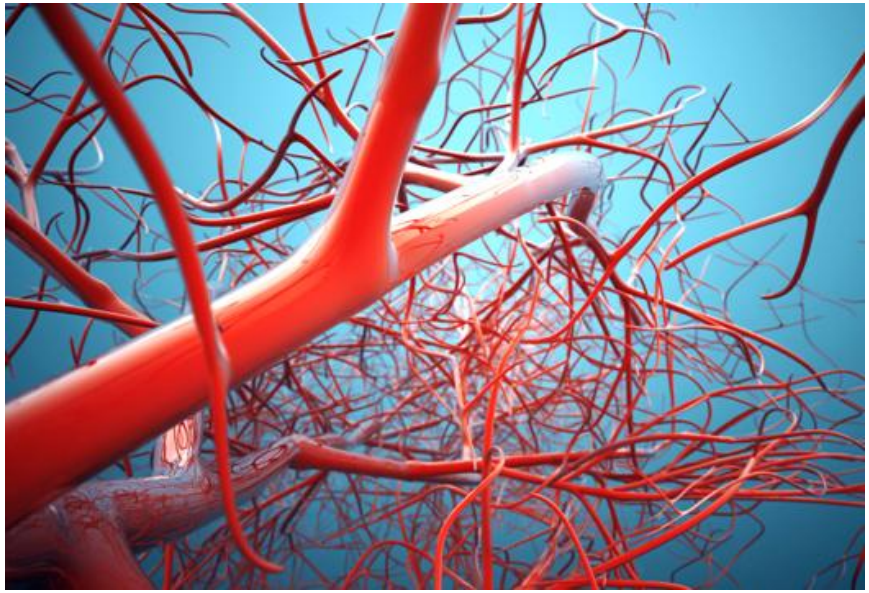

Physiology and Anatomy of Blood Vessels

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Disclosure

- The material and the illustrations are adopted from the textbook **“Human Anatomy and Physiology / Ninth edition/ Eliane N. Marieb 2013”**

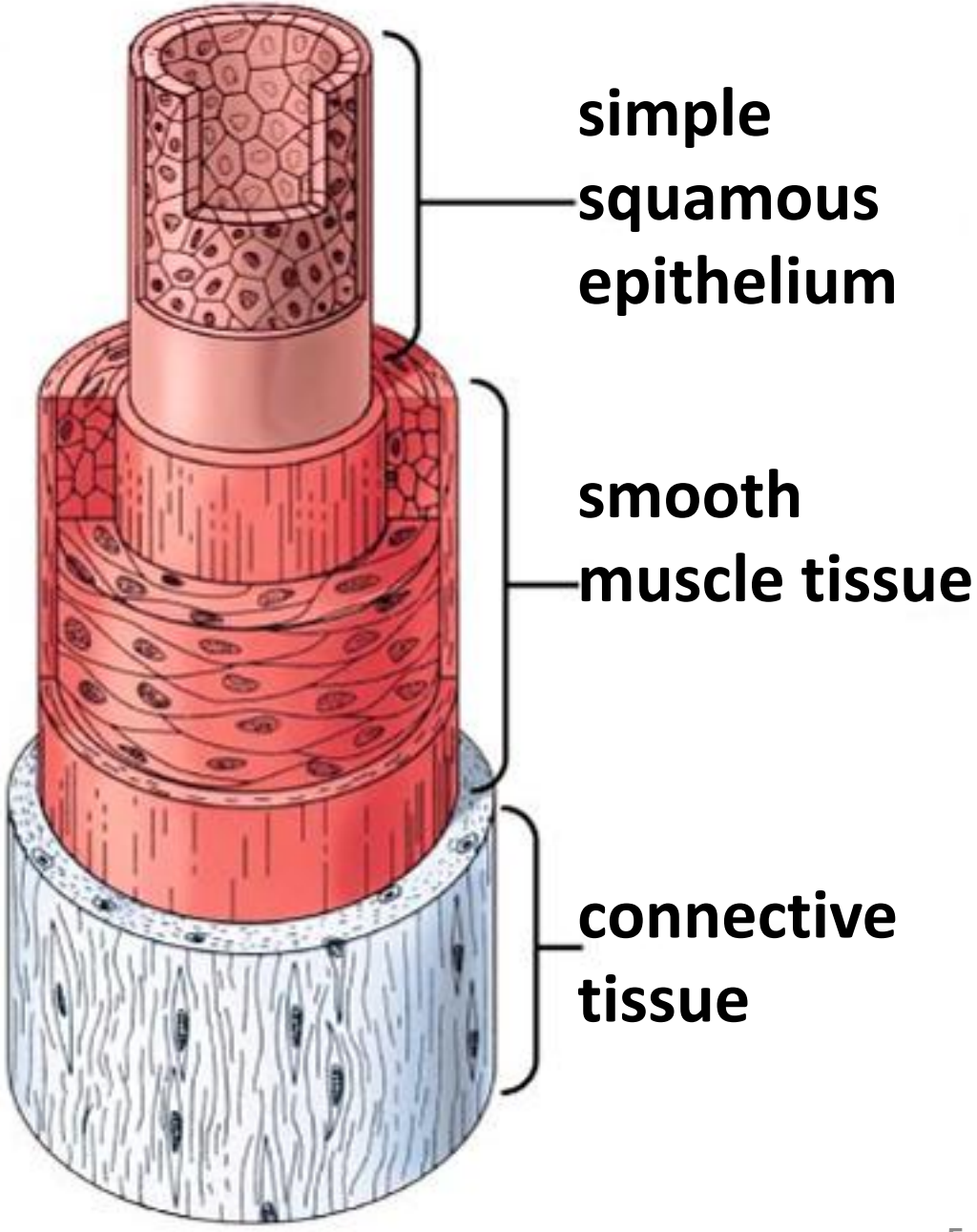
Blood vessels

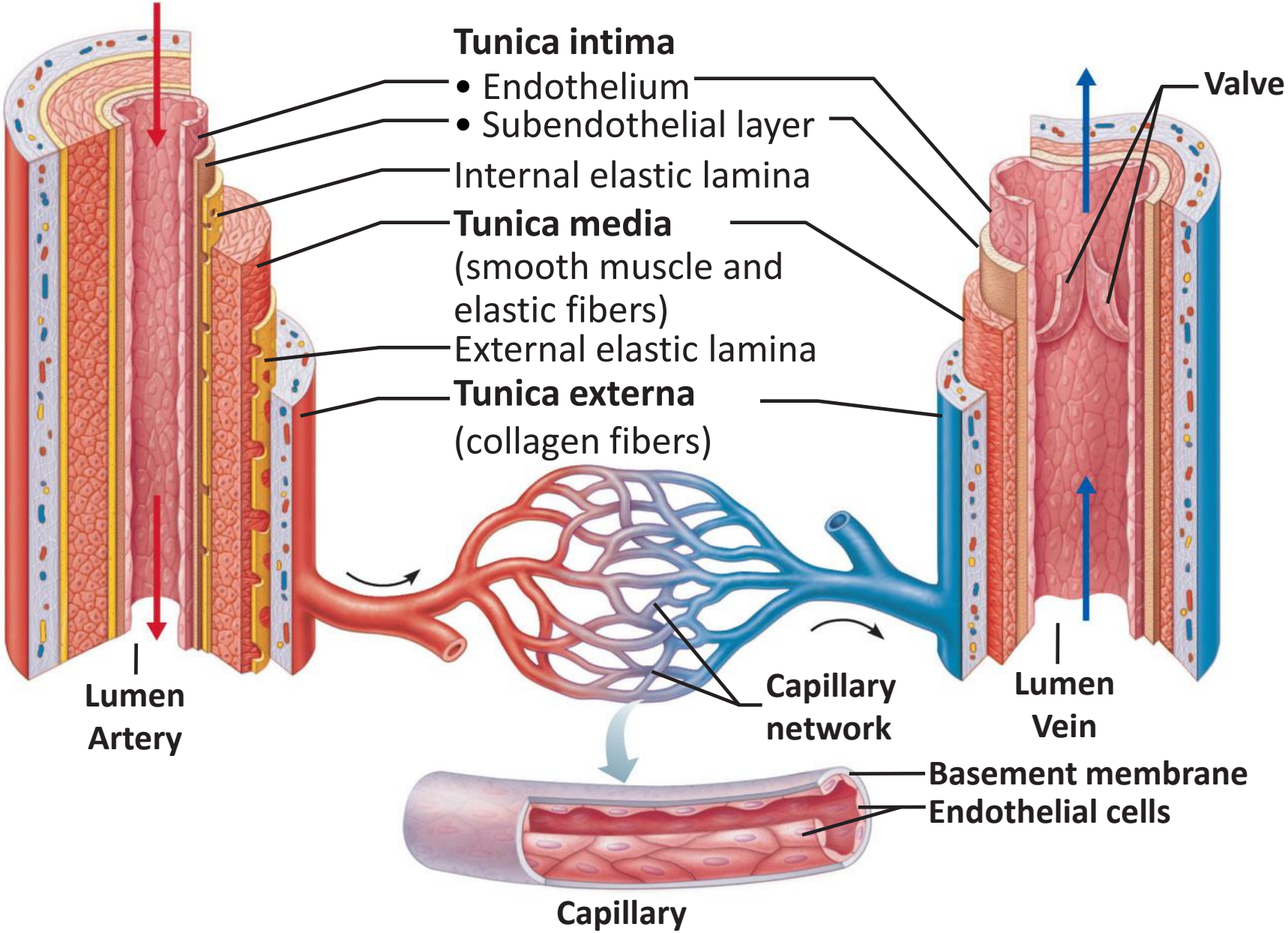
- Blood is carried in a closed system of vessels that begins and ends at the heart
- The three major types of vessels are arteries, capillaries, and veins
- Arteries carry blood away from the heart, veins carry blood toward the heart
- Capillaries contact tissue cells and directly serve cellular needs

