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Dr. Brasington

The Cardiovascular System: Blood Vessels: Part 1

Blood Vessels

- Delivery system of dynamic structures that begins and ends at heart
  - **Arteries**: carry blood away from heart; oxygenated except for pulmonary circulation and umbilical vessels of fetus
  - **Capillaries**: contact tissue cells; directly serve cellular needs
  - **Veins**: carry blood toward heart

Figure 19.1a Generalized structure of arteries, veins, and capillaries.

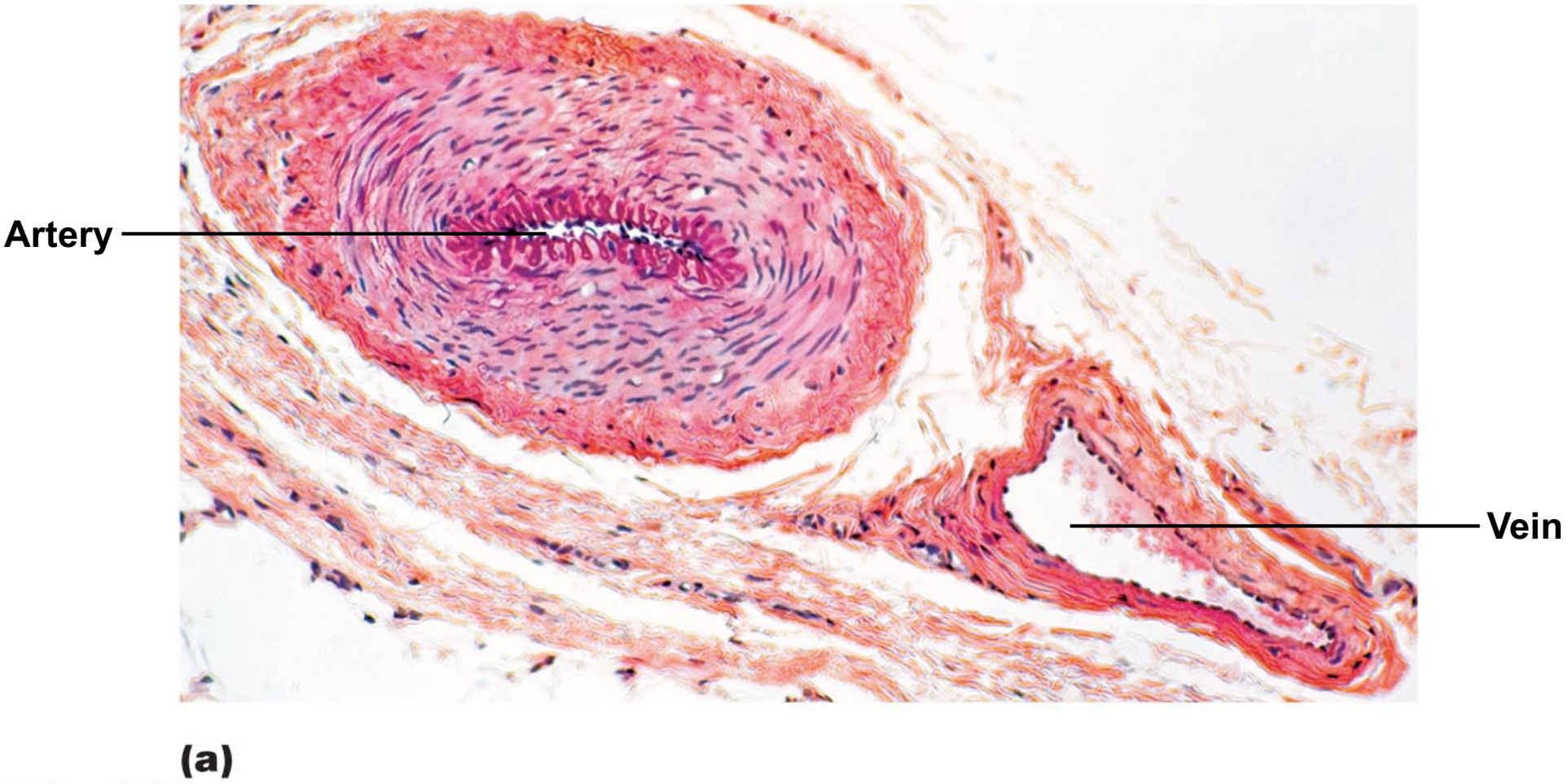
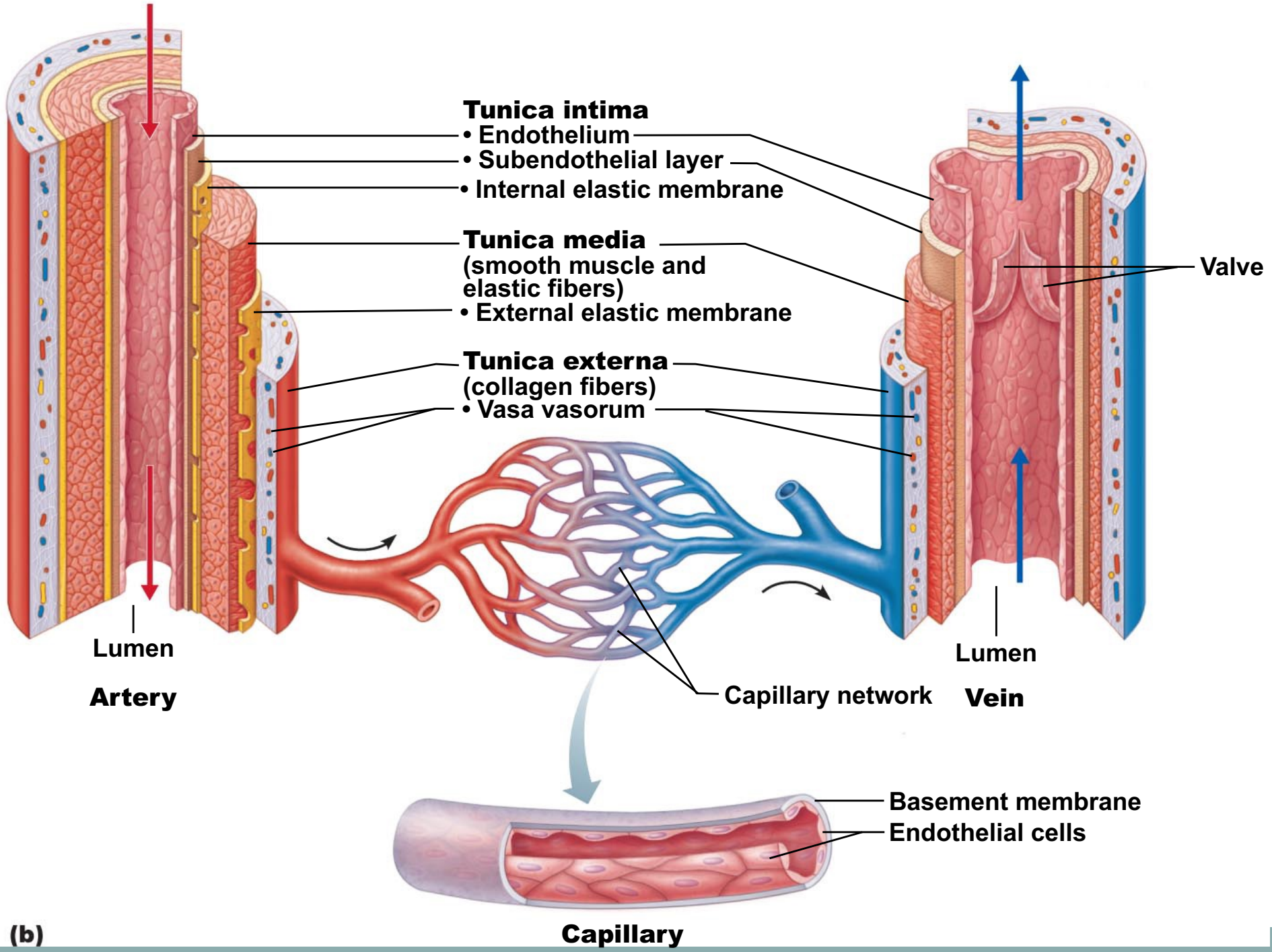


