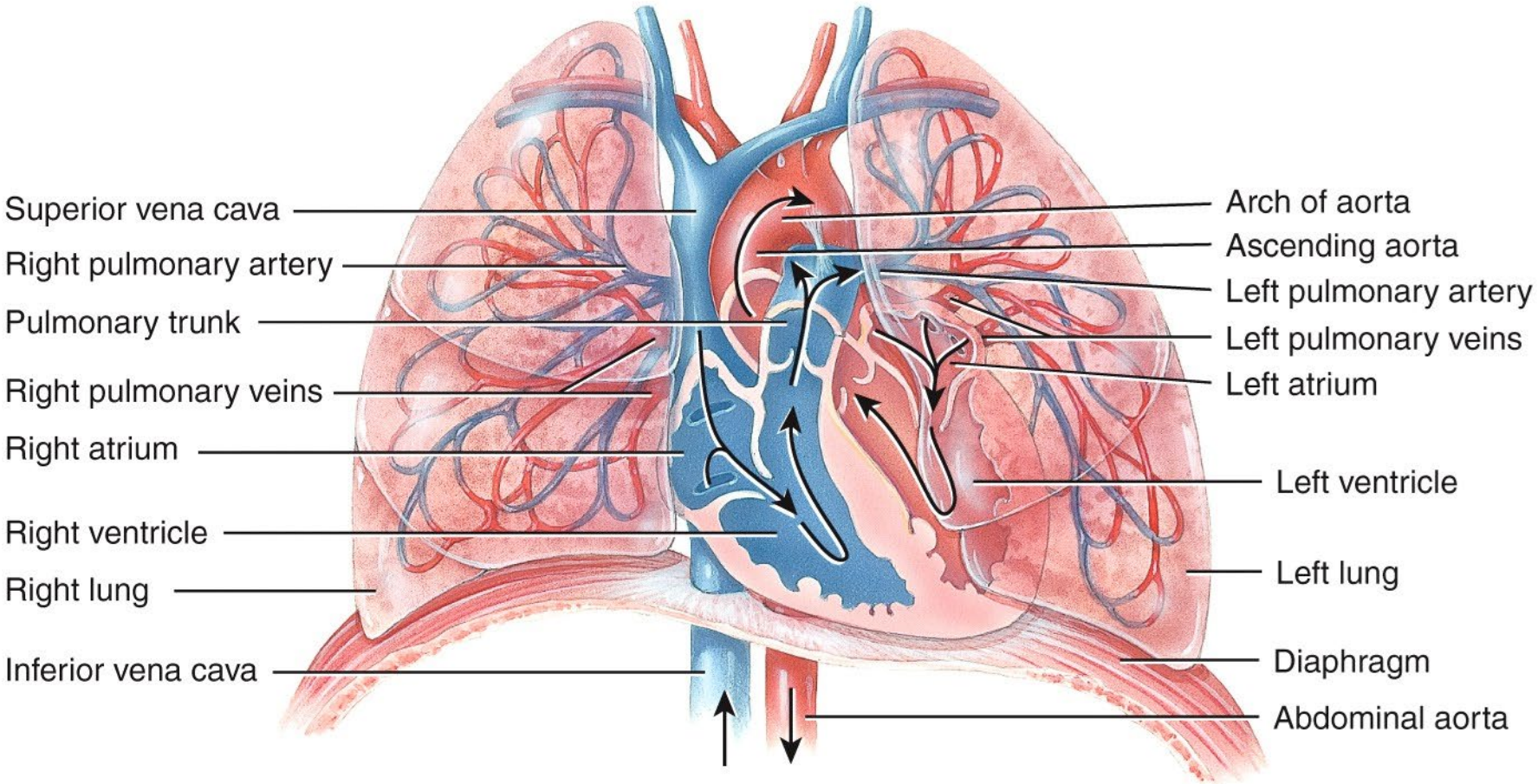


Anterior view of coronary arteries and their major branches

SCHEME OF DISTRIBUTION





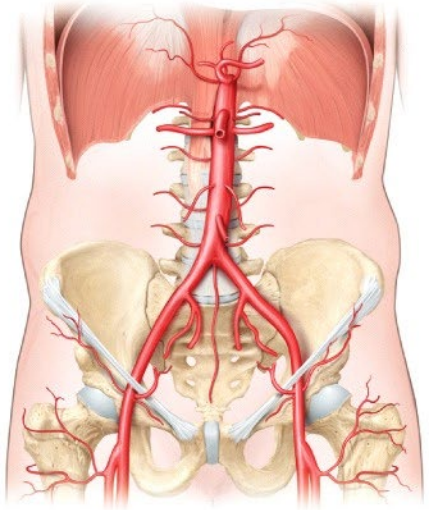


(a) Anterior view

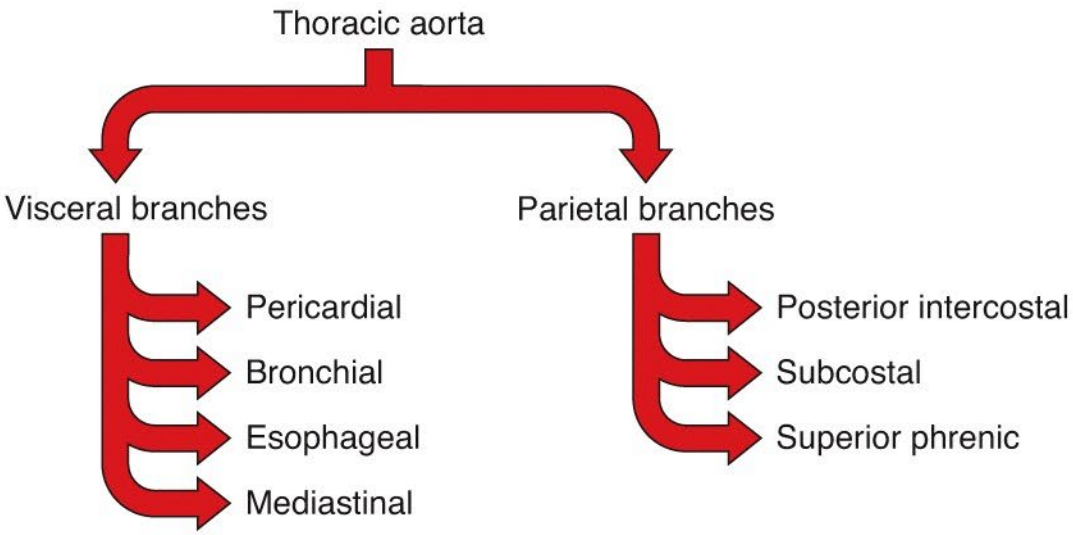
SCHEME OF DISTRIBUTION

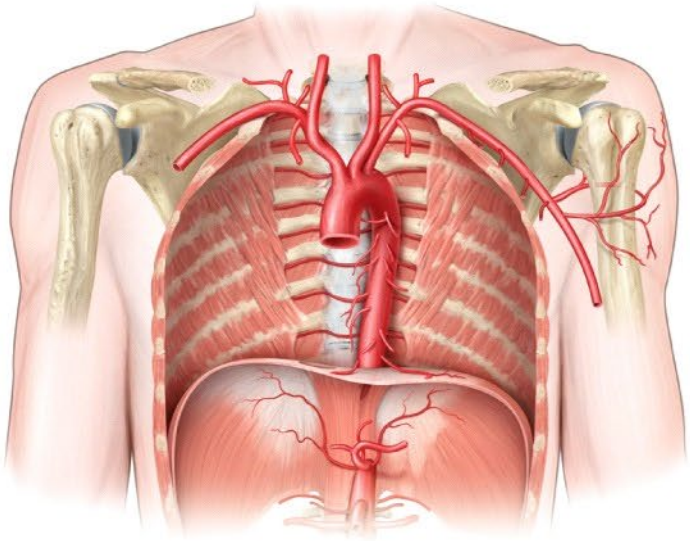
Abdominal aorta

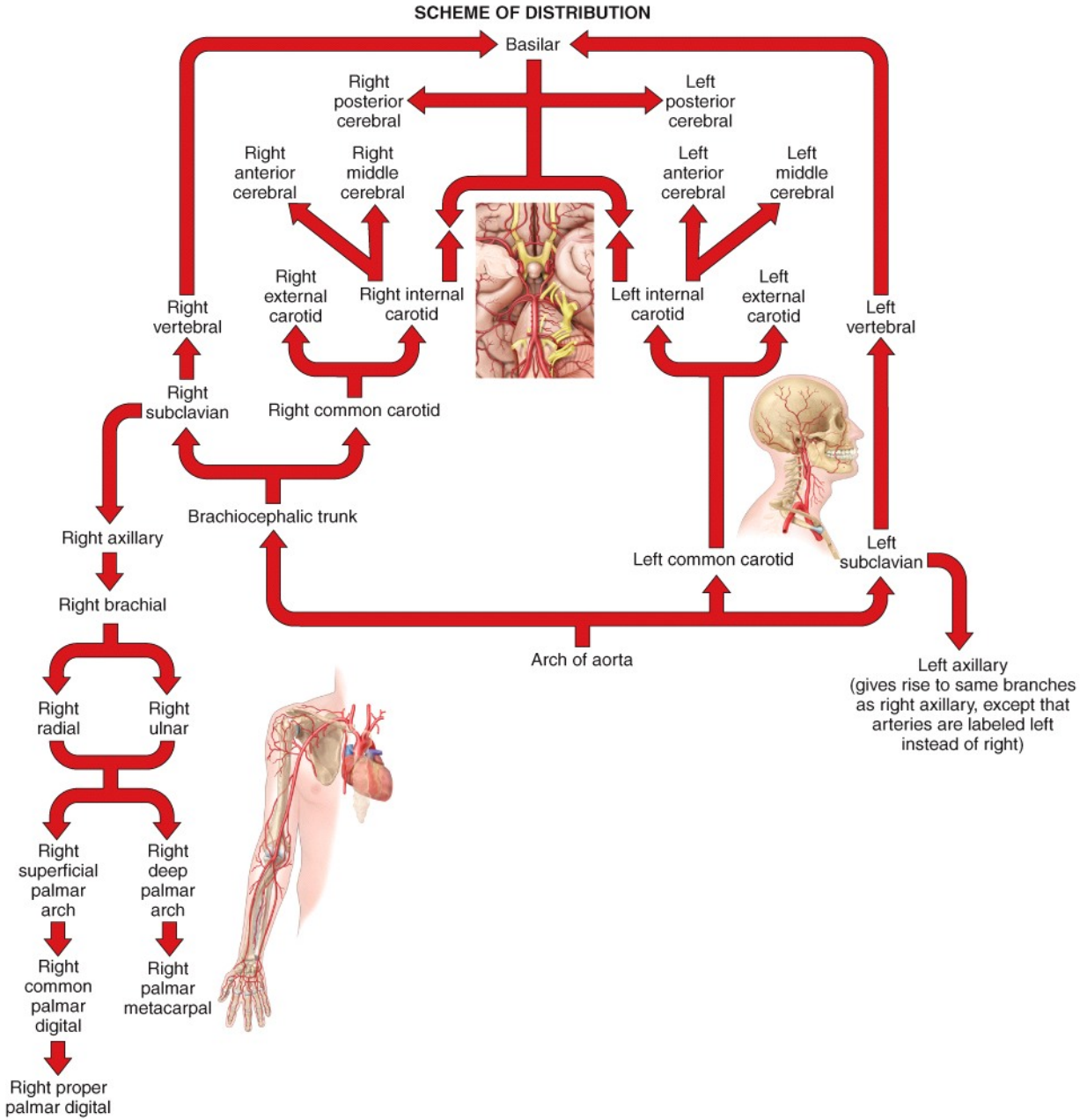
- Visceral branches
  - 1. Celiac trunk
    - Left gastric
    - Splenic
    - Common hepatic
      - Hepatic artery proper
      - Right gastric
      - Gastro-duodenal
    - Pancreatic
    - Left Gastro-omental
    - Short gastric
  - 2. Superior mesenteric
    - Inferior pancreatico-duodenal
    - Jejunal
    - Ileocolic
    - Right colic
    - Middle colic
  - 3. Suprarenal
  - 4. Renal
  - 5. Gonadal (testicular or ovarian)
  - 6. Inferior mesenteric
    - Left colic
    - Sigmoid
    - Superior rectal
- Parietal branches
  - 1. Inferior phrenic
  - 2. Lumbar
  - 3. Median sacral



