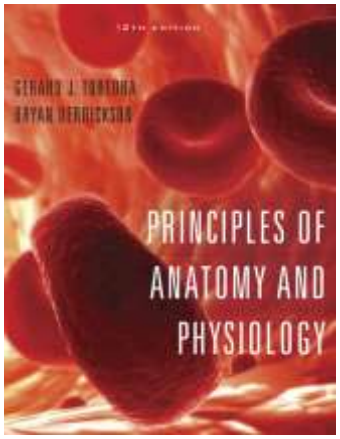
# Lecture 24. Systemic blood circulation, hemodynamic laws, blood vessels' role

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# Structure and function of blood vessels

- 5 main types
  - Arteries – carry blood AWAY from the heart
  - Arterioles
  - Capillaries – site of exchange
  - Venules
  - Veins – carry blood TO the heart

# Basic structure

- 3 layers or tunics
  1. Tunica interna (intima)
  2. Tunica media
  3. Tunica externa
- Modifications account for 5 types of blood vessels and their structural/ functional differences

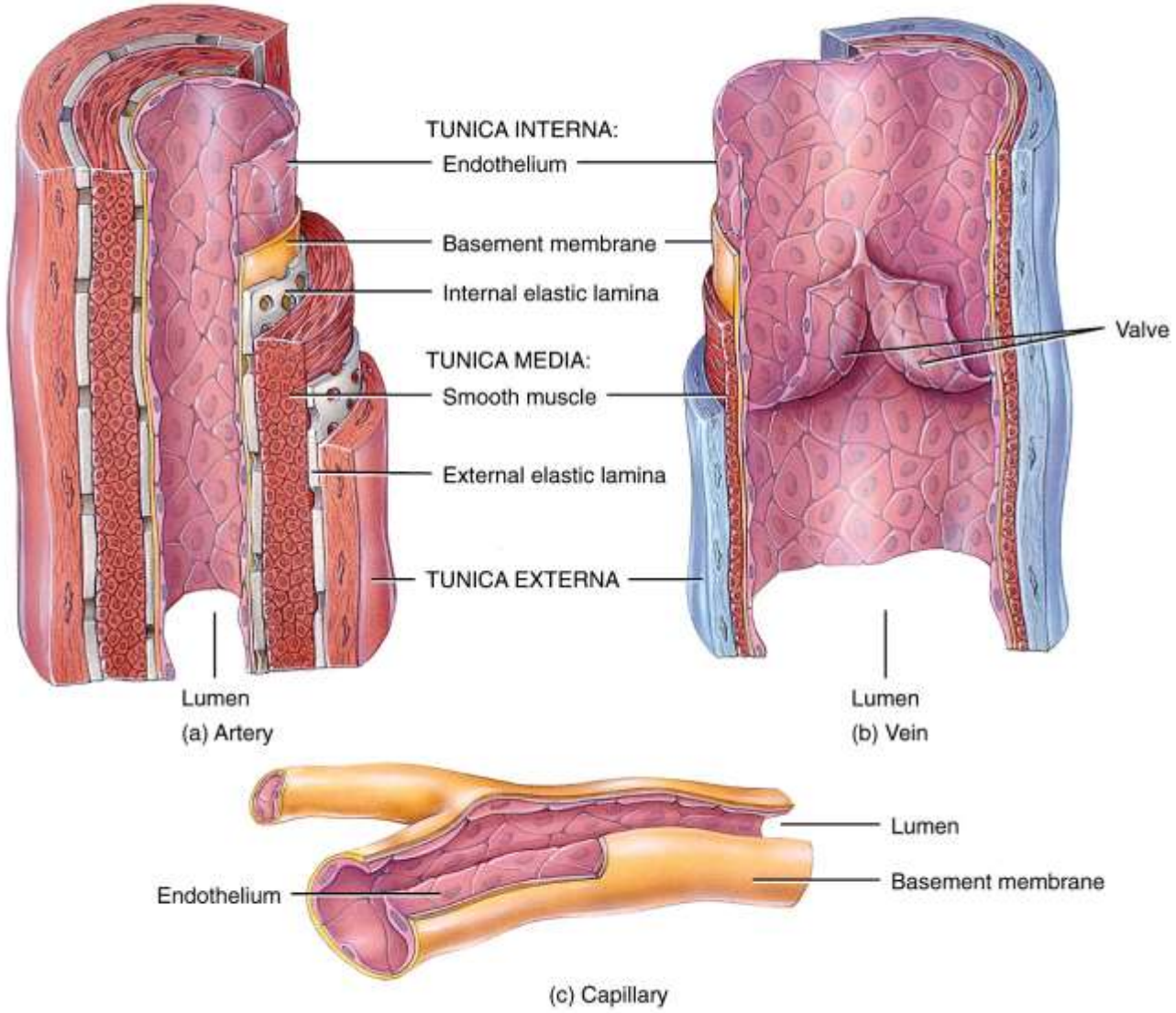



Figure 21.01abc Tortora - PAP 12/e

# Structure

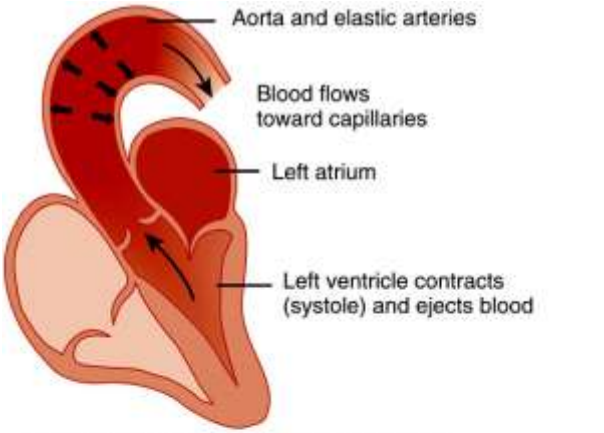
- Tunica interna (intima)
  - Inner lining in direct contact with blood
  - Endothelium continuous with endocardial lining of heart
  - Active role in vessel-related activities
- Tunica media
  - Muscular and connective tissue layer
  - Greatest variation among vessel types
  - Smooth muscle regulates diameter of lumen
- Tunica externa
  - Elastic and collagen fibers
  - Vasa vasorum
  - Helps anchor vessel to surrounding tissue