Structure of Blood Vessel Walls

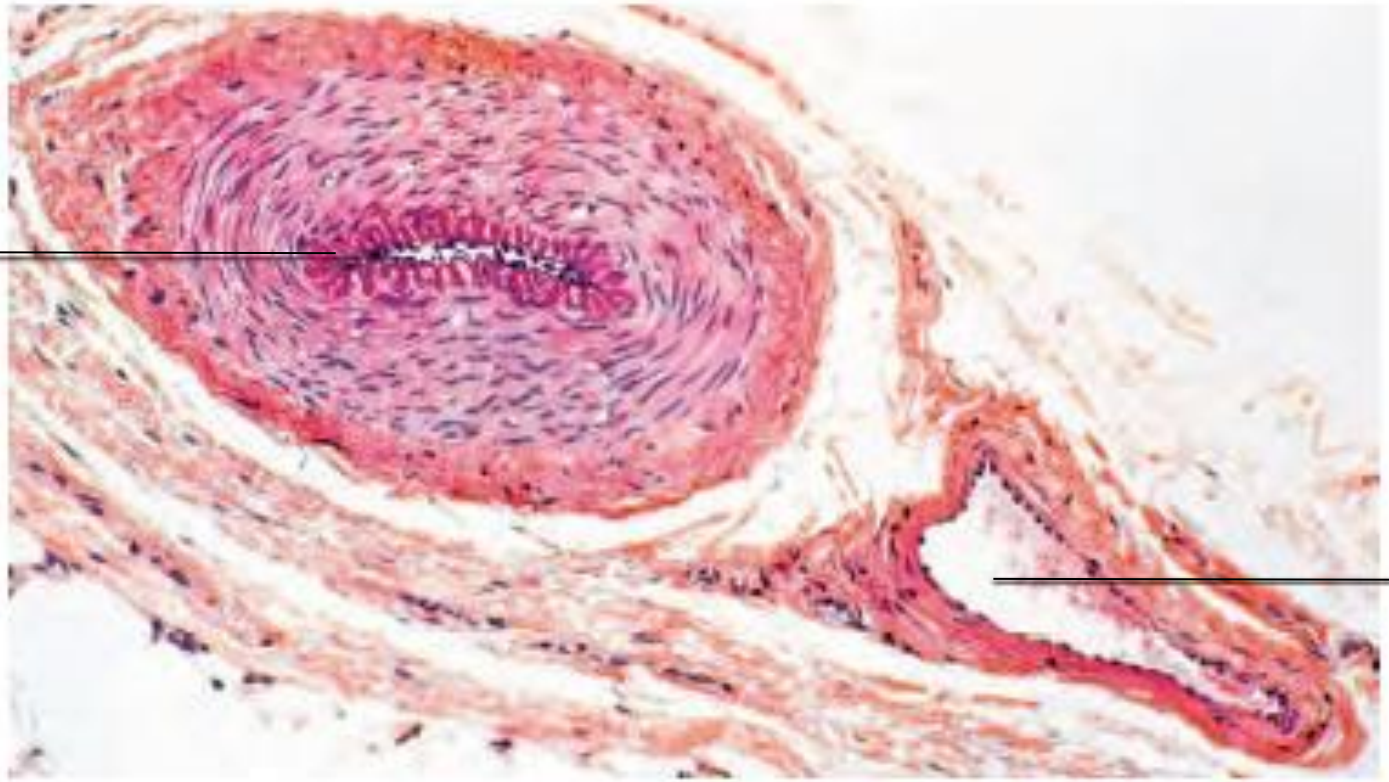
- The walls of all blood vessels, except small capillaries, have three distinct layers, or **tunics** (“coverings”), that surround a central blood-containing space, the vessel **lumen**

Blood Vessel Structur




Tunica intima
• Endothelium
• Subendothelial layer
Internal elastic lamina
Tunica media
(smooth muscle and elastic fibers)
External elastic lamina
Tunica externa
(collagen fibers)
Valve
Lumen
Artery
Capillary network
Lumen
Vein
Basement membrane
Endothelial cells
Capillary

Structure of Blood Vessel Walls



Tunics

Tunica interna (tunica intima)

- Endothelial layer that lines the lumen of all vessels
- In vessels larger than 1 mm in diameter, a subendothelial connective tissue basement membrane is present

Tunica media

- Smooth muscle and elastic fiber layer, regulated by sympathetic nervous system
- Controls vasoconstriction/vasodilation of vessels

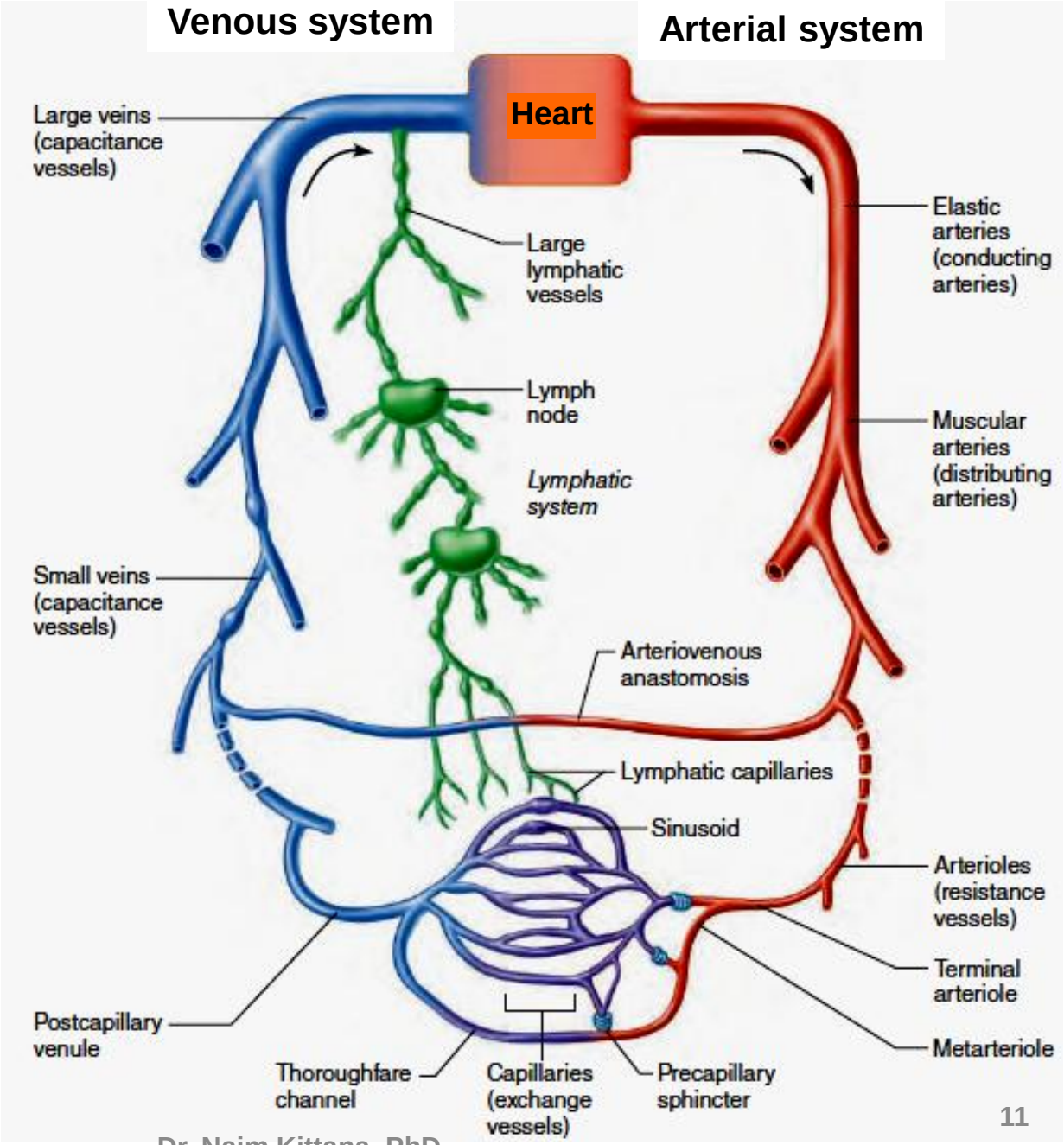
Tunics

Tunica externa (tunica adventitia)

- Collagen fibers that protect and reinforce vessels

- Larger vessels contain vasa vasorum: system of tiny blood vessels vessels of the vessels”—that nourish the more external tissues of the blood vessel wall

The relationship of blood vessels to each other and to lymphatic vessels



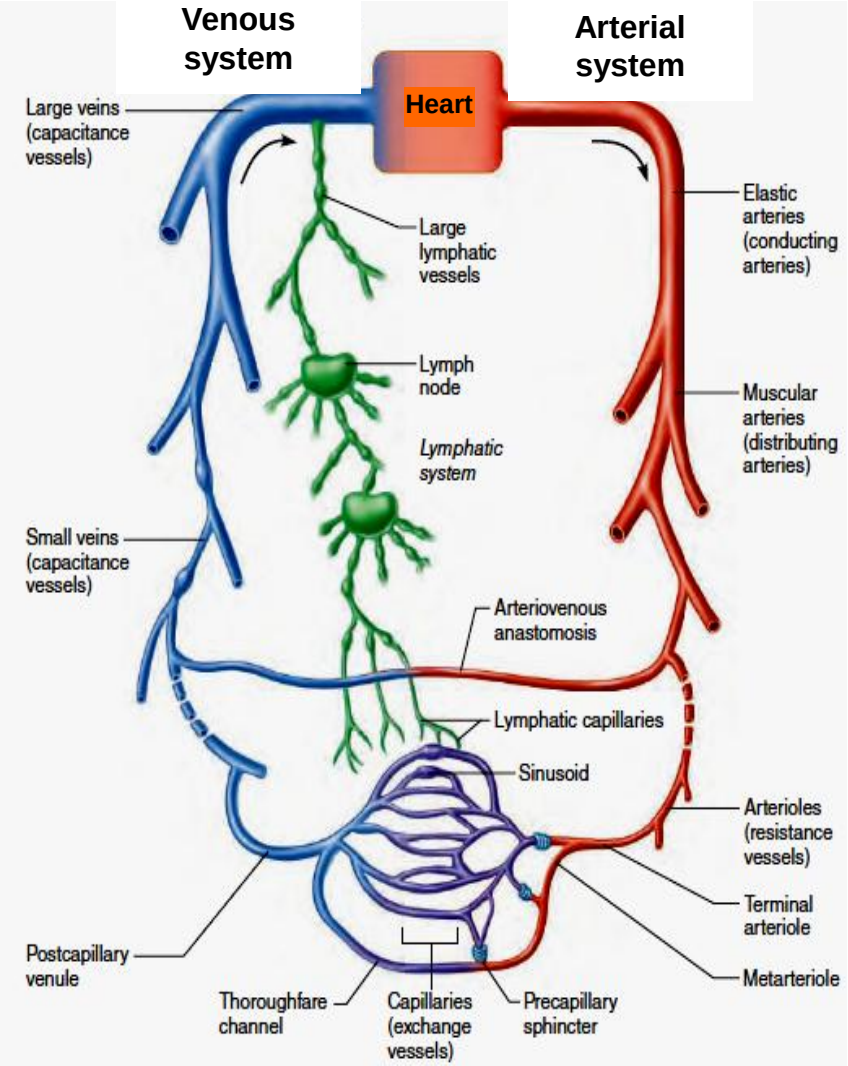
Arteries

1. Carry blood away from the heart.
2. Thick-walled to withstand hydrostatic pressure of the blood during ventricular systole.
3. Blood pressure pushes blood through the vessel

Elastic (Conducting) Arteries

Thick-walled arteries near the heart; the aorta and its major branches

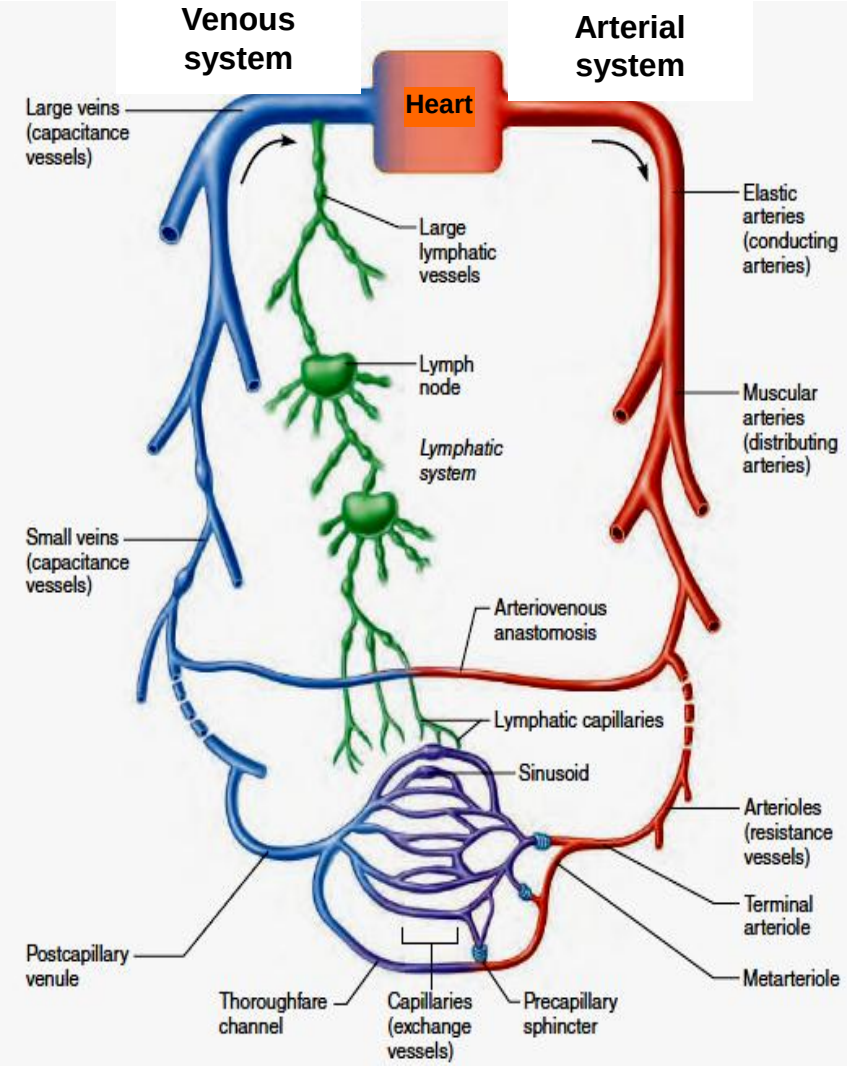
- Large lumen allow low-resistance conduction of blood
- Contain elastin in all three tunics
- Withstand and smooth out large blood pressure fluctuations
- Allow blood to flow fairly continuously through the body



