Role of vessels in blood circulation.

Prof. Zaporozhets
T.Viber +380972420098

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

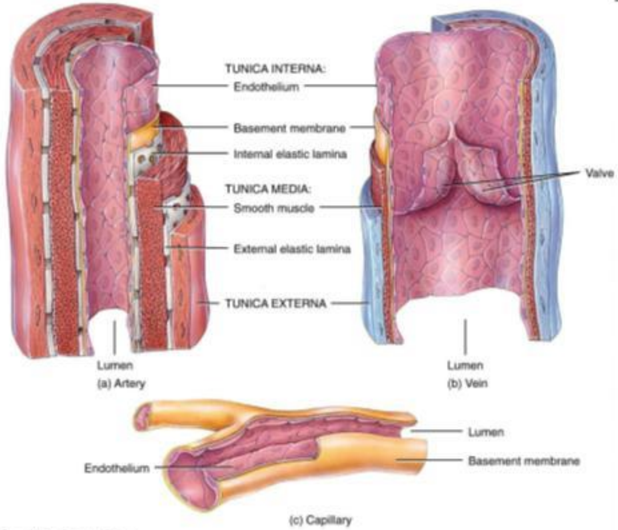


Figure 21.01abc Tortora - PAP 12/e

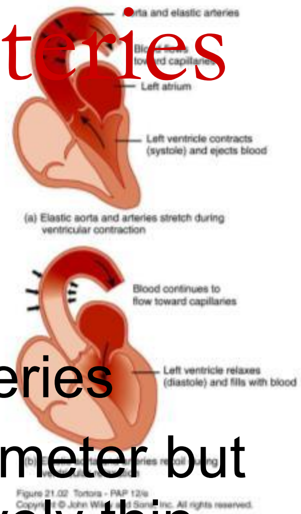
Structure

- 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

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

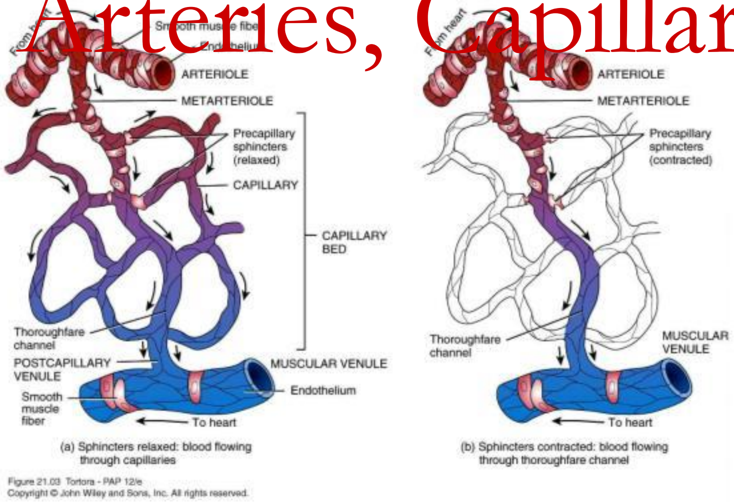
Arterioles

- 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

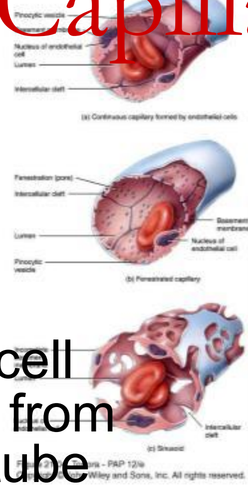
Capillaries

