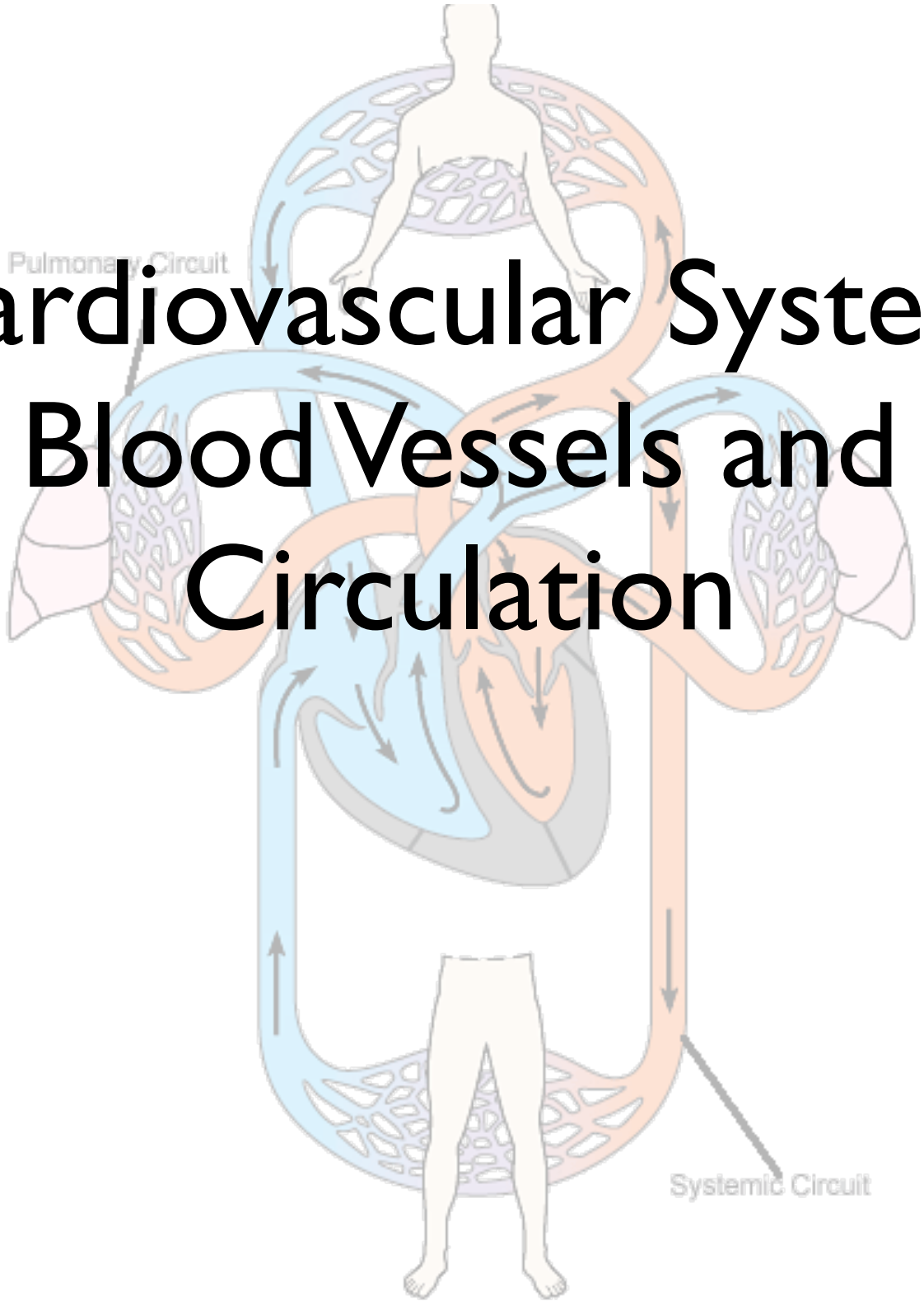
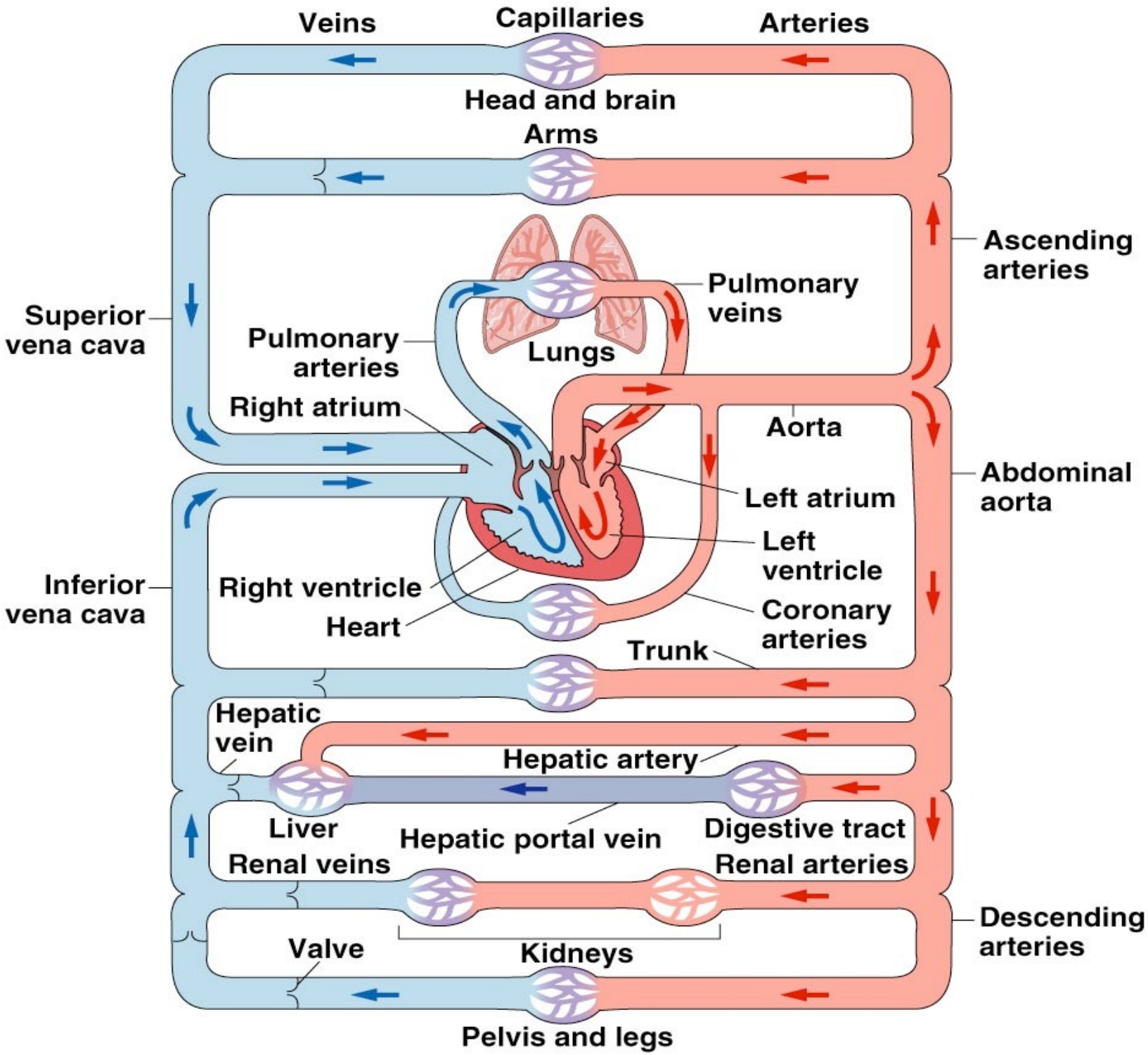
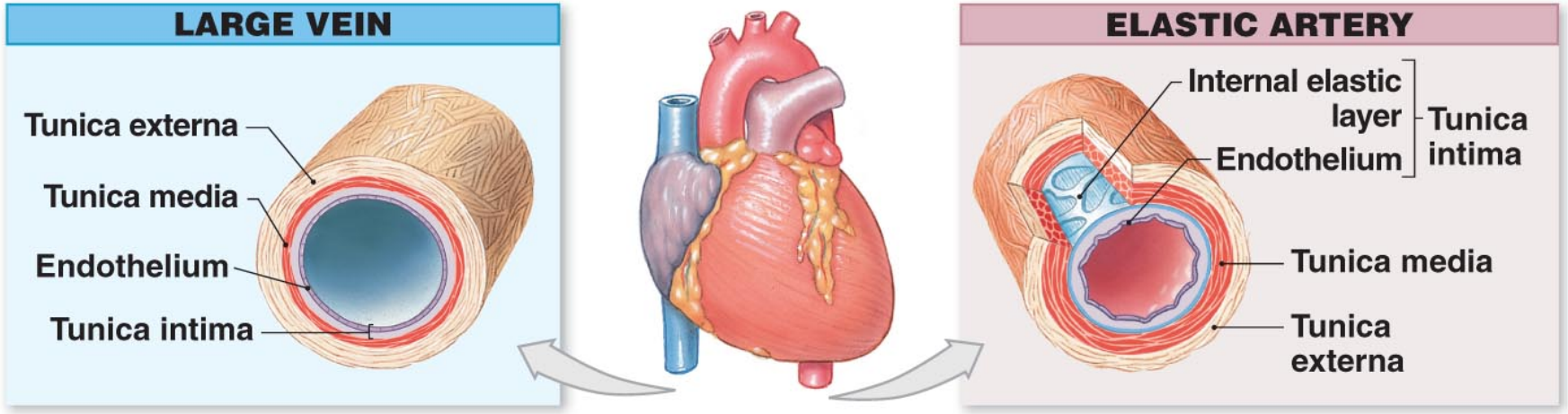
# Cardiovascular System: Blood Vessels and Circulation



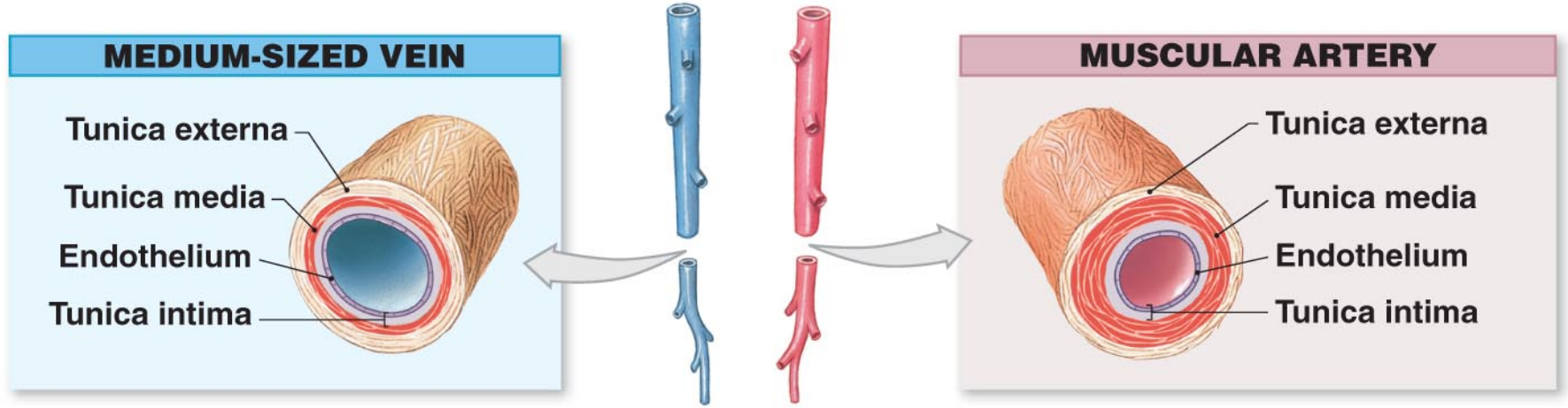

Veins
Capillaries
Arteries
Head and brain
Arms
Ascending arteries
Superior vena cava
Pulmonary veins
Pulmonary arteries
Lungs
Right atrium
Aorta
Abdominal aorta
Left atrium
Left ventricle
Inferior vena cava
Right ventricle
Heart
Coronary arteries
Trunk
Hepatic vein
Hepatic artery
Liver
Hepatic portal vein
Digestive tract
Renal veins
Renal arteries
Descending arteries
Valve
Kidneys
Pelvis and legs