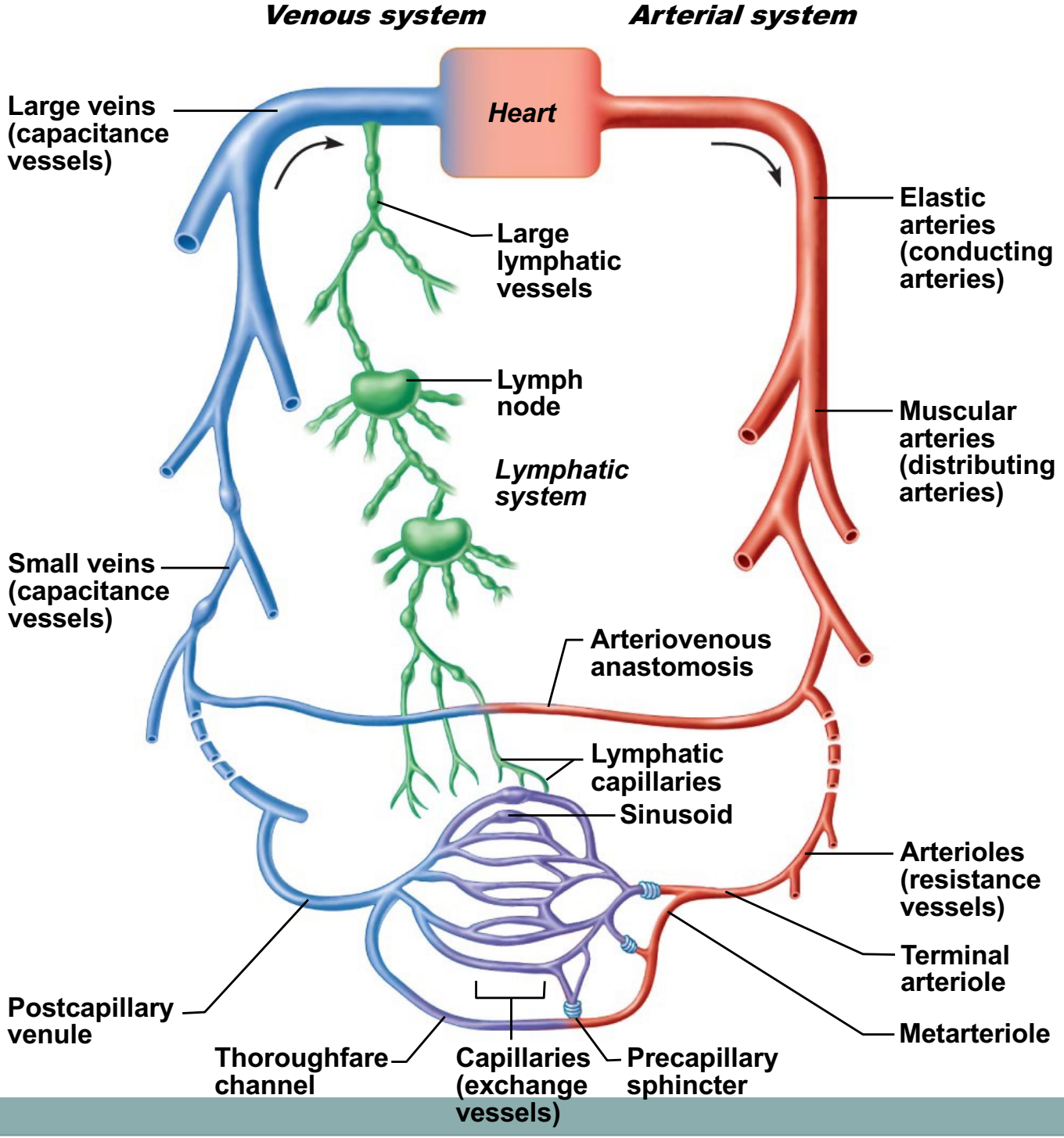
Figure 19.1b Generalized structure of arteries, veins, and capillaries.



Blood Vessels

- Vessels vary in length, diameter, wall thickness, tissue makeup
- Interact with lymph vessels

Figure 19.2 The relationship of blood vessels to each other and to lymphatic vessels.

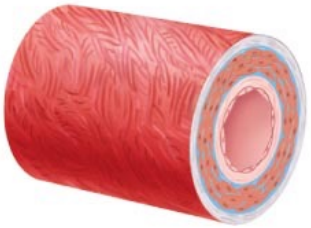
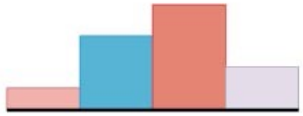
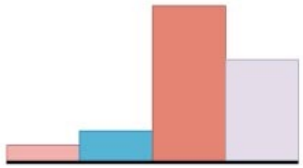
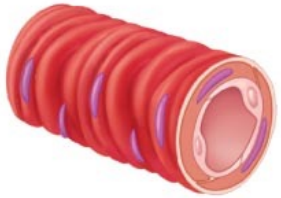


Arterial System: Elastic Arteries

- Large thick-walled arteries with elastin in all three tunics
- Aorta and its major branches
- Large lumen offers low-resistance
- Inactive in vasoconstriction
- Act as pressure reservoirs—expand and recoil as blood ejected from heart
  - Smooth pressure downstream

Table 19.1 Summary of Blood Vessel Anatomy (1 of 2)

Table 19.1 Summary of Blood Vessel Anatomy

VESSEL TYPE/ ILLUSTRATION*	AVERAGE LUMEN DIAMETER (D) AND WALL THICKNESS (T)	*RELATIVE TISSUE MAKEUP*			
		Endothelium	*Elastic Tissues*	*Smooth Muscles*	*Fibrous (Collagenous) Tissues*
 Elastic artery	D: 1.5 cm T: 1.0 mm				
 Muscular artery	D: 6.0 mm T: 1.0 mm				
 Arteriole	D: 37.0 µm T: 6.0 µm				

Capillaries

- Microscopic blood vessels
- Walls of thin tunica intima
  - In smallest one cell forms entire circumference
- Pericytes help stabilize their walls and control permeability
- Diameter allows only single RBC to pass at a time