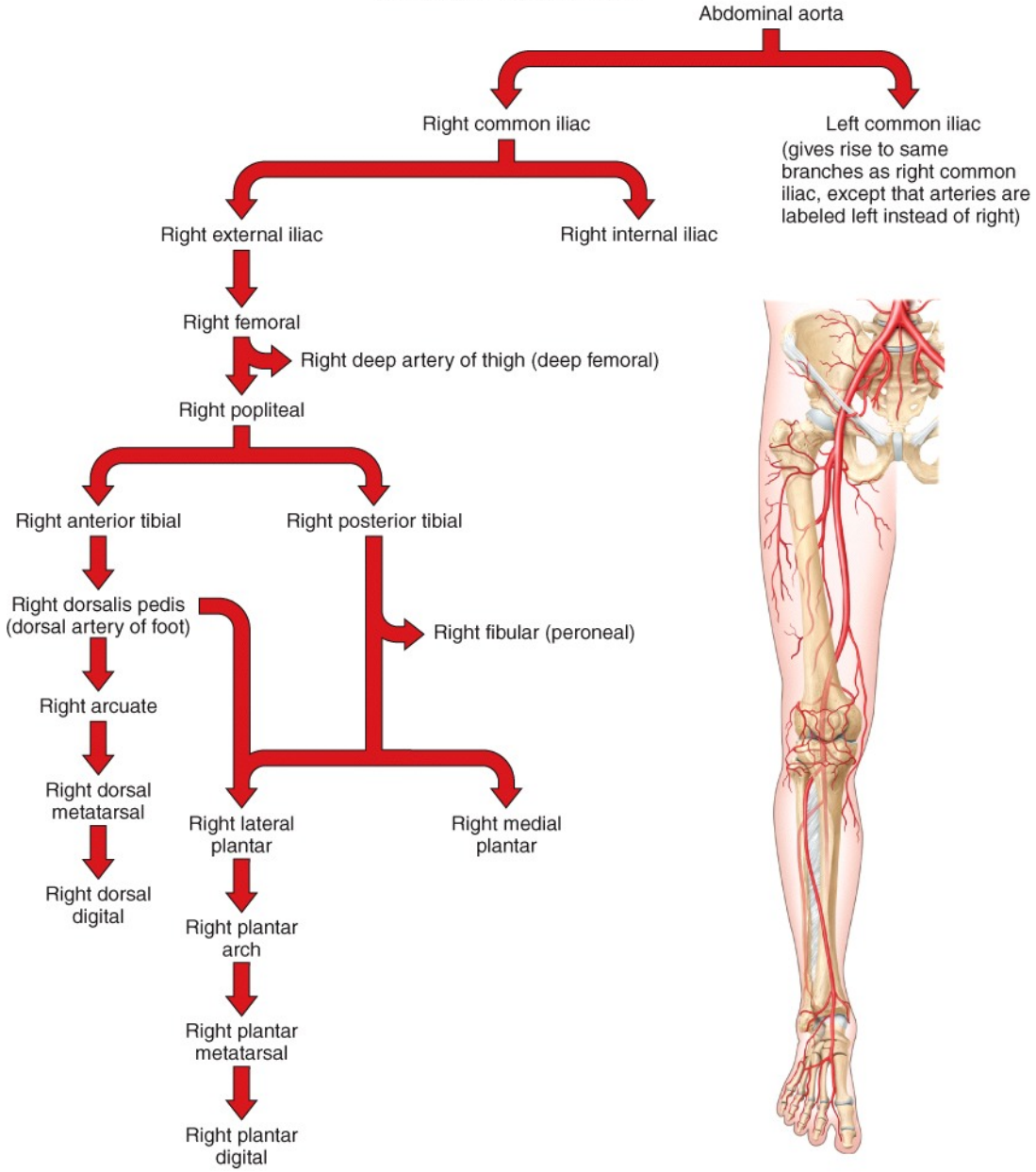
SCHEME OF DISTRIBUTION

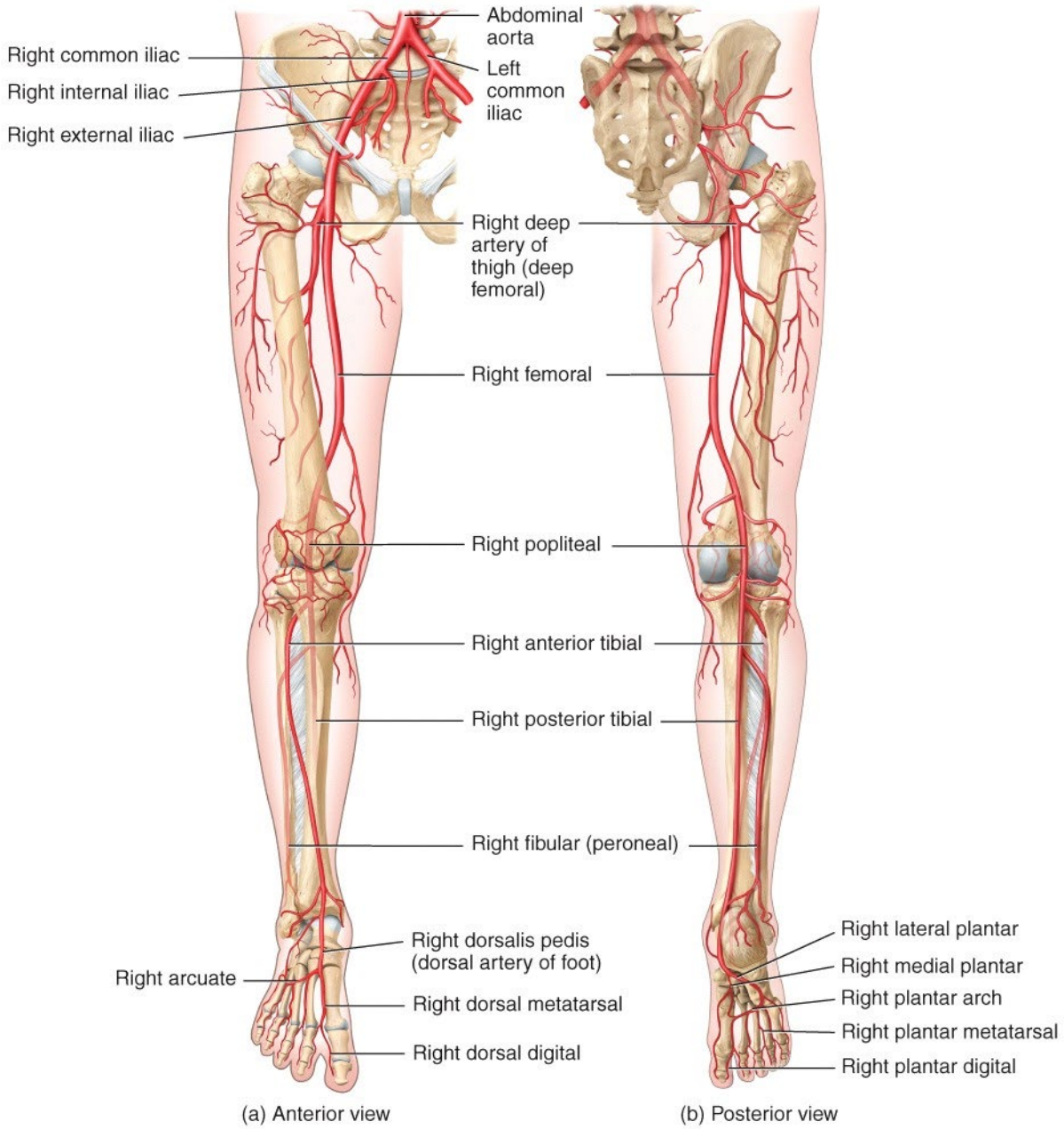


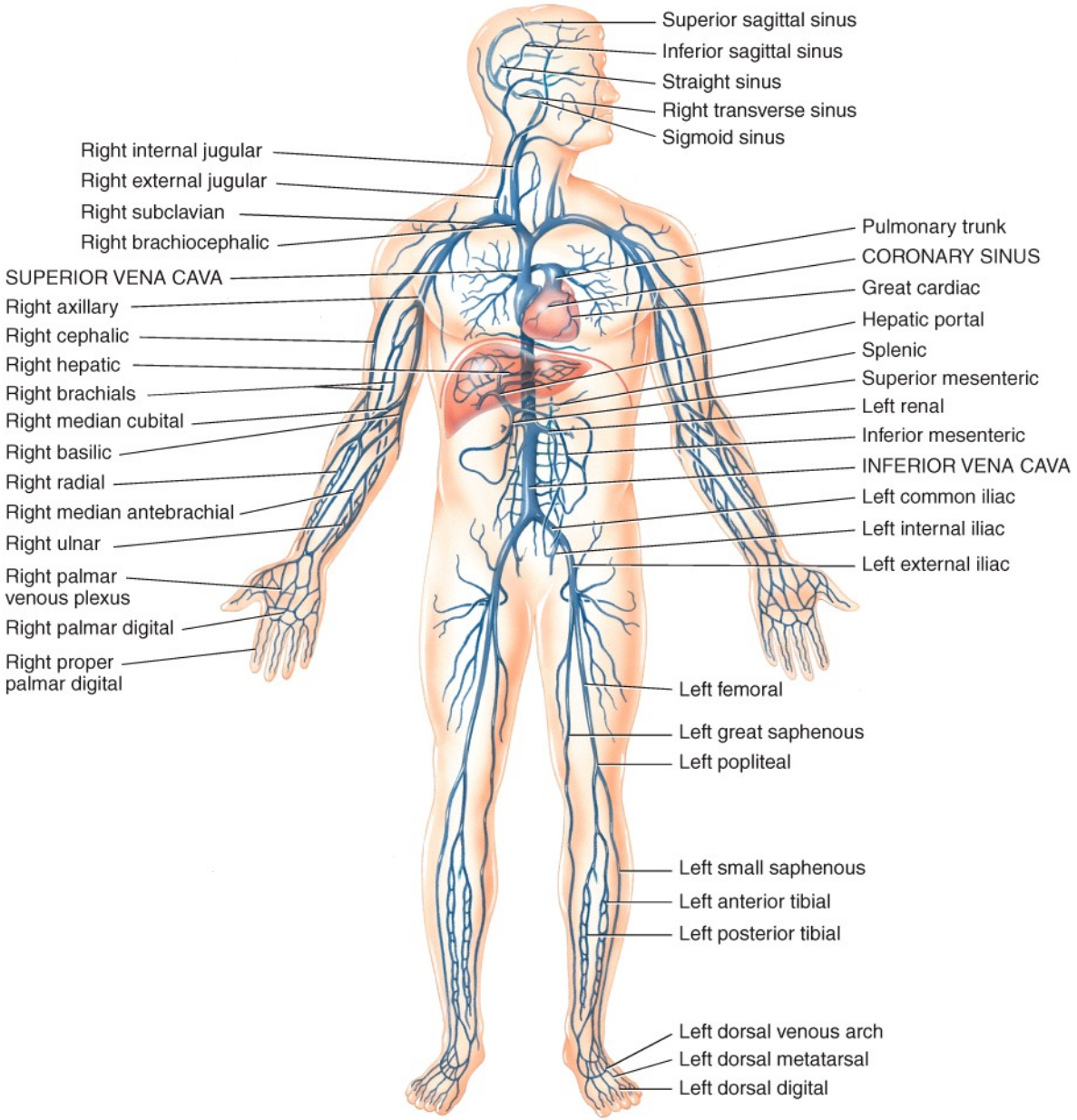



SCHEME OF DISTRIBUTION
Basilar
Right posterior cerebral
Left posterior cerebral
Right anterior cerebral
Right middle cerebral
Left anterior cerebral
Left middle cerebral
Right external carotid
Right internal carotid
Left internal carotid
Left external carotid
Right vertebral
Left vertebral
Right subclavian
Right common carotid
Brachiocephalic trunk
Right axillary
Left common carotid
Left subclavian
Right brachial
Arch of aorta
Left axillary
(gives rise to same branches as right axillary, except that arteries are labeled left instead of right)
Right radial
Right ulnar