# Blood Vessels

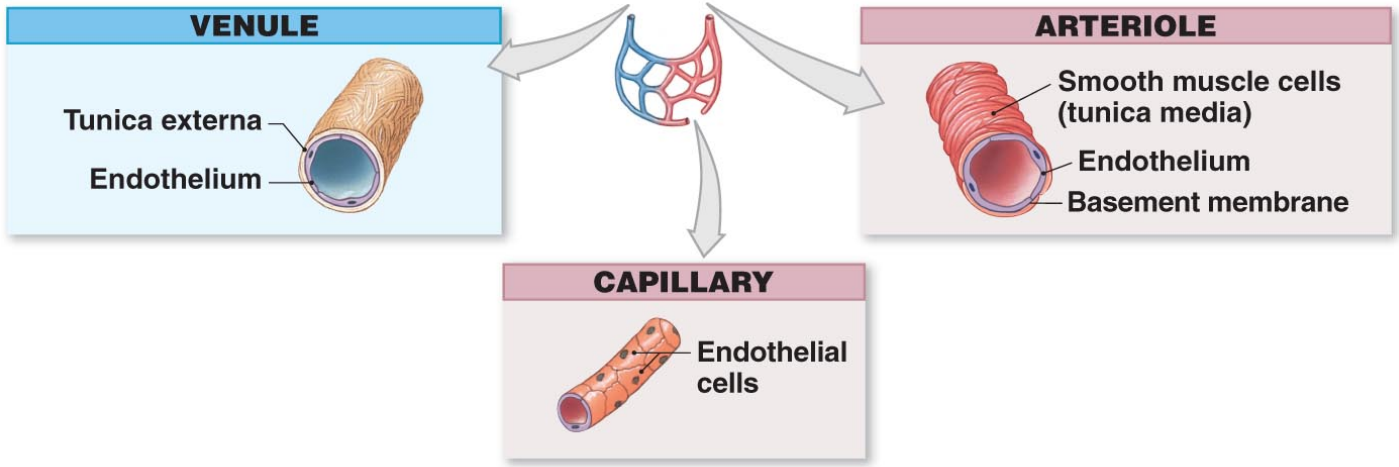
- Arteries --> arterioles --> capillaries --> venules --> veins
- Vessel Anatomy:
  - Tunica externa
  - Tunica media
  - Tunica interna =

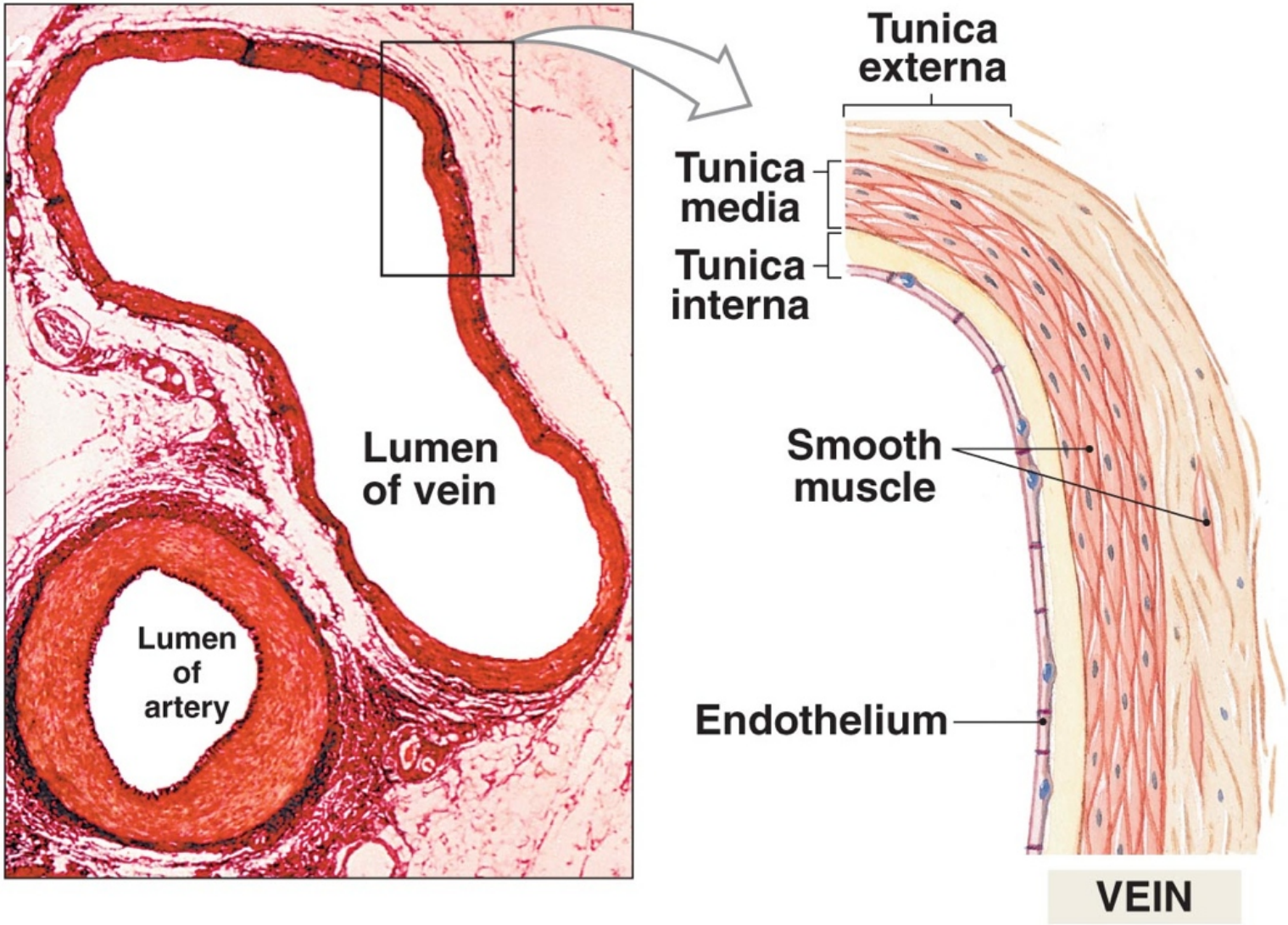



Copyright © 2010 Pearson Education, Inc.




Copyright © 2010 Pearson Education, Inc.



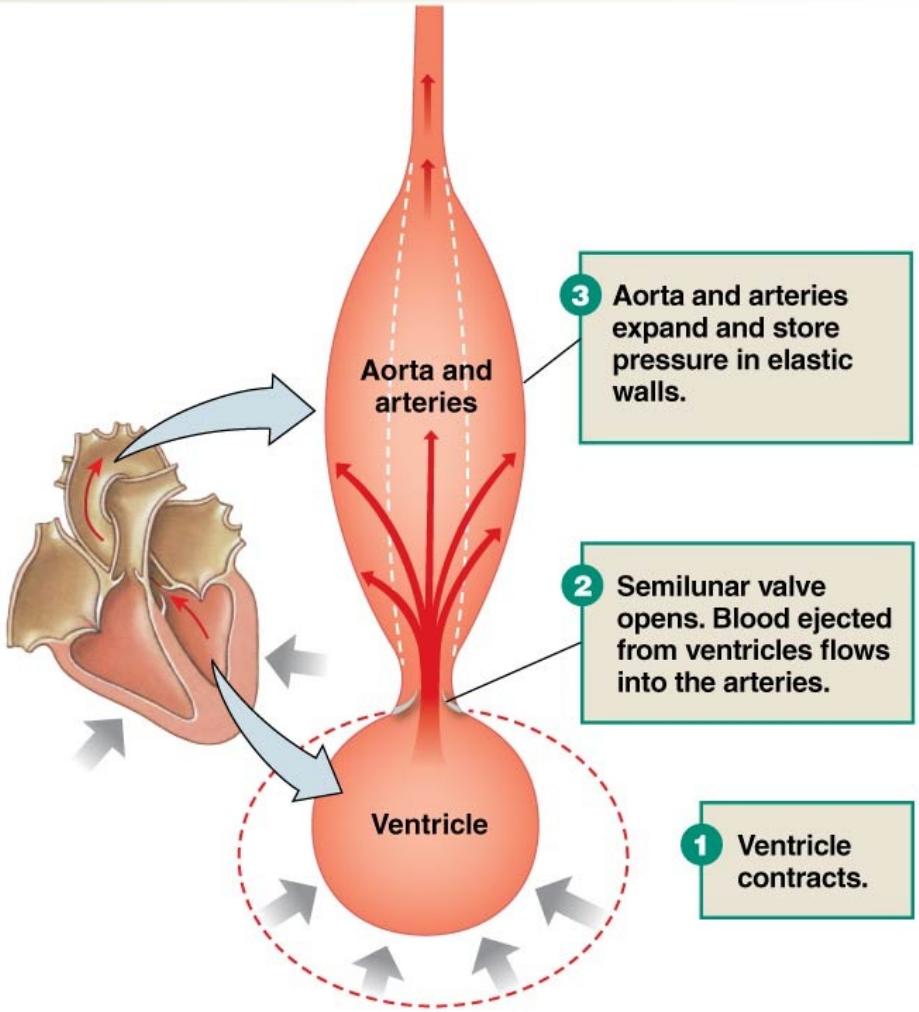

Lumen of vein
Lumen of artery
Tunica externa
Tunica media
Tunica interna
Smooth muscle
Endothelium
VEIN

# Blood Vessels

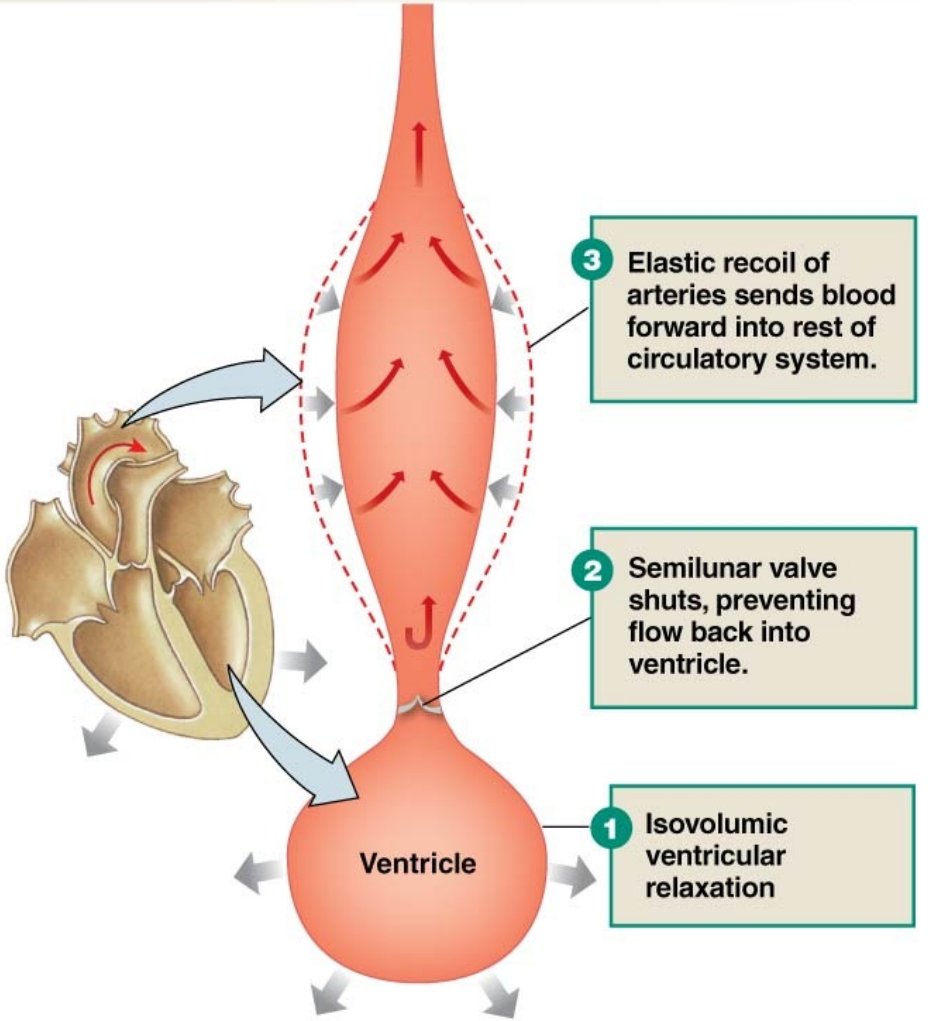
- Arteries
  - Arteries Always carry blood Away from the heart
  - Large arteries are muscular and provide

## ARTERIES ARE A PRESSURE RESERVOIR

**(a) Ventricular contraction.** Contraction of the ventricles pushes blood into the elastic arteries, causing them to stretch.