Muscular (Distributing) Arteries and Arterioles

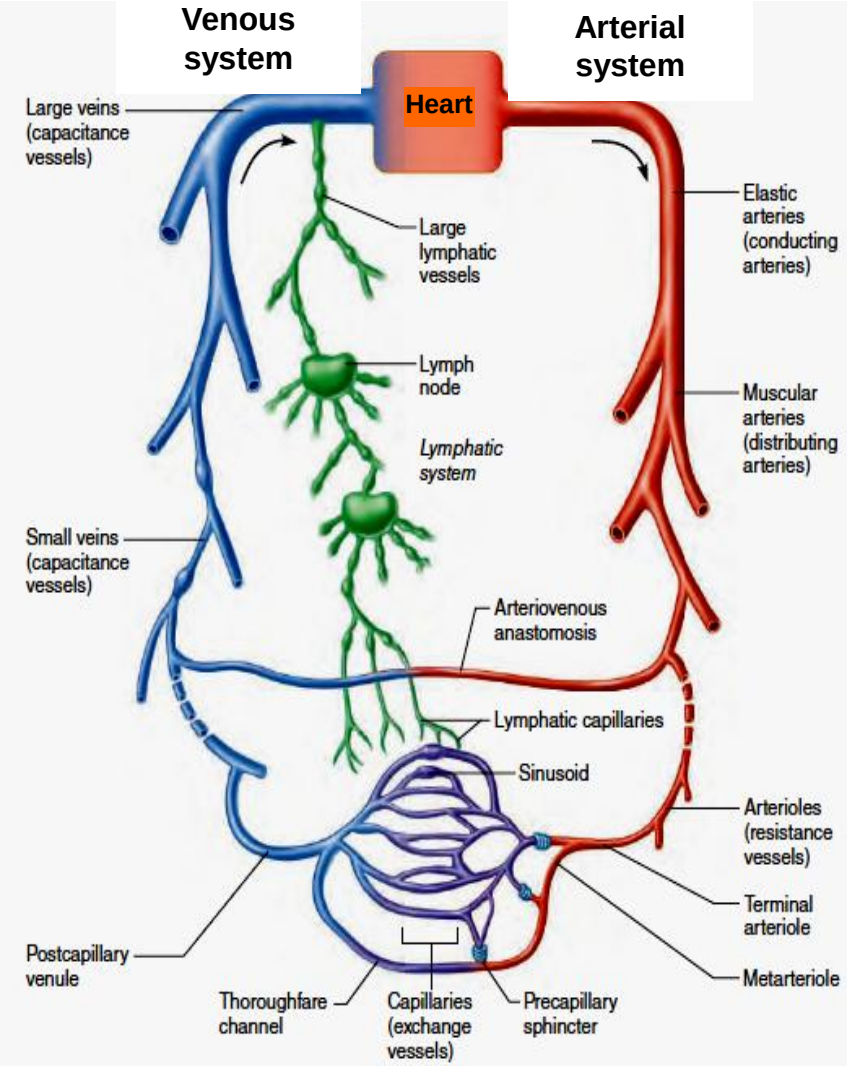
Muscular arteries – distal to elastic arteries; deliver blood to body organs

- Have thick tunica media with more smooth muscle and less elastic tissue
- Active in vasoconstriction



Arterioles

- The smallest arteries
- Lead to capillary beds
- Control flow into capillary beds via vasodilation and constriction



Capillaries

Capillaries are the smallest blood vessels

- Walls consisting of a thin tunica interna, one cell thick
- Allow only a single RBC to pass at a time
- Pericytes on the outer surface stabilize their walls

There are three structural types of capillaries: continuous, fenestrated, and sinusoids

Capillaries

- Average capillary length is 1 mm and average lumen diameter is 8–10 µm, just large enough for red blood cells to slip through in single file.

- **Most tissues have a rich capillary supply, but there are exceptions.**
  - Tendons and ligaments are poorly vascularized.
  - Cartilage lack capillaries, but receive nutrients from blood vessels in nearby connective tissues,
  - The avascular cornea and lens of the eye receive nutrients from the aqueous humor.

Capillaries

- **There are three structural types of capillaries:**
  - Continuous
  - Fenestrated
  - Sinusoids

Continuous Capillaries

Continuous capillaries are abundant in the skin and muscles, and have:

- Endothelial cells that provide an uninterrupted lining
- Adjacent cells that are held together with tight junctions
- these junctions are usually incomplete and leave gaps of unjoined membrane called **intercellular clefts**
- Intercellular clefts are just large enough to allow limited passage of fluids and small solutes

Continuous Capillaries

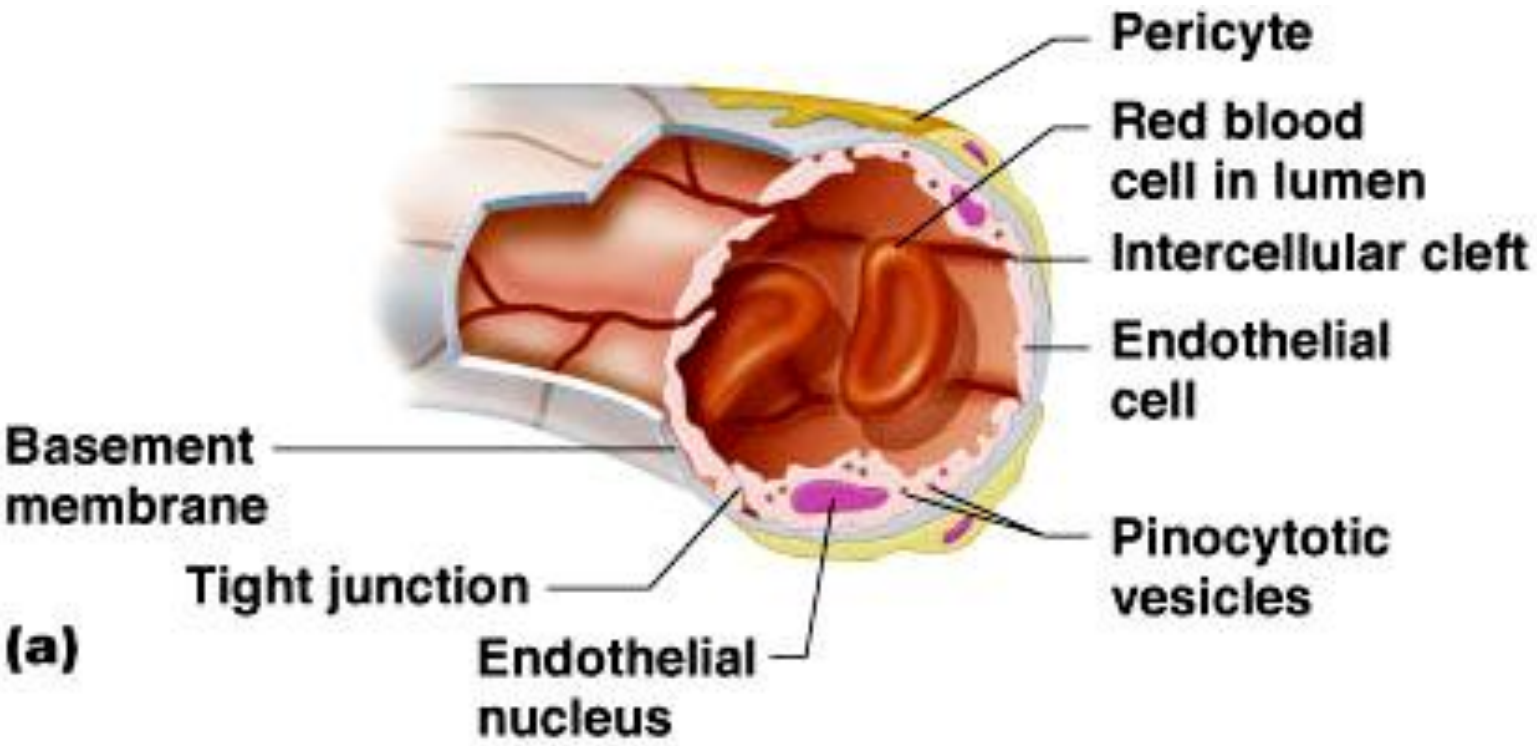
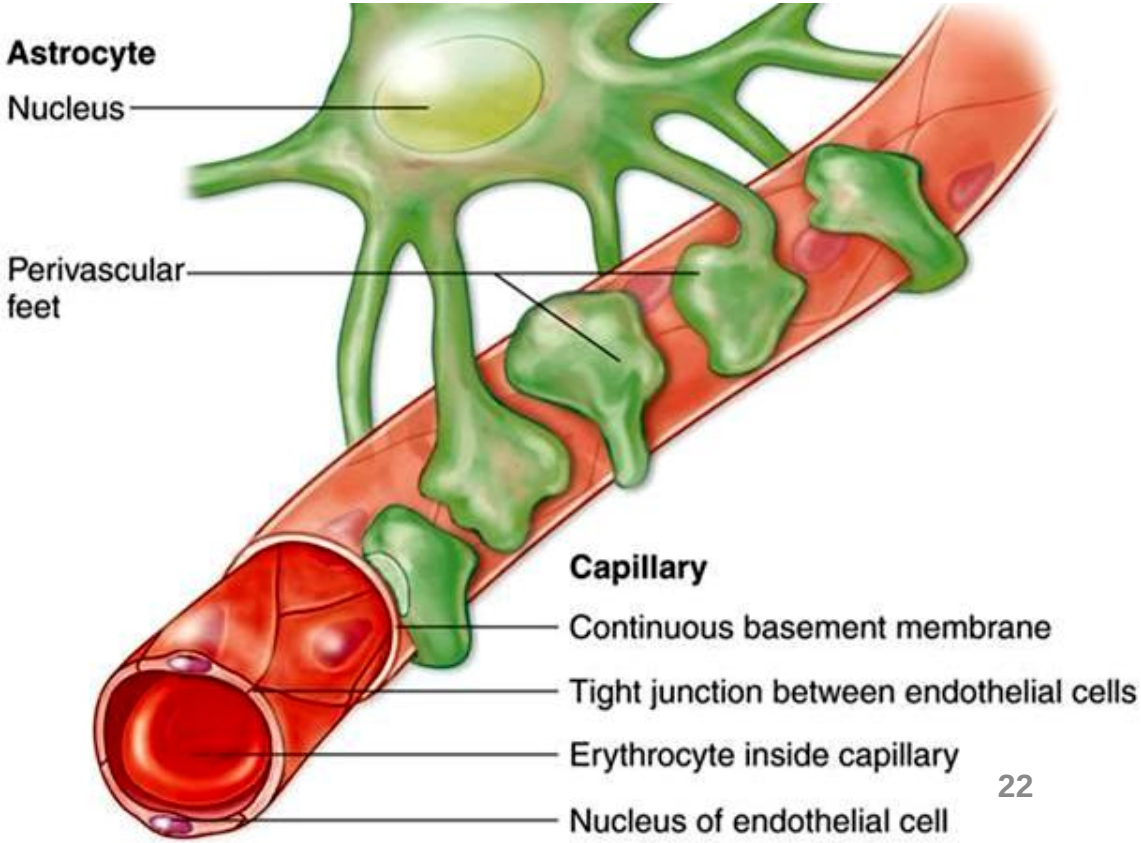