Right superficial palmar arch
Right deep palmar arch
Right common palmar digital
Right palmar metacarpal
Right proper palmar digital

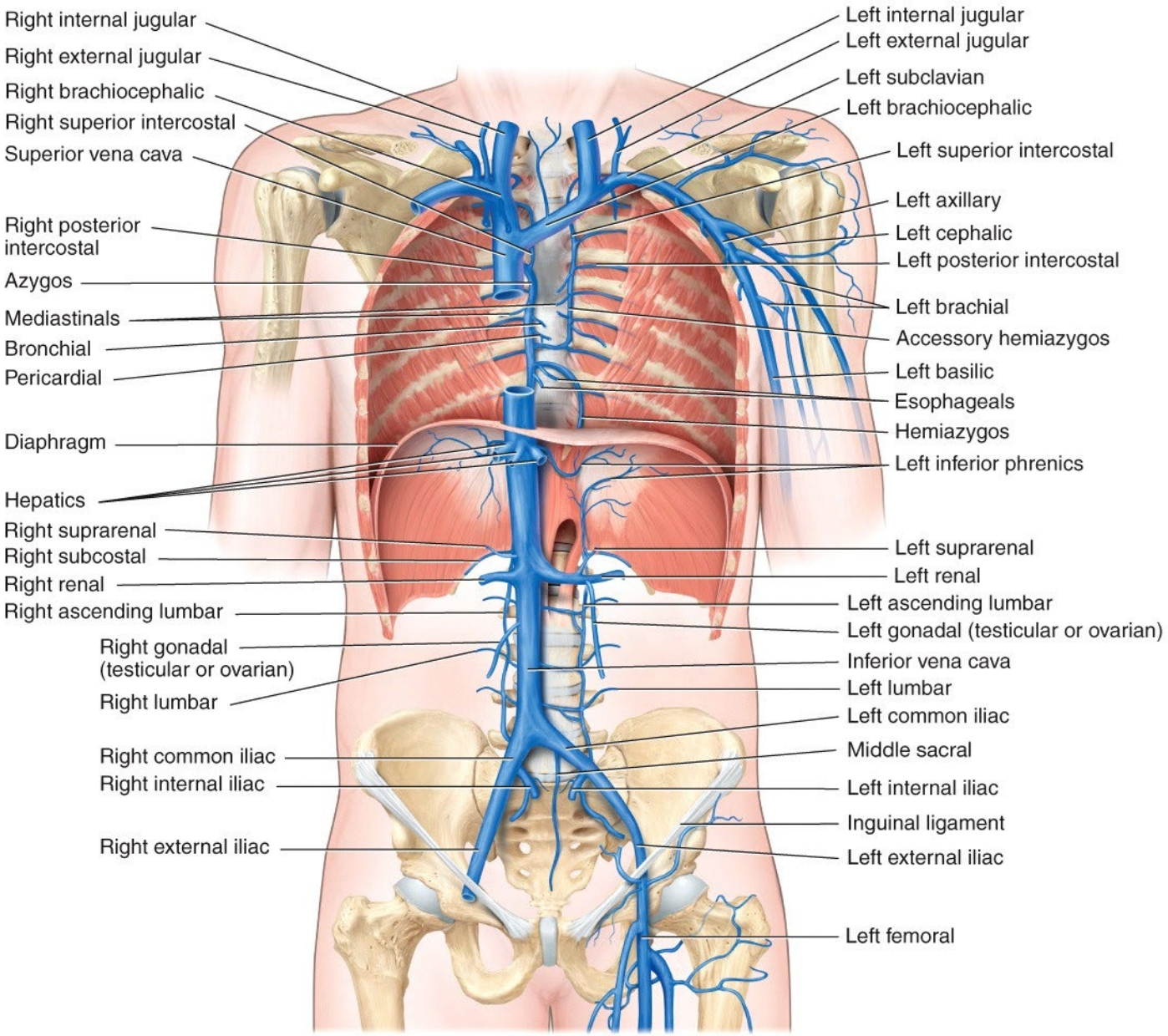
SCHEME OF DISTRIBUTION



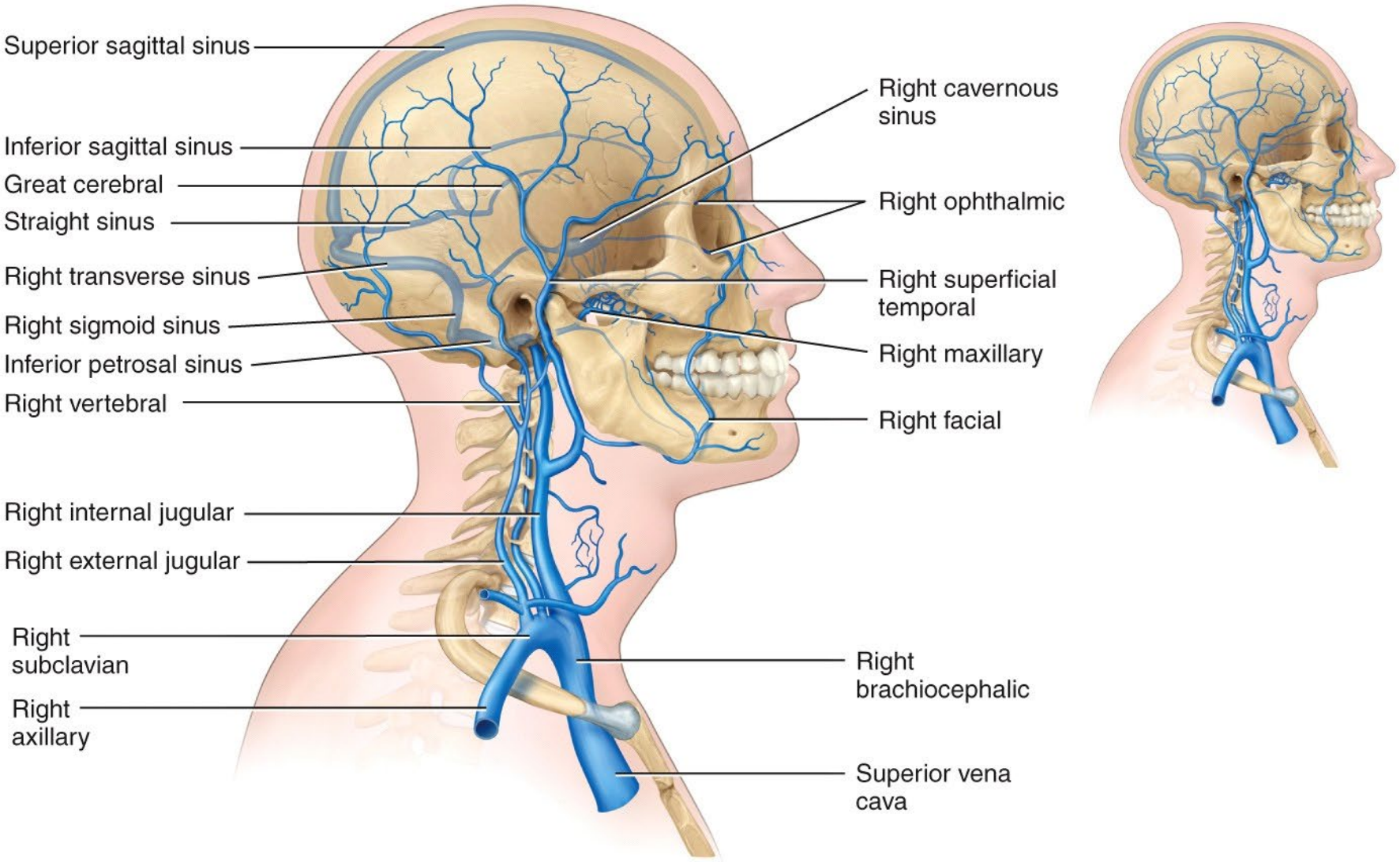

Abdominal aorta
Right common iliac
Left common iliac
Right internal iliac
Right external iliac
Right deep artery of thigh (deep femoral)
Right femoral
Right popliteal
Right anterior tibial
Right posterior tibial
Right fibular (peroneal)
Right dorsalis pedis (dorsal artery of foot)
Right arcuate
Right dorsal metatarsal
Right dorsal digital
Right lateral plantar
Right medial plantar
Right plantar arch
Right plantar metatarsal
Right plantar digital
(a) Anterior view
(b) Posterior view