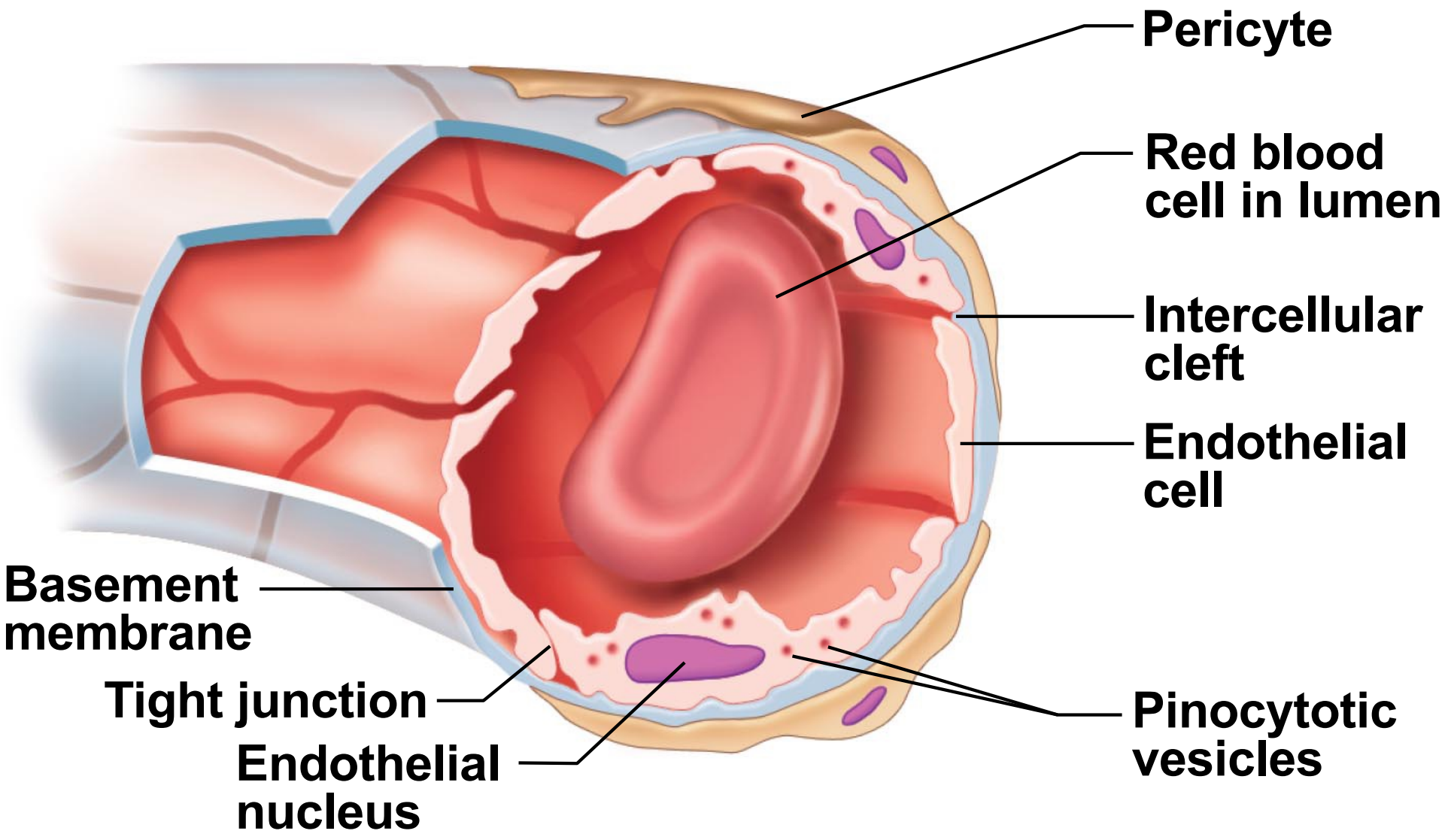
Capillaries

- In all tissues except for cartilage, epithelia, cornea and lens of eye
- Provide direct access to almost every cell
- Functions
  - Exchange of gases, nutrients, wastes, hormones, etc., between blood and interstitial fluid

Capillaries

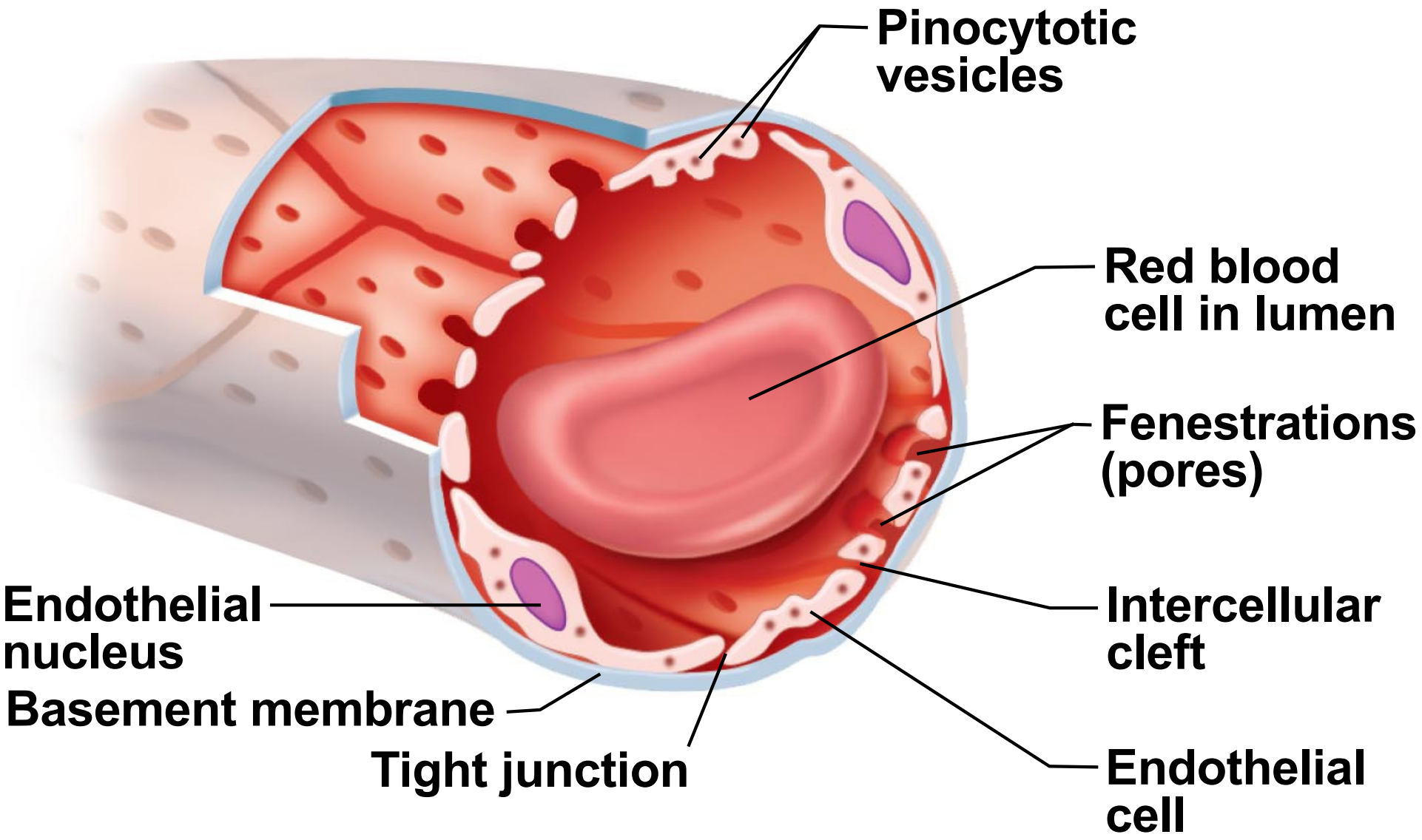
- Three structural types
  1. Continuous capillaries
  2. Fenestrated capillaries
  3. Sinusoid capillaries (sinusoids)

Figure 19.3a Capillary structure.