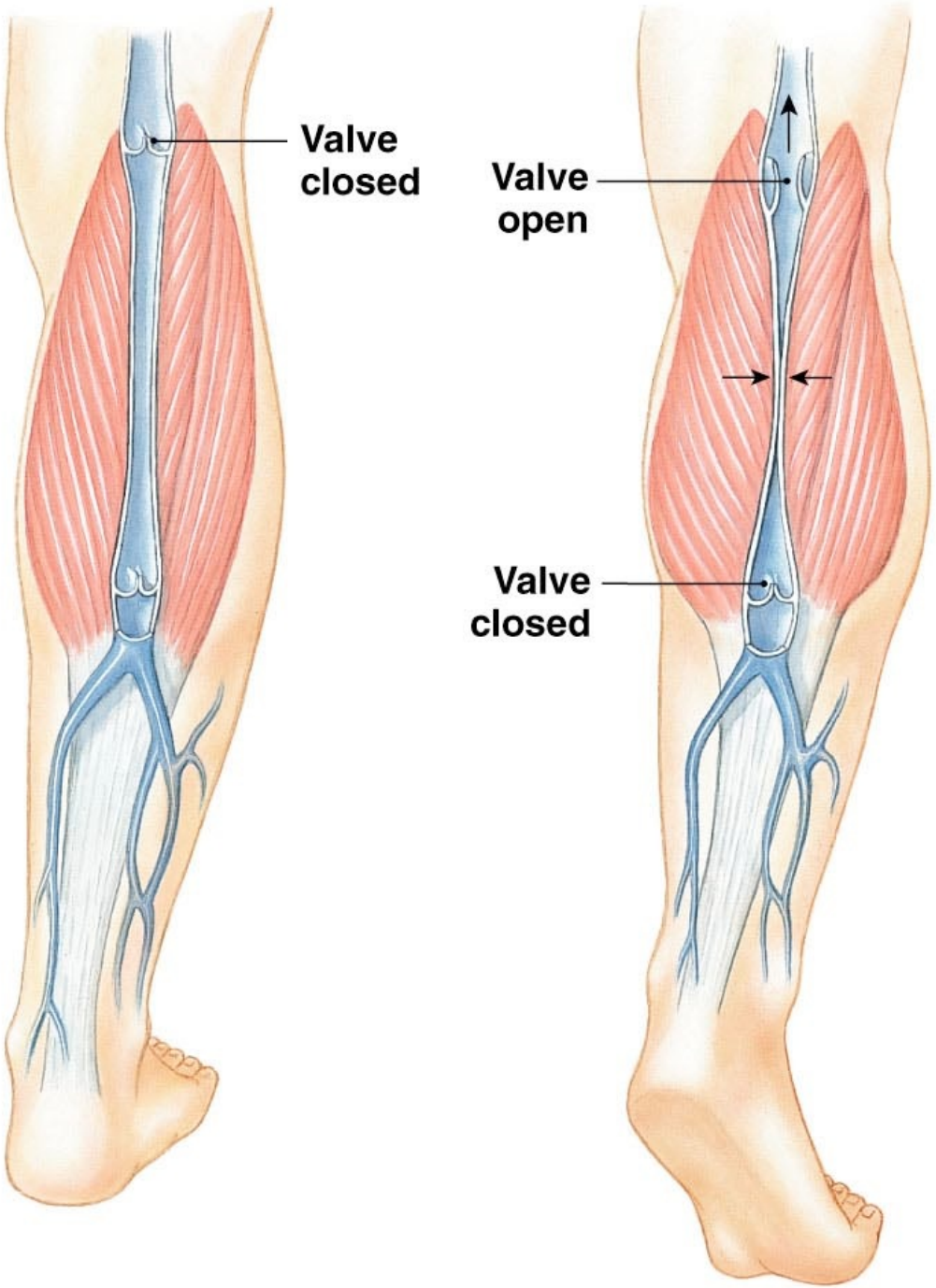

**(b) Ventricular relaxation.** Elastic recoil in the arteries maintains driving pressure during ventricular diastole.



# Veins and Venules

- Veins
  - Carry blood toward the heart
  - They are [ ] vessels; they do NOT provide resistance; they expand to allow blood flow through.
  - How is blood pumped back to the heart under such low pressure?

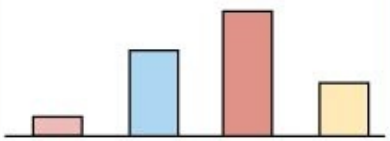
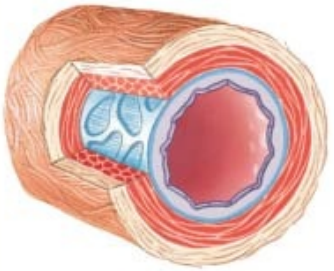
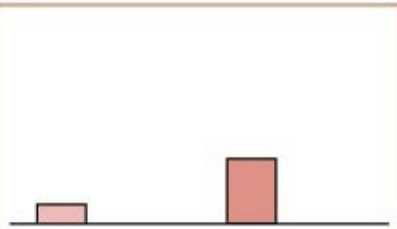
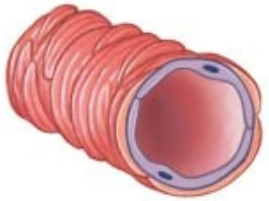
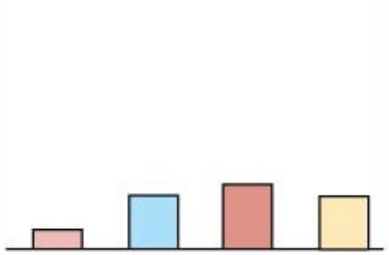
Valves in the veins prevent backflow of blood.

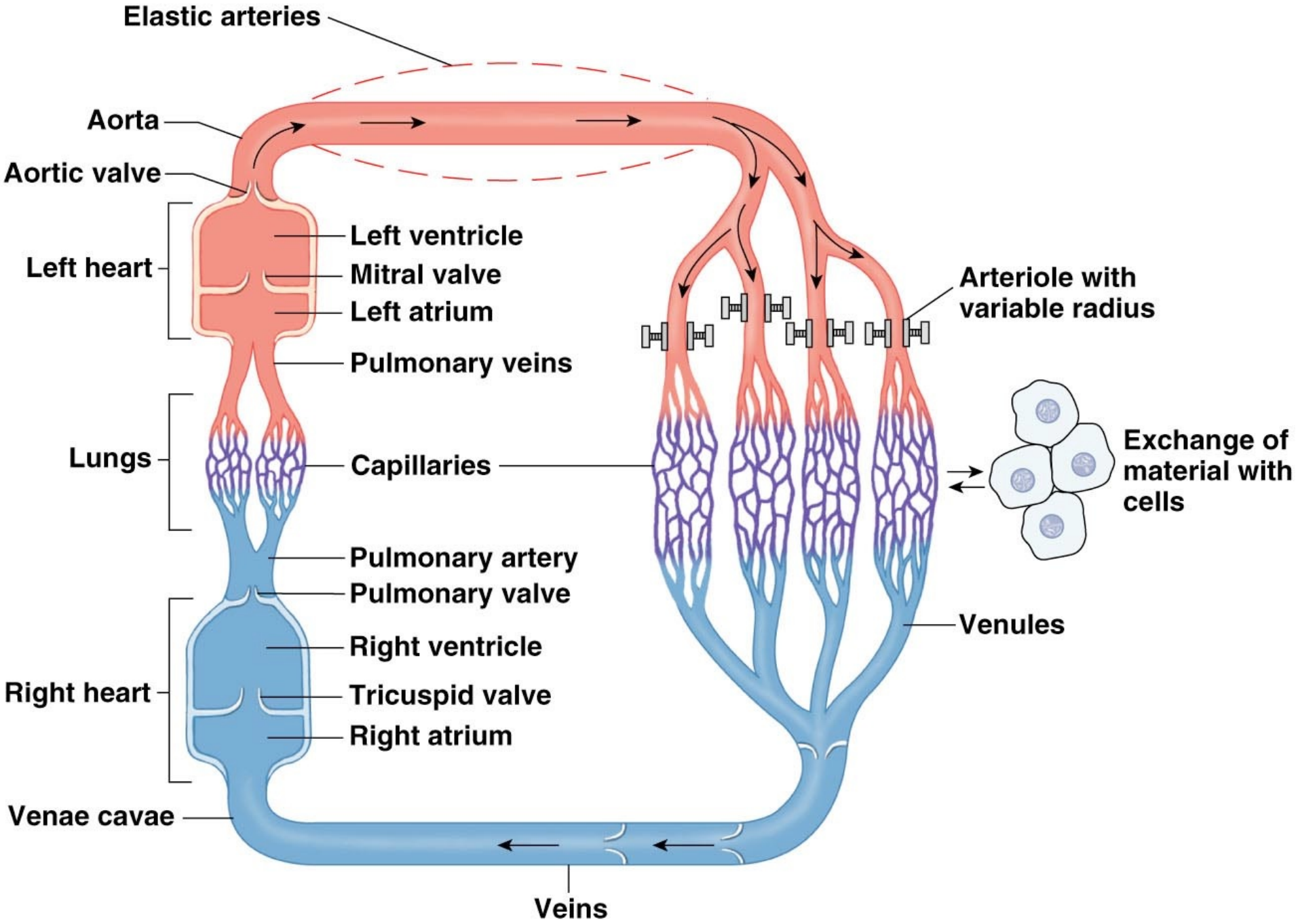


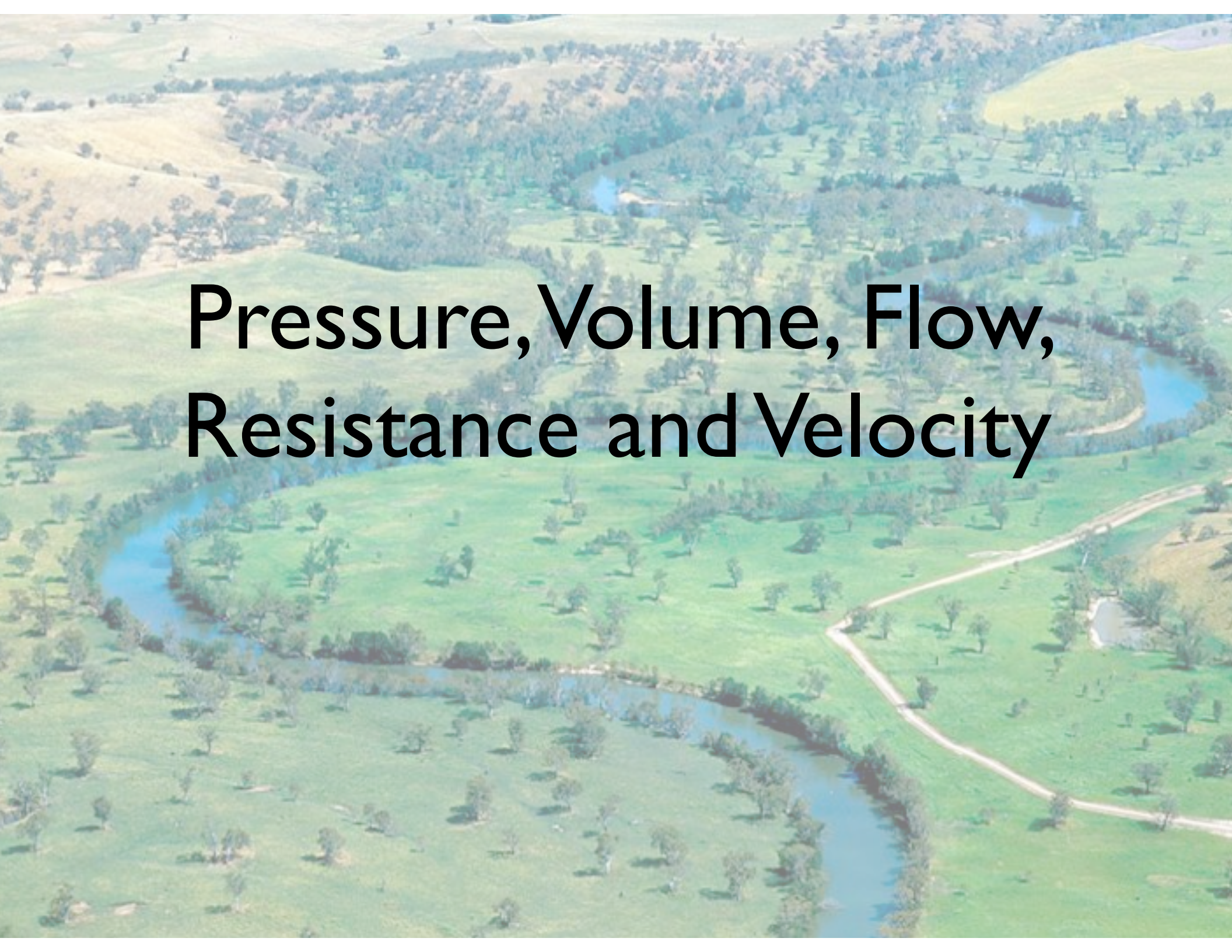

When the skeletal muscles compress the veins, they force blood toward the heart (the skeletal muscle pump).