- 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



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

- 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

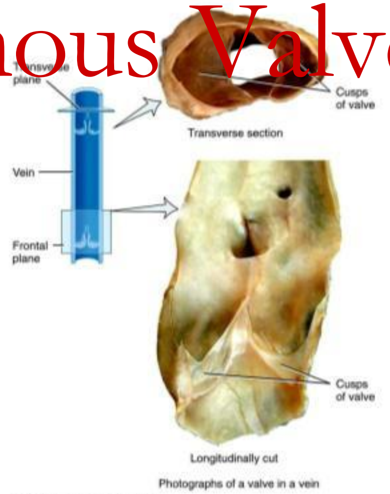
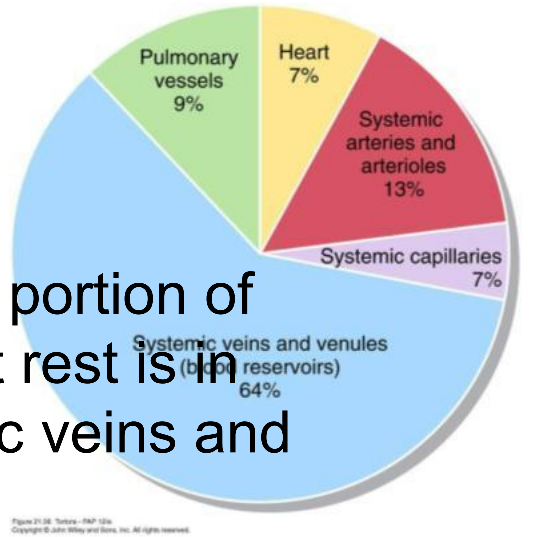


Figure 21.05 Tortora - PAP 12/e

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

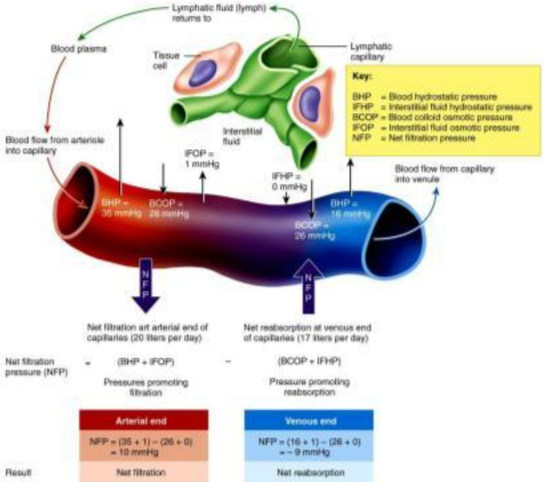


Figure 21.07 Tortora - PAP 12/e

Dynamics of Capillary Exchange

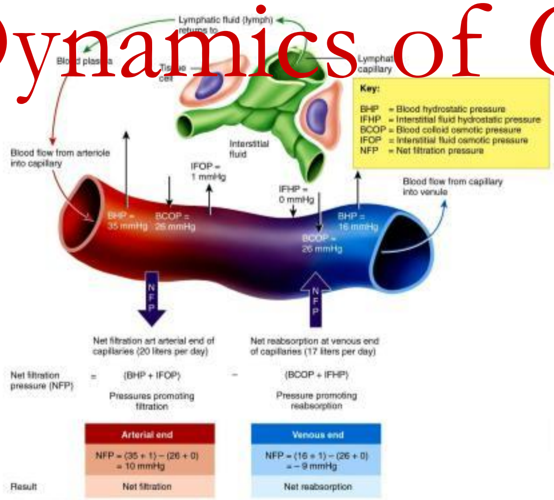
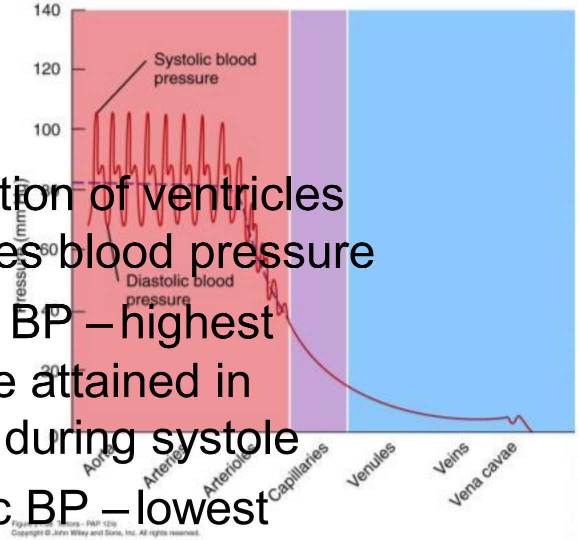