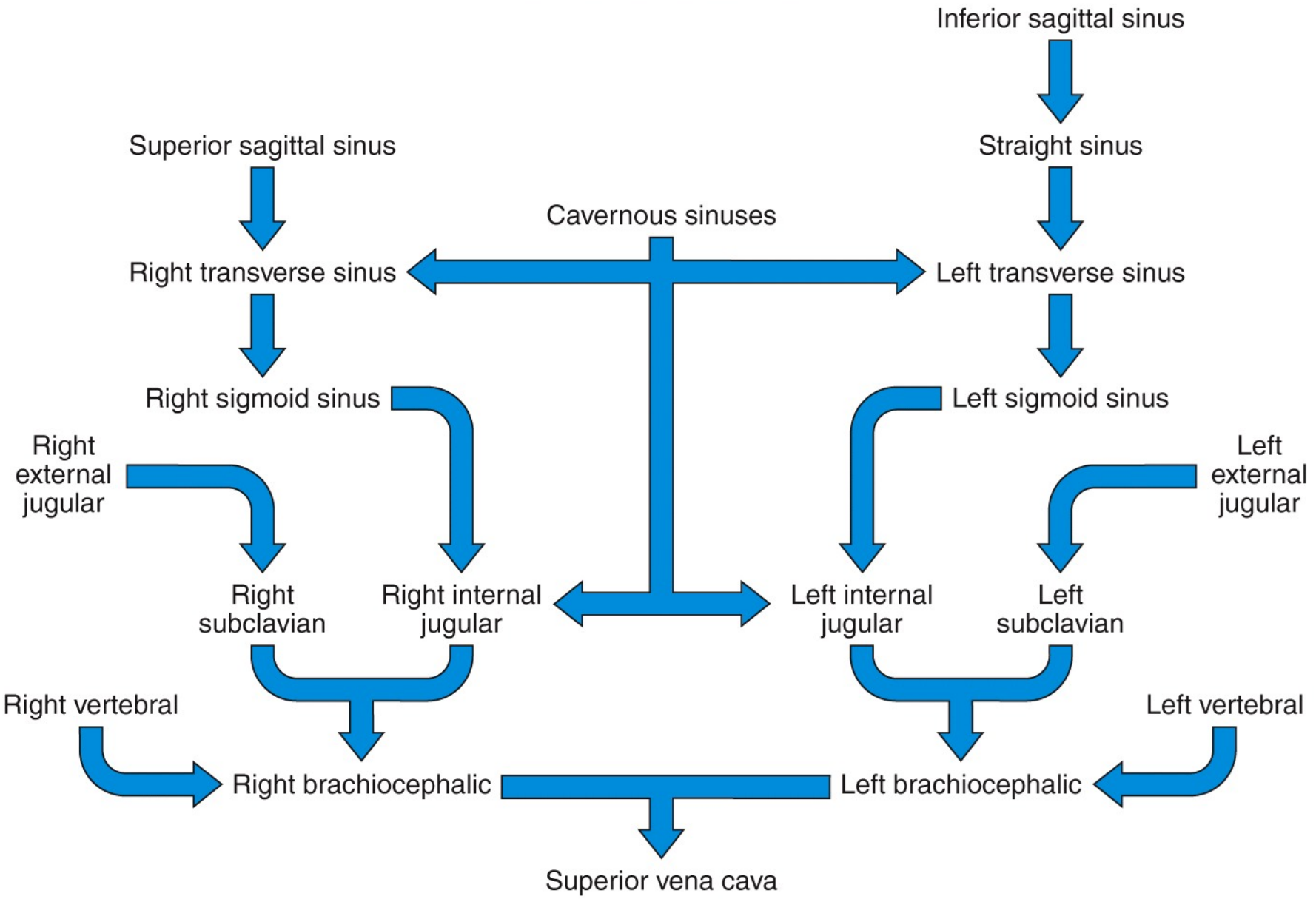
Overall anterior view of the principal veins



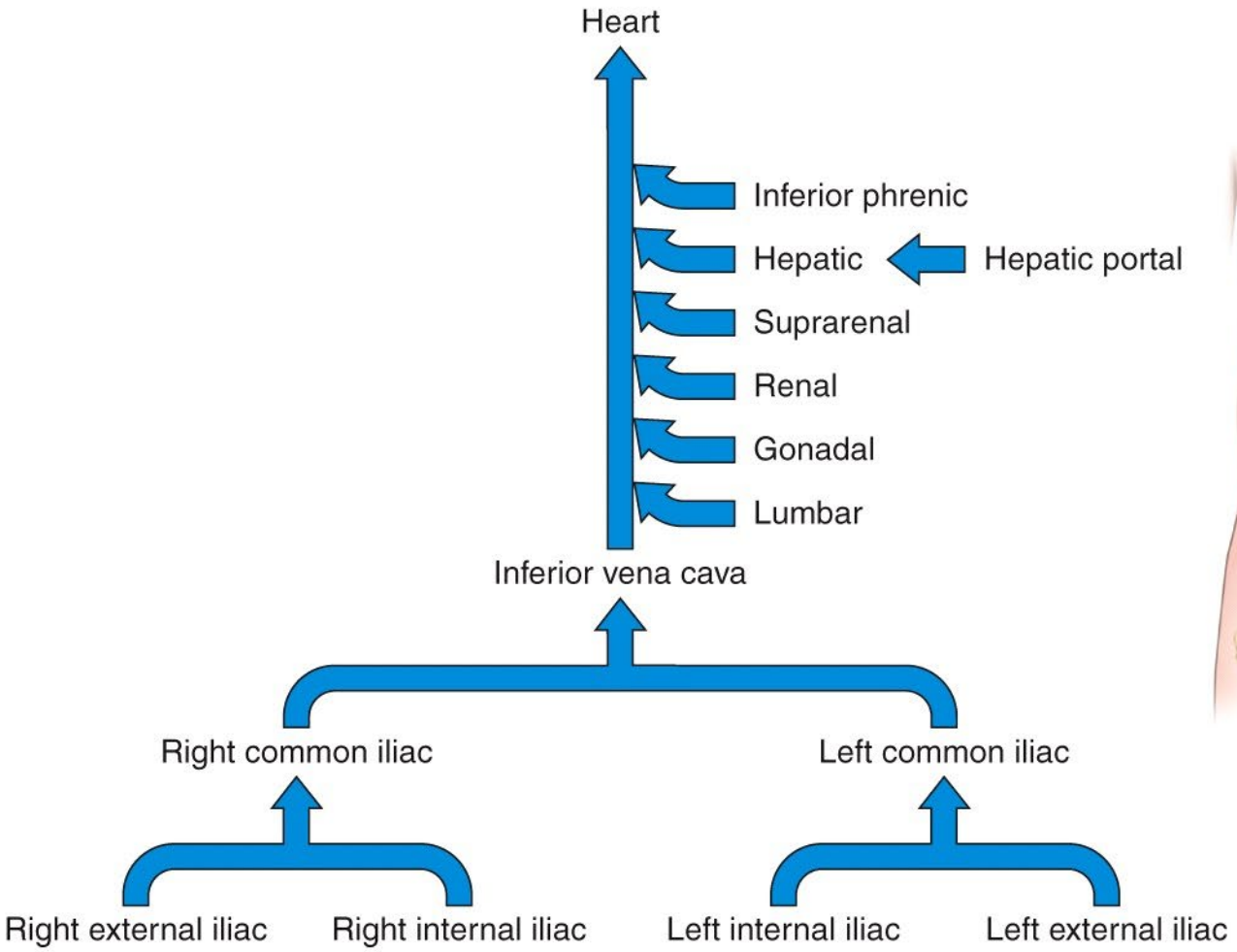
Anterior view

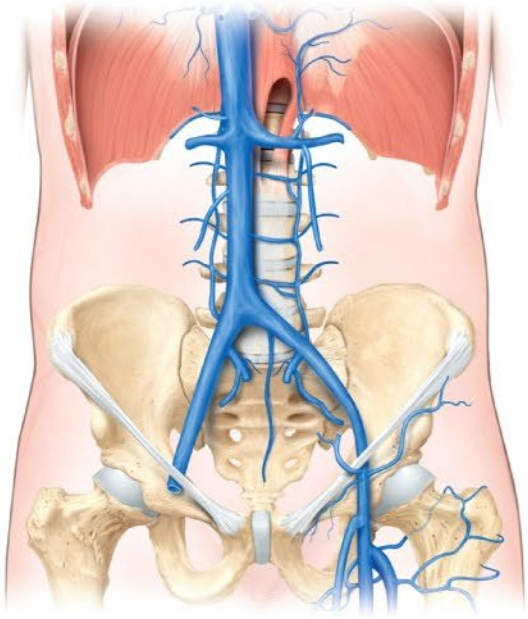


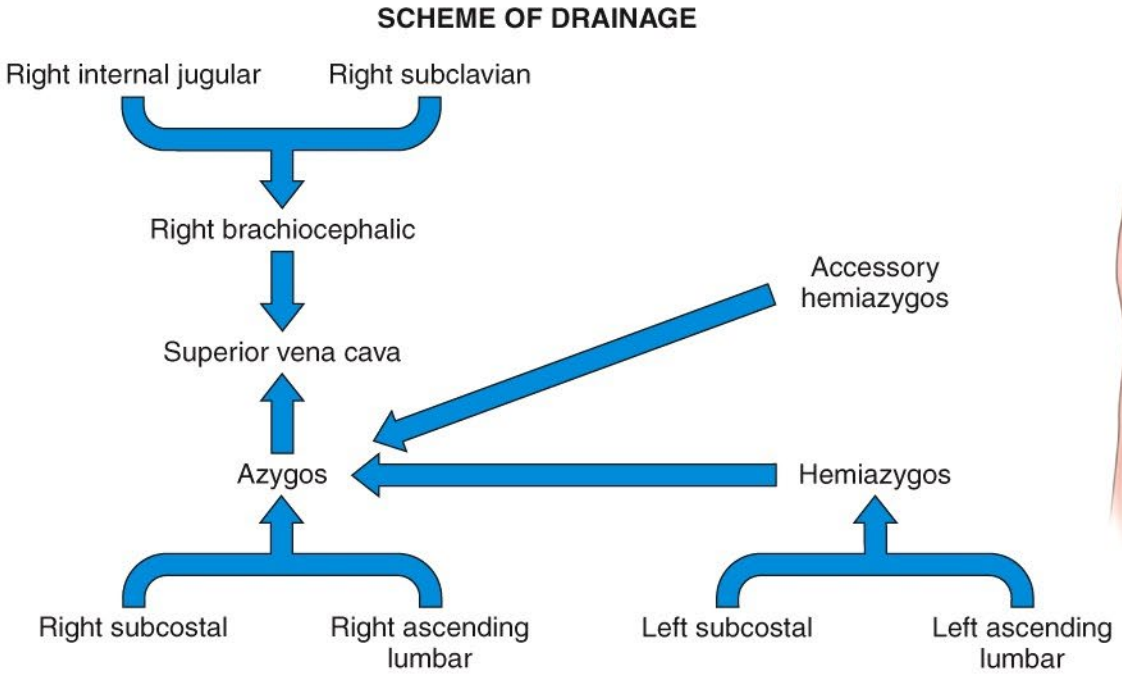
Right lateral view

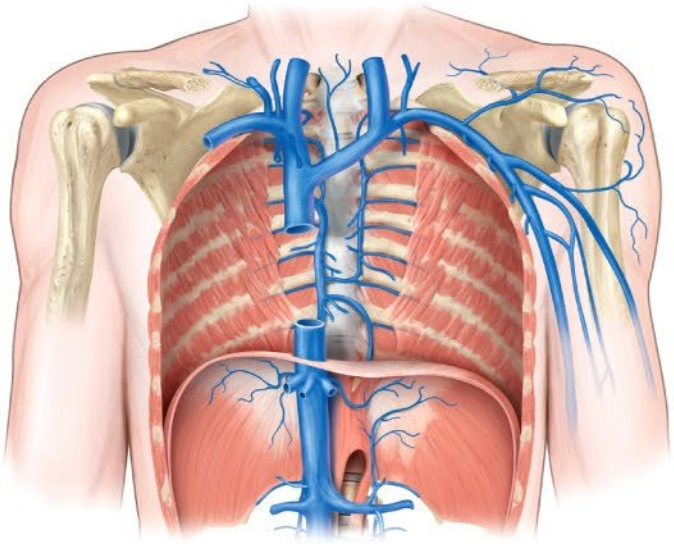

SCHEME OF DRAINAGE
Inferior sagittal sinus
Superior sagittal sinus
Straight sinus
Cavernous sinuses
Right transverse sinus
Left transverse sinus
Right sigmoid sinus
Left sigmoid sinus
Right external jugular
Left external jugular
Right subclavian
Right internal jugular
Left internal jugular
Left subclavian
Right vertebral
Left vertebral
Right brachiocephalic
Left brachiocephalic
Superior vena cava