# Arteries

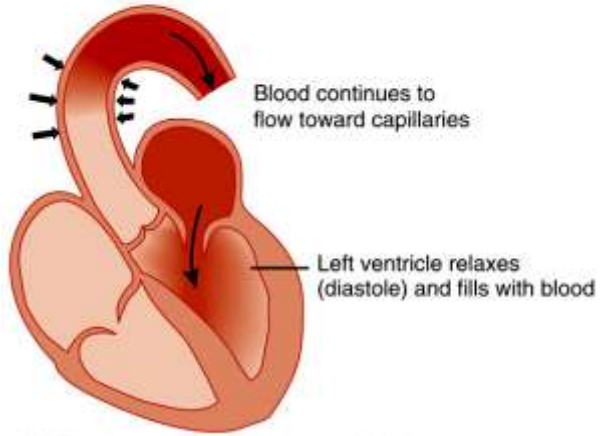
- 3 layers of typical blood vessel
- Thick muscular-to-elastic tunica media
- High compliance – walls stretch and expand in response to pressure without tearing
- Vasoconstriction – decrease in lumen diameter
  - Vasodilation – increase in lumen diameter

# Elastic Arteries

- Largest arteries
- Largest diameter but walls relatively thin
- Function as pressure reservoir
- Help propel blood forward while ventricles relaxing
- Also known as conducting arteries – conduct blood to medium-sized arteries




(a) Elastic aorta and arteries stretch during ventricular contraction




(b) Elastic aorta and arteries recoil during ventricular relaxation

Figure 21.02 Tortora - PAP 12/e

# Arteries

- Muscular arteries
  - Tunica media contains more smooth muscle and fewer elastic fibers than elastic arteries
  - Walls relatively thick
  - Capable of great vasoconstriction/ vasodilatation to adjust rate of blood flow
  - Also called distributing arteries
- Anastomoses
  - Union of the branches of 2 or more arteries supplying the same body region
  - Provide alternate routes – collateral circulation

# Arterioles

- Abundant microscopic vessels
- Metarteriole has precapillary sphincter which monitors blood flow into capillary
- Sympathetic innervation and local chemical mediators can alter diameter and thus blood flow and resistance
- Resistance vessels – resistance is opposition to blood flow
- Vasoconstriction can raise blood pressure

# Capillaries

- Capillaries
  - Smallest blood vessels connect arterial outflow and venous return
  - Microcirculation – flow from metarteriole through capillaries and into postcapillary venule
  - Exchange vessels – primary function is exchange between blood and interstitial fluid
  - Lack tunica media and tunica externa
    - Substances pass through just one layer of endothelial cells and basement membrane
  - Capillary beds – arise from single metarteriole
    - Vasomotion – intermittent contraction and relaxation
    - Throughfare channel – bypasses capillary bed