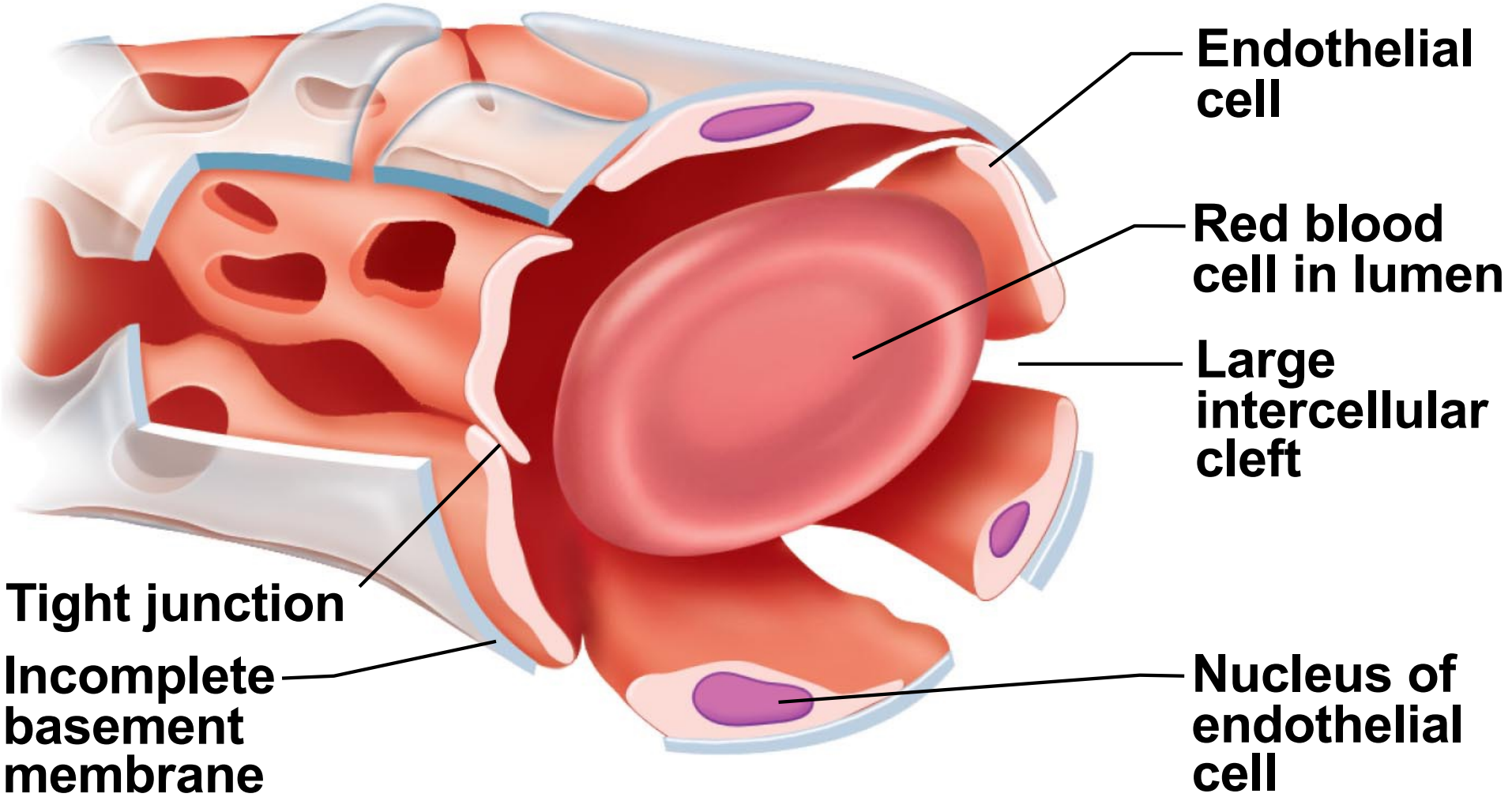
(a) Continuous capillary. Least permeable, and most common (e.g., skin, muscle).

Figure 19.3b Capillary structure.



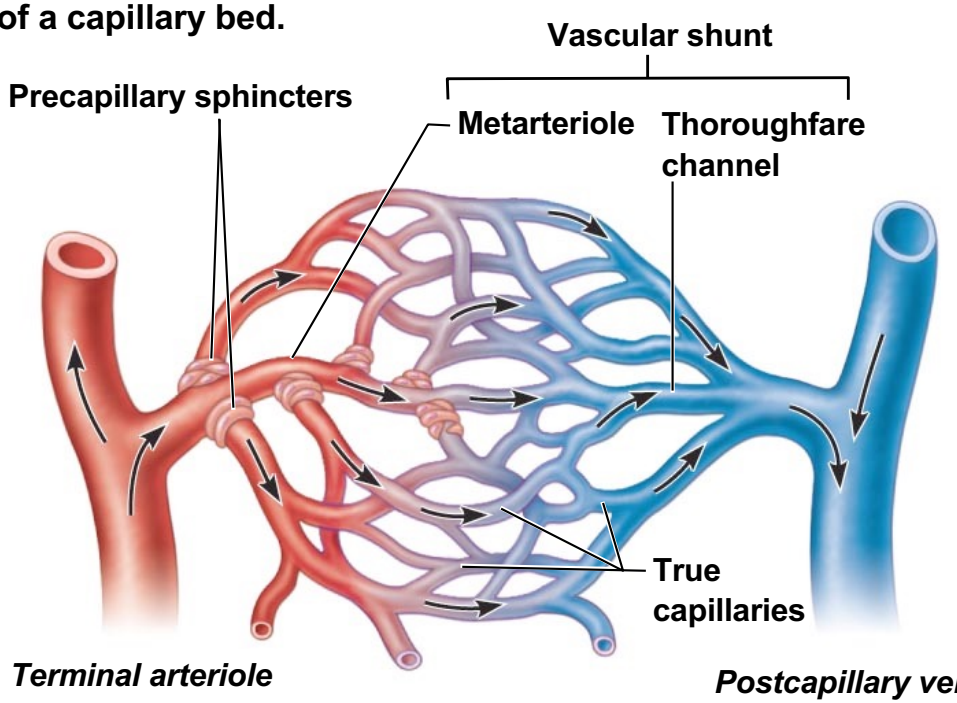
(b) **Fenestrated capillary.** Large fenestrations (pores) increase permeability. Occurs in areas of active absorption or filtration (e.g., kidney, small intestine).

Figure 19.3c Capillary structure.

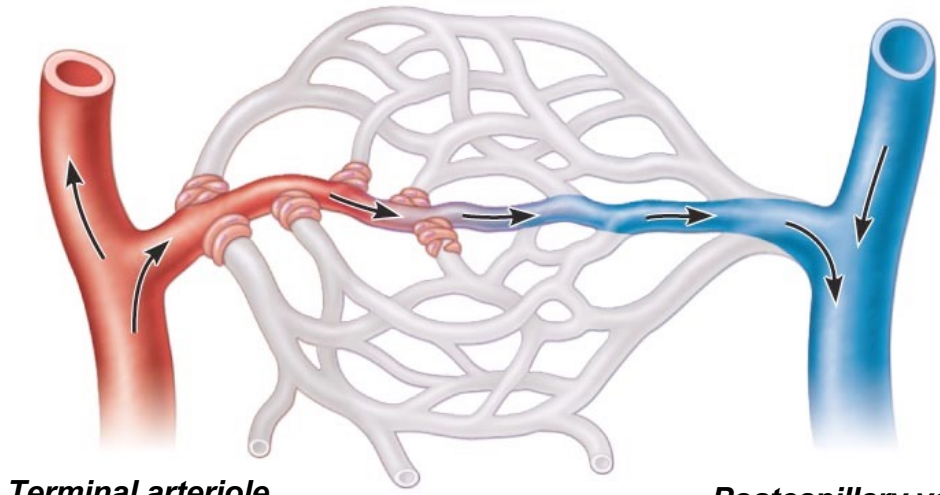


(c) Sinusoid capillary. Most permeable. Occurs in special locations (e.g., liver, bone marrow, spleen).

Figure 19.4 Anatomy of a capillary bed.



(a) **Sphincters open**—blood flows through true capillaries.



(b) **Sphincters closed**—blood flows through metarteriole – thoroughfare channel and bypasses true capillaries.