# Capillaries

- Capillaries are one cell layer thick, allowing for [ ] of materials
- Capillaries are the on and off-ramps of the cardiovascular freeway
- Why does blood leave and then return to the capillaries? More later.

| | Mean diameter | Mean wall thickness | Endothelium / Elastic tissue / Smooth muscle / Fibrous tissue | |
|---|---|---|---|---|
| Artery | 4.0 mm | 1.0 mm |  |  |
| Arteriole | 30.0 μm | 6.0 μm |  |  |
| Capillary | 8.0 μm | 0.5 μm | | |
| Venule | 20.0 μm | 1.0 μm | | |
| Vein | 5.0 mm | 0.5 mm |  | |

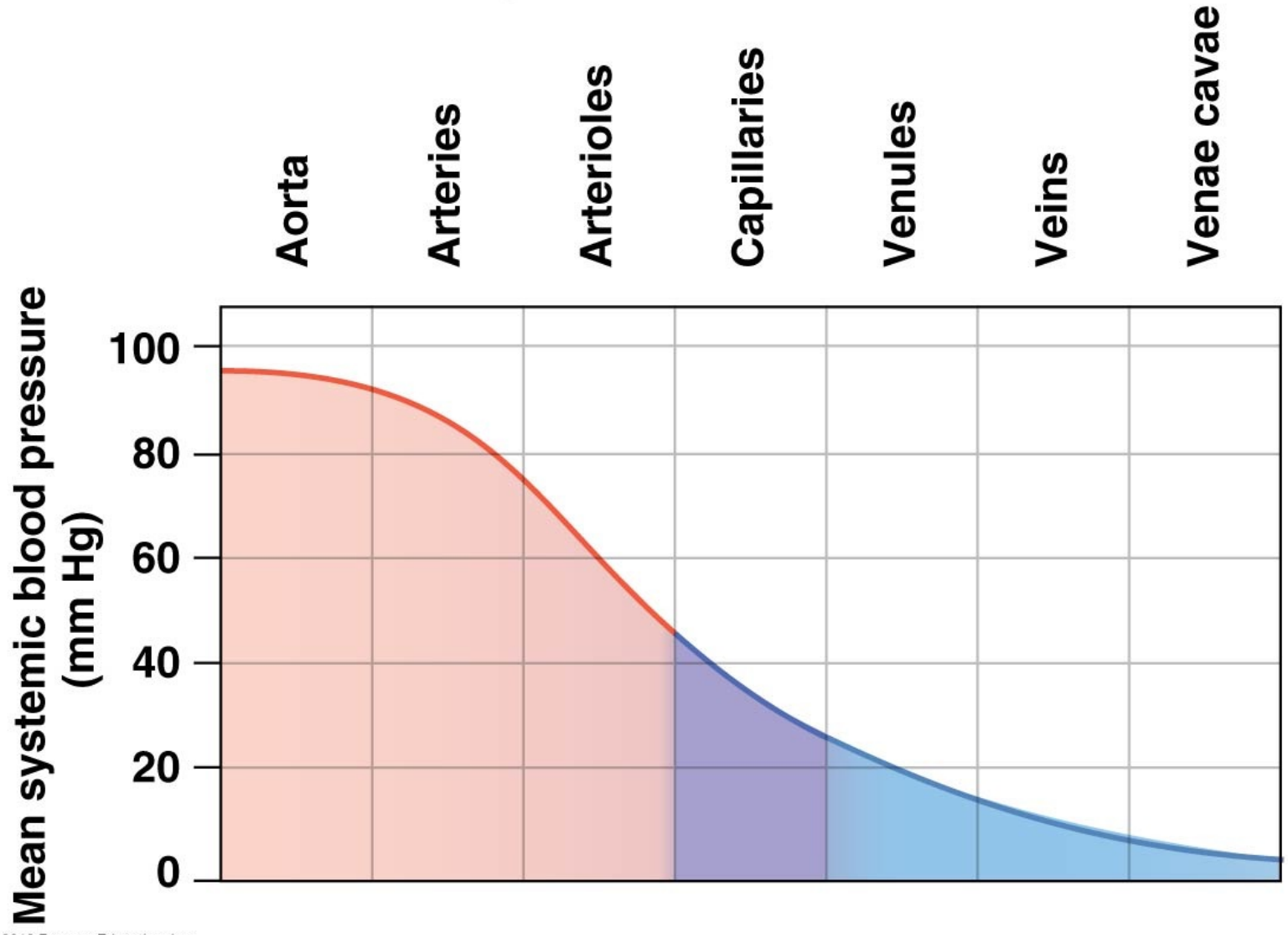

Elastic arteries
Aorta
Aortic valve
Left heart
Left ventricle
Mitral valve
Left atrium
Pulmonary veins
Lungs
Capillaries
Pulmonary artery
Pulmonary valve
Right heart
Right ventricle
Tricuspid valve
Right atrium
Venae cavae
Veins
Arteriole with variable radius
Exchange of material with cells
Venules



# Pressure, Volume, Flow, Resistance and Velocity

## Blood Flows Down a Pressure Gradient.

The mean blood pressure of the systemic circulation ranges from a high of 93 mm Hg (millimeters of mercury) in the aorta to a low of a few mm Hg in the venae cavae.



# Basic Principles:

- [ ] = force exerted by a fluid (or a gas) on a container holding the fluid (or gas)

# Basic Principles:

- Measured in mm Hg

  the pressure exerted by a column of Hg that is 1mm high

  = 1 torr

  = 1/1760 atom

  = 133.3 Pascals

# Basic Principles

Liquids (and gasses) flow from areas of high pressure to areas of low pressure until [ ] is reached.

# Basic Principles

The pressure of fluid (or a gas) in motion decreases over distance, due to [ ] of the fluid as it comes in contact with surfaces and other water molecules.

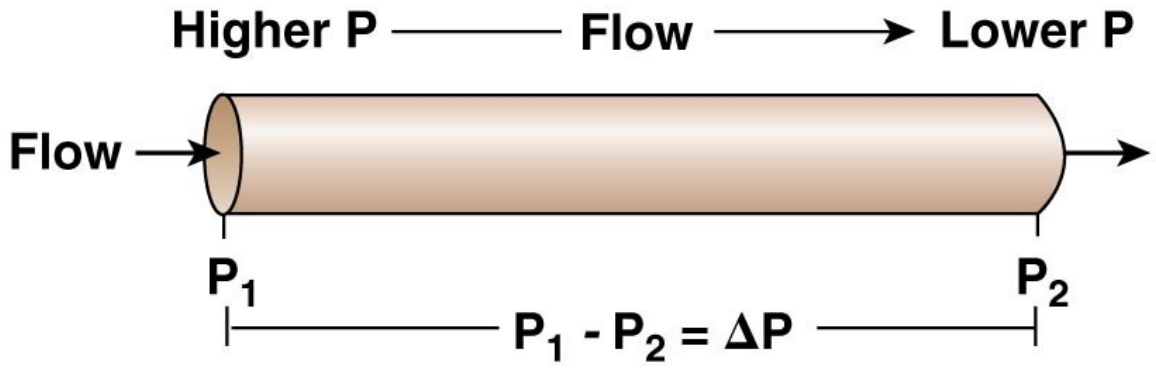
# Why Fluid Moves Through a Tube

- Pressure gradients make liquids and gasses move
- Resistance impedes liquids and gasses from moving

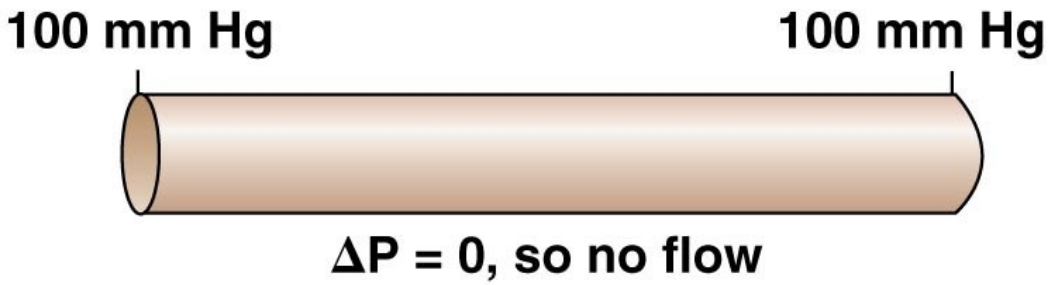
- Blood flows from an area of high pressure to of lower pressure until equilibrium is reached
- Flow = volume of fluid passing one point per unit time (gal / hour) or (ml / min)
- The greater the pressure differential, the faster the flow

# Fluid flow through a tube depends on the pressure gradient.

**(c) Fluid flows only if there is a positive pressure gradient ($\Delta P$).**

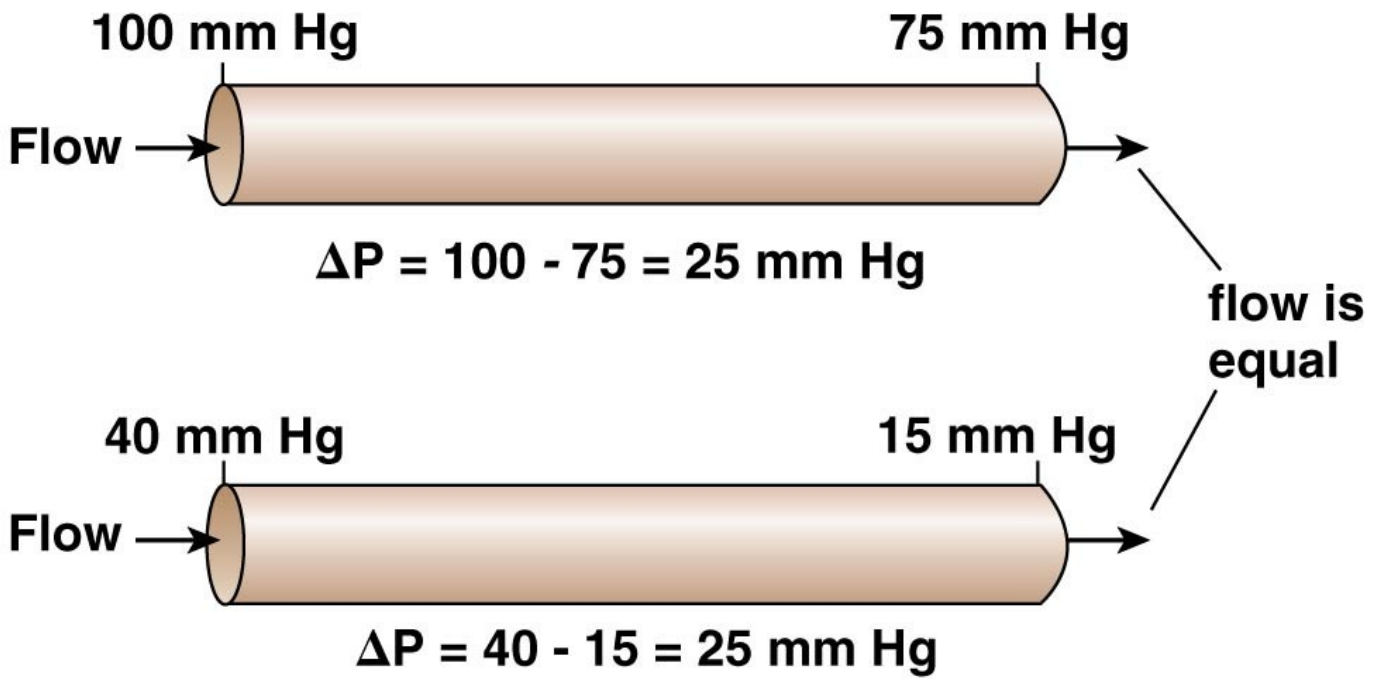



This tube has no pressure gradient, so no flow.