# Arteries, Capillaries, and Venule

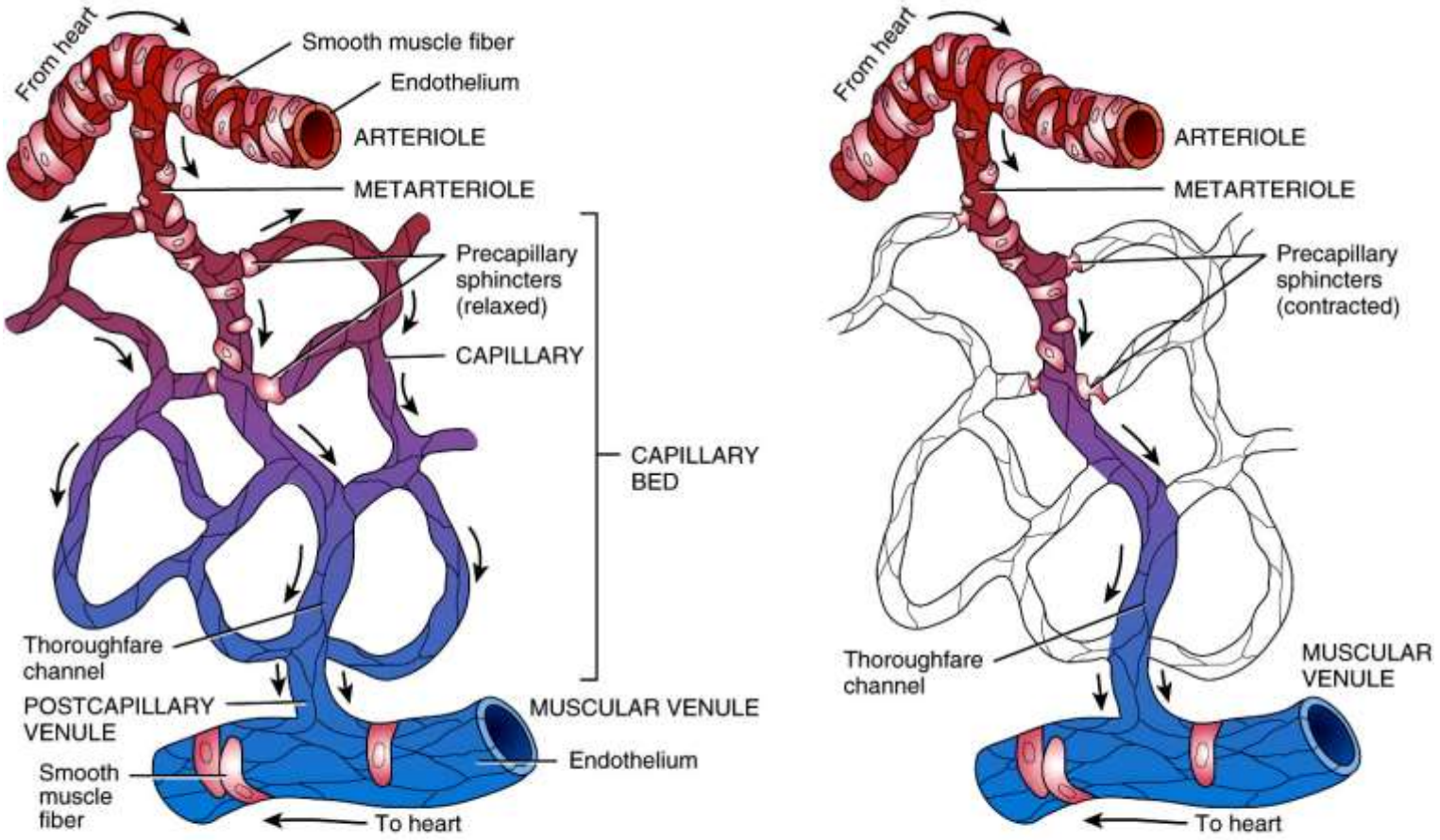



Figure 21.03 Tortora - PAP 12/e

# Types of Capillaries

- 3 types

1. Continuous
   - Endothelial cell membranes from continuous tube
2. Fenestrated
   - Have fenestrations or pores
3. Sinusoids
   - Wider and more winding
   - Unusually large fenestrations

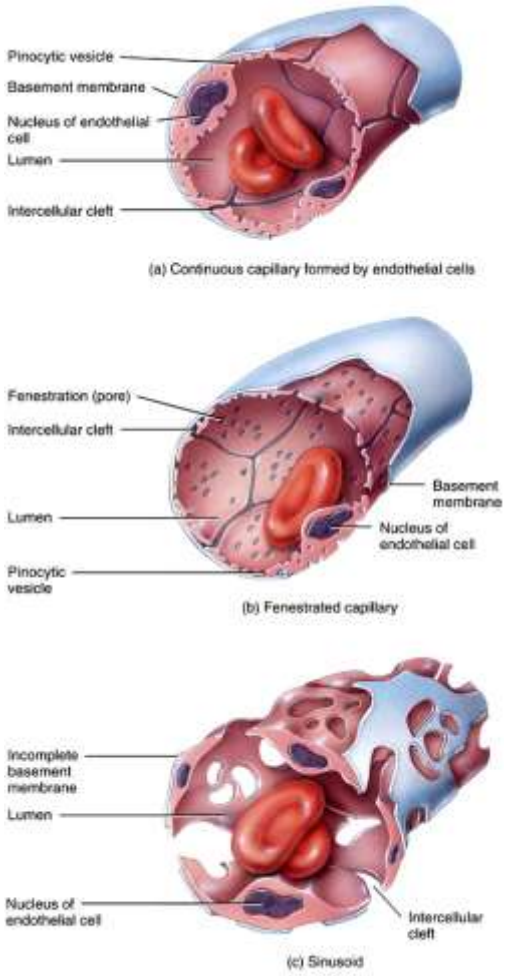



Figure 21.04 Tortora - PAP 12/e

- Portal vein – blood passes through second capillary bed
  - Hepatic or hypophyseal
- Venules
  - Thinner walls than arterial counterparts
  - Postcapillary venule – smallest venule
  - Form part of microcirculatory exchange unit with capillaries
  - Muscular venules have thicker walls with 1 or 2 layers of smooth muscle

# Veins

- Structural changes not as distinct as in arteries
- In general, very thin walls in relation to total diameter
- Same 3 layers
  - Tunica interna thinner than arteries
  - Tunica interna thinner with little smooth muscle
  - Tunica externa thickest layer
- Not designed to withstand high pressure
- Valves – folds on tunica interna forming cusps
  - Aid in venous return by preventing backflow