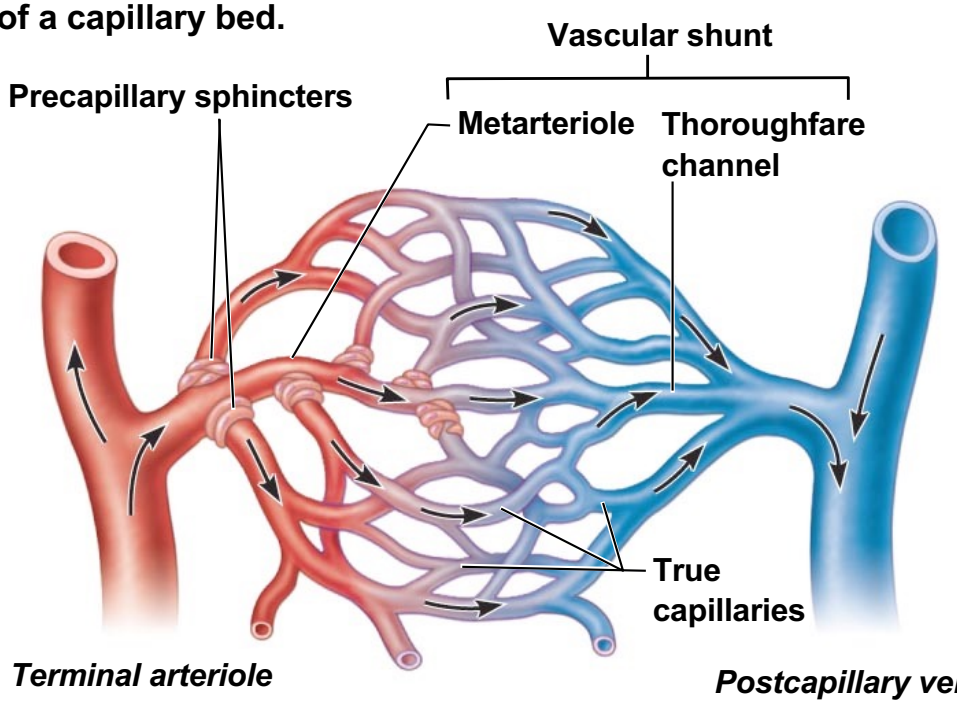
Capillary Beds: Two Types of Vessels

- **Vascular shunt** (metarteriole—thoroughfare channel)
  - Directly connects terminal arteriole and postcapillary venule
- **True capillaries**
  - 10 to 100 exchange vessels per capillary bed
  - Branch off metarteriole or terminal arteriole

Blood Flow Through Capillary Beds

- True capillaries normally branch from metarteriole and return to thoroughfare channel
- **Precapillary sphincters** regulate blood flow into true capillaries
  - Blood may go into true capillaries or to shunt
- Regulated by local chemical conditions and vasomotor nerves

Figure 19.4 Anatomy of a capillary bed.



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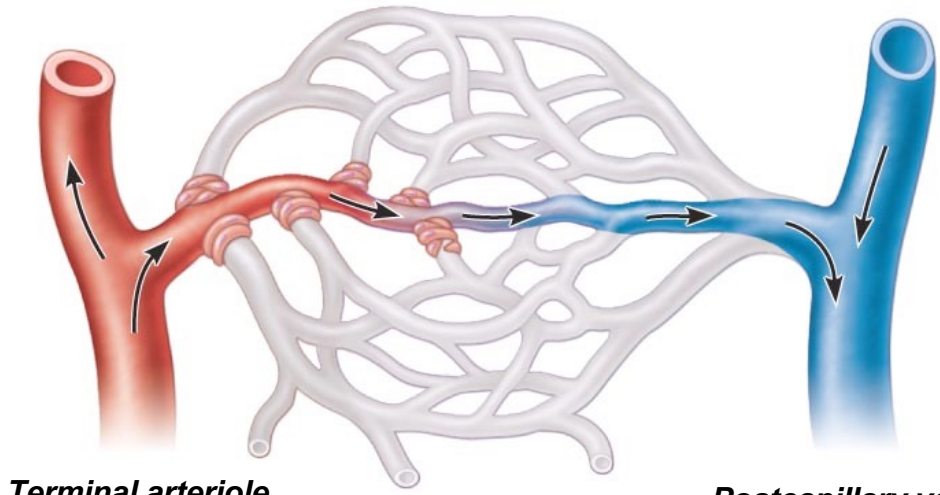
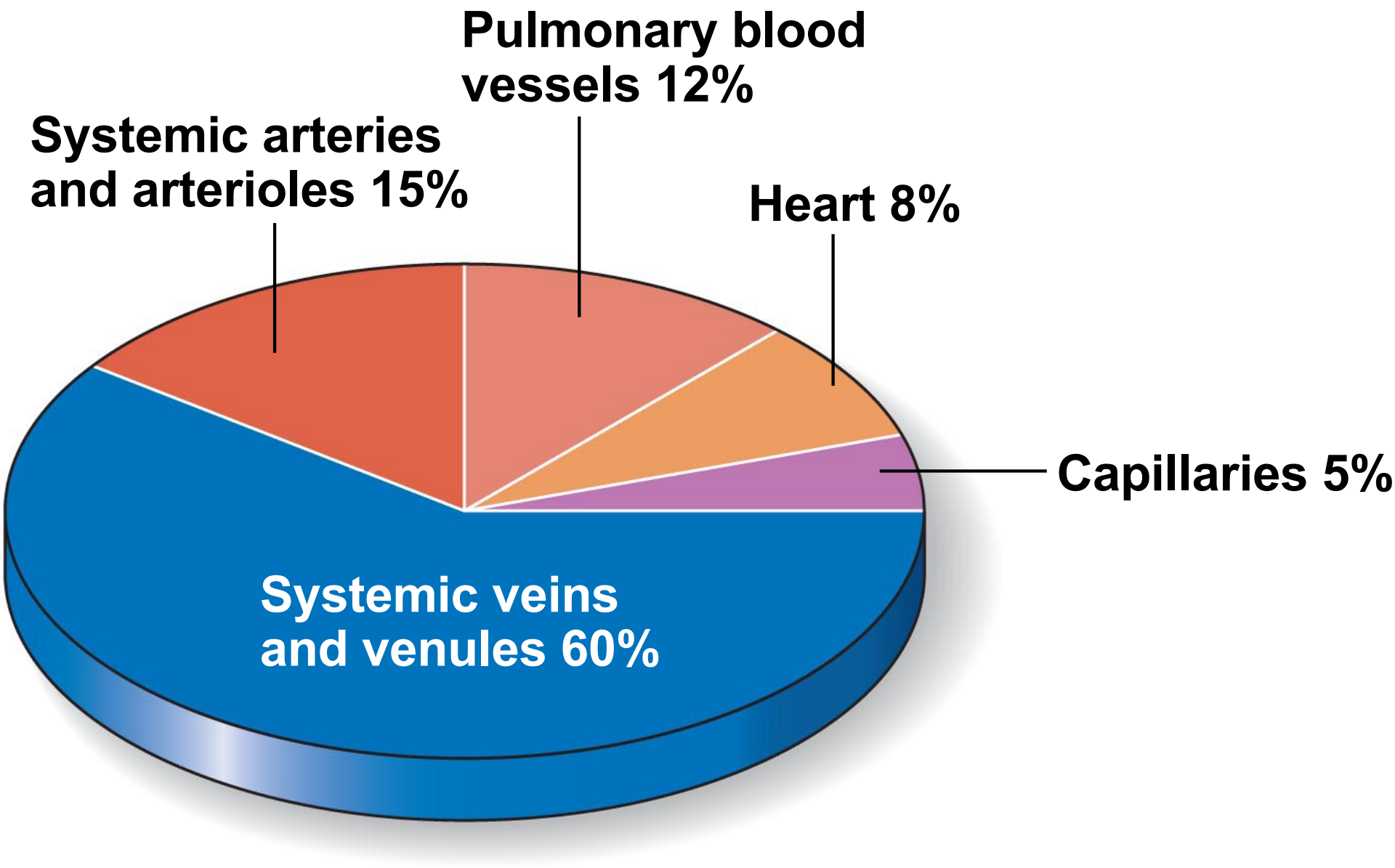


(b) **Sphincters closed**—blood flows through metarteriole – thoroughfare channel and bypasses true capillaries.

Veins

- Formed when venules converge
- Have thinner walls, larger lumens compared with corresponding arteries
- Blood pressure lower than in arteries
- Thin tunica media; thick tunica externa of collagen fibers and elastic networks
- Called **capacitance vessels** (blood reservoirs); contain up to 65% of blood supply

Figure 19.5 Relative proportion of blood volume throughout the cardiovascular system.