# Fluid flow through a tube depends on the pressure gradient.

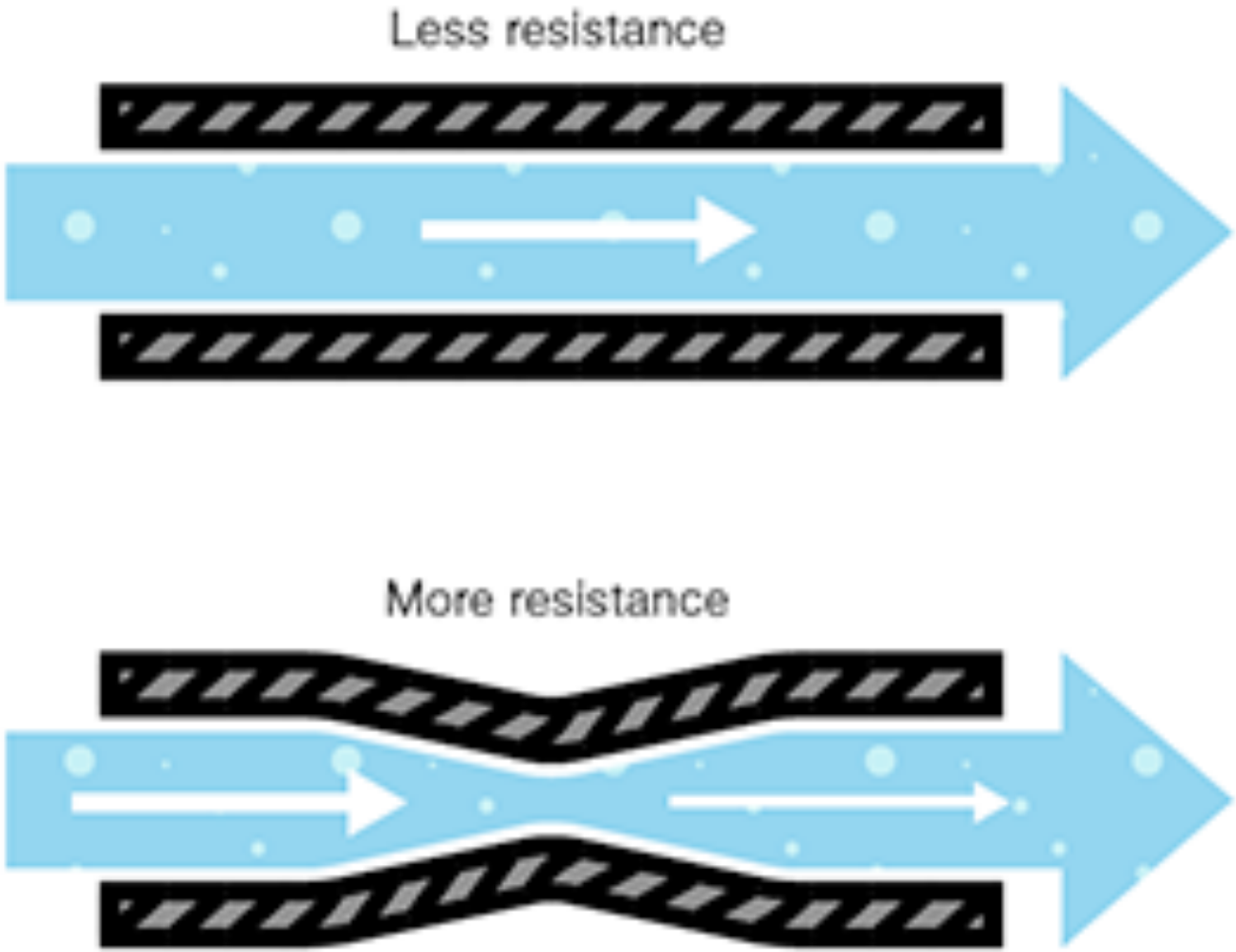
**(d)** Flow depends on the pressure gradient ($\Delta P$), not on the absolute pressure (P). $\Delta P$ is equal in these tubes so flow is the same.



# Resistance

- Resistance (R) = tendency of the system to oppose flow
- Blood flowing through vessels encounters friction from:
  - 1. Vessel walls
  - 2. Blood cell

# Resistance



# What Factors Affect Flow and Resistance?

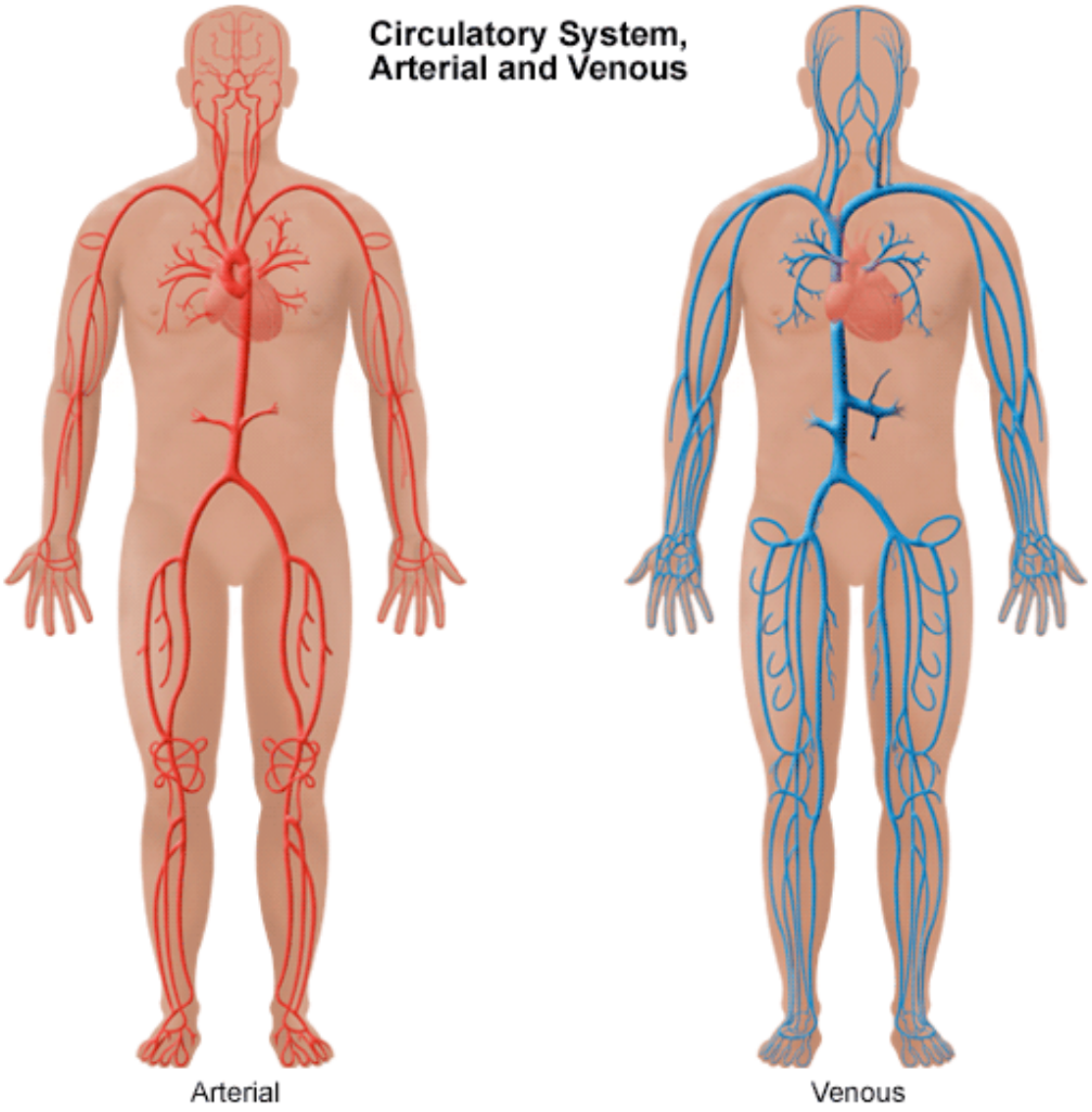
Tube Length

Tube radius

Fluid

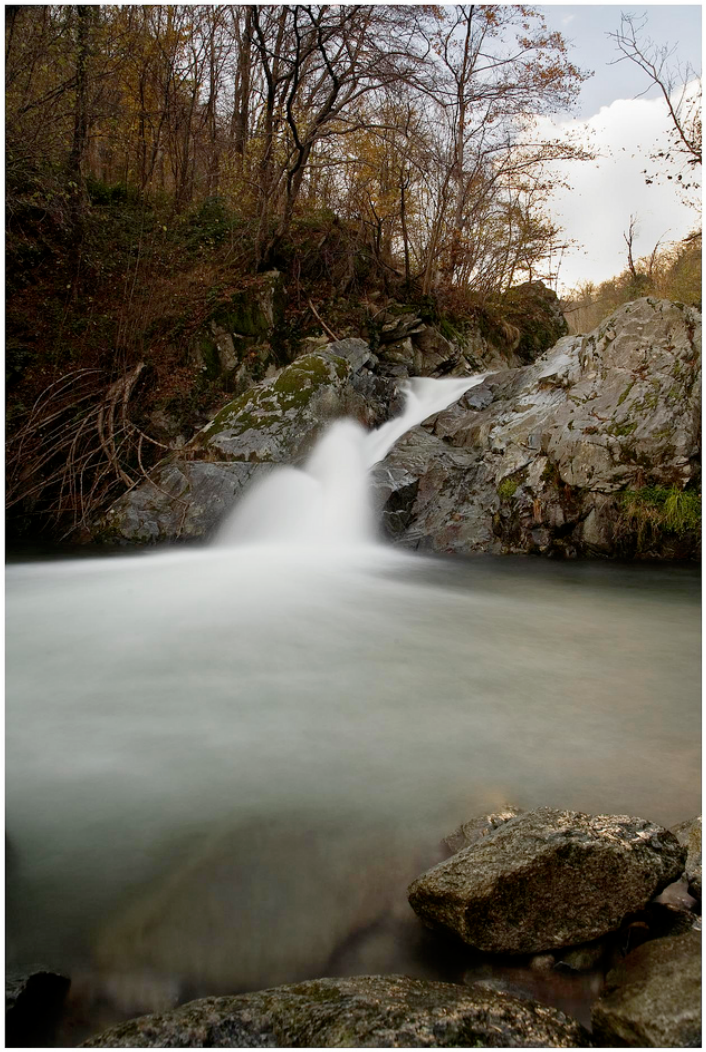
# Flow and Resistance

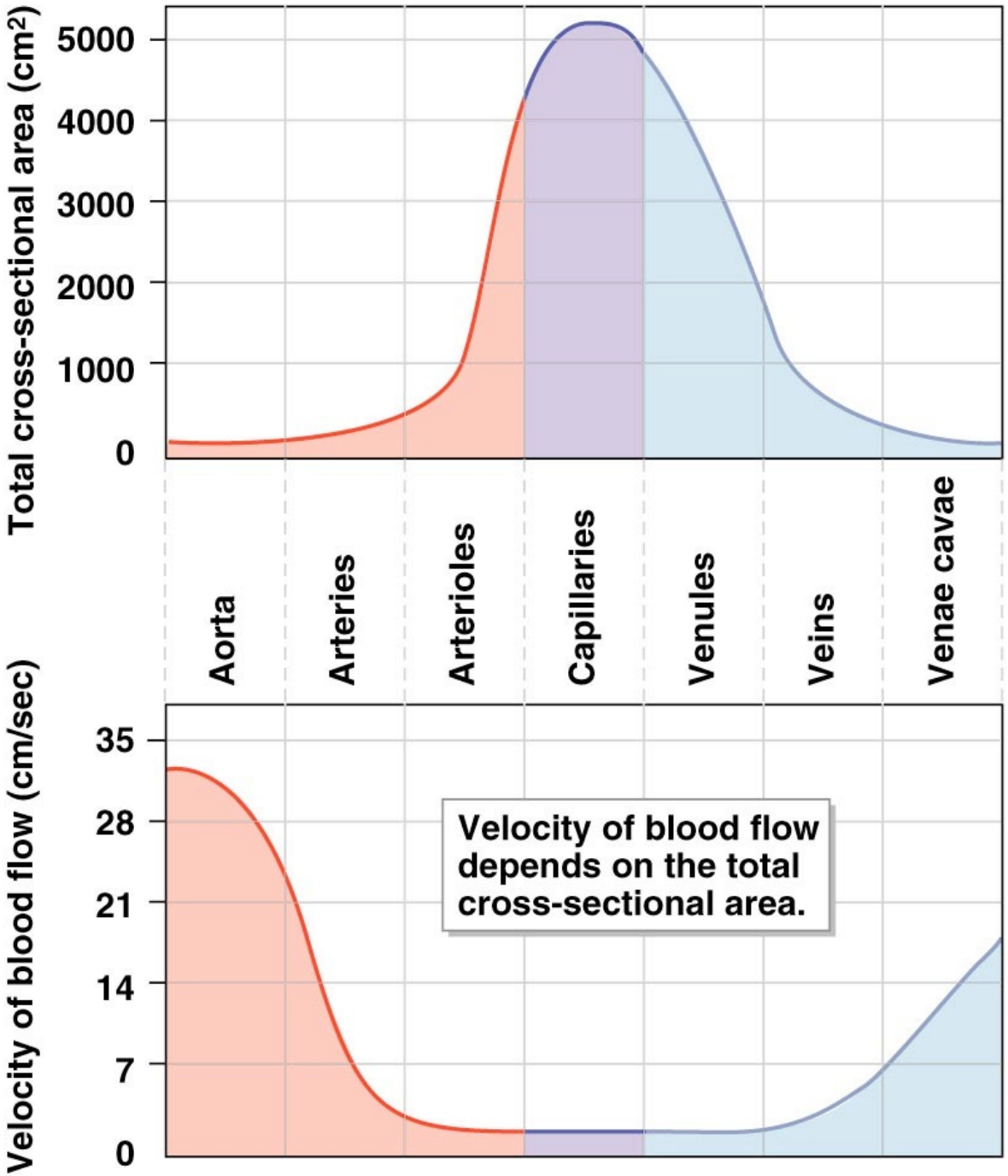
What factor most greatly affects blood flow in the body?