Figure 19.3a

Continuous Capillaries

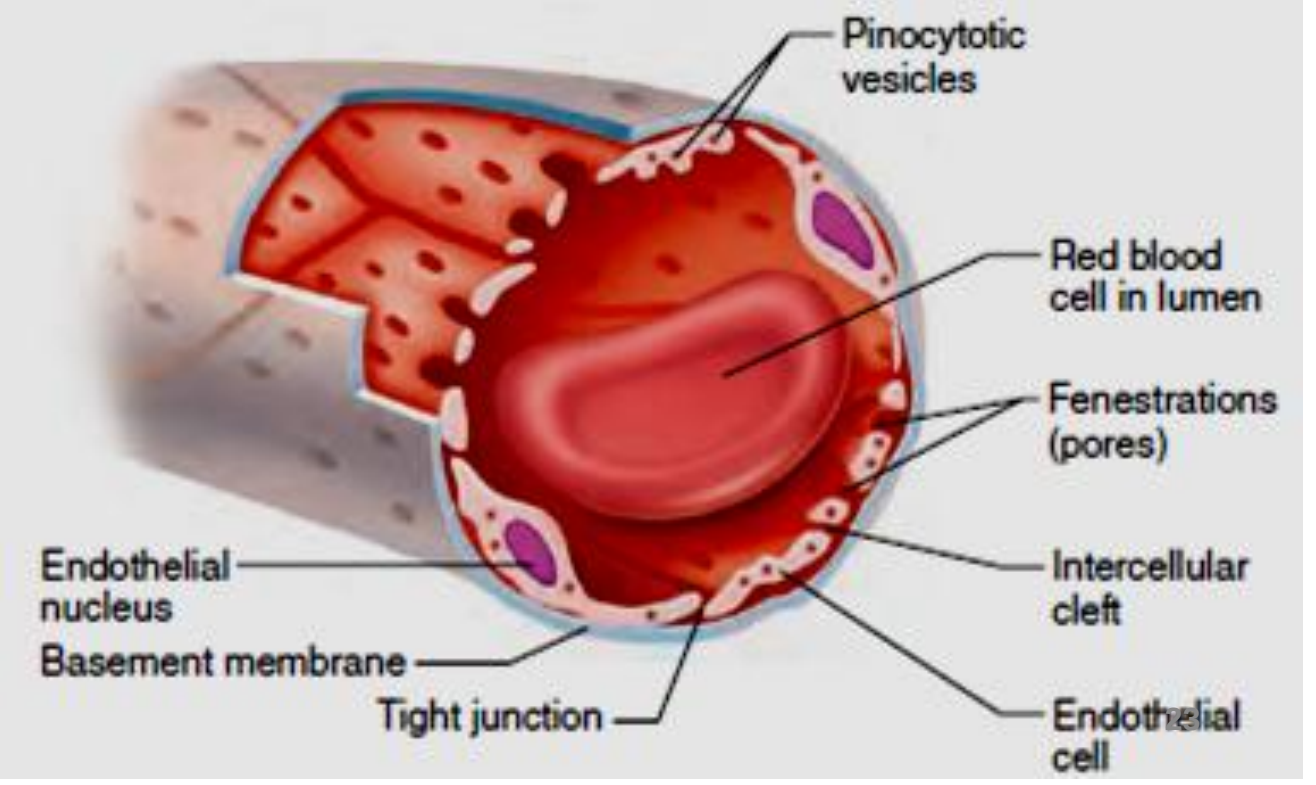
The unique continuous capillaries of the brain:

- The tight junctions of the continuous capillaries are complete and extend around the entire perimeter of the endothelial cells, constituting the structural basis of the Blood Brain Barrier



Fenestrated Capillaries

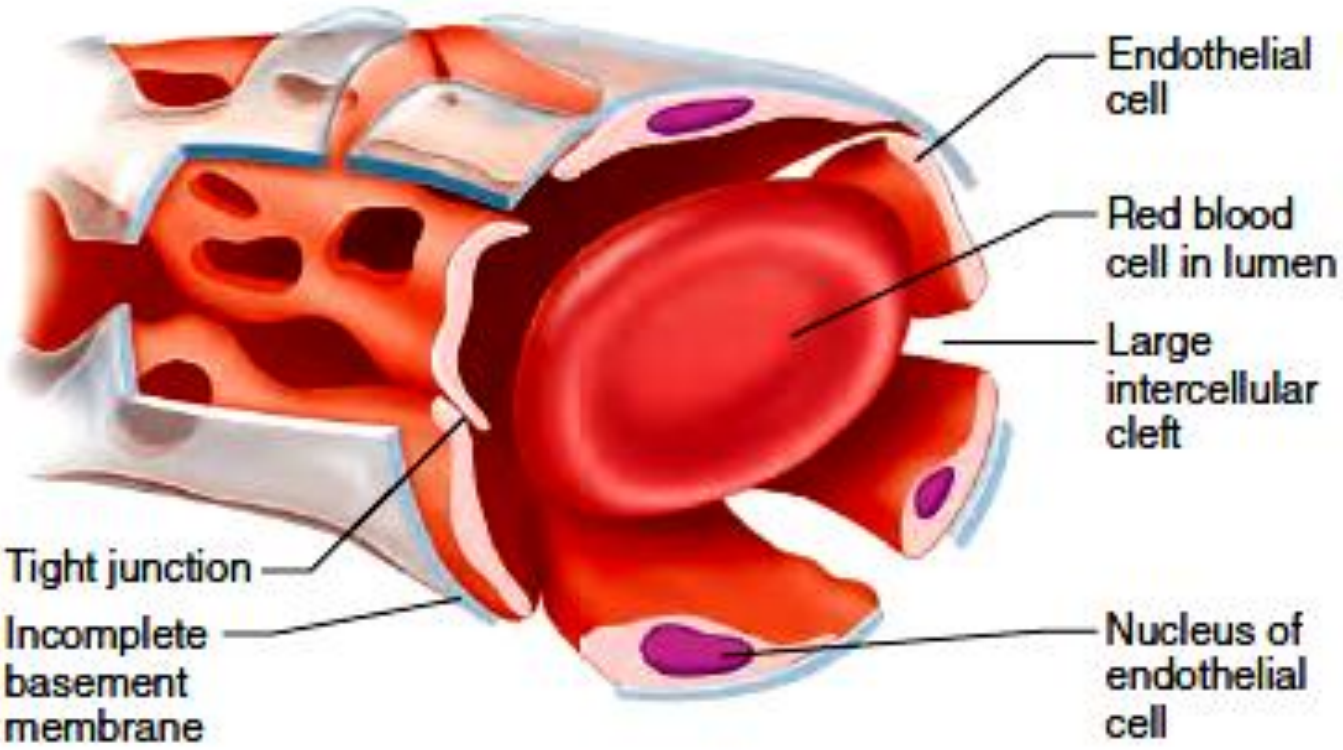
- Found wherever active capillary absorption or filtrate formation occurs (e.g., small intestines, endocrine glands, and kidneys)
- Characterized by:
  - An endothelium riddled with pores (fenestrations)
  - Greater permeability to solutes and fluids than other capillaries



Sinusoid Capillaries (Sinusoids)

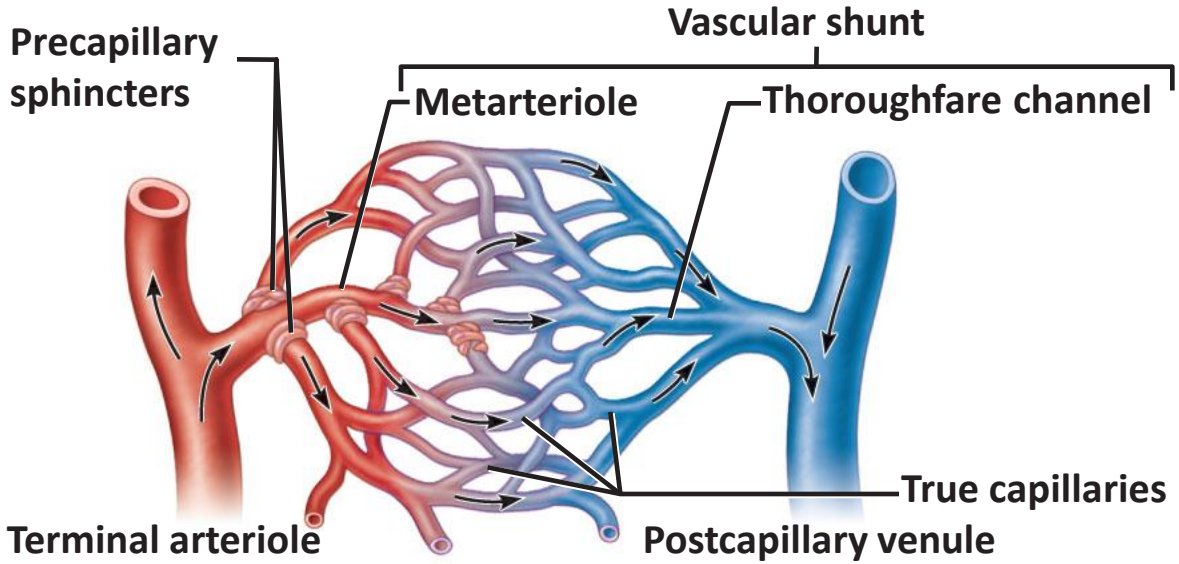
- Highly modified, leaky, fenestrated capillaries with large lumens
- Found in the liver, bone marrow, lymphoid tissue, and in some endocrine organs
- Allow large molecules (proteins and blood cells) to pass between the blood and surrounding tissues
- Their endothelial lining has fewer tight junctions and larger intercellular clefts than ordinary capillaries

Sinusoid Capillaries (Sinusoids)

