Chapter 21

Blood Vessels and Circulation

An Introduction to Blood Vessels and Circulation

- Blood Vessels
  - Are classified by size and histological organization
  - Are instrumental in overall cardiovascular regulation

21-1 Classes of Blood Vessels

- **Arteries**
  - Carry blood *away* from heart
- **Arterioles**
  - Are smallest branches of arteries
- **Capillaries**
  - Are smallest blood vessels
  - Location of exchange between blood and interstitial fluid
- **Venules**
  - Collect blood from capillaries
- **Veins**
  - Return blood *to* heart

21-1 Blood Vessels

- The Largest Blood Vessels
  - Attach to heart
  - Pulmonary trunk
    - Carries blood from right ventricle
    - To pulmonary circulation
  - Aorta
    - Carries blood from left ventricle
    - To systemic circulation

21-1 Blood Vessels

- The Smallest Blood Vessels
  - Capillaries
    - Have small diameter and thin walls
    - Chemicals and gases diffuse across walls

21-1 Blood Vessels

- The Structure of Vessel Walls

- Walls have three layers
  1. **Tunica intima**
  2. **Tunica media**
  3. **Tunica externa**

21-1 Blood Vessels

- The **Tunica Intima** (Inner Layer)
  - Includes:
    - The endothelial lining
    - Connective tissue layer
    - **Internal elastic membrane**
      - In arteries, is a layer of elastic fibers in outer margin of tunica intima

21-1 Blood Vessels

- The **Tunica Media** (Middle Layer)
  - Contains concentric sheets of smooth muscle in loose connective tissue
  - Binds to inner and outer layers
  - **External elastic membrane** of the tunica media
    - Separates tunica media from tunica externa

21-1 Blood Vessels

- The **Tunica Externa** (Outer Layer)
  - Anchors vessel to adjacent tissues in arteries
    - Contains collagen fibers
    - Elastic fibers
  - In veins
    - Contains elastic fibers
    - Smooth muscle cells
  - **Vasa vasorum** (“vessels of vessels”)
    - Small arteries and veins
    - In walls of large arteries and veins
    - Supply cells of tunica media and tunica externa

21-1 Blood Vessels

- Differences between Arteries and Veins
  - Arteries and veins run side by side
  - Arteries have thicker walls and higher blood pressure
  - Collapsed artery has small, round lumen (internal space)
  - Vein has a large, flat lumen
  - Vein lining contracts, artery lining does not
  - Artery lining folds
  - Arteries more elastic
  - Veins have valves

21-1 Structure and Function of Arteries

- Arteries
  - Elasticity allows arteries to absorb pressure waves that come with each heartbeat
  - Contractility
    - Arteries change diameter
    - Controlled by sympathetic division of ANS
    - **Vasoconstriction**
      - The contraction of arterial smooth muscle by the ANS
    - **Vasodilation**
      - The relaxation of arterial smooth muscle
      - Enlarging the lumen

21-1 Structure and Function of Arteries

- Vasoconstriction and Vasodilation
  - Affect:
    1. Afterload on heart
    2. Peripheral blood pressure
    3. Capillary blood flow

21-1 Structure and Function of Arteries

- Arteries
  - From heart to capillaries, arteries change
    - From **elastic arteries**
    - To **muscular arteries**
    - To *arterioles*

21-1 Structure and Function of Arteries

- Elastic Arteries
  - Also called *conducting arteries*
  - Large vessels (e.g., pulmonary trunk and aorta)
  - Tunica media has many elastic fibers and few muscle cells
  - Elasticity evens out pulse force

21-1 Structure and Function of Arteries

- **Muscular Arteries**
  - Also called *distribution* arteries
  - Are medium sized (most arteries)
  - Tunica media has many muscle cells

21-1 Structure and Function of Arteries

- Arterioles
  - Are small
  - Have little or no tunica externa
  - Have thin or incomplete tunica media

21-1 Structure and Function of Arteries

- Artery Diameter
  - Small muscular arteries and arterioles
    - Change with sympathetic or endocrine stimulation
    - Constricted arteries oppose blood flow
      - **Resistance** (R**)**
        - **Resistance vessels** – arterioles

21-1 Structure and Function of Arteries

- **Aneurysm**
  - A bulge in an arterial wall
  - Is caused by weak spot in elastic fibers
  - Pressure may rupture vessel

21-1 Structure and Function of Capillaries

- Capillaries
  - Are smallest vessels with thin walls
  - Microscopic capillary networks permeate all active tissues
  - Capillary function
    - Location of all exchange functions of cardiovascular system
    - Materials diffuse between blood and interstitial fluid