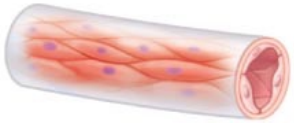
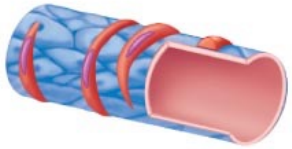
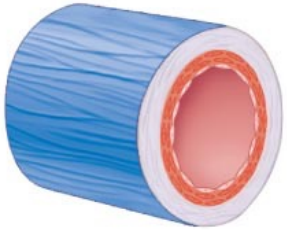
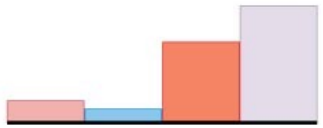


Veins

- Adaptations ensure return of blood to heart despite low pressure
  - Large-diameter lumens offer little resistance
  - **Venous valves** prevent backflow of blood
    - Most abundant in veins of limbs
  - **Venous sinuses**: flattened veins with extremely thin walls (e.g., coronary sinus of the heart and dural sinuses of the brain)

Table 19.1 Summary of Blood Vessel Anatomy (2 of 2)

Table 19.1 Summary of Blood Vessel Anatomy *(continued)*

VESSEL TYPE/ ILLUSTRATION*	AVERAGE LUMEN DIAMETER (D) AND WALL THICKNESS (T)	*RELATIVE TISSUE MAKEUP*			
		Endothelium	*Elastic Tissues*	*Smooth Muscles*	*Fibrous (Collagenous) Tissues*
 Capillary	D: 9.0 µm T: 0.5 µm				
 Venule	D: 20.0 µm T: 1.0 µm				
 Vein	D: 5.0 mm T: 0.5 mm				

*Size relationships are not proportional. Smaller vessels are drawn relatively larger so detail can be seen. See column 2 for actual dimensions.

Physiology of Circulation: Definition of Terms

- **Blood flow**
  - Volume of blood flowing through vessel, organ, or entire circulation in given period
    - Measured as ml/min
    - Equivalent to cardiac output (CO) for entire vascular system
    - Relatively constant when at rest
    - Varies widely through individual organs, based on needs

Physiology of Circulation: Definition of Terms

- **Blood pressure** (BP)
  - Force per unit area exerted on wall of blood vessel by blood
    - Expressed in mm Hg
    - Measured as systemic arterial BP in large arteries near heart
  - Pressure gradient provides driving force that keeps blood moving from higher to lower pressure areas

Physiology of Circulation: Definition of Terms

- **Resistance** (peripheral resistance)
  - Opposition to flow
  - Measure of amount of friction blood encounters with vessel walls, generally in peripheral (systemic) circulation
- Three important sources of resistance
  - Blood viscosity
  - Total blood vessel length
  - Blood vessel diameter

Resistance

- Factors that remain relatively constant:
  - Blood viscosity
    - The "stickiness" of blood due to formed elements and plasma proteins
    - Increased viscosity = increased resistance
  - Blood vessel length
    - Longer vessel = greater resistance encountered

Resistance

- Blood vessel diameter
  - Greatest influence on resistance
- Frequent changes alter peripheral resistance
- Varies inversely with fourth power of vessel radius
  - E.g., if radius is doubled, the resistance is 1/16 as much
  - E.g., Vasoconstriction → increased resistance

Resistance

- Small-diameter arterioles major determinants of peripheral resistance
- Abrupt changes in diameter or fatty plaques from atherosclerosis dramatically increase resistance
  - Disrupt laminar flow and cause turbulent flow
    - Irregular fluid motion → increased resistance

Arterial Blood Pressure

- Reflects two factors of arteries close to heart
  - Elasticity (compliance or distensibility)
  - Volume of blood forced into them at any time
- Blood pressure near heart is **pulsatile**

Arterial Blood Pressure

- **Systolic pressure**: pressure exerted in aorta during ventricular contraction
  - Averages 120 mm Hg in normal adult
- **Diastolic pressure**: lowest level of aortic pressure
- **Pulse pressure** = difference between systolic and diastolic pressure
  - Throbbing of arteries (pulse)

Arterial Blood Pressure

- Mean arterial pressure (MAP): pressure that propels blood to tissues
- MAP = diastolic pressure + 1/3 pulse pressure
- Pulse pressure and MAP both decline with increasing distance from heart
- Ex. BP = 120/80; MAP = 93 mm Hg

- Concerning blood pressure
  - 170/90 52 year-old pt.
  - 140/90 75 year-old pt.

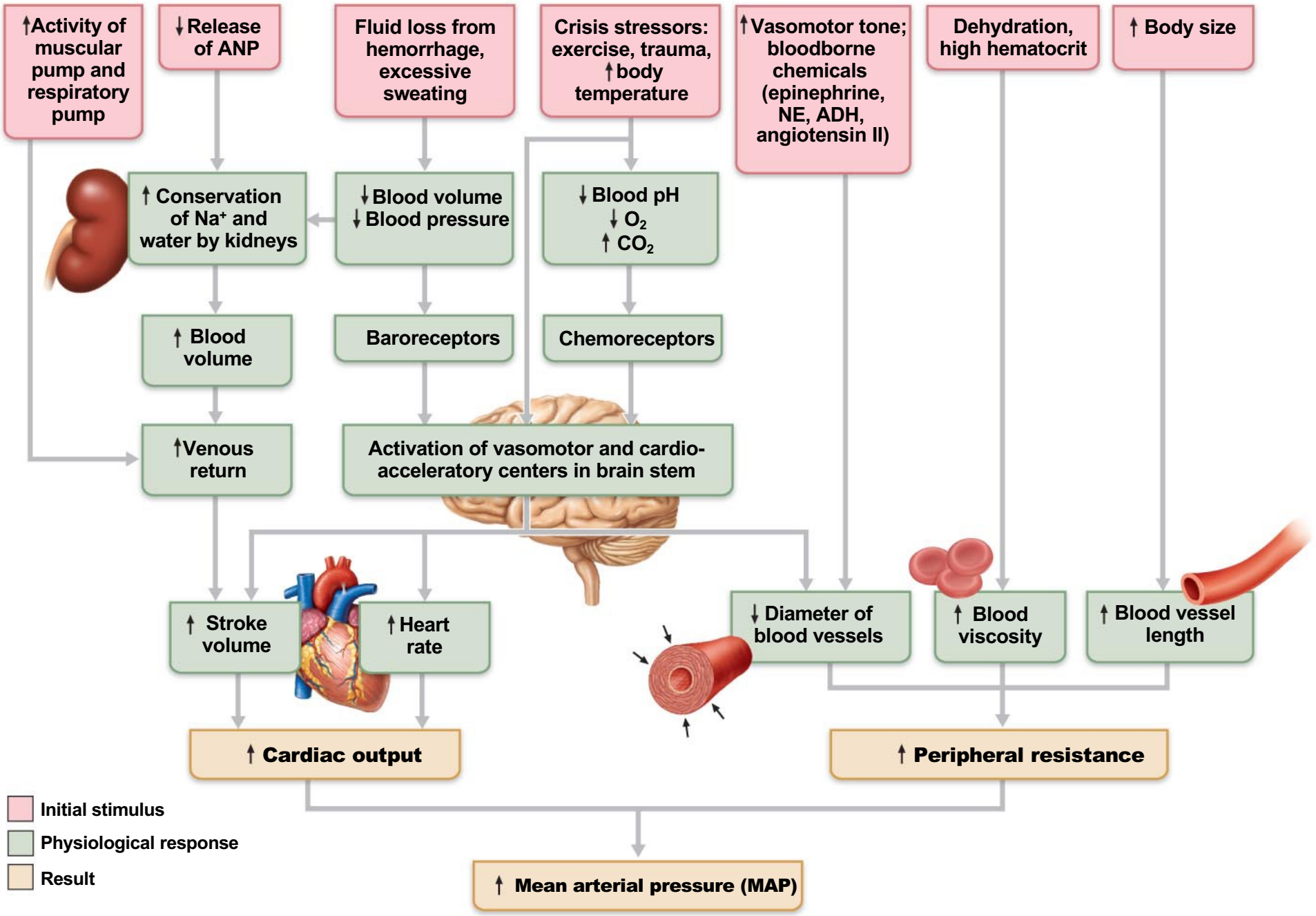
Factors Aiding Venous Return

1. **Muscular pump**: contraction of skeletal muscles "milks" blood toward heart; valves prevent backflow
2. **Respiratory pump**: pressure changes during breathing move blood toward heart by squeezing abdominal veins as thoracic veins expand
3. **Venoconstriction** under sympathetic control pushes blood toward heart

Maintaining Blood Pressure

- Requires
  - Cooperation of heart, blood vessels, and kidneys
  - Supervision by brain
- Main factors influencing blood pressure
  - Cardiac output (CO)
  - Peripheral resistance (PR)
  - Blood volume

Figure 19.11 Factors that increase MAP.