Figure 21.07 Tortora - PAP 12/e

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

Vascular resistance

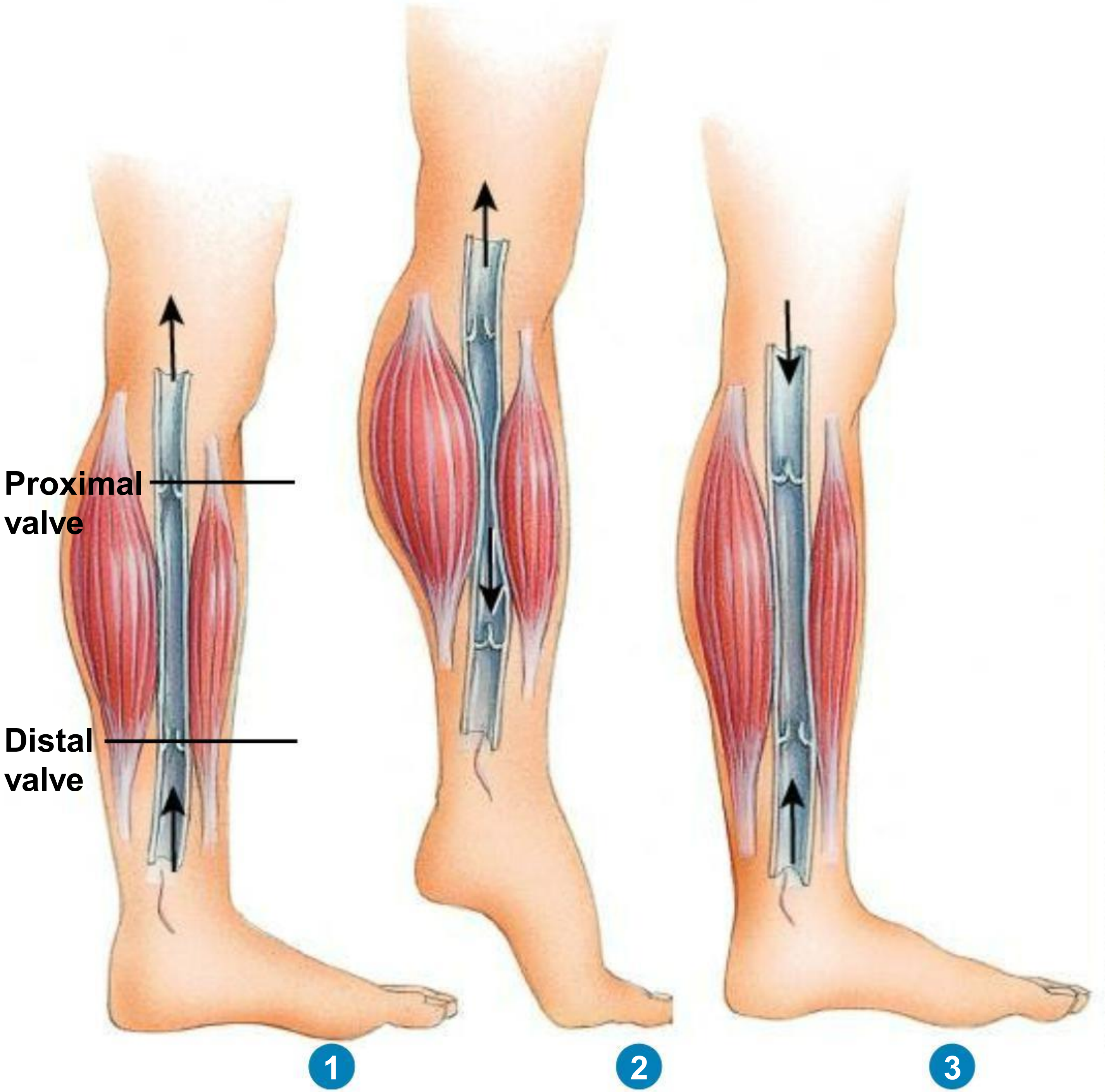
- Opposition to blood flow due to friction between blood and walls of blood vessels
- Depends on
  1. Size of lumen – vasoconstriction males lumen smaller meaning greater resistance
  2. Blood viscosity – ratio of RBCs to plasma and protein concentration, higher viscosity means higher resistance
  3. 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