21-1 Structure and Function of Capillaries

- Capillary Structure
  - Endothelial tube, inside thin basement membrane
  - No tunica media
  - No tunica externa
  - Diameter is similar to red blood cell

21-1 Structure and Function of Capillaries

- **Continuous Capillaries**
  - Have complete endothelial lining
  - Are found in all tissues except epithelia and cartilage
  - Functions of continuous capillaries
    - Permit diffusion of water, small solutes, and lipid-soluble materials
    - Block blood cells and plasma proteins

21-1 Structure and Function of Capillaries

- Specialized Continuous Capillaries
  - Are in CNS and thymus
  - Have very restricted permeability
  - For example, *the blood–brain barrier*

21-1 Structure and Function of Capillaries

- **Fenestrated Capillaries**
  - Have pores in endothelial lining
  - Permit rapid exchange of water and larger solutes between plasma and interstitial fluid
  - Are found in:
    - *Choroid plexus*
    - Endocrine organs
    - Kidneys
    - Intestinal tract

21-1 Structure and Function of Capillaries

- **Sinusoids** (**Sinusoidal Capillaries**)
  - Have gaps between adjacent endothelial cells
    - Liver
    - Spleen
    - Bone marrow
    - Endocrine organs
  - Permit free exchange
    - Of water and large plasma proteins
    - Between blood and interstitial fluid
  - Phagocytic cells monitor blood at sinusoids

21-1 Structure and Function of Capillaries

- **Capillary Beds** (**Capillary Plexus**)
  - Connect one arteriole and one venule
  - **Precapillary sphincter**
    - Guards entrance to each capillary
    - Opens and closes, causing capillary blood to flow in pulses

21-1 Structure and Function of Capillaries

- **Thoroughfare Channels**
  - Direct capillary connections between arterioles and venules
  - Controlled by smooth muscle segments (**metarterioles**)

21-1 Structure and Function of Capillaries

- **Collaterals**
  - Multiple arteries that contribute to one capillary bed
  - Allow circulation if one artery is blocked
  - **Arterial anastomosis**
    - Fusion of two collateral arteries
  - **Arteriovenous anastomoses**
    - Direct connections between arterioles and venules
    - Bypass the capillary bed

21-1 Structure and Function of Capillaries

- **Angiogenesis**
  - Formation of new blood vessels
  - **Vascular endothelial growth factor** (**VEGF**)
  - Occurs in the embryo as tissues and organs develop
  - Occurs in response to factors released by cells that are *hypoxic*, or oxygen-starved
    - Most important in cardiac muscle, where it takes place in response to a chronically constricted or occluded vessel

21-1 Structure and Function of Capillaries

- **Vasomotion**
  - Contraction and relaxation cycle of capillary sphincters
  - Causes blood flow in capillary beds to constantly change routes

21-1 Structure and Function of Veins

- Veins
  - Collect blood from capillaries in tissues and organs
  - Return blood to heart
  - Are larger in diameter than arteries
  - Have thinner walls than arteries
  - Have lower blood pressure

21-1 Structure and Function of Veins

- Venules
  - Very small veins
  - Collect blood from capillaries
- **Medium-Sized Veins**
  - Thin tunica media and few smooth muscle cells
  - Tunica externa with longitudinal bundles of elastic fibers

21-1 Structure and Function of Veins

- **Large Veins**
  - Have all three *tunica* layers
  - Thick tunica externa
  - Thin tunica media
- Venous Valves
  - Folds of tunica intima
  - Prevent blood from flowing backward
  - Compression pushes blood toward heart

21-1 Blood Vessels

- The Distribution of Blood
  - Heart, arteries, and capillaries
    - 30–35 percent of blood volume
  - Venous system
    - 60–65 percent
      - 1/3 of venous blood is in the large venous networks of the liver, bone marrow, and skin

21-1 Blood Vessels

- Capacitance of a Blood Vessel
  - The ability to stretch
  - Relationship between blood volume and blood pressure
  - Veins (**capacitance vessels**) stretch more than arteries

21-1 Blood Vessels

- Venous Response to Blood Loss
  - *Vasomotor center* stimulates sympathetic nerves
    - Systemic veins constrict (**venoconstriction**)
    - Veins in liver, skin, and lungs redistribute **venous reserve**

21-2 Pressure and Resistance

- Total Capillary Blood Flow
  - Equals cardiac output
  - Is determined by:
    - *Pressure* (*P*) and *resistance* (*R*) in the cardiovascular system

21-2 Pressure and Resistance

- Pressure (*P*)
  - The heart generates *P* to overcome resistance
  - Absolute pressure is less important than pressure gradient

- The *Pressure Gradient* (ΔP)
  - Circulatory pressure
  - The difference between:
    - Pressure at the heart
    - And pressure at peripheral capillary beds