# Venous Valves

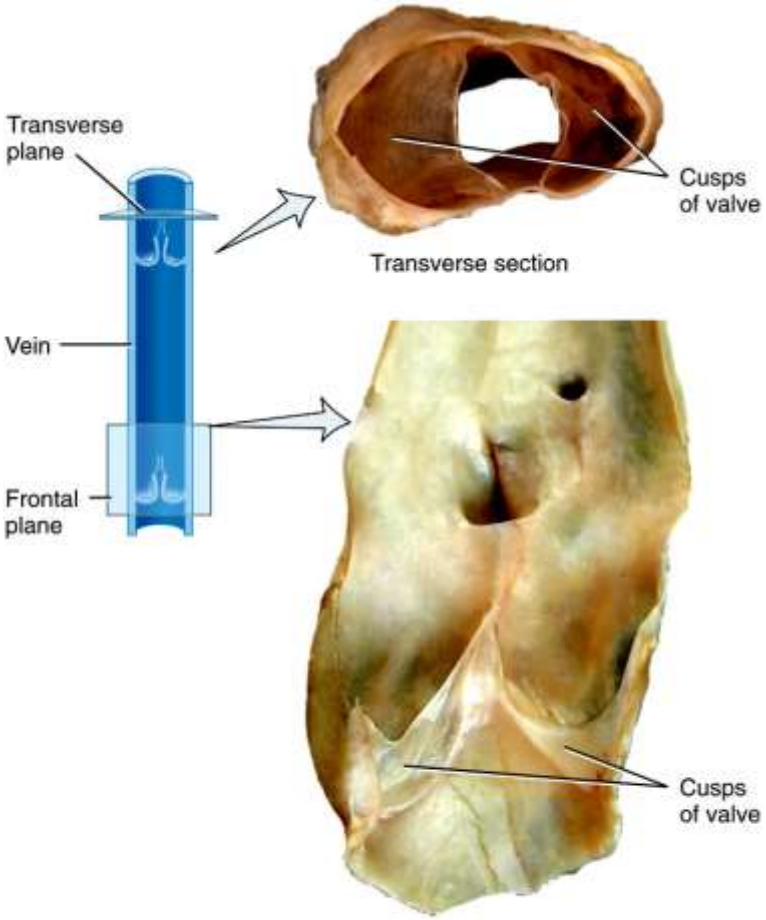
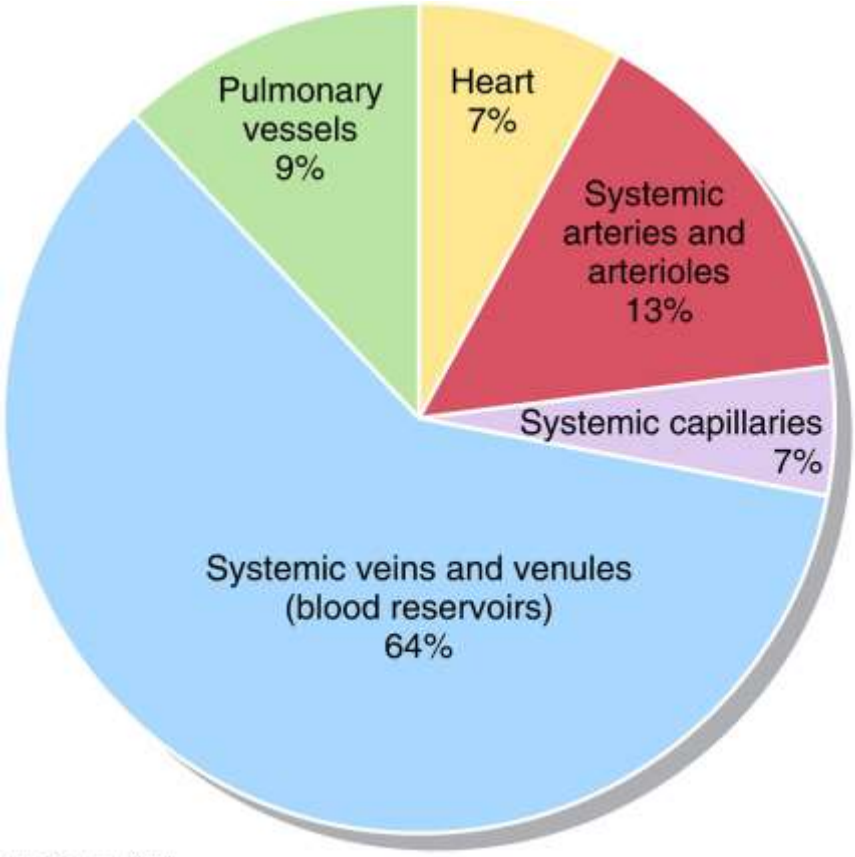



Figure 21.05 Tortora - PAP 12/e

# Blood Distribution

- Largest portion of blood at rest is in systemic veins and venules
  - Blood reservoir
- Venoconstriction reduces volume of blood in reservoirs and allows greater blood volume to flow where needed



# Capillary exchange

- Movement of substances between blood and interstitial fluid
- 3 basic methods
  1. Diffusion
  2. Transcytosis
  3. Bulk flow

# Diffusion

- Most important method
- Substances move down their concentration gradient
  - $O_2$ and nutrients from blood to interstitial fluid to body cells
  - $CO_2$ and wastes move from body cells to interstitial fluid to blood
- Can cross capillary wall through intracellular clefts, fenestrations or through endothelial cells
  - Most plasma proteins cannot cross
  - Except in sinusoids – proteins and even blood cells leave
  - Blood-brain barrier – tight junctions limit diffusion

# Transcytosis

- Small quantity of material
- Substances in blood plasma become enclosed within pinocytotic vessicles that enter endothelial cells by endocytosis and leave by exocytosis
- Important mainly for large, lipid-insoluble molecules that cannot cross capillary walls any other way

# Bulk Flow

- Passive process in which large numbers of ions, molecules, or particles in a fluid move together in the same direction
- Based on pressure gradient
- Diffusion is more important for solute exchange
- Bulk flow more important for regulation of relative volumes of blood and interstitial fluid
- Filtration – from capillaries into interstitial fluid
- Reabsorption – from interstitial fluid into capillaries

# NFP = (BHP + IFOP) – (BCOP + IFHP)

- Net filtration pressure (NFP) balance of 2 pressures

1. 2 pressures promote filtration
   - Blood hydrostatic pressure (BHP) generated by pumping action of heart
     - Falls over capillary bed from 35 to 16 mmHg
   - Interstitial fluid osmotic pressure (IFOP)
     - 1 mmHg

# NFP = (BHP + IFOP) – (BCOP + IFHP)

2. 2 pressures promote reabsorption
   - Blood colloid osmotic pressure (BCOP) promotes reabsorption
     - Due to presence of blood plasma proteins to large to cross walls
     - Averages 36 mmHg
   - Interstitial fluid hydrostatic pressure (IFHP)
     - Close to zero mmHg

# Starling's Law

- Nearly as much reabsorbed as filtered
  - At the arterial end, net outward pressure of 10 mmHg and fluid leaves capillary (filtration)
  - At the venous end, fluid moves in (reabsoprtion) due to -9 mmHg
  - On average, about 85% of fluid filtered in reabsorpbed
  - Excess enters lymphatic capillaries (about 3L/ day) to be eventually returned to blood