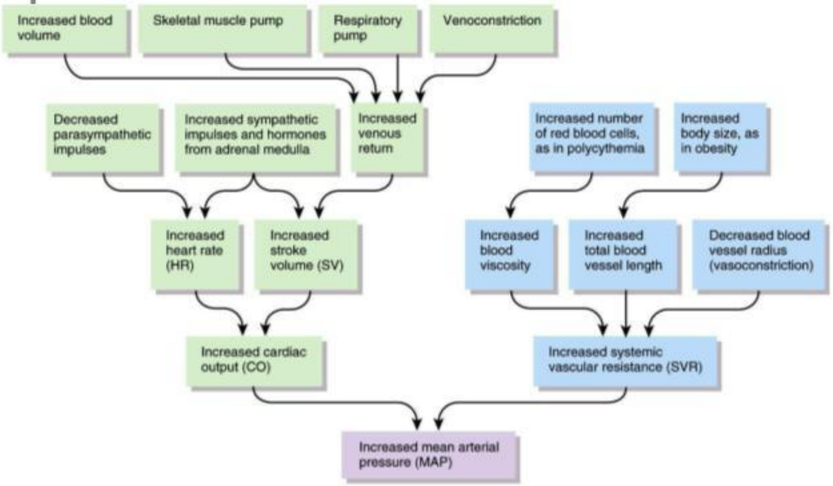
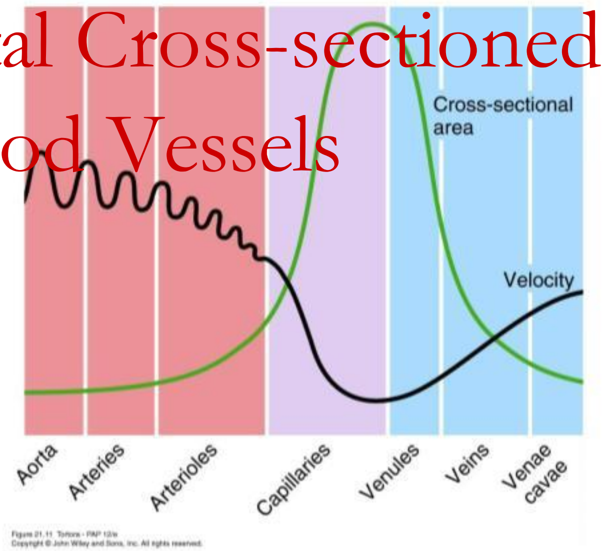


Figure 21.10 Tortora - PAP 12/e

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



Control of blood pressure and blood flow

- Interconnected negative feedback systems control blood pressure by adjusting heart rate, stroke volume, systemic vascular resistance, and blood volume
- Some act faster that others
- Some shorter- or longer-term

Role of cardiovascular center (CV)

- In medulla oblongata
- Helps regulate heart rate and stroke volume
- Also controls neural, hormonal, and local negative feedback systems that regulate blood pressure and blood flow to specific tissues
- Groups of neurons regulate heart rate, contractility of ventricles, and blood vessel diameter
- Cardiostimulatory and cardioinhibitory centers
- Vasomotor center control blood vessel diameter
- Receives input from both higher brain regions and sensory receptors

CV Center

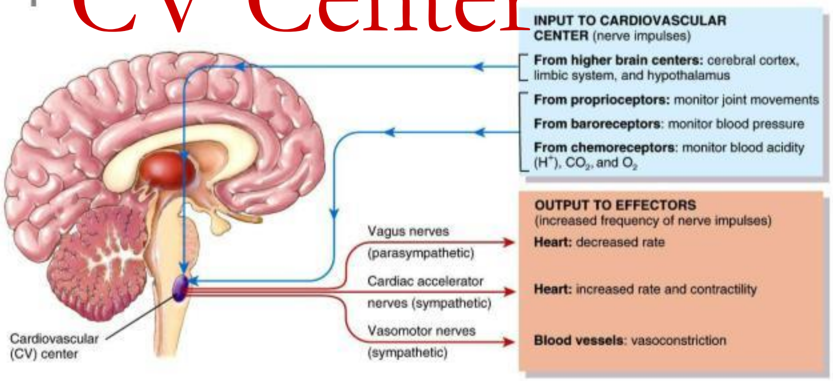


Figure 21.12 Tortora - PAP 12/e

3 main types of sensory receptors

- Proprioceptors – monitor movements of joints and muscles to provide input during physical activity
- Baroreceptors – monitor pressure changes and stretch in blood vessel walls
- Chemoreceptors – monitor concentration of various chemicals in the blood

- Output from CV flows along neurons of ANS
  - Sympathetic (stimulatory) opposes parasympathetic (inhibitory)