21-2 Pressure and Resistance

- Flow (*F*)
  - Is proportional to the pressure difference (Δ*P*)
  - Divided by *R*

21-2 Pressure and Resistance

- Measuring Pressure
  - **Blood pressure** (**BP**)
    - Arterial pressure (mm Hg)
  - **Capillary hydrostatic pressure** (**CHP**)
    - Pressure within the capillary beds
  - **Venous pressure**
    - Pressure in the venous system

21-2 Pressure and Resistance

- Circulatory Pressure
  - Δ*P* across the systemic circuit (about 100 mm Hg)
  - Circulatory pressure must overcome **total peripheral resistance**
    - *R* of entire cardiovascular system

21-2 Pressure and Resistance

- Total Peripheral Resistance
  - **Vascular resistance**
  - Blood viscosity
  - **Turbulence**

21-2 Pressure and Resistance

- **Vascular Resistance**
  - Due to friction between blood and vessel walls
  - Depends on vessel length and vessel diameter
    - Adult vessel length is constant
    - Vessel diameter varies by vasodilation and vasoconstriction
      - R increases exponentially as vessel diameter decreases

21-2 Pressure and Resistance

- *Viscosity*
  - *R* caused by molecules and suspended materials in a liquid
  - Whole blood viscosity is about four times that of water

21-2 Pressure and Resistance

- **Turbulence**
  - Swirling action that disturbs smooth flow of liquid
  - Occurs in heart chambers and great vessels
  - Atherosclerotic plaques cause abnormal turbulence

21-2 Pressure and Resistance

- An Overview of Cardiovascular Pressures
  - *Vessel diameters*
  - *Total cross-sectional areas*
  - *Pressures*
  - *Velocity of blood flow*

21-2 Pressure and Resistance

- Arterial Blood Pressure
  - **Systolic pressure**
    - Peak arterial pressure during ventricular systole
  - **Diastolic pressure**
    - Minimum arterial pressure during diastole

21-2 Pressure and Resistance

- Arterial Blood Pressure
  - **Pulse pressure**
    - Difference between systolic pressure and diastolic pressure
  - **Mean arterial pressure** (**MAP**)
    - MAP = diastolic pressure + 1/3 pulse pressure

21-2 Pressure and Resistance

- Abnormal Blood Pressure
- Normal = 120/80
  - **Hypertension**
    - Abnormally high blood pressure
      - Greater than 140/90
  - **Hypotension**
    - Abnormally low blood pressure

21-2 Pressure and Resistance

- **Elastic Rebound**
  - Arterial walls
    - Stretch during systole
    - Rebound (recoil to original shape) during diastole
    - Keep blood moving during diastole

21-2 Pressure and Resistance

- Pressures in Small Arteries and Arterioles
  - Pressure and distance
    - MAP and pulse pressure decrease with distance from heart
    - Blood pressure decreases with friction
    - Pulse pressure decreases due to elastic rebound

21-2 Pressure and Resistance

- Venous Pressure and Venous Return
  - Determines the amount of blood arriving at right atrium each minute
  - Low effective pressure in venous system

21-2 Pressure and Resistance

- Venous Pressure and Venous Return
  - Low venous resistance is assisted by:
    - Muscular compression of peripheral veins
      - Compression of skeletal muscles pushes blood toward heart (one-way valves)
    - The **respiratory pump**
      - Thoracic cavity action
      - Inhaling decreases thoracic pressure
      - Exhaling raises thoracic pressure

21-2 Pressure and Resistance

- Capillary Pressures and Capillary Exchange
  - Vital to homeostasis
  - Moves materials across capillary walls by:
    - *Diffusion*
    - *Filtration*
    - *Reabsorption*

21-2 Pressure and Resistance

- Diffusion
  - Movement of ions or molecules
    - From high concentration
    - To lower concentration

- Along the *concentration gradient*

21-2 Pressure and Resistance

- Diffusion Routes
  1. Water, ions, and small molecules such as glucose
     - Diffuse between adjacent endothelial cells
     - Or through fenestrated capillaries
  2. Some ions (Na^+, K^+, Ca^{2+}, Cl^-)
     - Diffuse through channels in plasma membranes

21-2 Pressure and Resistance

- Diffusion Routes
  - Large, water-soluble compounds
    - Pass through fenestrated capillaries
  - Lipids and lipid-soluble materials such as O_2 and CO_2
    - Diffuse through endothelial plasma membranes
  - Plasma proteins
    - Cross endothelial lining in sinusoids

21-2 Pressure and Resistance

- Filtration
  - Driven by hydrostatic pressure
  - Water and small solutes forced through capillary wall
  - Leaves larger solutes in bloodstream