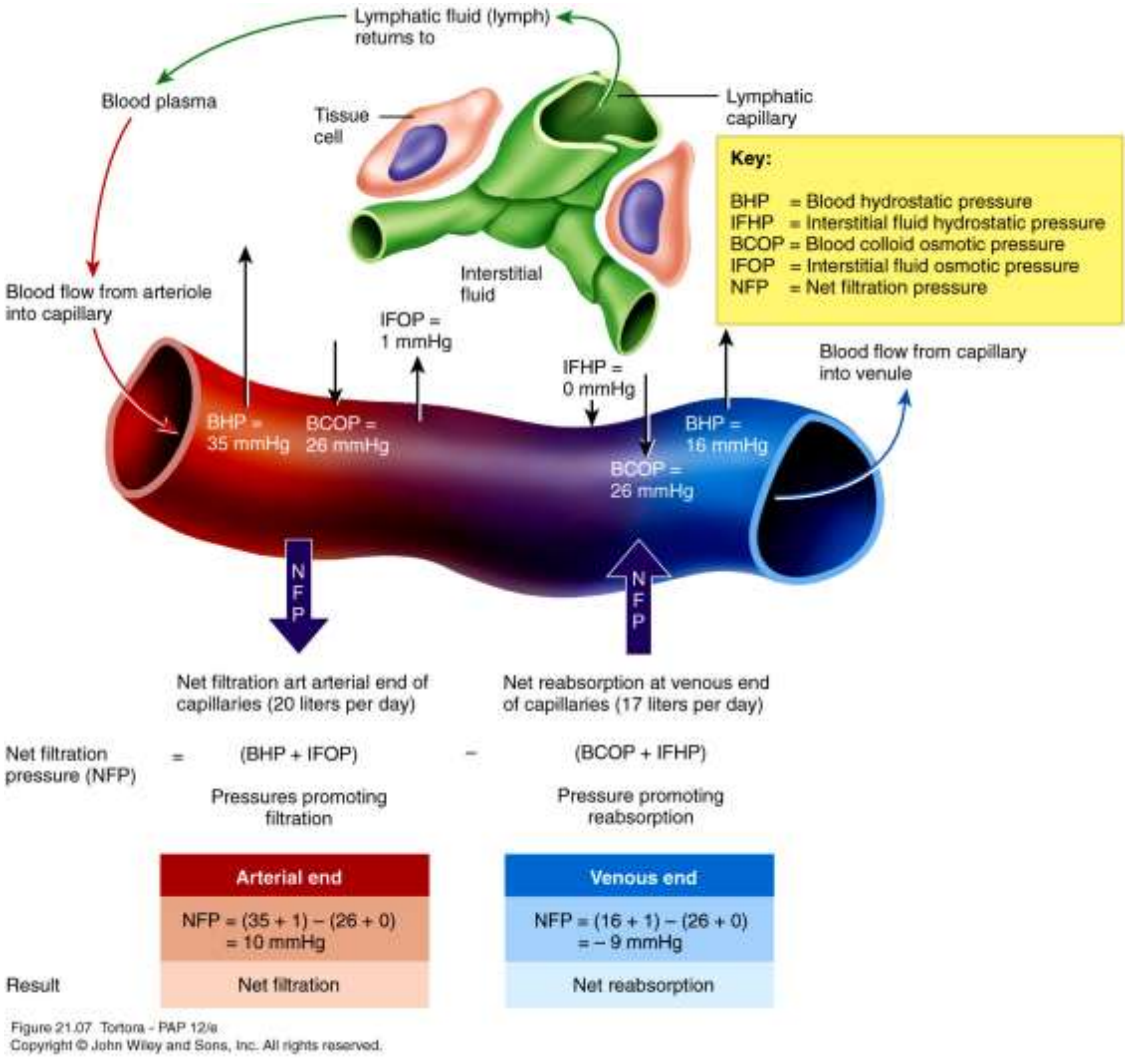



Figure 21.07 Tortora - PAP 12/e

# Dynamics of Capillary Exchange

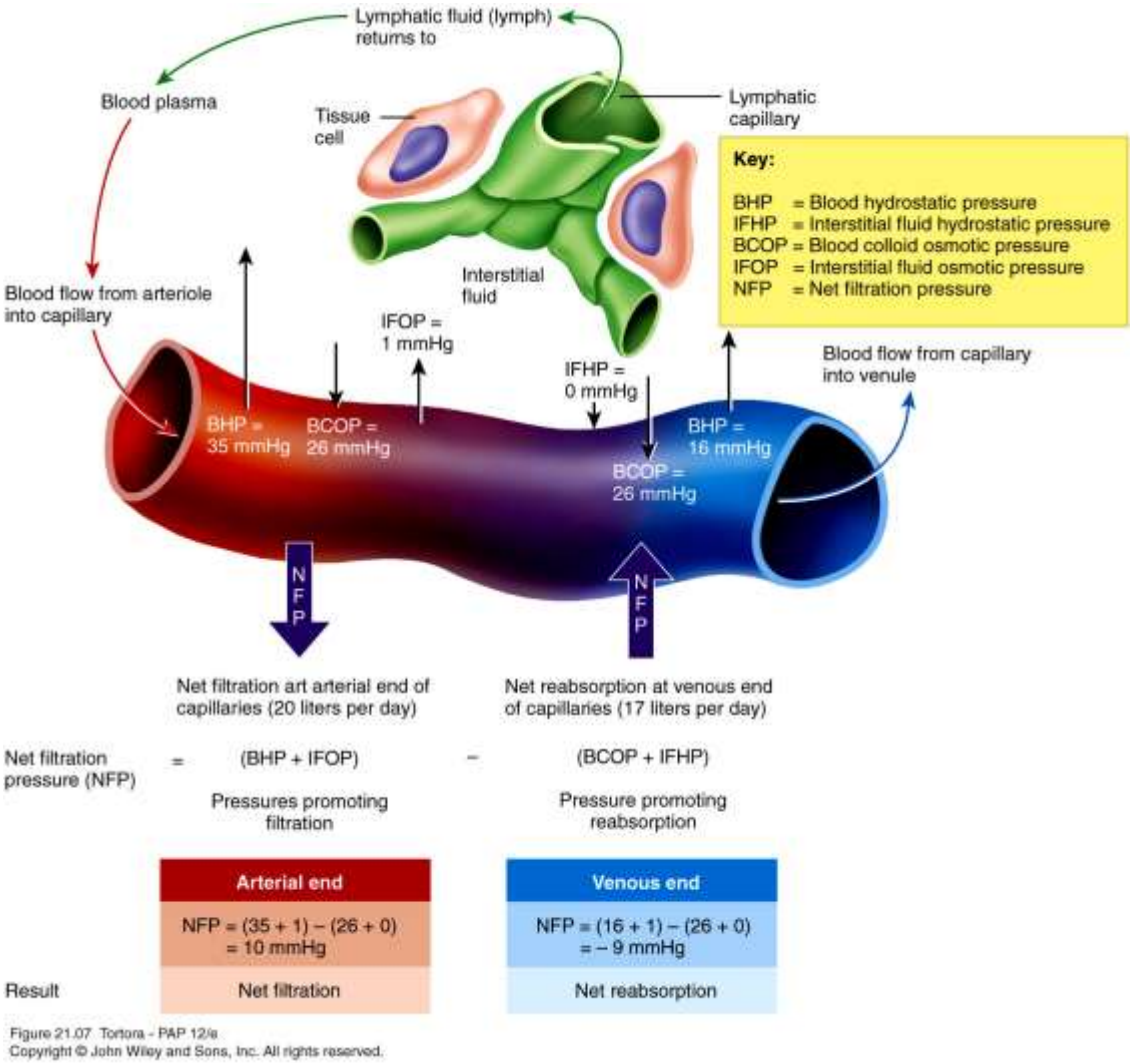



Figure 21.07 Tortora - PAP 12/e

# Hemodynamics: Factors affecting blood flow

- Blood flow – volume of blood that flows through any tissue in a given period of time (in mL/min)
- Total blood flow is cardiac output (CO)
  - Volume of blood that circulates through systemic (or pulmonary) blood vessels each minute
- CO = heart rate (HR) x stroke volume (SV)
- Distribution of CO depends on
  - Pressure differences that drive blood through tissue