Neural regulation of blood pressure

- Negative feedback loops from 2 types of reflexes

1. Baroreceptor reflexes
   - Pressure-sensitive receptors in internal carotid arteries and other large arteries in neck and chest
     - Carotid sinus reflex helps regulate blood pressure in brain
     - Aortic reflex regulates systemic blood pressure
   - When blood pressure falls, baroreceptors stretched less, slower rate of impulses to CV
   - CV decreases parasympathetic stimulation and increases sympathetic stimulation

Neural regulation of blood pressure

2. Chemoreceptor reflexes
   - Receptors located close to baroreceptors of carotid sinus (carotid bodies) and aortic arch (aortic bodies)
   - Detect hypoxia (low O_2), hypercapnia (high CO_2), acidosis (high H^+) and send signals to CV
   - CV increases sympathetic stimulation to arterioles and veins, producing vasoconstriction and an increase in blood pressure
   - Receptors also provide input to respiratory center to adjust breathing rate

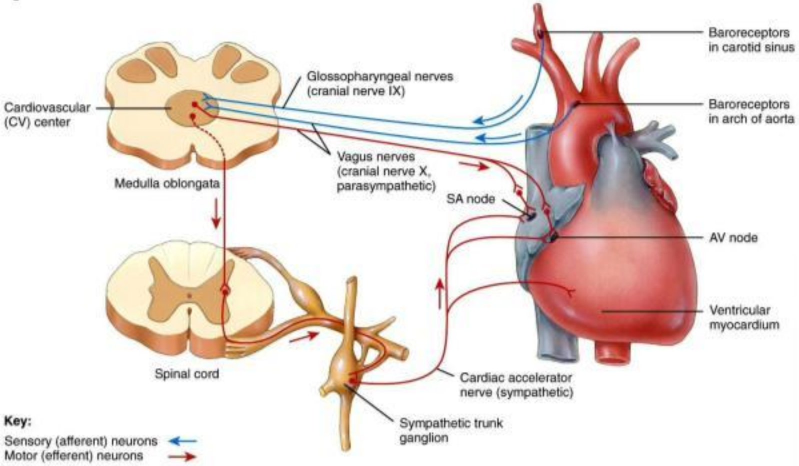


Figure 21.13 Tortora - PAP 12/e

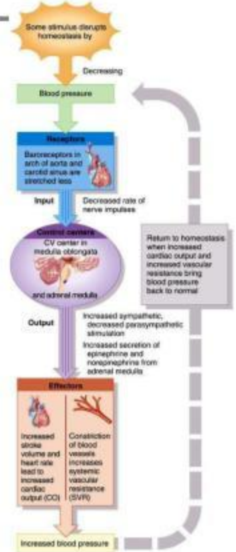


Figure 21.14 Tortora - PAP 12/e

Hormonal regulation of blood pressure

- Renin-angiotensin-aldosterone (RAA) system
  - Renin (released by kidney when blood volume falls or blood flow decreases) and angiotensin converting enzyme (ACE) act on substrates to produce active hormone angiotensin II
    - Raises BP by vasoconstriction and secretion of aldosterone (increases water reabsorption in kidneys to raise blood volume and pressure)

Hormonal regulation of blood pressure

- Epinephrine and norepinephrine
  - Adrenal medulla releases in response to sympathetic stimulation
  - Increase cardiac output by increasing rate and force of heart contractions
- Antidiuretic hormone (ADH) or vasopressin
  - Produced by hypothalamus, released by posterior pituitary
  - Response to dehydration or decreased blood volume
  - Causes vasoconstriction which increases blood pressure

Atrial natriuretic peptide (ANP)

- Released by cells of atria
- Lowers blood pressure by causing vasodilation and promoting loss of salt and water in urine
- Reduces blood volume

Autoregulation of blood pressure

- Ability of tissue to automatically adjust its blood flow to match metabolic demands
- Demand of O_2 and nutrients can rise tenfold during exercise in heart and skeletal muscles
- Also controls regional blood flow in the brain during different mental and physical activities
- 2 general types of stimuli
  1. Physical – temperature changes, myogenic response
  2. Vasodilating and vasoconstricting chemicals alter blood vessel diameter

Circulation

- Important difference between pulmonary and systemic circulation in autoregulatory response
  - Systemic blood vessel walls dilate in response to low O_2 to increase O_2 delivery
  - Walls of pulmonary blood vessels constrict under low O_2 to ensure most blood flows to better ventilated areas of lung