SCHEME OF DRAINAGE

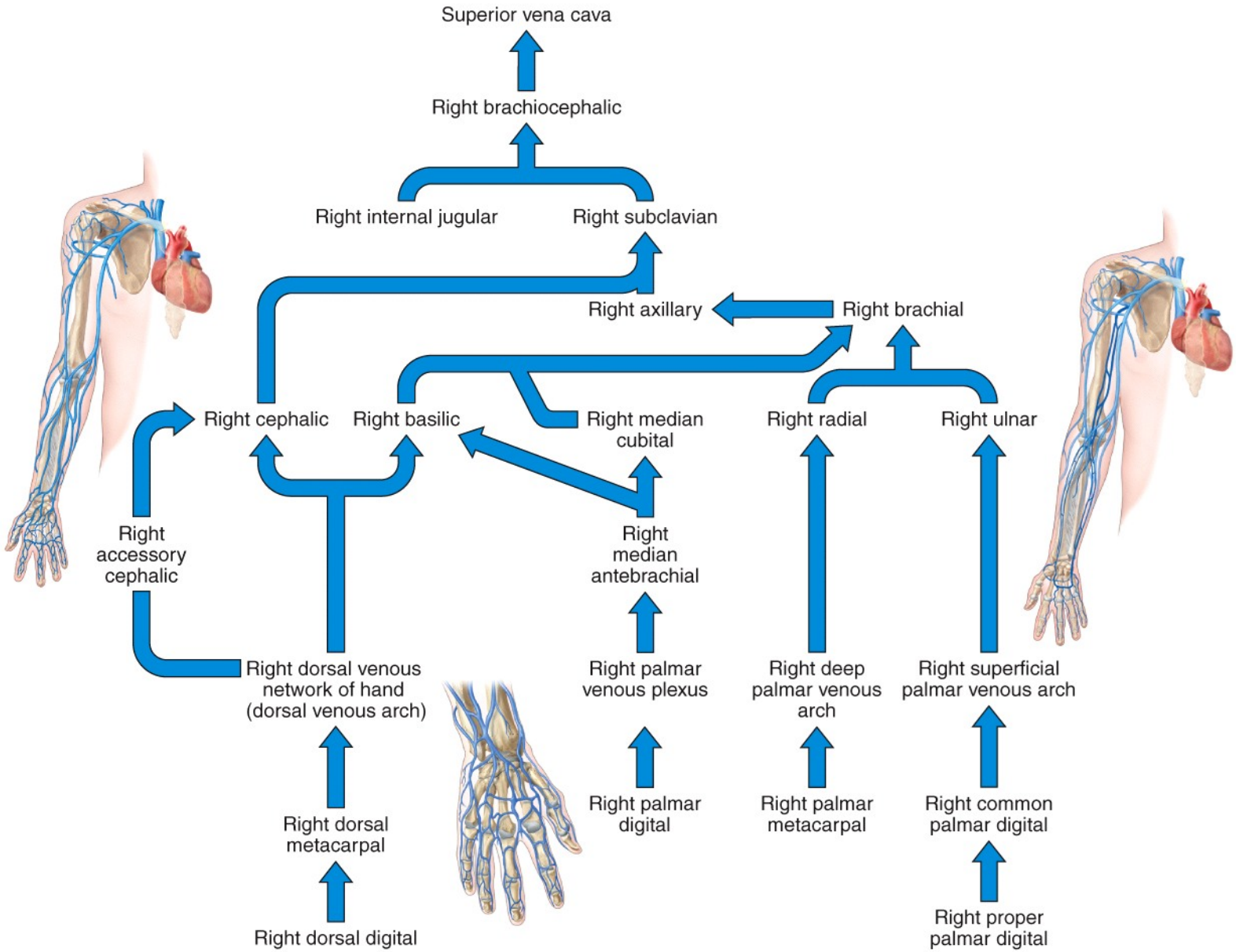




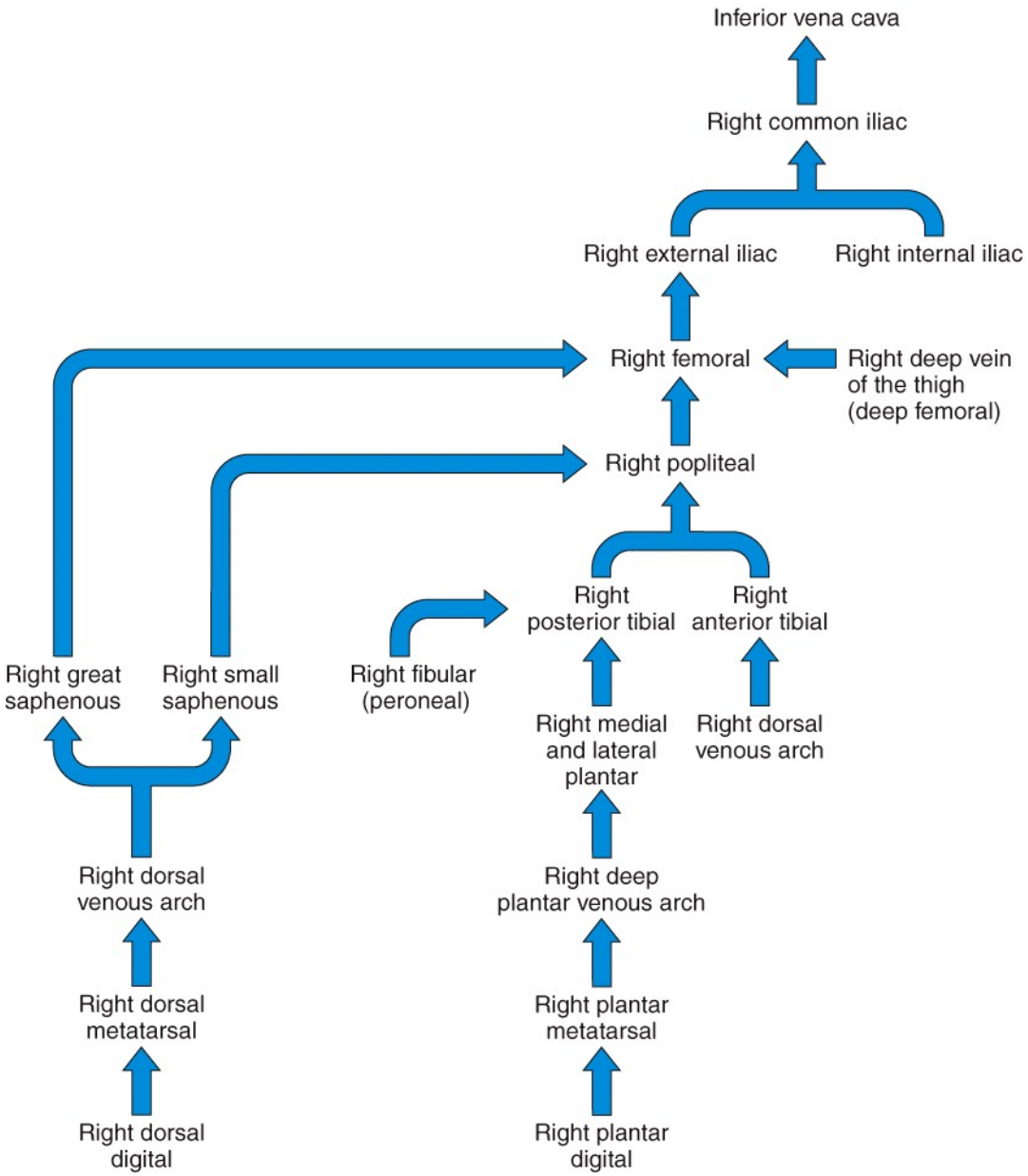

SCHEME OF DRAINAGE
Right internal jugular
Right subclavian
Right brachiocephalic
Accessory hemiazygos
Superior vena cava
Azygos
Hemiazygos
Right subcostal
Right ascending lumbar
Left subcostal
Left ascending lumbar