    - Flows from higher to lower pressure
  - Resistance to blood flow in specific blood vessels
    - Higher resistance means smaller blood flow

# Blood Pressure

- Contraction of ventricles generates blood pressure
- Systolic BP – highest pressure attained in arteries during systole
- Diastolic BP – lowest arterial pressure during diastole
- Pressure falls progressively with distance from left ventricle
- Blood pressure also depends on total volume of blood

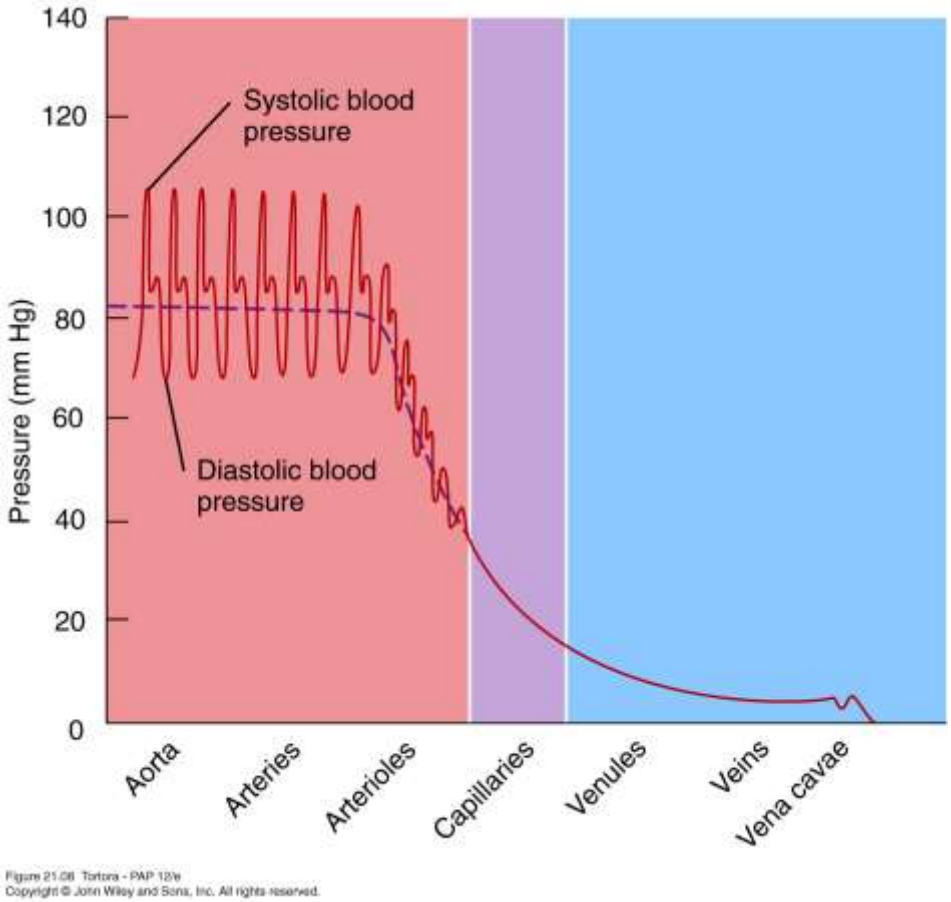



Figure 21.08 Tortora - PAP 12/e
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# Vascular resistance