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Dr. Brasington

The Cardiovascular System: Blood Vessels: Part 2

Monitoring Circulatory Efficiency

- **Vital signs**: pulse and blood pressure, along with respiratory rate and body temperature
- **Pulse**: pressure wave caused by expansion and recoil of arteries
- **Radial pulse** (taken at the wrist) routinely used
- **Pressure points** where arteries close to body surface
  - Can be compressed to stop blood flow

Measuring Blood Pressure

- Systemic arterial BP
  - Measured indirectly by **auscultatory method** using a **sphygmomanometer**
  - Pressure increased in cuff until it exceeds systolic pressure in brachial artery
  - Pressure released slowly and examiner listens for **sounds of Korotkoff** with a stethoscope

Measuring Blood Pressure

- **Systolic pressure**, normally less than 120 mm Hg, is pressure when sounds first occur as blood starts to spurt through artery
- **Diastolic pressure**, normally less than 80 mm Hg, is pressure when sounds disappear because artery no longer constricted; blood flowing freely

Alterations in Blood Pressure

- **Hypertension**: high blood pressure
  - Sustained elevated arterial pressure of 140/90 or higher
  - Age and sex of patient plays a role
  - **Prehypertension** if values elevated but not yet in hypertension range
    - May be transient adaptations during fever, physical exertion, and emotional upset
    - Often persistent in obese people

Alterations in Blood Pressure

- **Hypotension**: low blood pressure
  - Blood pressure below 90/60 mm Hg
  - Usually not a concern
    - Only if leads to inadequate blood flow to tissues
  - Often associated with long life and lack of cardiovascular illness

Homeostatic Imbalance: Hypotension

- **Orthostatic hypotension**: temporary low BP and dizziness when suddenly rising from sitting or reclining position
- **Chronic hypotension**: hint of poor nutrition and warning sign for Addison's disease or hypothyroidism
- **Acute hypotension**: important sign of circulatory shock; threat for surgical patients and those in ICU

Blood Flow: Skeletal Muscles

- Varies with fiber type and activity
  - At rest, myogenic and general neural mechanisms predominate - maintain ~ 1L /minute
  - During muscle activity
    - **Active or exercise hyperemia** - blood flow increases in direct proportion to metabolic activity
    - Local controls override sympathetic vasoconstriction
    - Muscle blood flow can increase 10×

Blood Flow: Brain

- Brain vulnerable under extreme systemic pressure changes
  - MAP below 60 mm Hg can cause **syncope** (fainting)
  - MAP above 160 can result in cerebral edema

Circulatory Pathways: Blood Vessels of the Body

- Two main circulations
  - **Pulmonary circulation**: short loop that runs from heart to lungs and back to heart
  - **Systemic circulation**: long loop to all parts of body and back to heart

Figure 19.19a Pulmonary circulation.

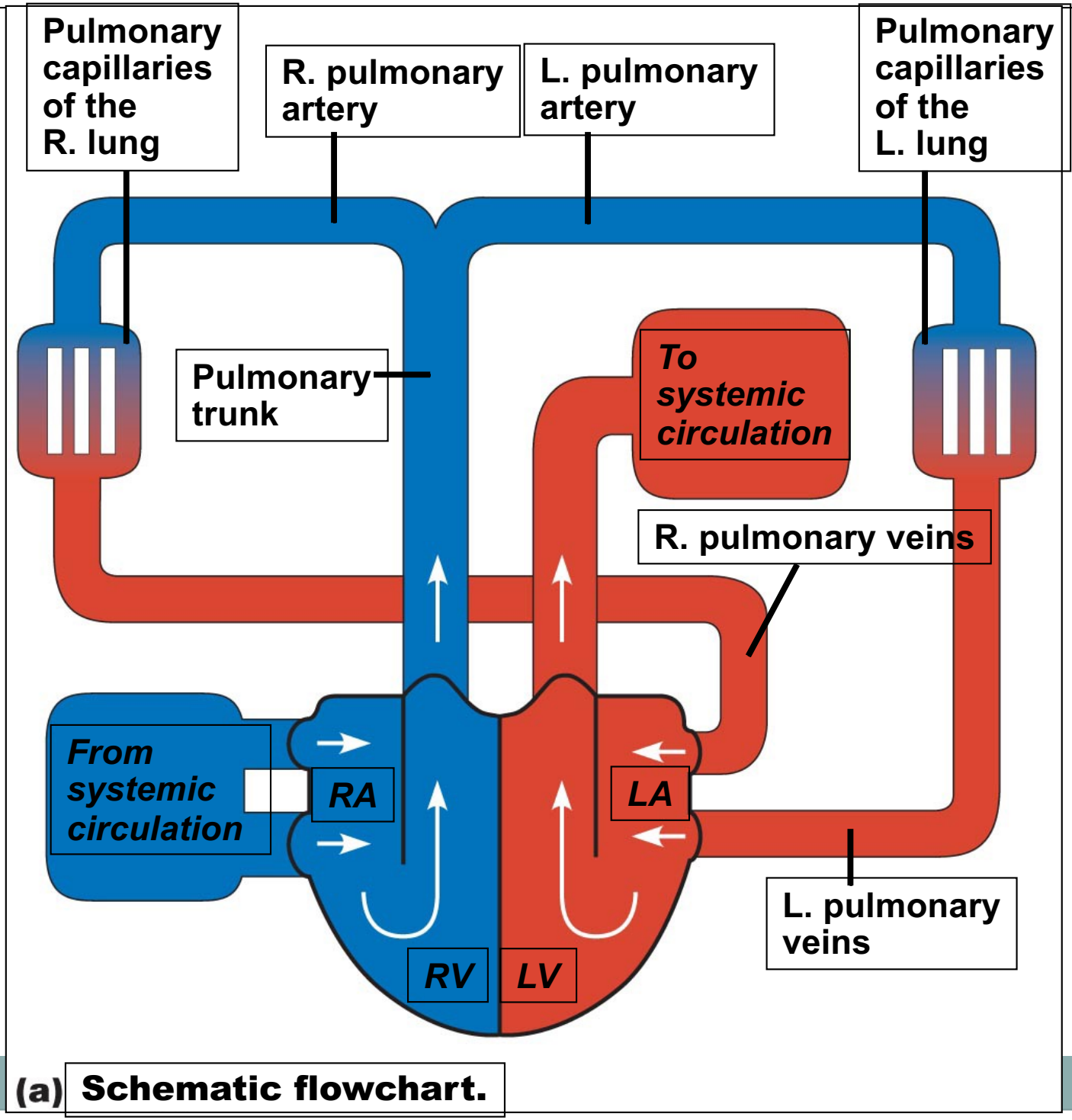
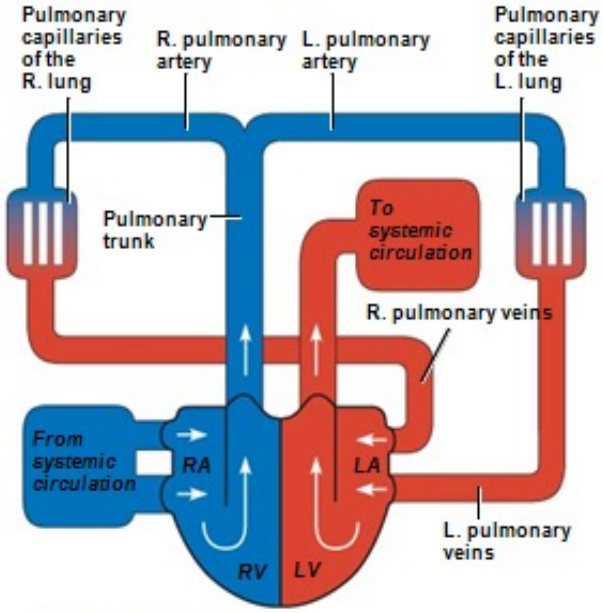
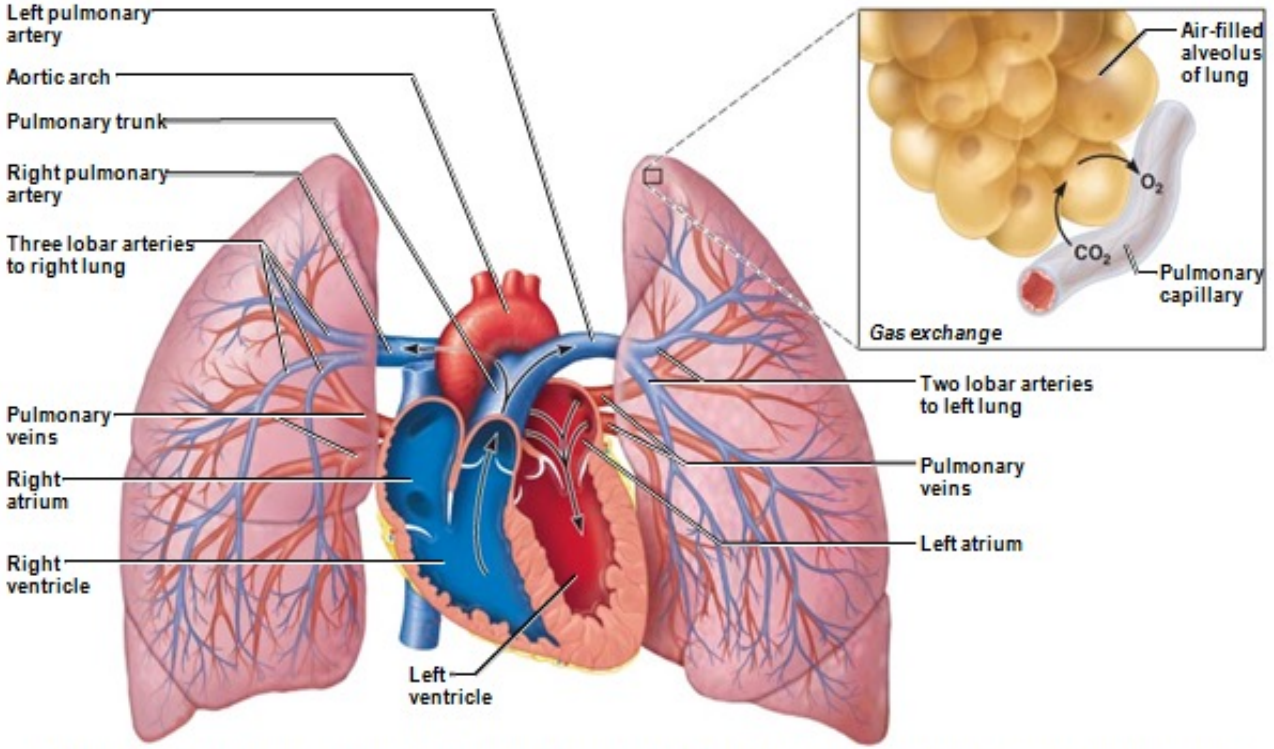