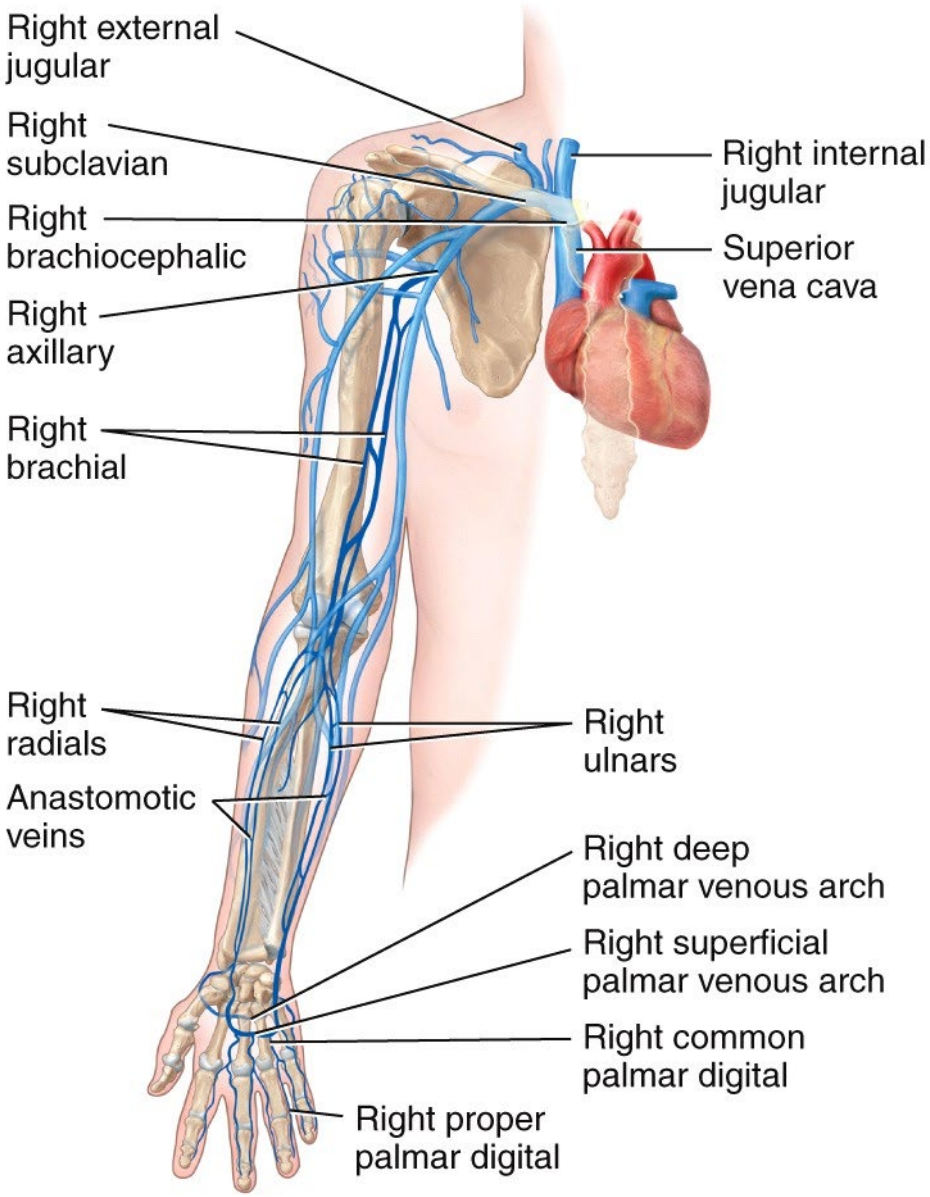


SCHEME OF DRAINAGE

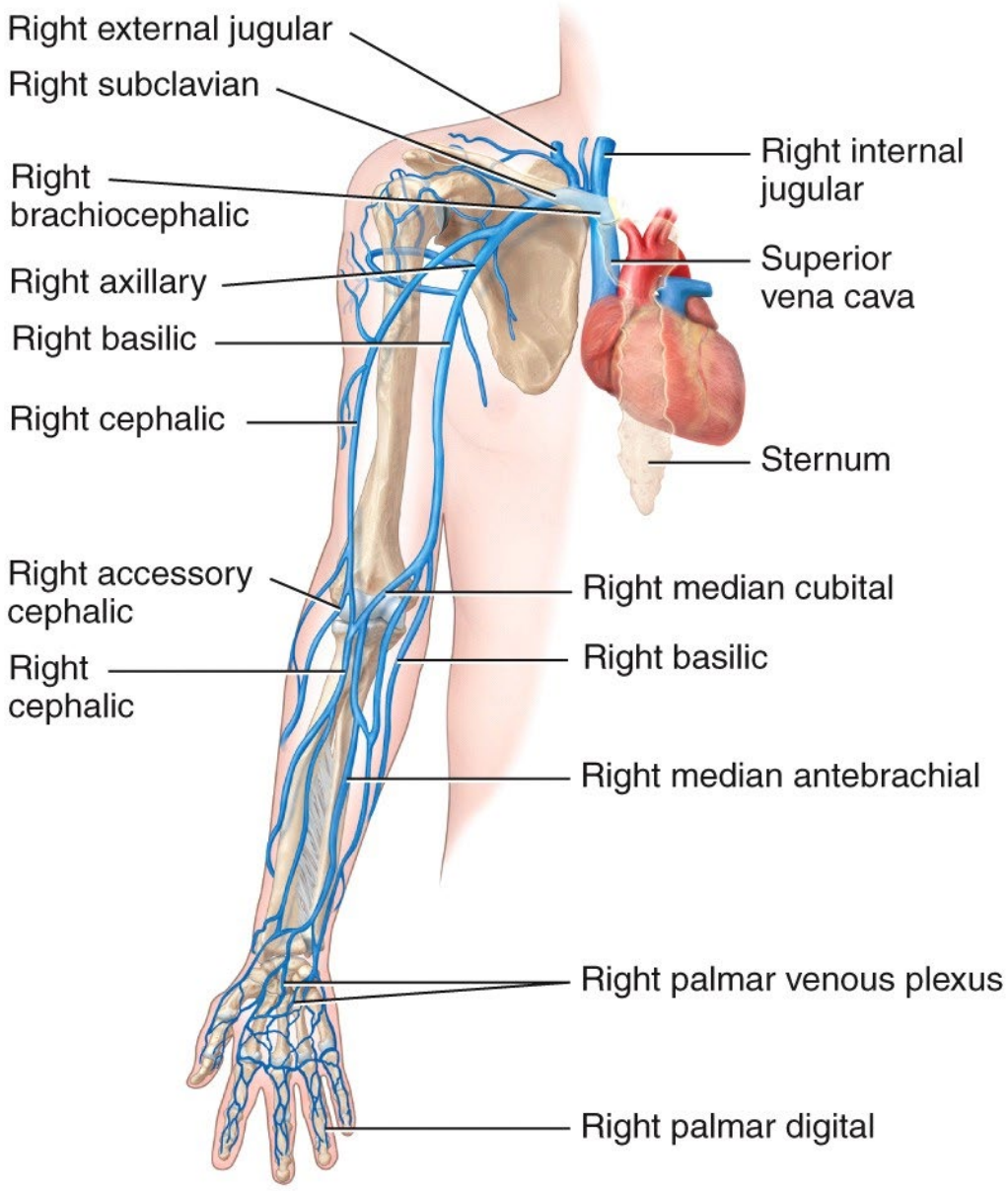


SCHEME OF DRAINAGE

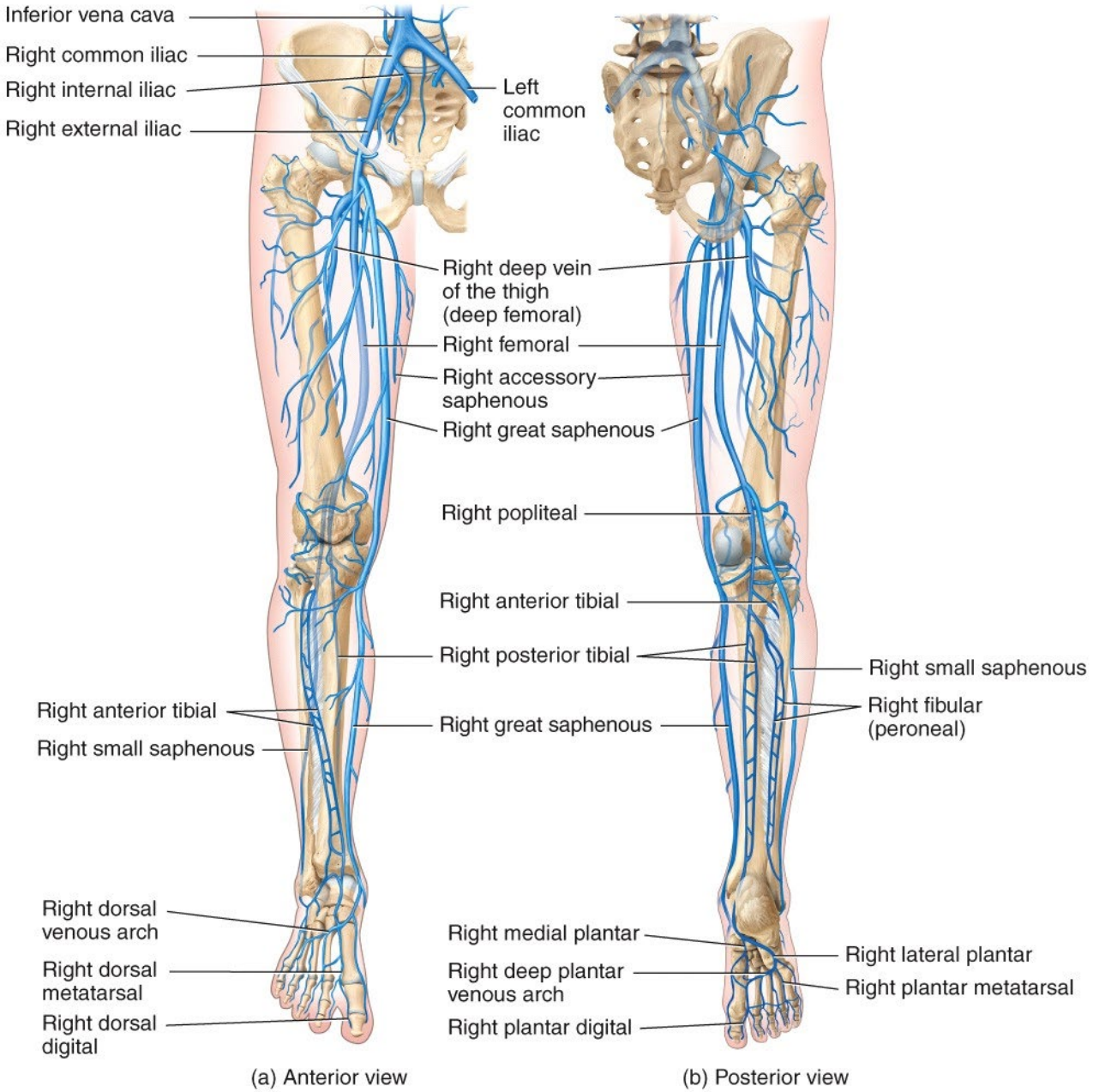


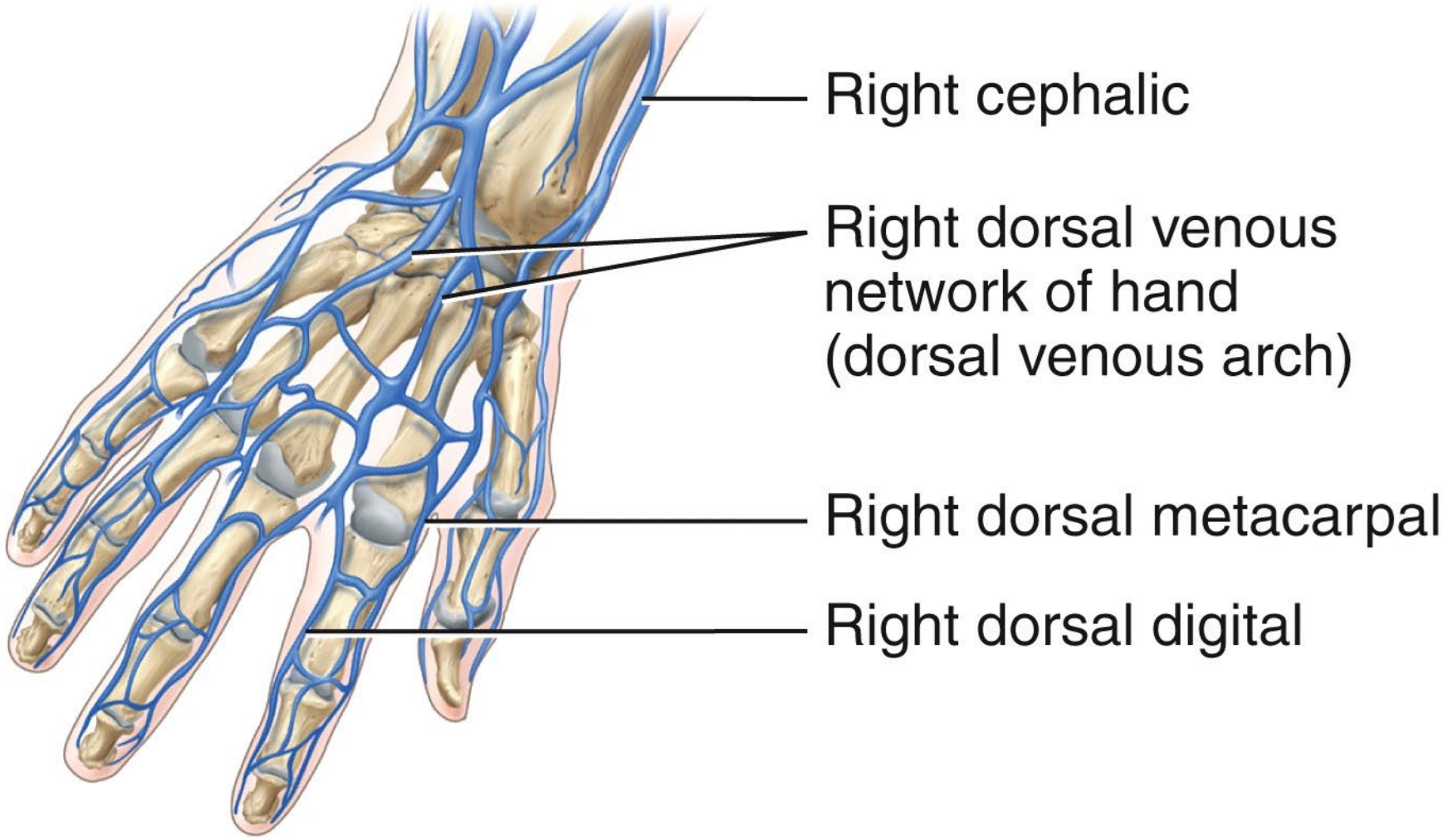


(b) Anterior view of deep veins

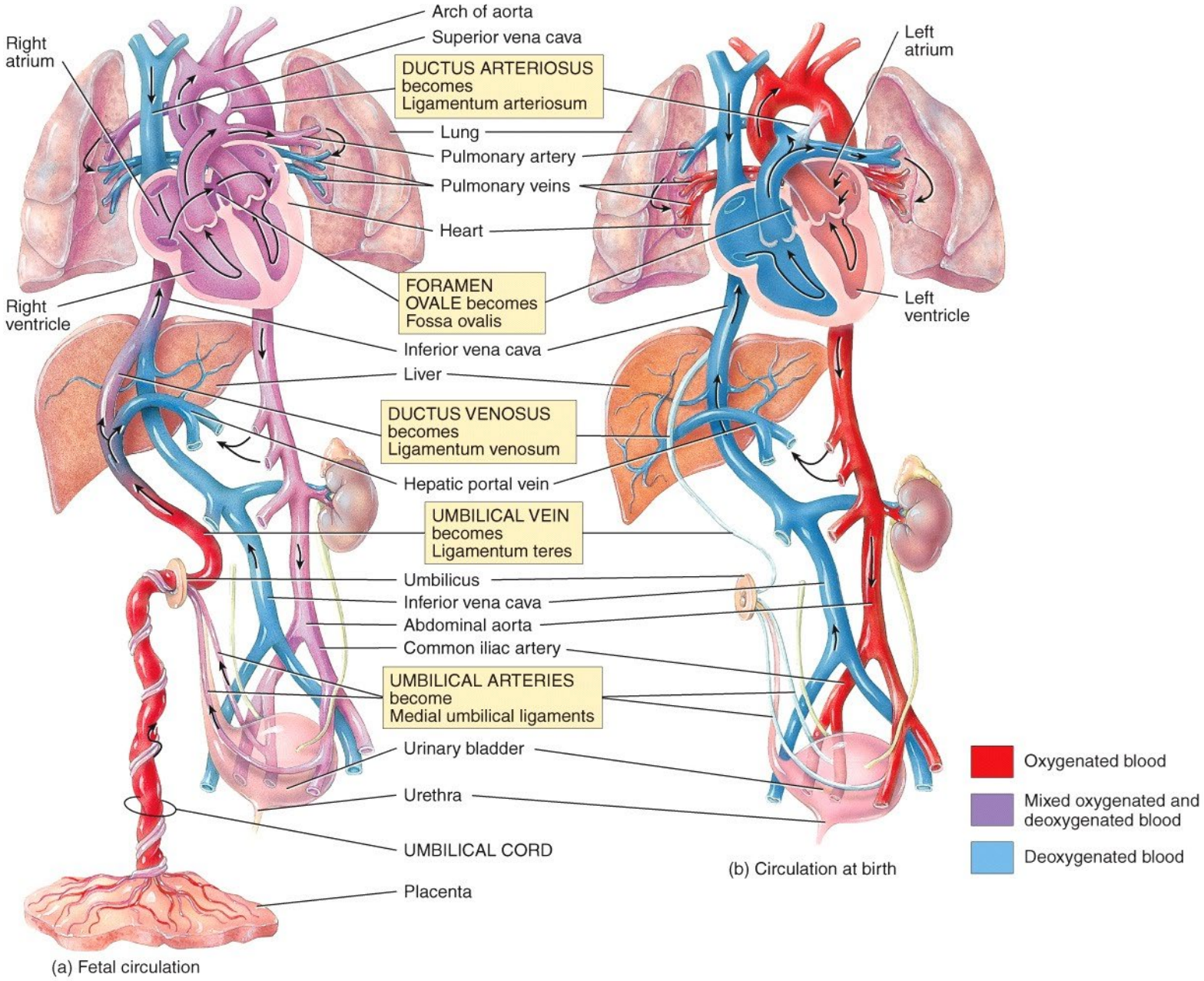


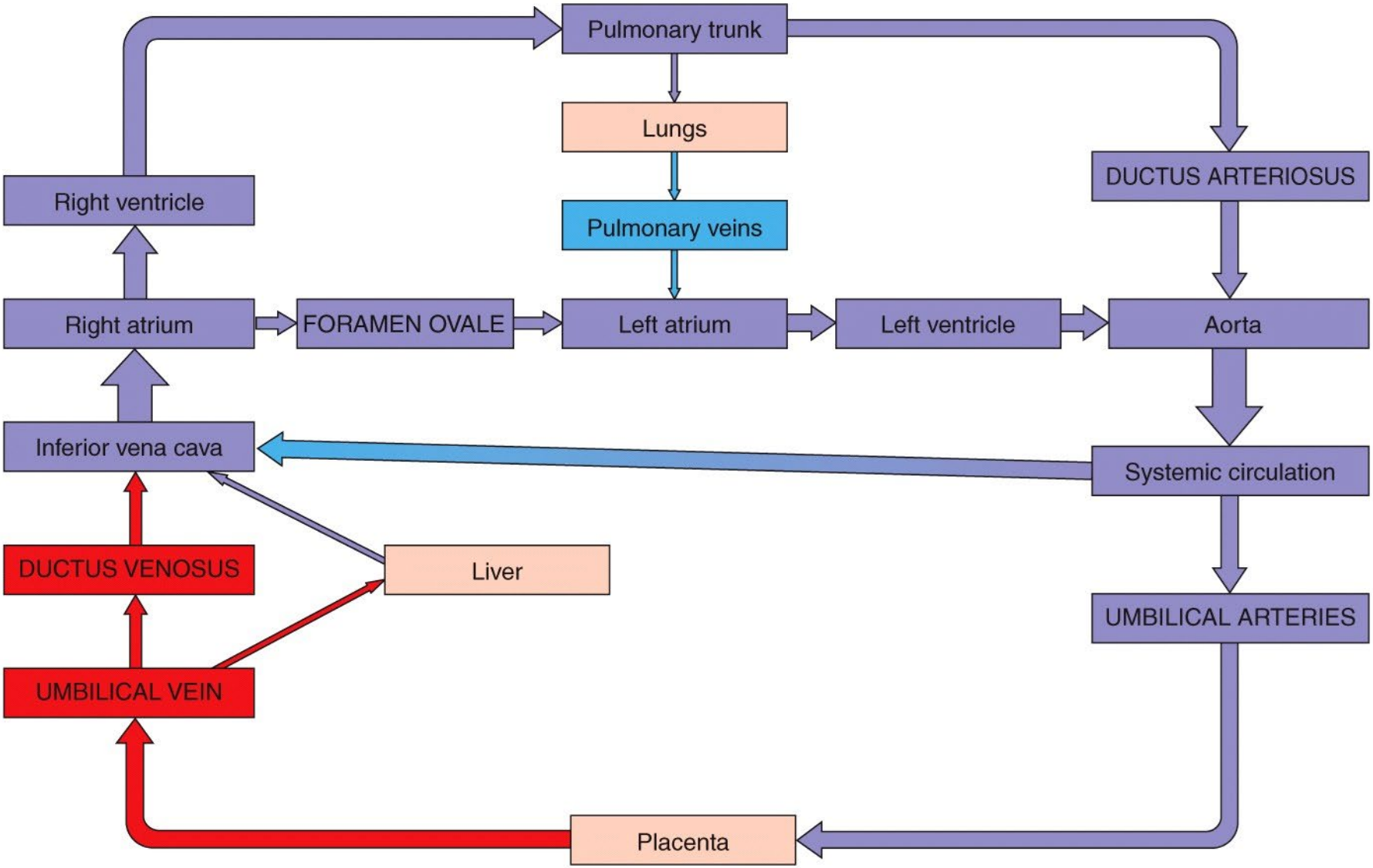
(a) Anterior view of superficial veins


Inferior vena cava
Right common iliac
Right internal iliac
Right external iliac
Left common iliac
Right deep vein of the thigh (deep femoral)
Right femoral
Right accessory saphenous
Right great saphenous
Right popliteal
Right anterior tibial
Right posterior tibial
Right small saphenous
Right fibular (peroneal)
Right great saphenous
Right anterior tibial
Right small saphenous
Right dorsal venous arch
Right dorsal metatarsal
Right dorsal digital
Right medial plantar
Right deep plantar venous arch
Right plantar digital
Right lateral plantar
Right plantar metatarsal
(a) Anterior view
(b) Posterior view