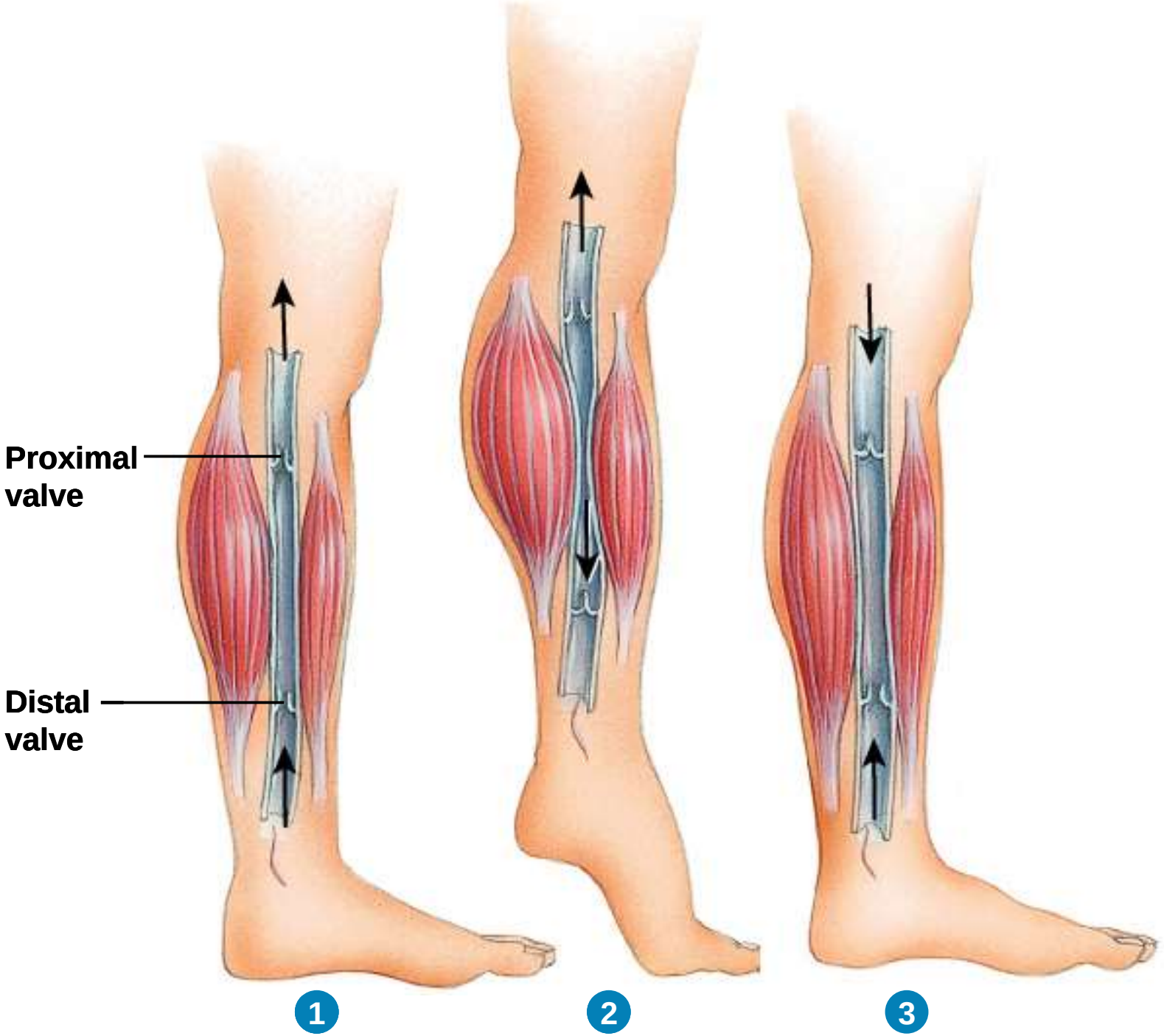
- Opposition to blood flow due to friction between blood and walls of blood vessels
- Depends on
  1. Size of lumen – vasoconstriction males lumen smaller meaning greater resistance
  2. Blood viscosity – ratio of RBCs to plasma and protein concentration, higher viscosity means higher resistance
  3. Total blood vessel length – resistance directly proportional to length of vessel
     - 400 miles of additional blood vessels for each 2.2lb. of fat

# Venous return

- Volume of blood flowing back to heart through systemic veins
- Occurs due to pressure generated by constriction of left ventricle
- Small pressure difference from venule (16 mmHg) to right ventricle (0 mmHg) sufficient

# Skeletal Muscle Pump

- 2 other mechanisms
  - Skeletal muscle pump – milks blood in 1 direction due to valves
  - Respiratory pump – due to pressure changes in thoracic and abdominal cavities