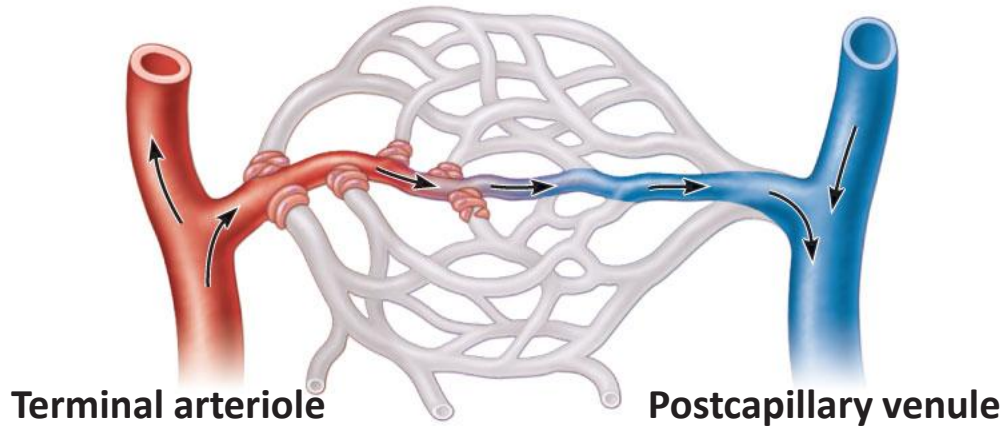


Capillary Beds

- A microcirculation of interweaving networks of capillaries, consisting of:
  - Vascular shunts: metarteriole– thoroughfare channel connecting an arteriole directly with a postcapillary venule
  - True capillaries – 10 to 100 per capillary bed, capillaries branch off the metarteriole and return to the thoroughfare channel at the distal end of the bed



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

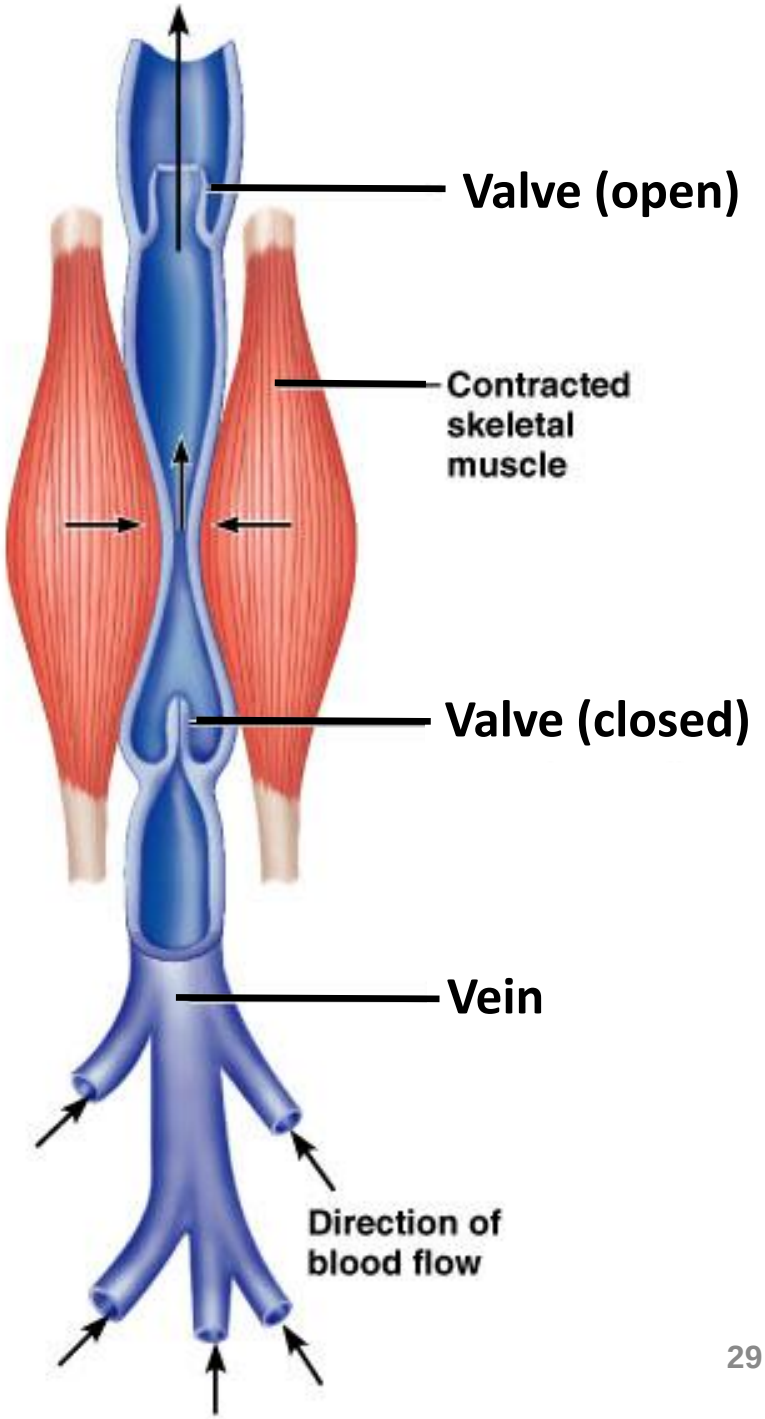


(b) Sphincters closed—**blood flows through metarteriole thoroughfare channel and bypasses true capillaries.**

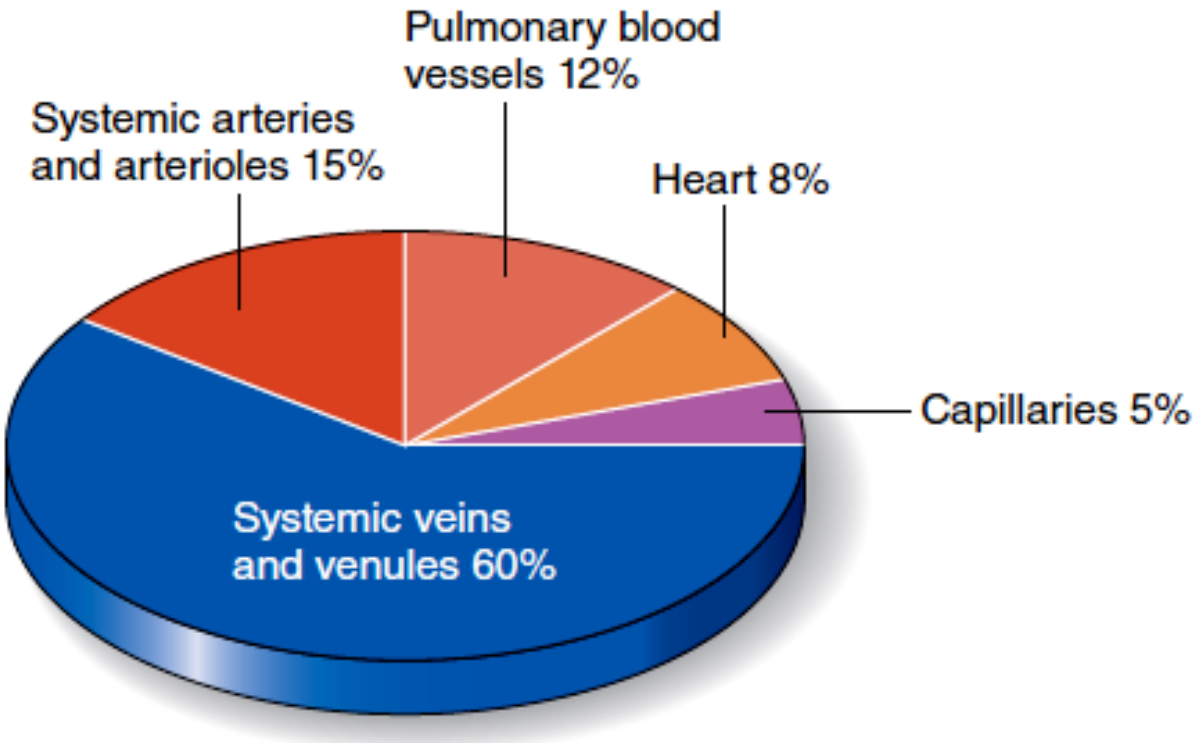
Veins

- Carry blood to the heart.
- Thinner-walled than arteries.
- Possess one-way valves that prevent backwards flow of blood.
- Blood flow due to body movements, not from blood pressure.

One-Way Valves in Veins



Relative proportion of blood volume throughout the cardiovascular system



Vascular Anastomoses

- Blood vessels form special interconnections
- Most organs receive blood from more than one arterial branch
- They provide alternate pathways, called **collateral channels, for blood to reach a given body** region
- They are also common in abdominal organs, the heart, and the brain

Physiology of Circulation

Blood Flow

- Blood flow is the volume of blood flowing through a vessel, an organ, or the entire circulation in a given period (ml/min).

- If we consider the entire vascular system, blood flow is equivalent to cardiac output (CO),

Blood pressure (BP)

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

Resistance (peripheral resistance)

- Opposition to flow
- Measure of the amount of friction blood encounters
- Generally encountered in the peripheral systemic circulation

Three important sources of resistance

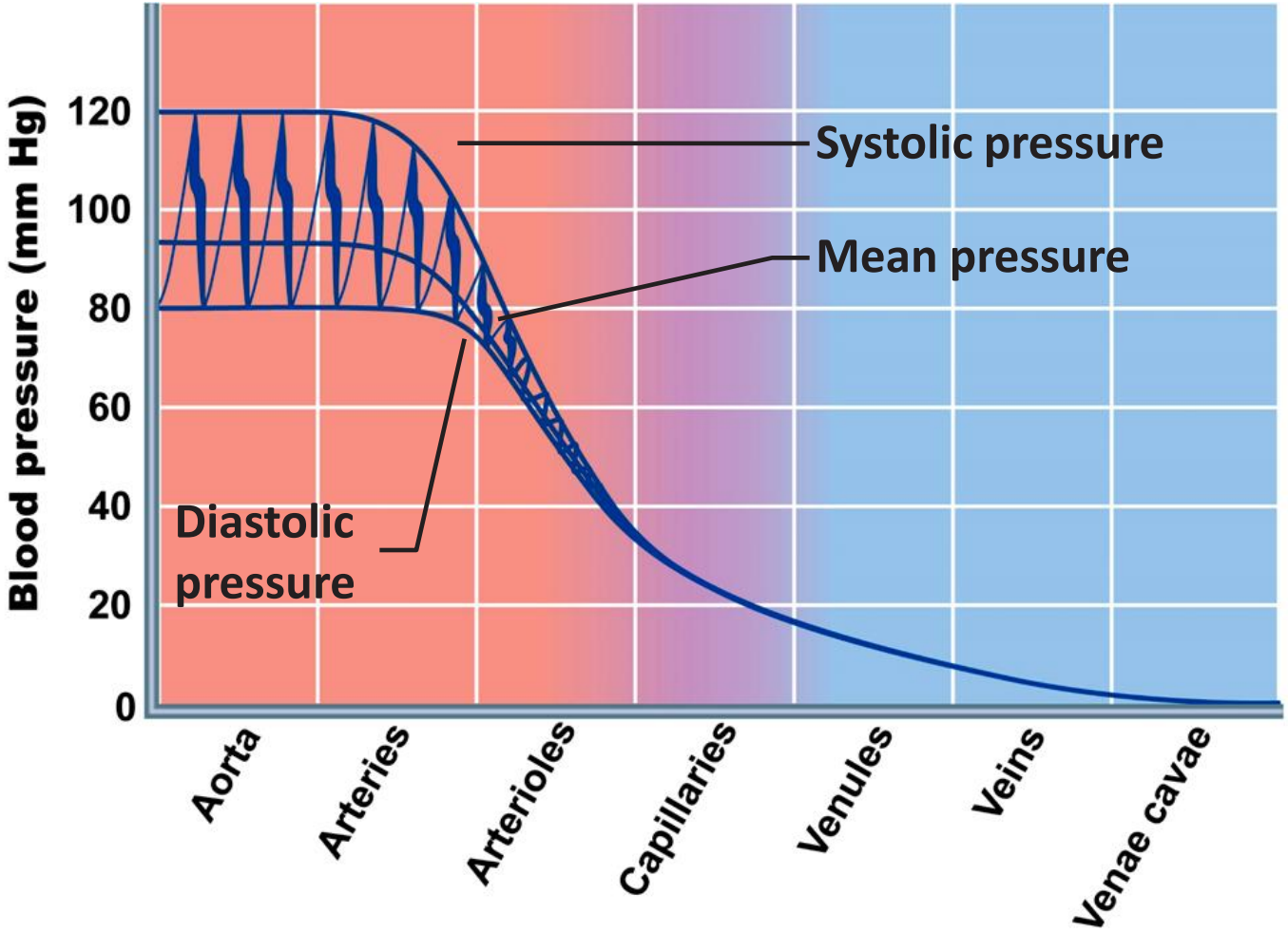
- Blood viscosity
- Total blood vessel length
- Blood vessel diameter

Systemic Blood Pressure

- Any fluid driven by a pump through a circuit of closed channels operates under pressure, and the nearer the fluid is to the pump, the greater the pressure exerted on the fluid

Systemic Blood Pressure

- The pumping action of the heart generates blood flow
- Pressure results when flow is opposed by resistance
- Systemic pressure
  - Is highest in the aorta
  - Declines throughout the pathway
  - Is 0 mm Hg in the right atrium
- The steepest drop occurs in arterioles



blood pressure is pulsatile—it rises and falls in a regular fashion—in the elastic arteries near the heart.