# Blood Velocity

- Flow = volume of blood passing one point per unit time (ml / min)
- Velocity = Flow / total cross-sectional area ( )
  - ex: miles / hour
  - ex: m / sec




Total cross-sectional area (cm²)
5000
4000
3000
2000
1000
0
Aorta
Arteries
Arterioles
Capillaries
Venules
Veins
Venae cavae
Velocity of blood flow (cm/sec)
35
28
21
14
7
0
Velocity of blood flow depends on the total cross-sectional area.

# Blood Velocity and Total Cross-Sectional Area

- Damage or weakening of a vessel puts strain on the others
  - Closure of a highway lane increases traffic in adjacent lanes (cars have to go through somehow!)

# Is Blood Velocity Highly Variable?

During exercise, blood pressure and cardiac output increase significantly. What about blood velocity?

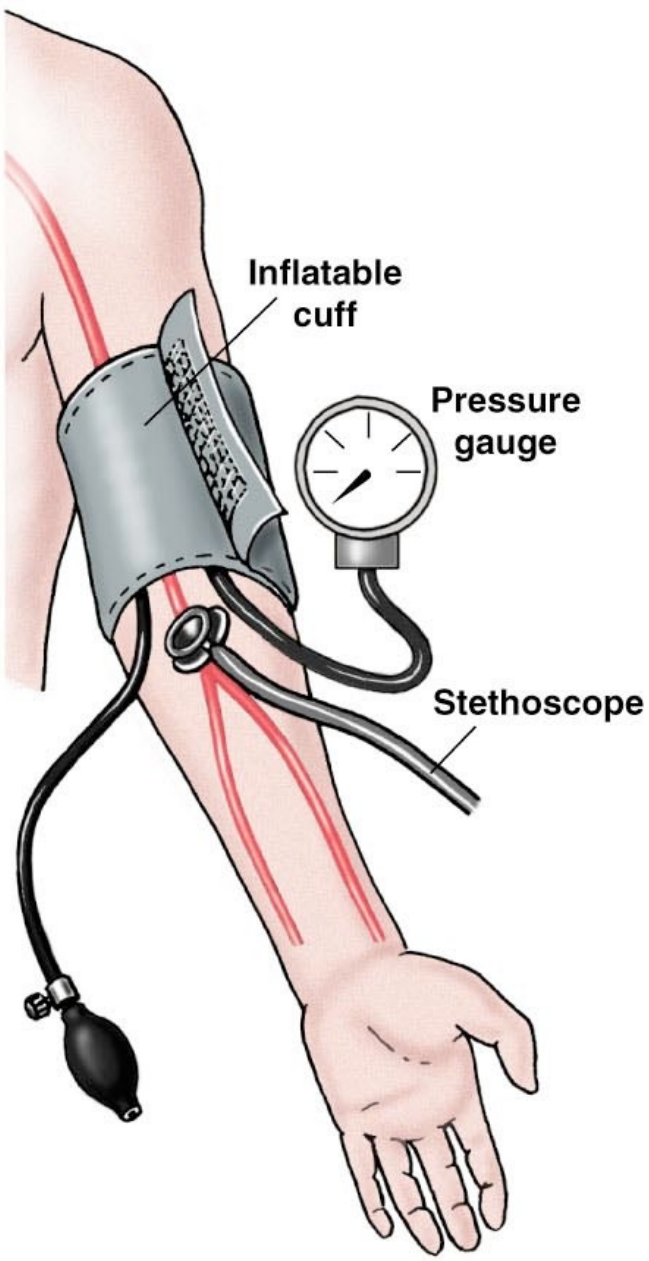
# Blood Pressure

# Blood Pressure

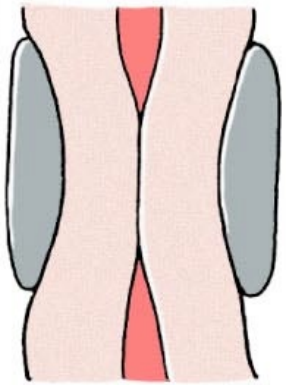
- Ventricular contraction creates driving pressure
- Arteries are high-pressure vessels in which blood moves with a pulsatile flow.
- If a patient is bleeding, how might you tell if it was an artery or vein that was cut?

# Blood Pressure Measurements

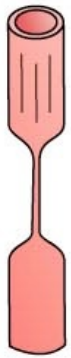
- Systolic Pressure: Avg. high of 120 mm Hg
- Diastolic Pressure: Avg. high of 80 mm Hg
- Sphygmomanometry is read as systolic / diastolic (120 / 80)
- [ ] = rapid pressure increase that occurs when ventricles push blood into the aorta




(a)

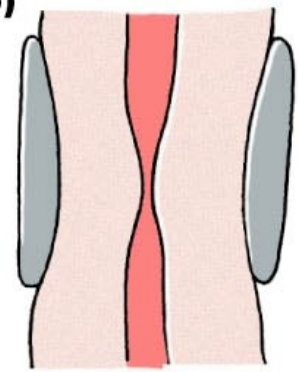


Cuff pressure > 120 mm Hg

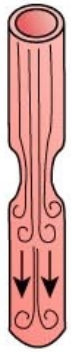


When the cuff is inflated so that it stops arterial blood flow, no sound can be heard through a stethoscope placed over the brachial artery distal to the cuff.

(b)

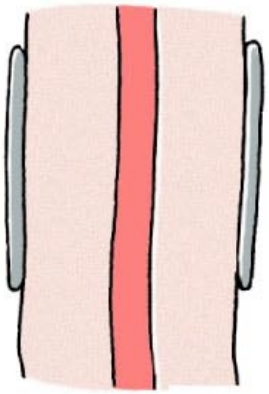


Cuff pressure between 80 and 120 mm Hg

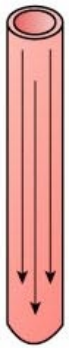


Korotkoff sounds are created by pulsatile blood flow through the compressed artery.

(c)



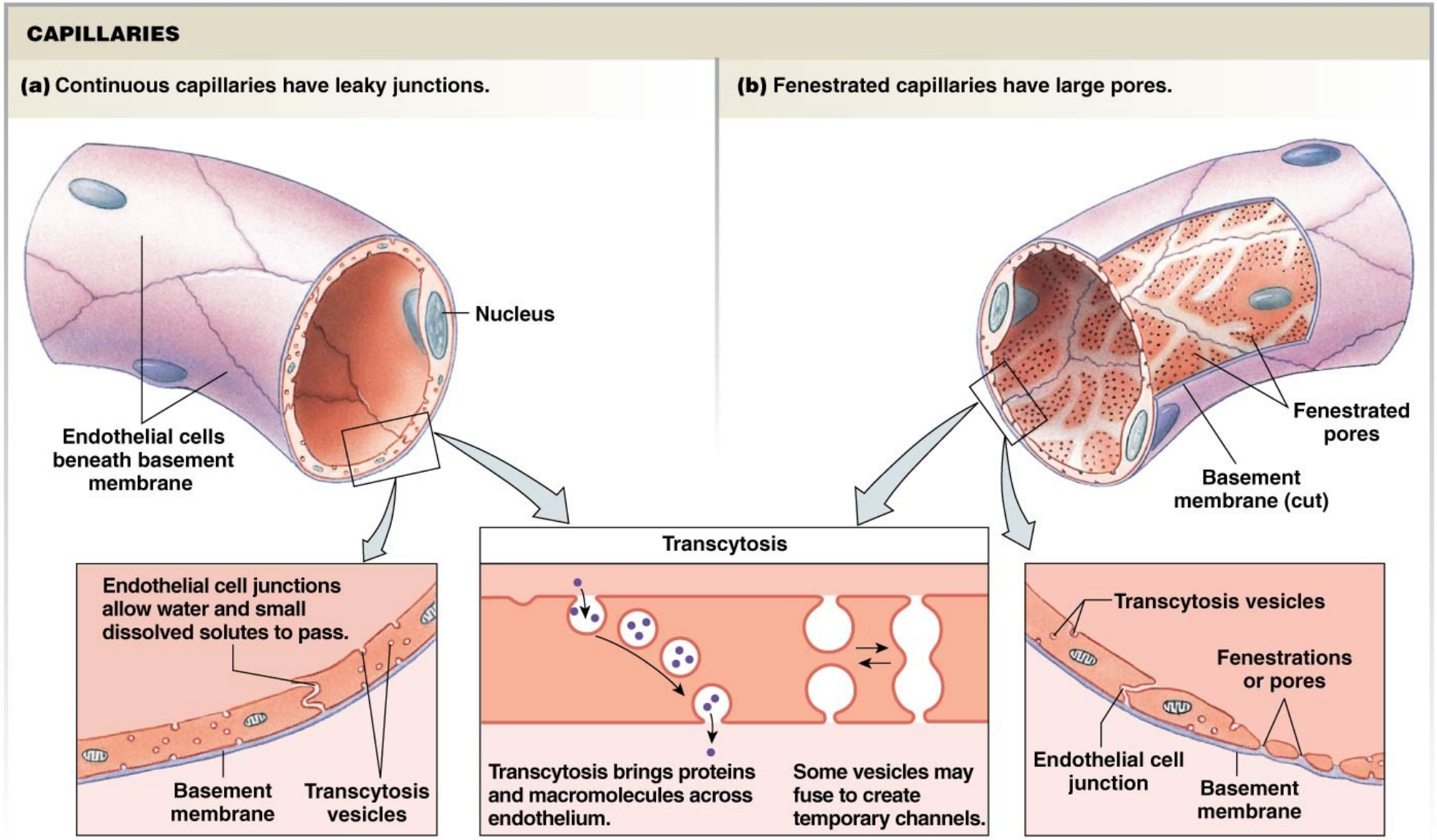
Cuff pressure < 80 mm Hg



Blood flow is silent when the artery is no longer compressed.