Proximal valve
Distal valve
1
2
3

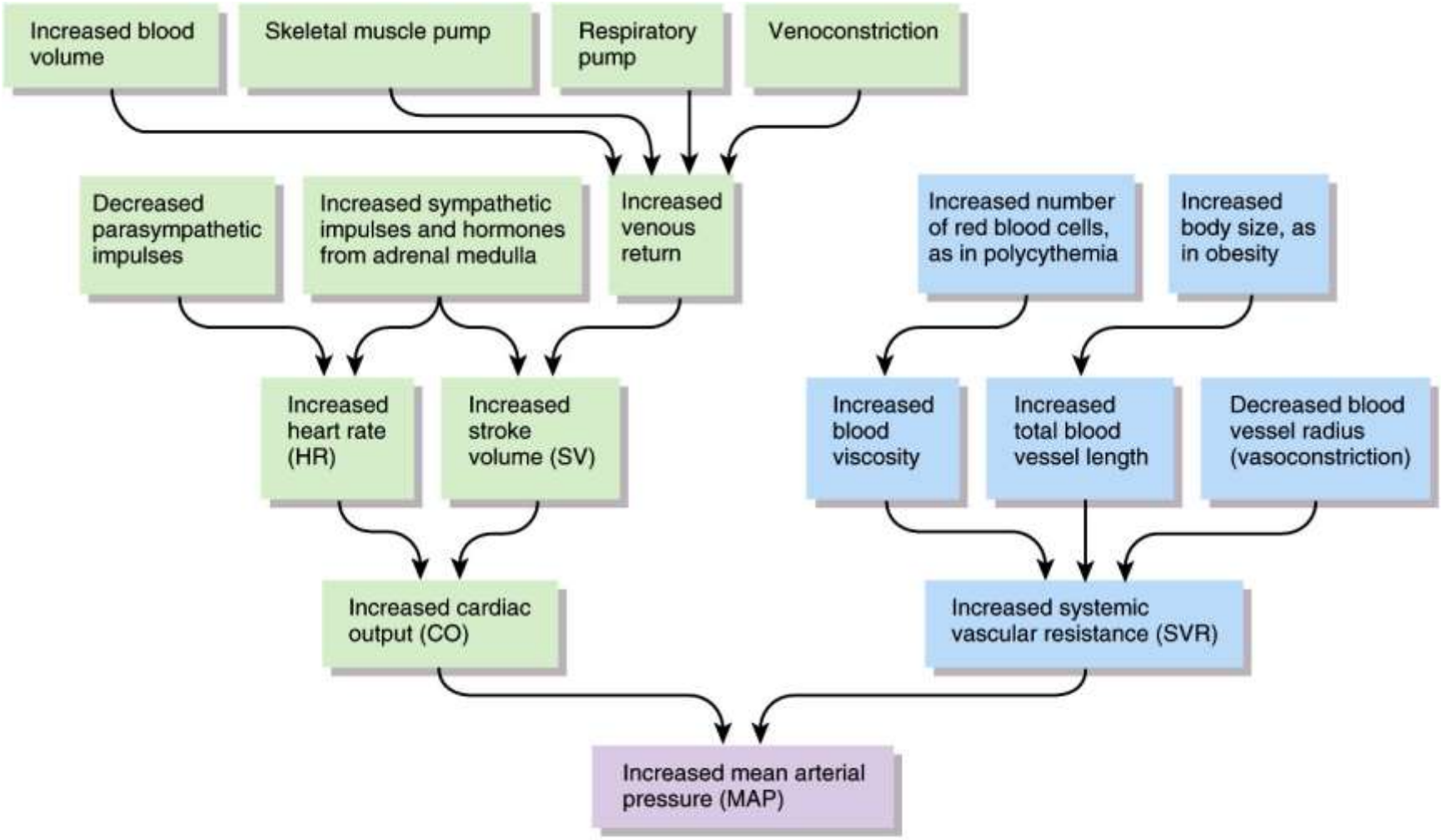
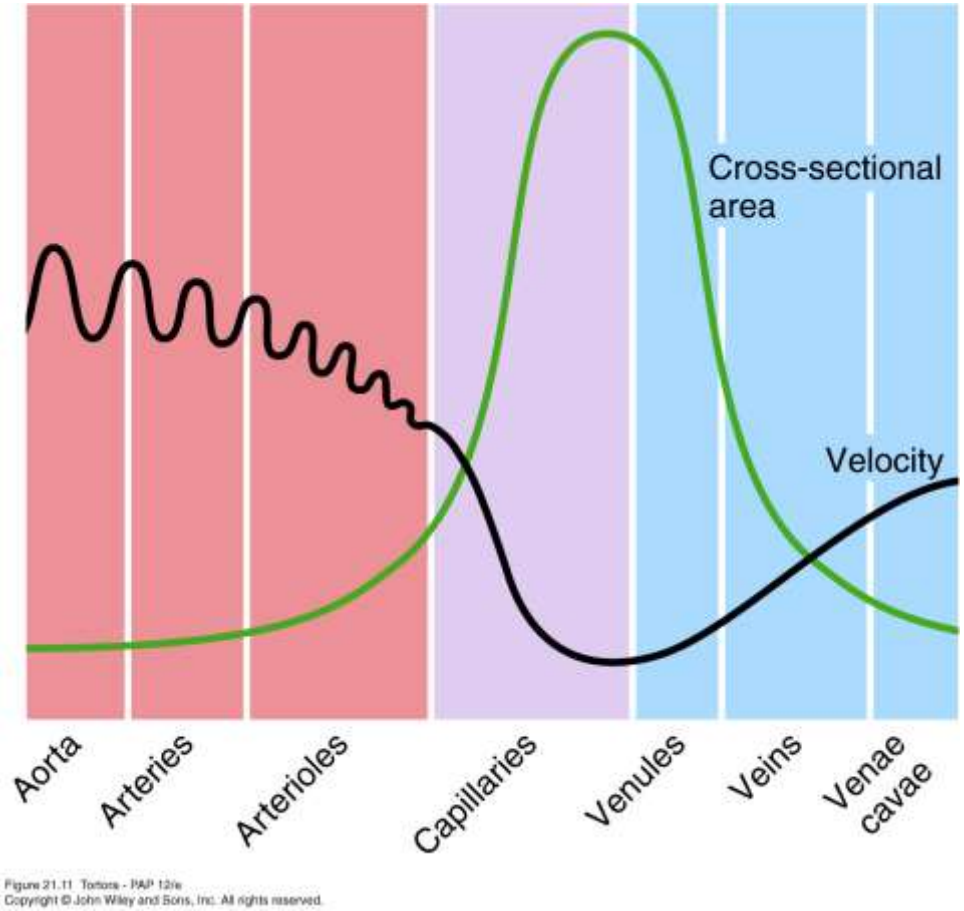



Figure 21.10 Tortora - PAP 12/e

# Velocity of blood flow

- Speed in cm/sec in inversely related to cross-sectional area
- Velocity is slowest where total cross sectional area is greatest
- Blood flow becomes slower farther from the heart
- Slowest in capillaries
- Aids in exchange
- Circulation time – time required for a drop of blood to pass from right atrium, through pulmonary and systemic circulation and back to right atrium
  - Normally 1 minute at rest

# Relationship between Velocity of Blood Flow and Total Cross-sectioned area in Different Types of Blood Vessels

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