Figure 19.19 Pulmonary circulation.

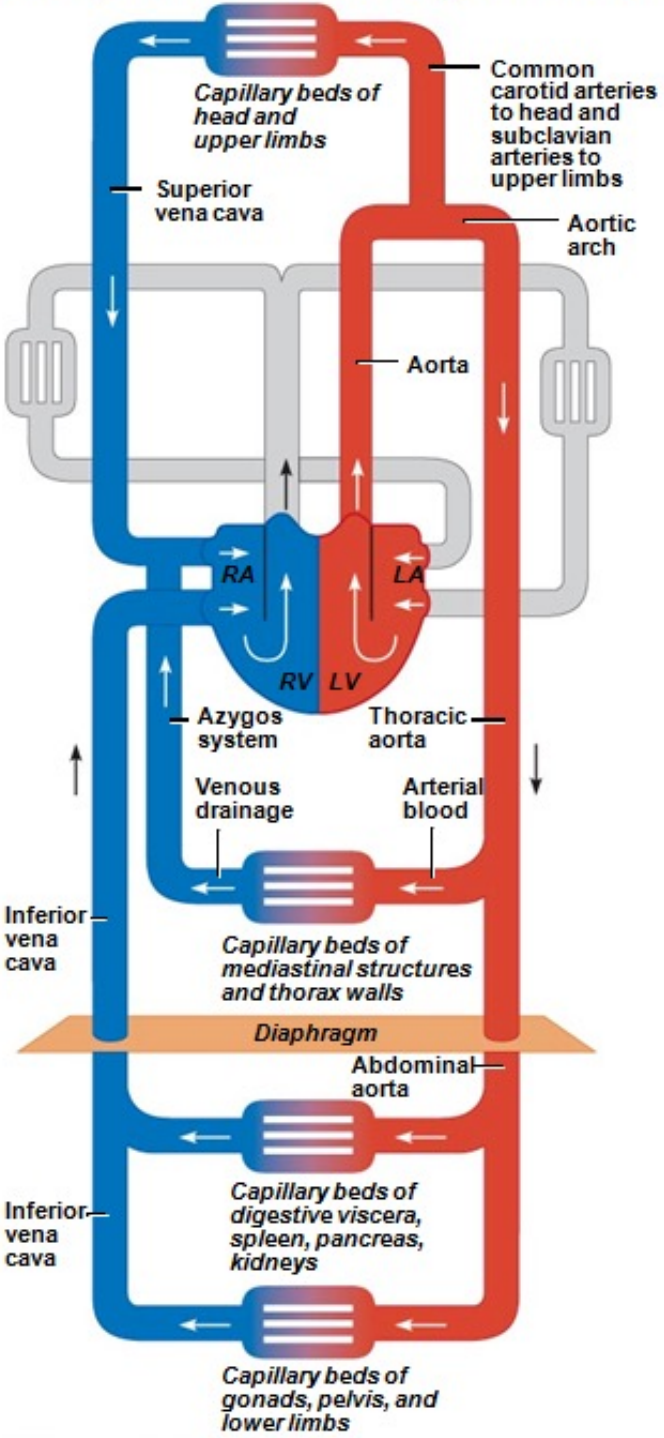


(a) Schematic flowchart.



(b) Illustration. The pulmonary arterial system is shown in blue to indicate that the blood it carries is oxygen-poor. The pulmonary venous drainage is shown in red to indicate that the blood it transports is oxygen-rich.

Figure 19.20 Schematic flowchart showing an overview of the systemic circulation.



Differences Between Arteries and Veins

	Arteries	Veins
Delivery	Blood pumped into single systemic artery—the aorta	Blood returns via superior and inferior venae cavae and the coronary sinus
Location	Deep, and protected by tissues	Both deep and superficial
Pathways	Fairly distinct	Numerous interconnections
Supply/drainage	Predictable supply	Usually similar to arteries, except dural sinuses and hepatic portal circulation