# Capillary Exchange

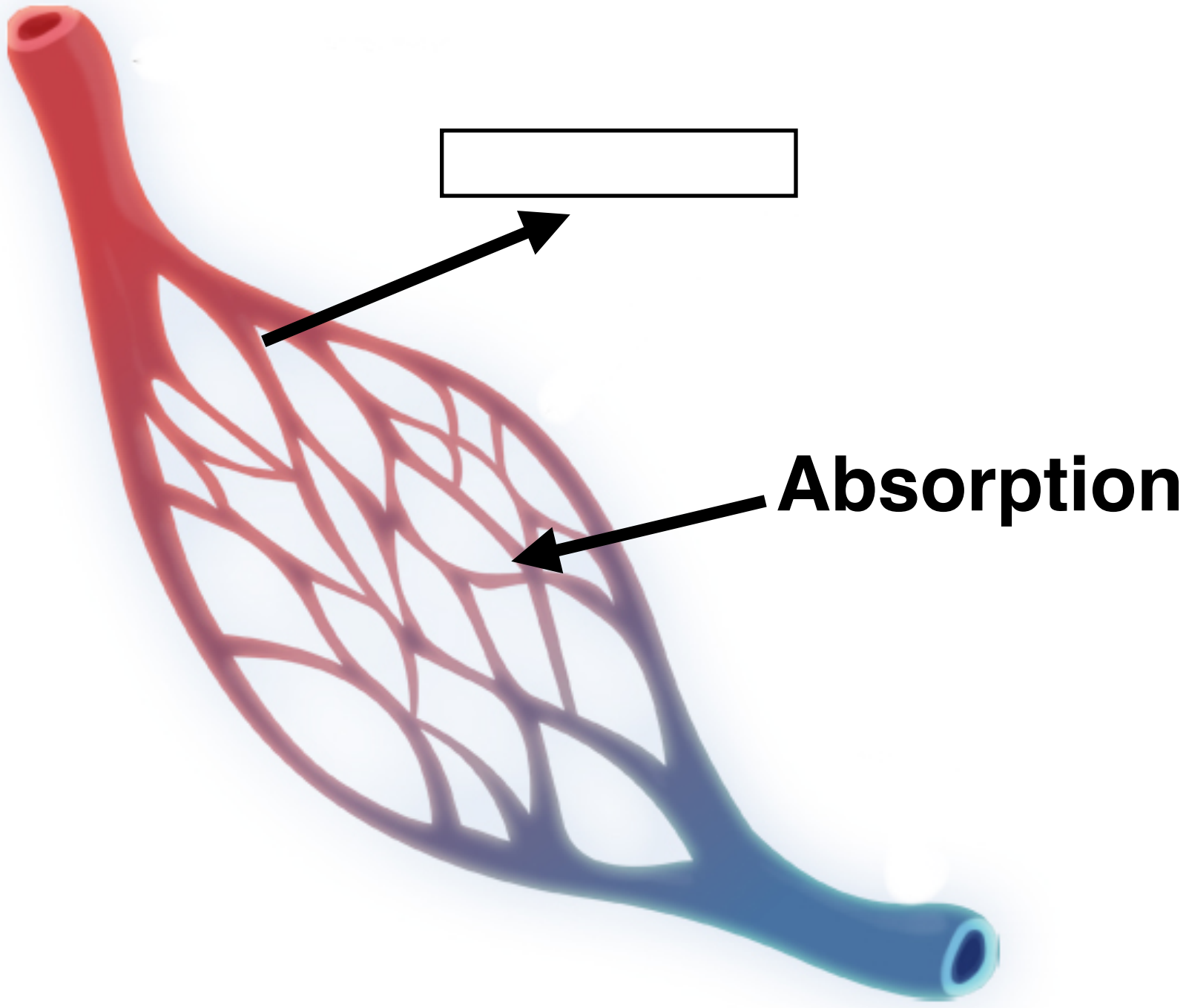
# Two Types of Capillaries



# Capillary Exchange

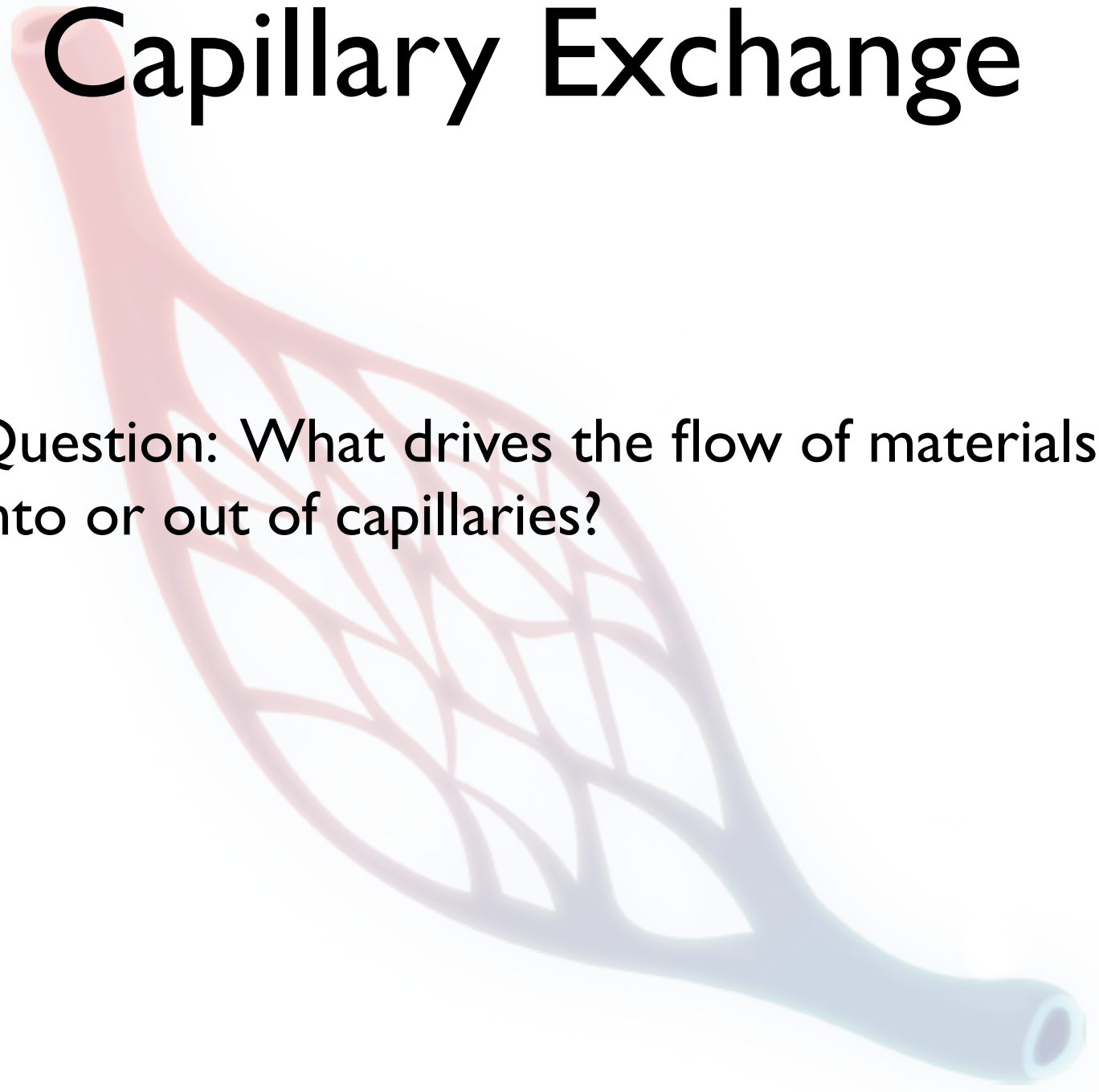
- Capillary density is proportional to the metabolic needs of the tissues served
- Velocity of blood flow is [ ] at capillaries, allowing diffusion to go to equilibrium
- Total cross-sectional area of ALL capillaries determines velocity

# Defining Blood Flow Direction



# Capillary Exchange

- Question: What drives the flow of materials into or out of capillaries?

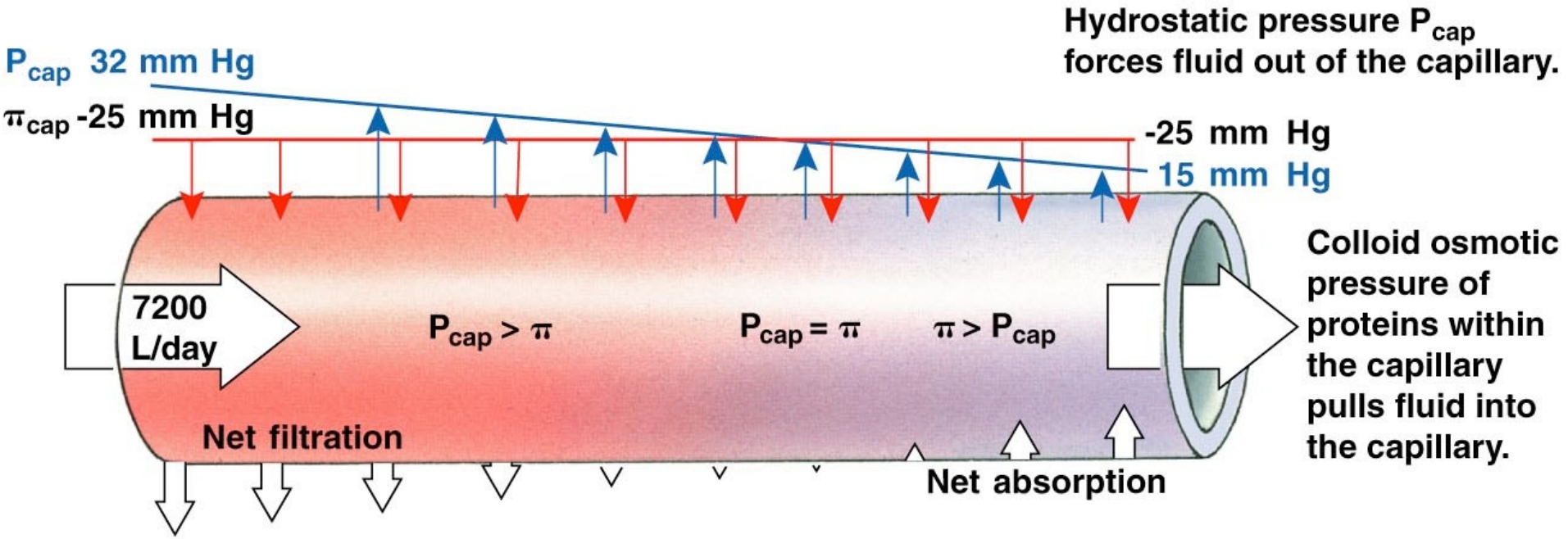


# Capillary Exchange

- Two opposing gradients:
  - 1. Hydraulic pressure decreases along the length of the capillary as energy is lost to friction
  - 2. (Colloid) osmotic pressure due to solute differences between the two sides of the capillary

## (a) Filtration in systemic capillaries

Net pressure = hydrostatic pressure – colloid osmotic pressure




**KEY**

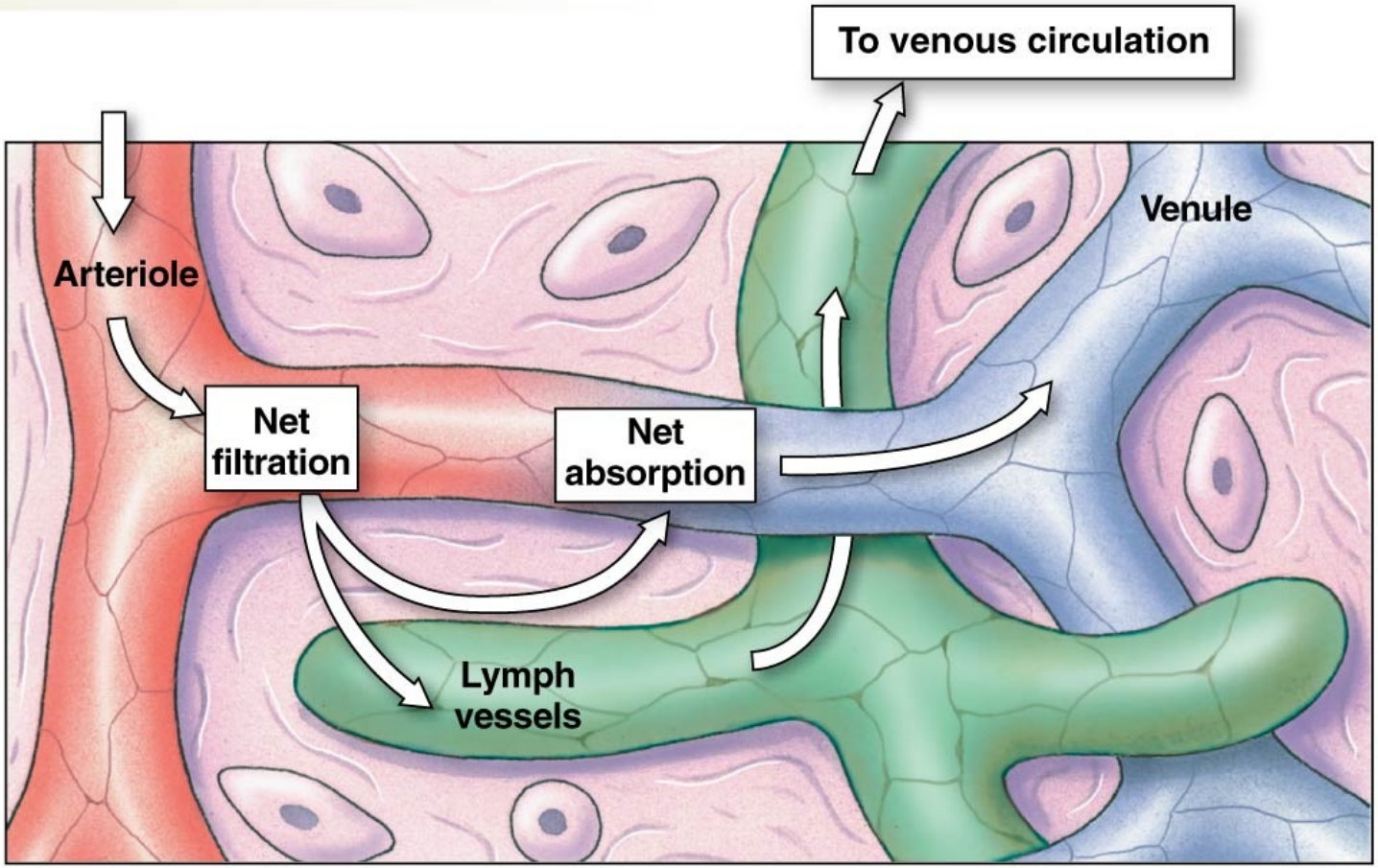
$P_{cap}$ = Capillary hydrostatic pressure

$\pi$ = Colloid osmotic pressure

# Capillary Exchange

- Net filtration at arterial end, net absorption at venous end
- 85% of the capillary filtrate is directly returned via capillaries
  - What happens to the rest?

**(a)** A net average of 3 L/day of fluid filters out of the capillaries. The excess water and solutes that filter out of the capillary are picked up by the lymph vessels and returned to the circulation.