Resistance

Factors that remain relatively constant:

- **Blood viscosity**

  The “stickiness” of the blood due to formed elements and plasma proteins

- **Blood vessel length**

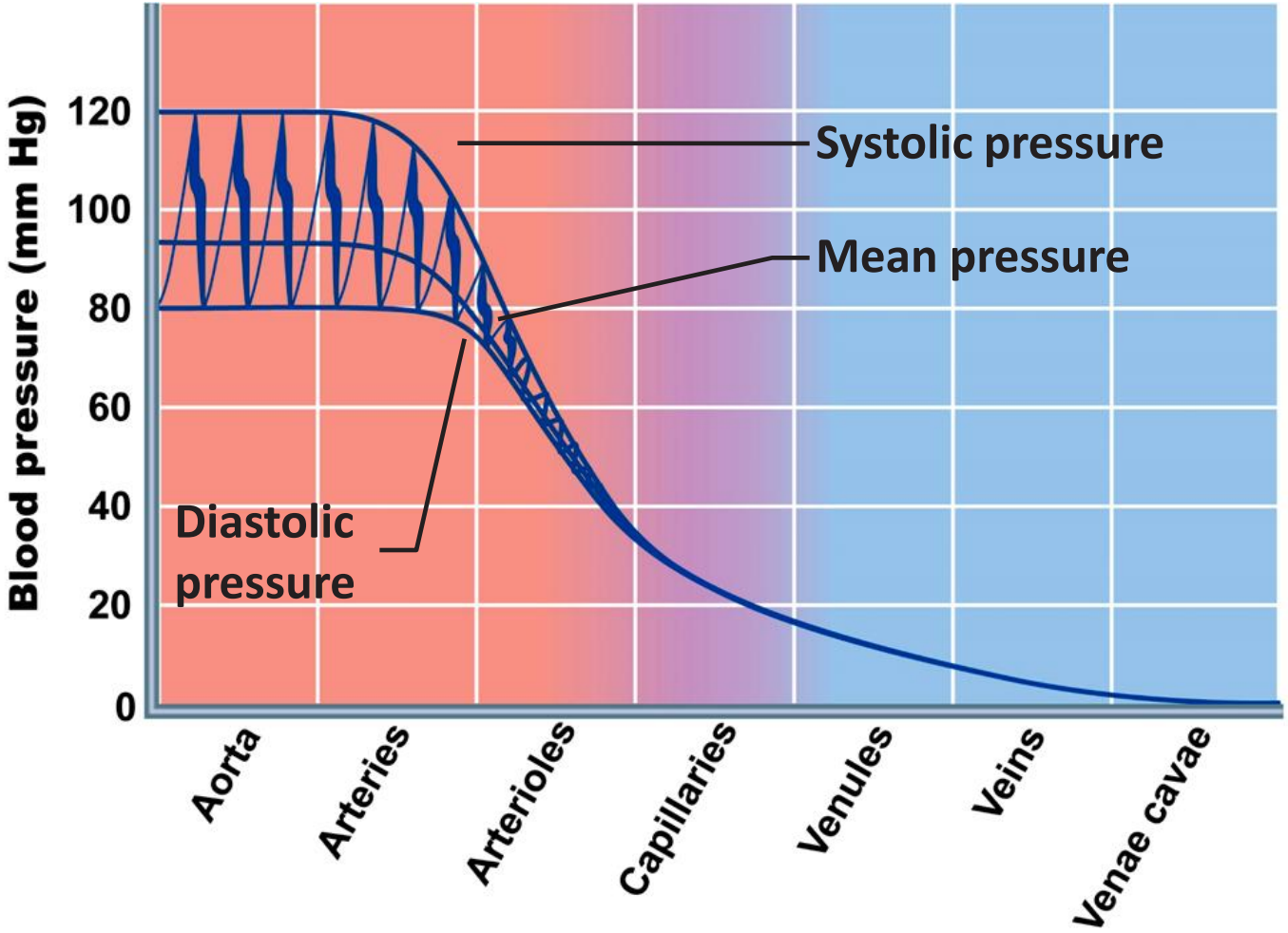
  The longer the vessel, the greater the resistance encountered

Resistance

- Small-diameter arterioles are the major determinants of peripheral resistance
- Abrupt changes in diameter or fatty plaques from atherosclerosis dramatically increase resistance
  - Disrupt laminar flow and cause turbulence
- Resistance varies inversely to vessel radius

Venous Blood Pressure

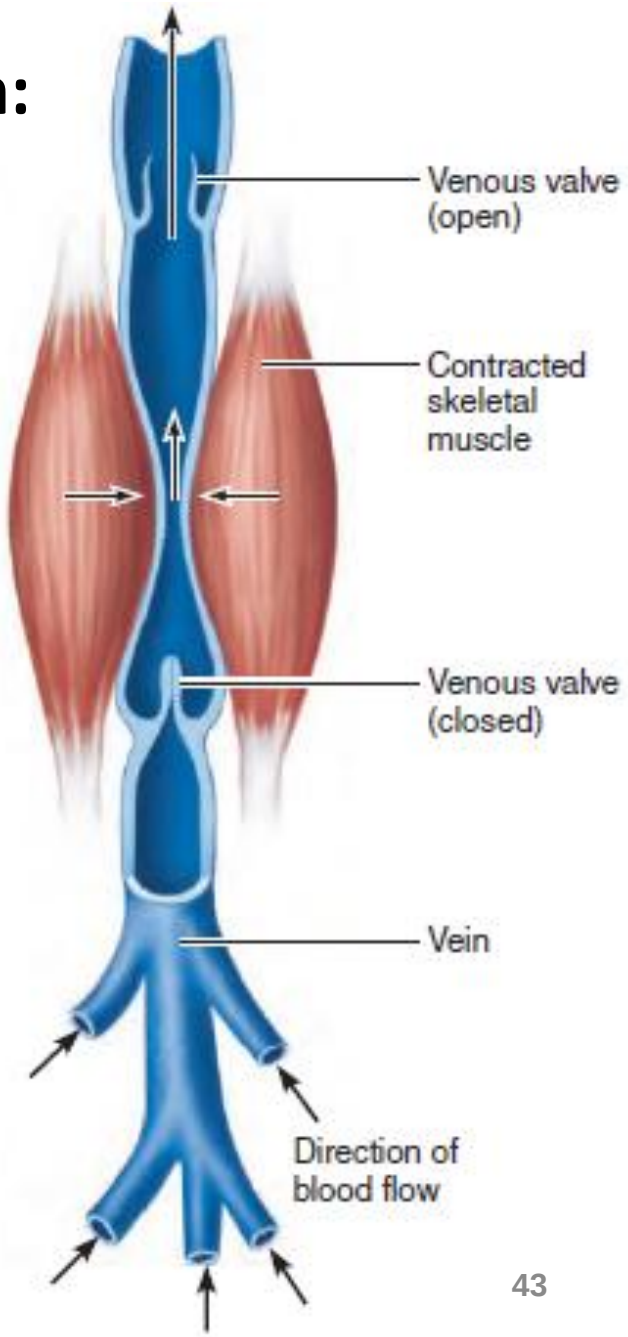
- Arterial pressure pulsates with each contraction of the left ventricle
- Venous blood pressure is steady and changes very little during the cardiac cycle.
- The pressure gradient in the veins, from venules to the termini of the venae cavae, is about 15 mm Hg
- The pressure gradient in the arteries gradient from the aorta to the ends of the arterioles is about 60 mm Hg.
- Venous pressure is normally too low to promote adequate venous return



blood pressure is pulsatile—it rises and falls in a regular fashion—in the elastic arteries near the heart.

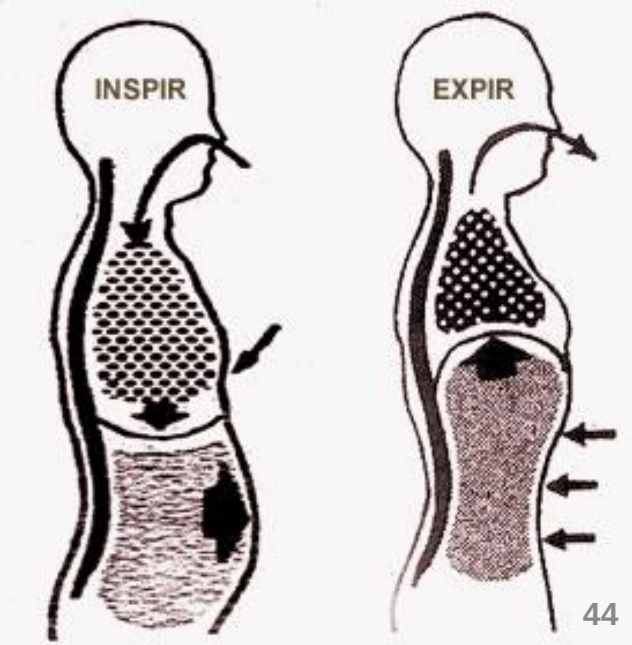
Factors contributing to venous return:

- **The muscular pump:**
  - As the skeletal muscles surrounding the deep veins contract and relax, they “milk” blood toward the heart
  - Once blood passes each successive valve, it cannot flow back



Factors contributing to venous return:

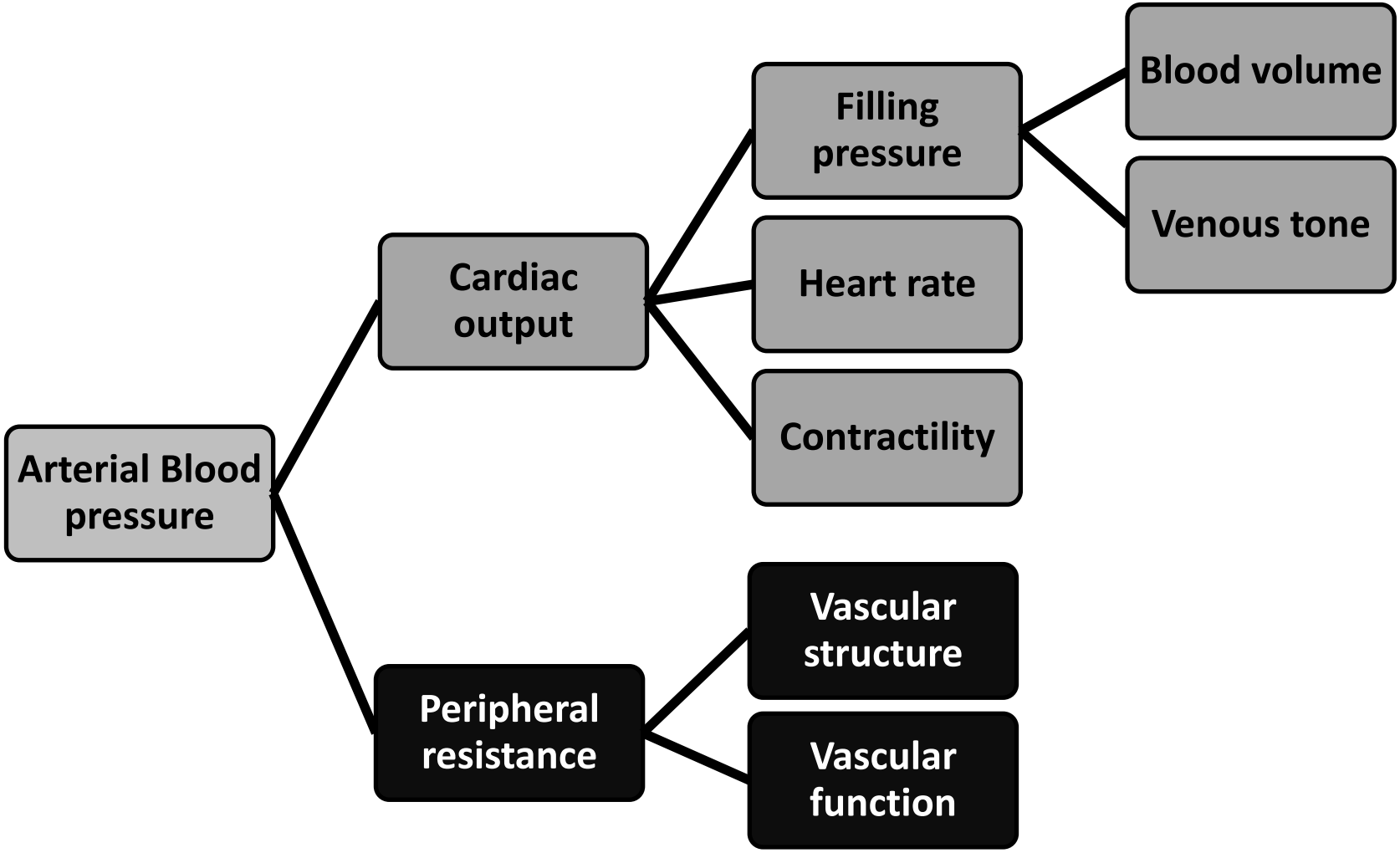
- **The respiratory pump**
  - As we inhale, abdominal pressure increases, squeezing local veins and forcing blood toward the heart.
  - At the same time, the pressure in the chest decreases, allowing thoracic veins to expand and speeding blood entry into the right atrium.



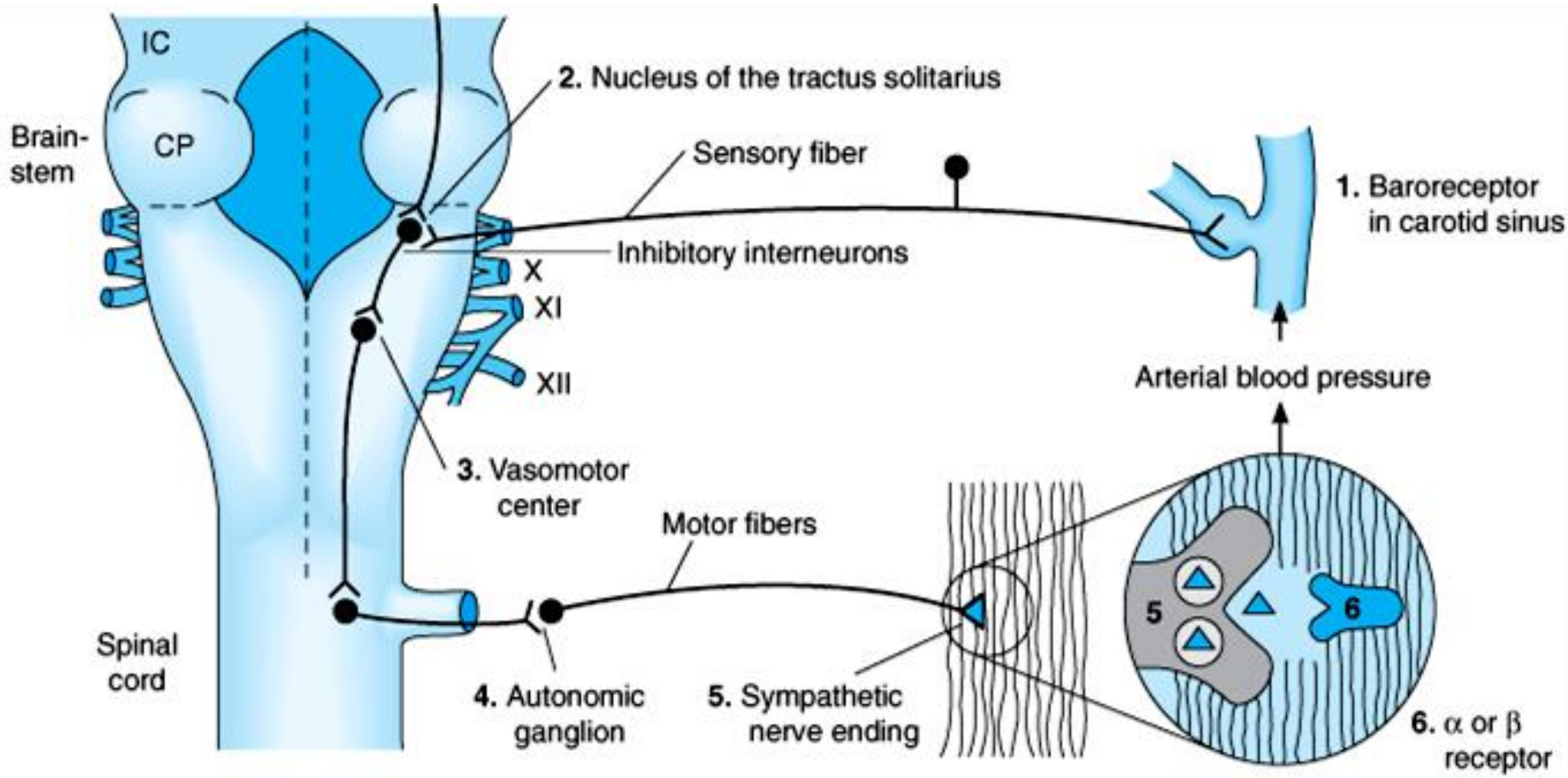
Factors contributing to venous return:

- **Sympathetic venoconstriction:**
  - Reduces the volume of blood in the veins—the capacitance vessels venous volume is reduced and blood is pushed toward the heart.