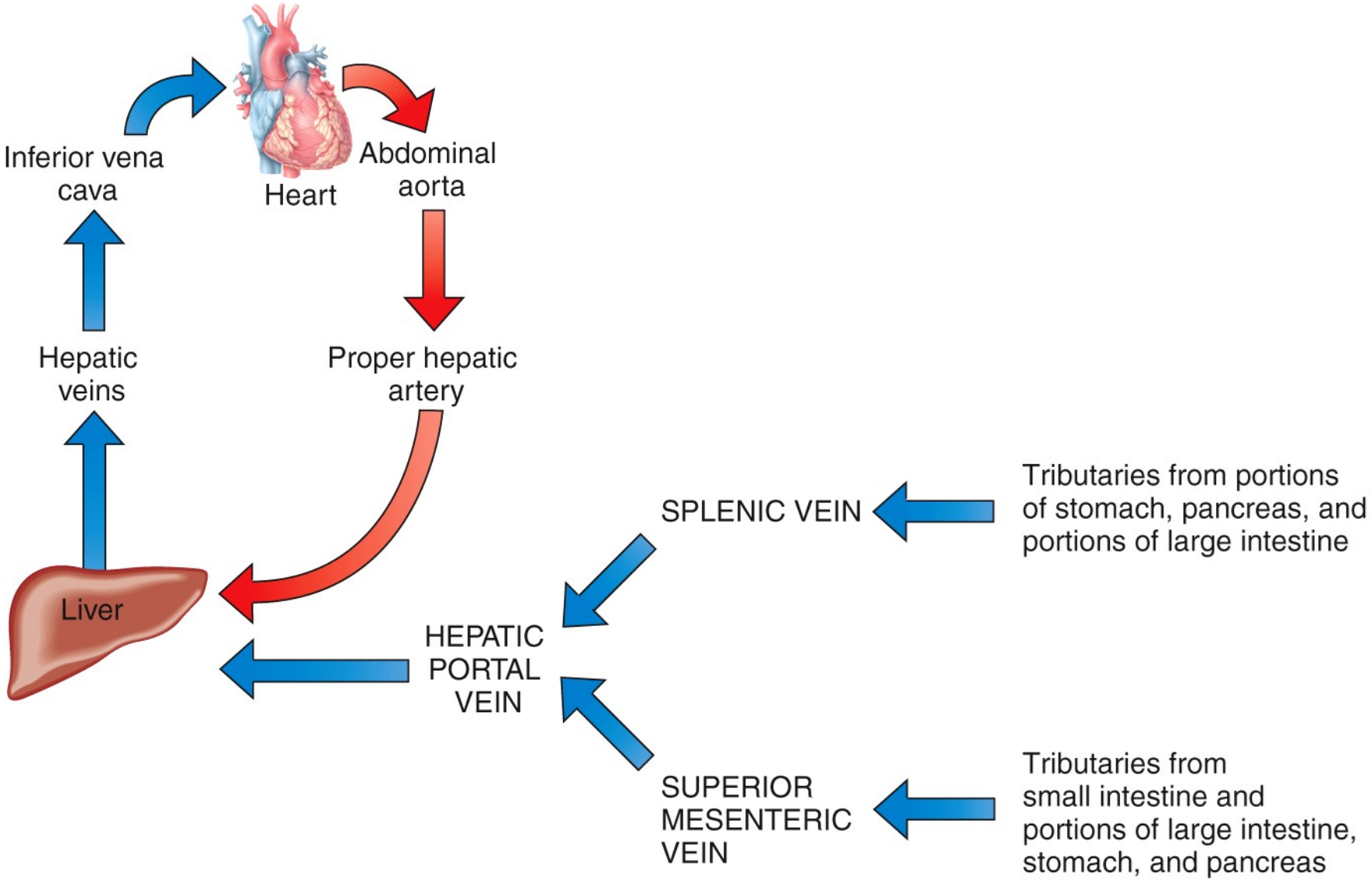


(c) Posterior view of superficial veins of hand

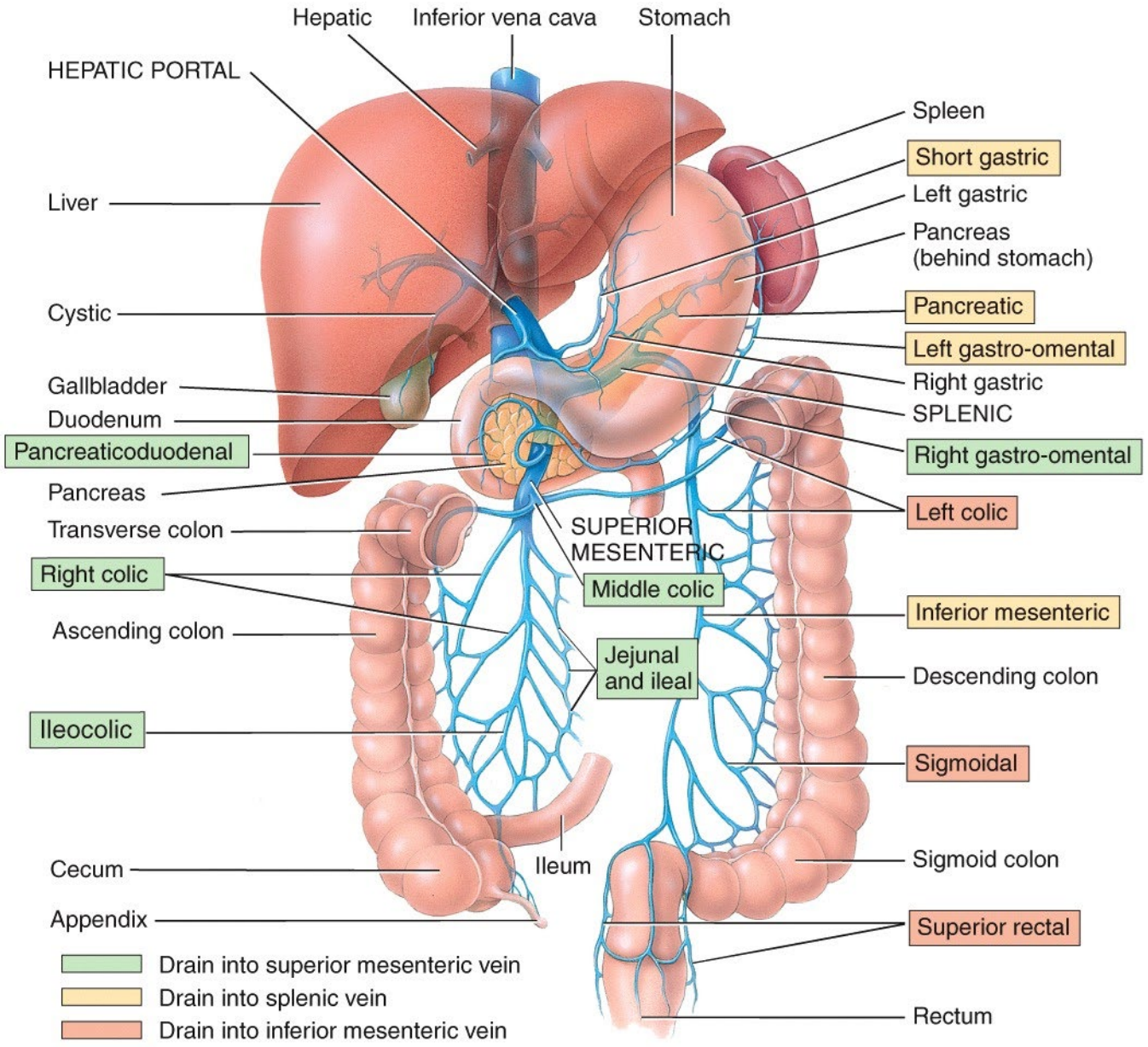

Arch of aorta
Superior vena cava
Right atrium
DUCTUS ARTERIOSUS becomes Ligamentum arteriosum
Lung
Pulmonary artery
Pulmonary veins
Heart
FORAMEN OVALE becomes Fossa ovalis
Right ventricle
Inferior vena cava
Liver
DUCTUS VENOSUS becomes Ligamentum venosum
Hepatic portal vein
UMBILICAL VEIN becomes Ligamentum teres
Umbilicus
Inferior vena cava
Abdominal aorta
Common iliac artery
UMBILICAL ARTERIES become Medial umbilical ligaments
Urinary bladder
Urethra
UMBILICAL CORD
Placenta
(a) Fetal circulation
Left atrium
Left ventricle
(b) Circulation at birth
Oxygenated blood
Mixed oxygenated and deoxygenated blood
Deoxygenated blood



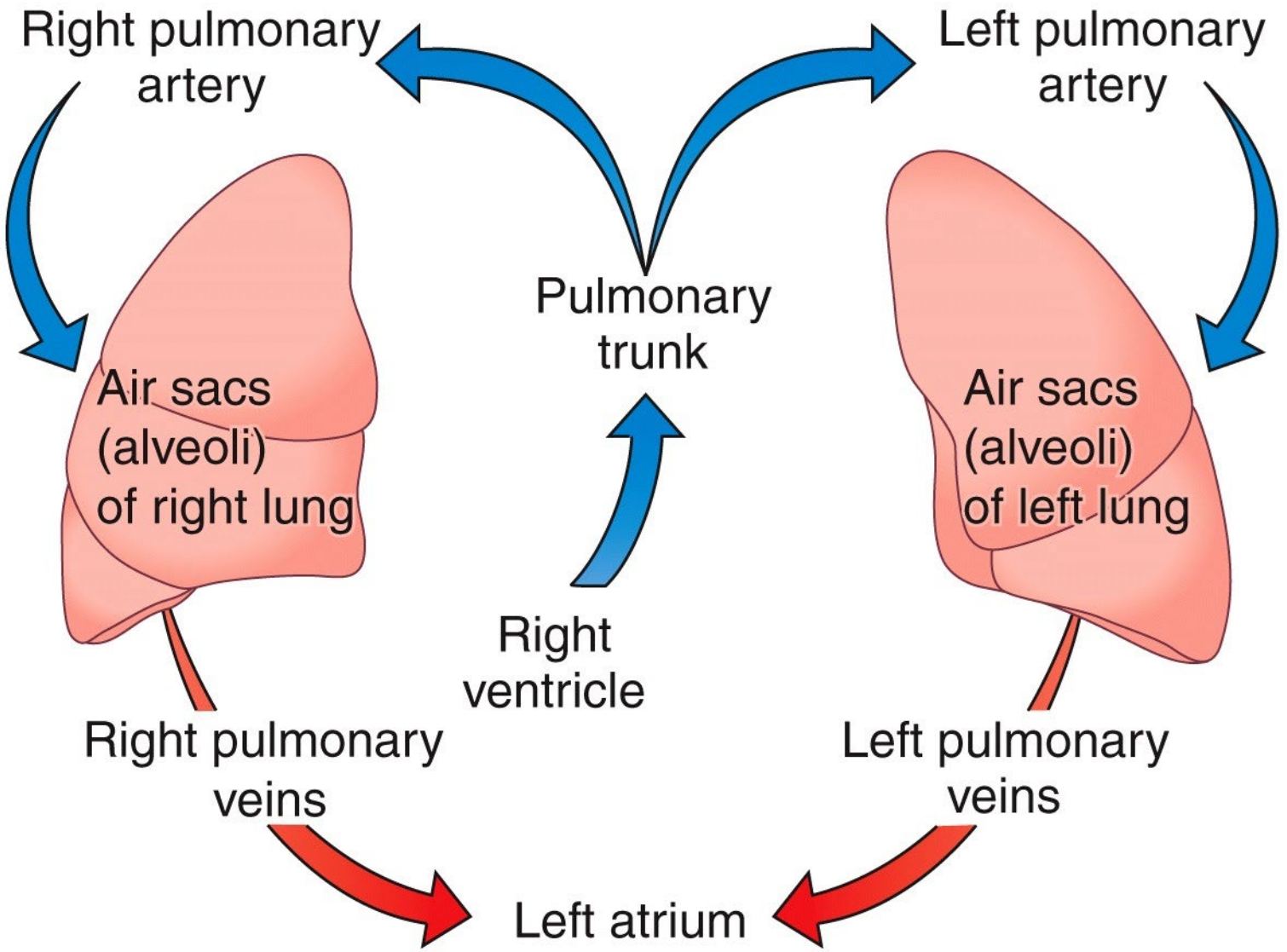
(c) Scheme of fetal circulation



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



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



(b) Scheme of pulmonary circulation