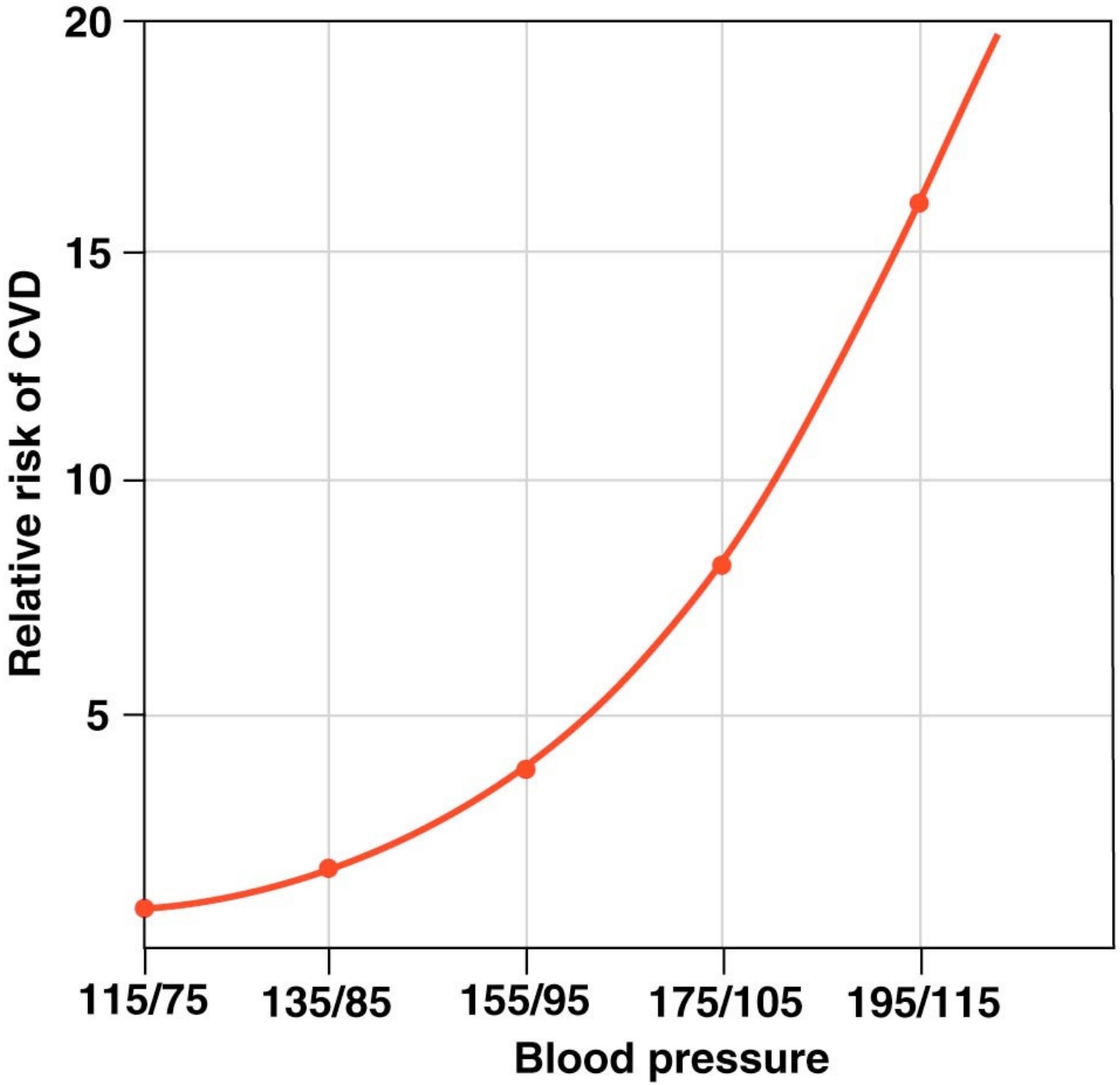
# Topics in Vascular Medicine

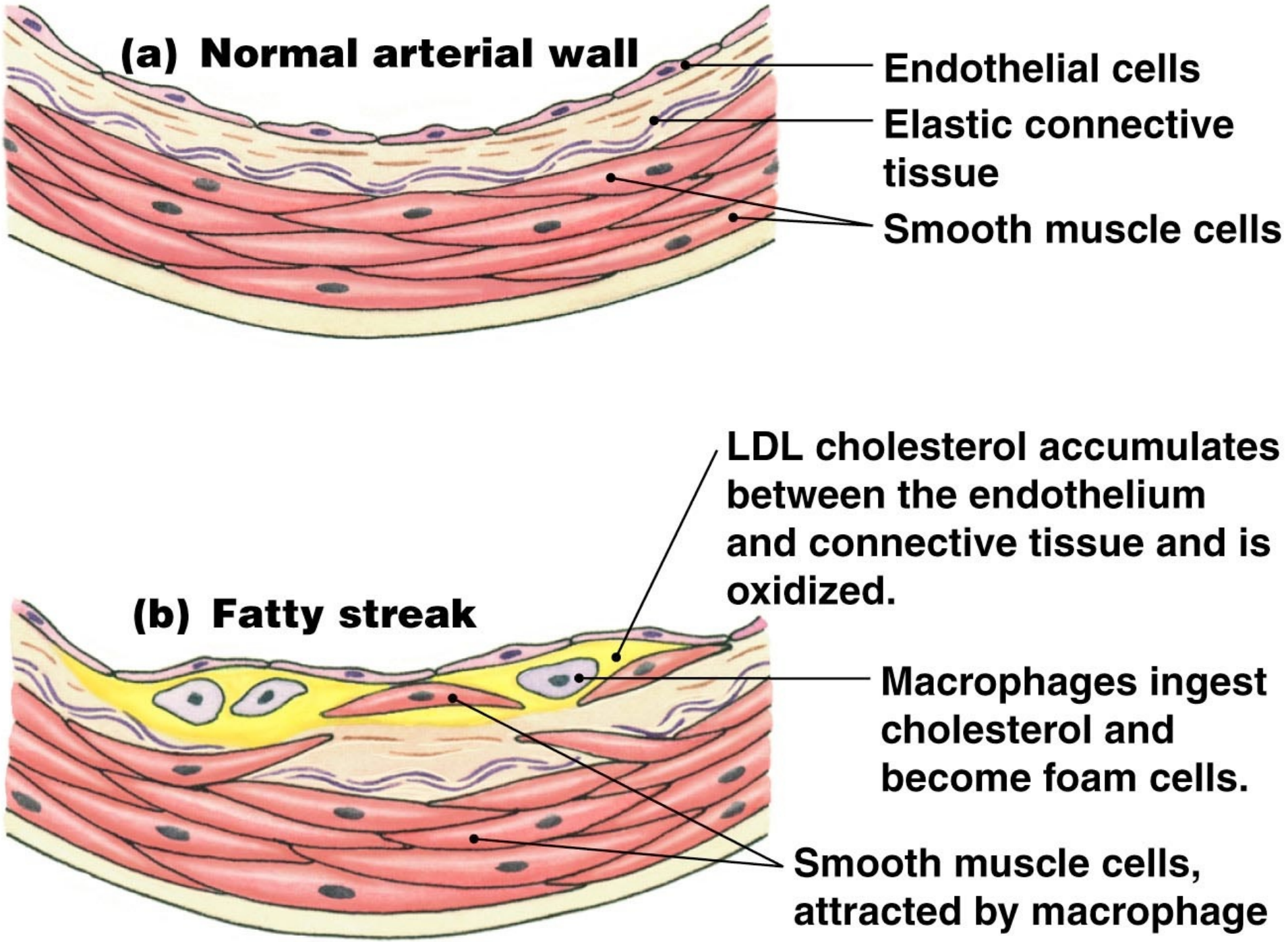
# Angiogenesis

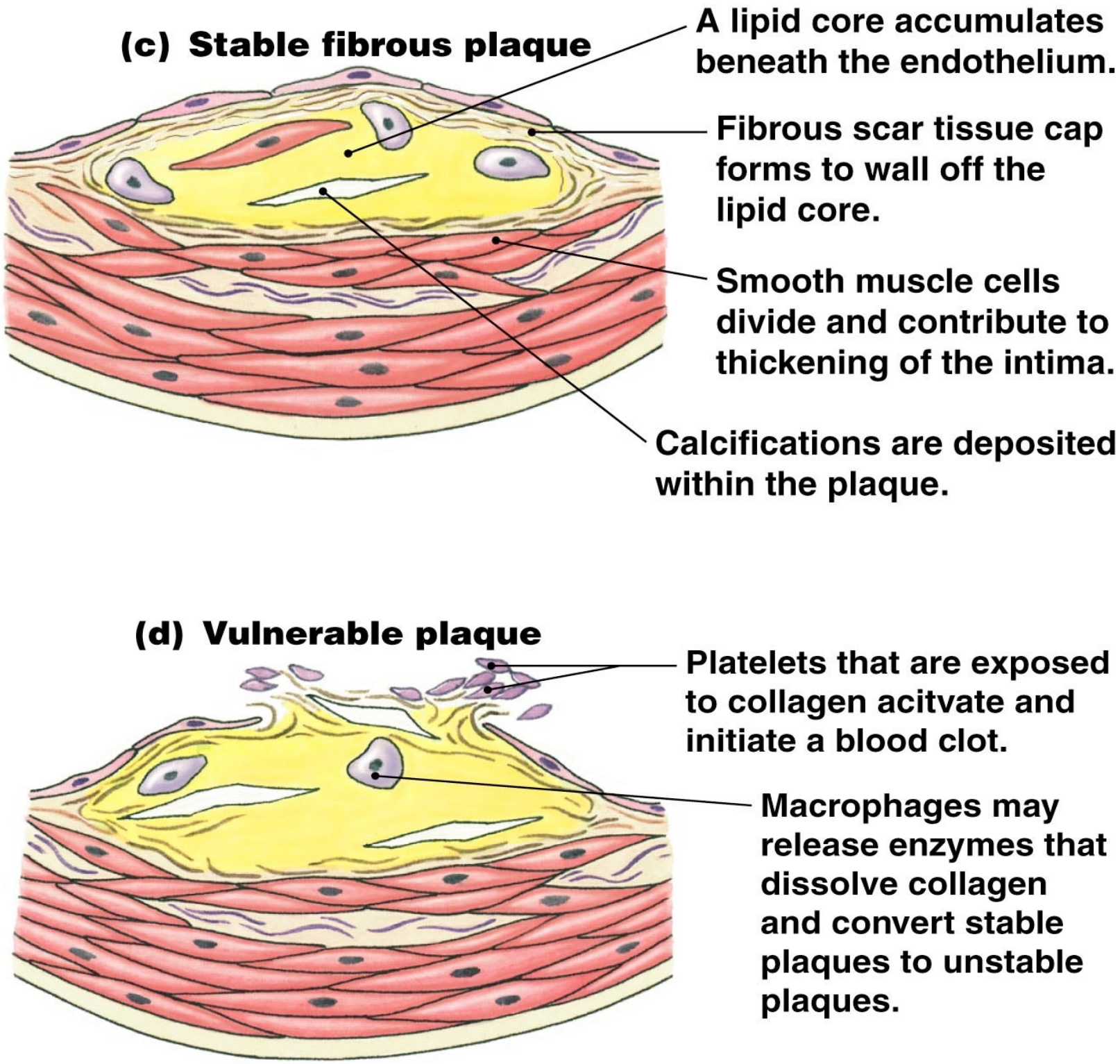
- Angiogenesis = process by which new blood vessels develop
- Understanding angiogenesis can lead to treatment of
  -
  - Coronary artery disease

# Hypertension

- Hypertension is blood pressure that is in excess for one's age and gender
- Treatment:
  - modification of lifestyle is first.
  - diuretic drugs
  - [ ] are used to lower heart rate


20
15
10
5
Relative risk of CVD
115/75
135/85
155/95
175/105
195/115
Blood pressure


(a) Normal arterial wall
Endothelial cells
Elastic connective tissue
Smooth muscle cells
LDL cholesterol accumulates between the endothelium and connective tissue and is oxidized.
(b) Fatty streak
Macrophages ingest cholesterol and become foam cells.
Smooth muscle cells, attracted by macrophage cytokines, begin to divide and take upcholesterol.


(c) Stable fibrous plaque
A lipid core accumulates beneath the endothelium.
Fibrous scar tissue cap forms to wall off the lipid core.
Smooth muscle cells divide and contribute to thickening of the intima.
Calcifications are deposited within the plaque.
(d) Vulnerable plaque
Platelets that are exposed to collagen acitvate and initiate a blood clot.
Macrophages may release enzymes that dissolve collagen and convert stable plaques to unstable plaques.

# Shock

- Shock occurs when low blood volume reaches an area of the body
- Hypovolemic Shock: circulatory shock due to low blood volume (due to bleeding, burns, dehydration)
- Septic Shock: circulatory shock due to sepsis (infection)
- Anaphylactic shock: due to an allergic reaction
- [ ] shock: due to heart problem