Factors influencing blood pressure

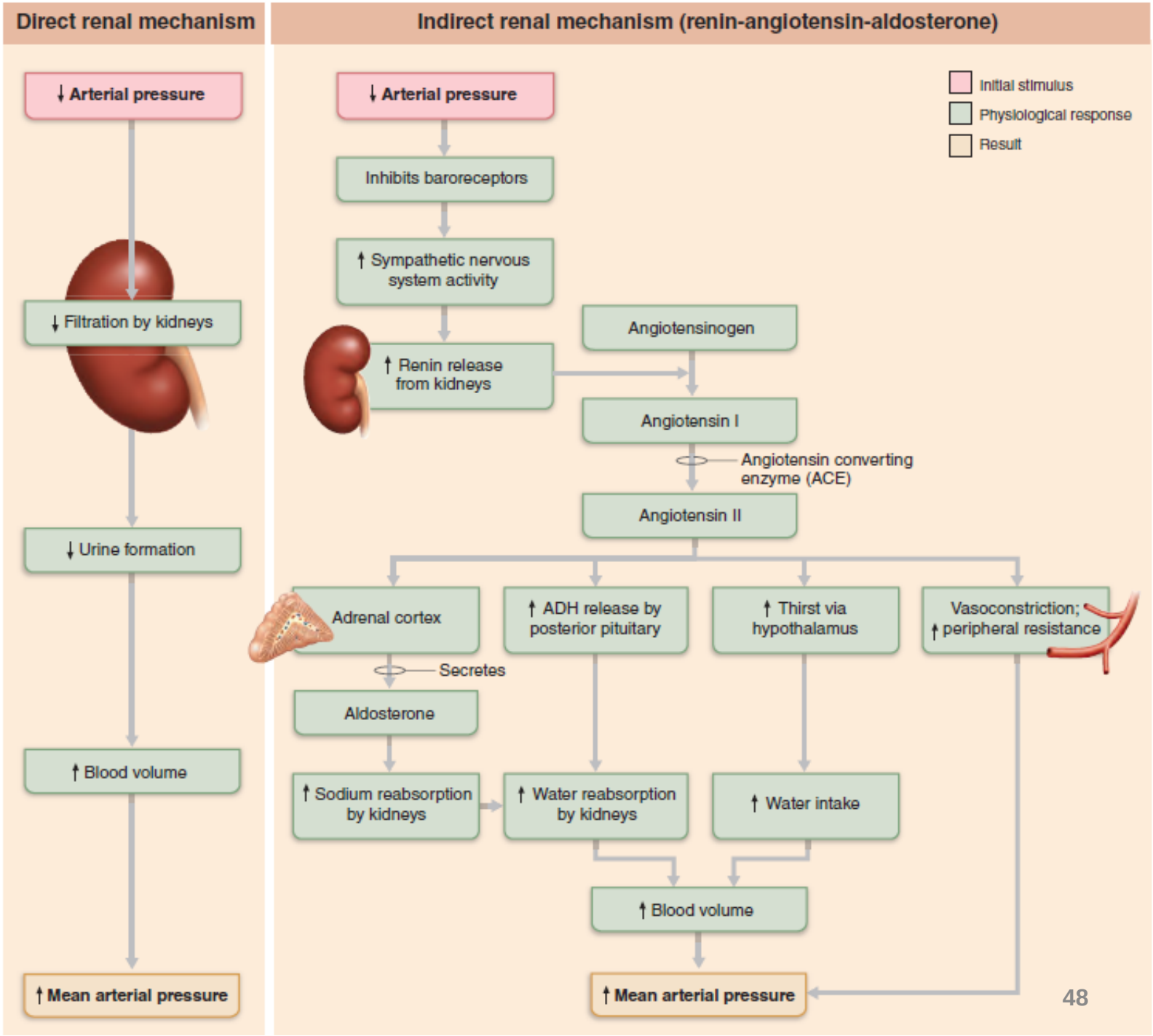


Baroreceptor reflex arc

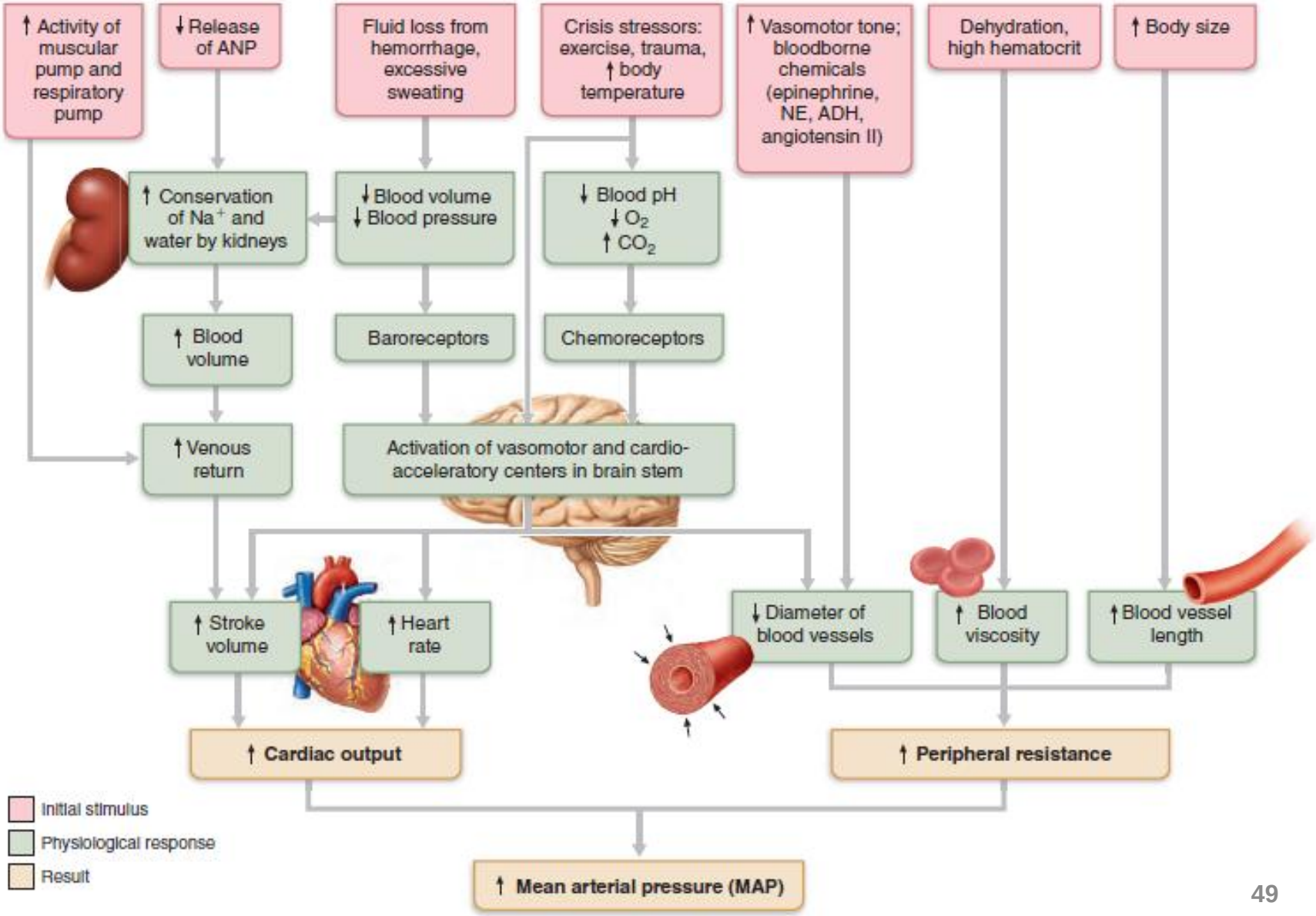


Baroreceptor reflex arc.

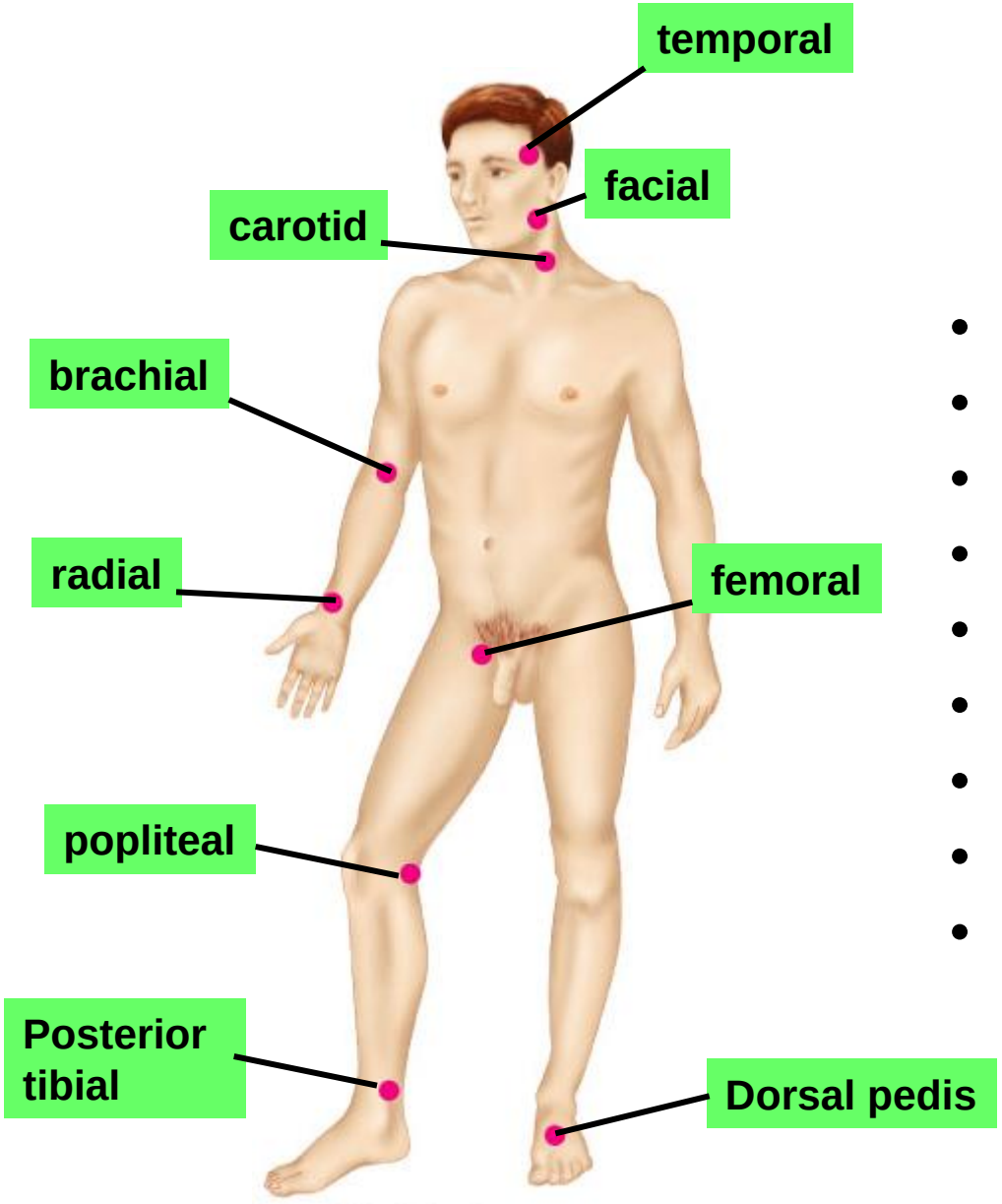
Direct and indirect (hormonal) mechanisms for renal control of blood pressure



Factors that increase Mean arterial pressure (MAP)



Superficial Pulse Points- arteries, not veins



60 beats/minute

- Temporal artery
- Facial artery
- Common carotid artery
- Brachial artery
- Radial artery
- Femoral artery
- Popliteal artery
- Posterior tibial artery
- Dorsal pedis artery

Homeostatic Imbalances

- **Tachycardia:** abnormally fast heart rate (>100 bpm)
  - If persistent, may lead to fibrillation
- **Bradycardia**: heart rate slower than 60 bpm
  - May result in grossly inadequate blood circulation
  - May be desirable result of endurance training

Circulatory Shock

- **Any condition in which**
  - Blood vessels are inadequately filled
  - Blood cannot circulate normally

- Results in inadequate blood flow to meet tissue needs

Classification of Circulatory Shock

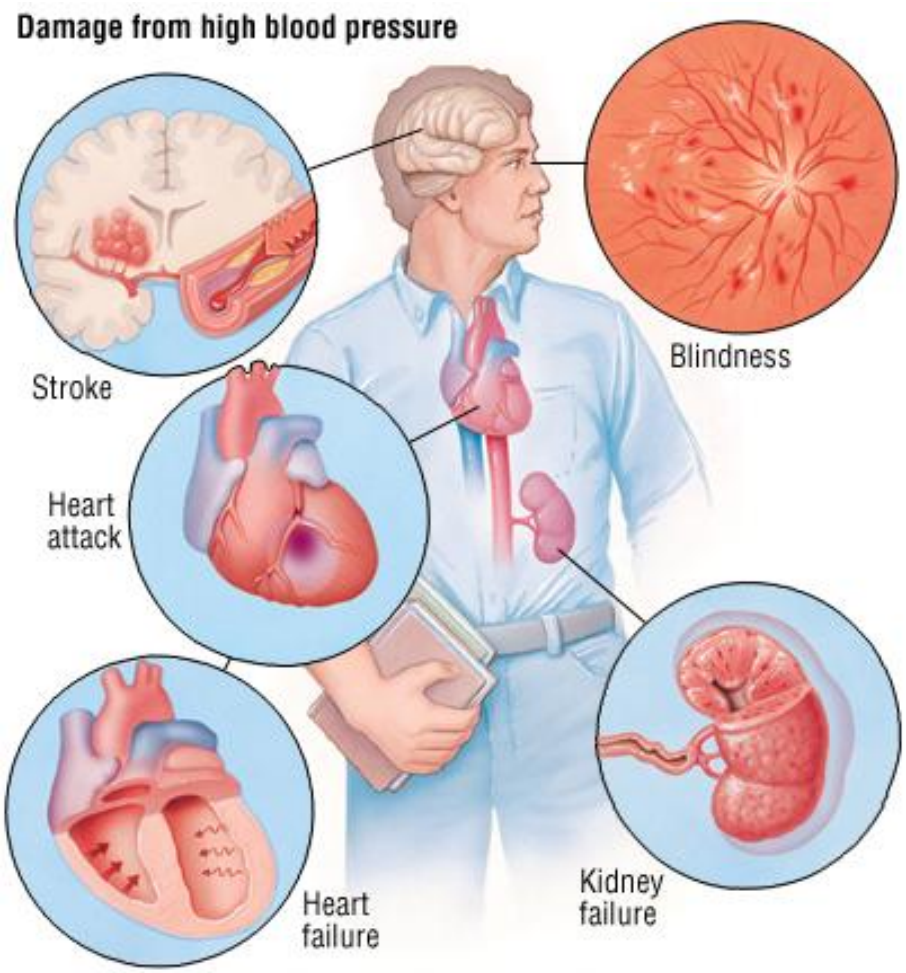
- **Hypovolemic shock:** results from large-scale blood loss
- **Vascular shock:** results from extreme vasodilation and decreased peripheral resistance
- **Cardiogenic shock:** results when an inefficient heart cannot sustain adequate circulation

Hypertension

- Hypertension (HTN) results from increased peripheral vascular arteriolar smooth muscle tone leading to increased arteriolar resistance and reduced capacitance of the venous system.

- The cause of elevated vascular tone is unknown

- HTN is a risk factor for chronic kidney disease, MI, heart failure, stroke and blindness



Etiology of HTN

- Essential HTN: 90% of patients with unknown cause

- Predisposing factors: diabetes, obesity, stressful lifestyle, high intake of sodium, smoking , race, and family history

Classification of Blood Pressure

	Systolic mm Hg		Diastolic mm Hg
Normal	<120	and	<80
Pre-hypertensive	120-139	or	80-90
Stage I	140-159	or	90-99
Stage II	≥160	or	≥100
Hypertensive emergency	≥180	or	≥120