21-2 Pressure and Resistance

- Reabsorption
  - The result of **osmotic pressure** (**OP**)
  - *Blood colloid osmotic pressure* (*BCOP*)
    - Equals pressure required to prevent osmosis
    - Caused by suspended blood proteins that are too large to cross capillary walls

21-2 Pressure and Resistance

- Interplay between Filtration and Reabsorption
  1. Ensures that plasma and interstitial fluid are in constant communication and mutual exchange
  2. Accelerates distribution of:
     - Nutrients, hormones, and dissolved gases throughout tissues

21-2 Pressure and Resistance

- Interplay between Filtration and Reabsorption
  3. Assists in the transport of:
     - Insoluble lipids and tissue proteins that cannot enter bloodstream by crossing capillary walls
  4. Has a flushing action that carries bacterial toxins and other chemical stimuli to:
     - Lymphatic tissues and organs responsible for providing immunity to disease

21-2 Pressure and Resistance

- Interplay between Filtration and Reabsorption
  - Net hydrostatic pressure
    - Forces water *out* of solution
  - Net osmotic pressure
    - Forces water *into* solution
  - Both control filtration and reabsorption through capillaries

21-2 Pressure and Resistance

- Factors that Contribute to Net Hydrostatic Pressure
  1. *Capillary hydrostatic pressure* (*CHP*)
  2. *Interstitial fluid hydrostatic pressure* (*IHP*)
  - Net capillary hydrostatic pressure tends to push water and solutes:
    - Out of capillaries
    - Into interstitial fluid

21-2 Pressure and Resistance

- *Net Capillary Colloid Osmotic Pressure*
  - Is the difference between:
    1. *Blood colloid osmotic pressure* (*BCOP*) and
    2. *Interstitial fluid colloid osmotic pressure* (*ICOP*)
  - Pulls water and solutes:
    - Into a capillary
    - From interstitial fluid

21-2 Pressure and Resistance

- **Net Filtration Pressure** (**NFP**)
  - The difference between:
    - Net hydrostatic pressure
    - Net osmotic pressure

NFP = (CHP – IHP) – (BCOP – ICOP)

21-2 Pressure and Resistance

- Capillary Exchange
  - At arterial end of capillary:
    - Fluid moves *out* of capillary
    - *Into* interstitial fluid
  - At venous end of capillary:
    - Fluid moves *into* capillary
    - *Out* of interstitial fluid

21-2 Pressure and Resistance

- Capillary Exchange
  - Transition point between filtration and reabsorption
    - Is closer to venous end than arterial end
  - Capillaries filter more than they reabsorb
    - Excess fluid enters lymphatic vessels

21-2 Pressure and Resistance

- Capillary Dynamics
  - Hemorrhaging
    - Reduces CHP and NFP
    - Increases reabsorption of interstitial fluid (*recall of fluids*)
  - Dehydration
    - Increases BCOP
    - Accelerates reabsorption
  - Increase in CHP or BCOP declines
    - Fluid moves out of blood
    - Builds up in peripheral tissues (*edema*)

21-3 Cardiovascular Regulation

- **Tissue Perfusion**
  - Blood flow through the tissues
  - Carries O_2 and nutrients to tissues and organs
  - Carries CO_2 and wastes away
  - Is affected by:
    - Cardiac output
    - Peripheral resistance
    - Blood pressure

21-3 Cardiovascular Regulation

- Cardiovascular Regulation Changes Blood Flow to a Specific Area
  1. At an appropriate time
  2. In the right area
  3. Without changing blood pressure and blood flow to vital organs

21-3 Cardiovascular Regulation

- Controlling Cardiac Output and Blood Pressure
  - *Autoregulation*
    - Causes immediate, localized homeostatic adjustments
  - *Neural mechanisms*
    - Respond quickly to changes at specific sites
  - *Endocrine mechanisms*
    - Direct long-term changes

21-3 Cardiovascular Regulation

- Autoregulation of Blood Flow within Tissues
  - Adjusted by peripheral resistance while cardiac output stays the same
    - **Local vasodilators** accelerate blood flow at tissue level
      - Low O_2 or high CO_2 levels
      - Low pH (acids)
      - Nitric oxide (NO)
      - High K^+ or H^+ concentrations
      - Chemicals released by inflammation (histamine)
      - Elevated local temperature

21-3 Cardiovascular Regulation

- Autoregulation of Blood Flow within Tissues
  - Adjusted by peripheral resistance while cardiac output stays the same
    - **Local vasoconstrictors**
      - Examples: prostaglandins and thromboxanes
      - Released by damaged tissues
      - Constrict precapillary sphincters
      - Affect a single capillary bed

21-3 Cardiovascular Regulation

- Neural Mechanisms
  - **Cardiovascular** (**CV**) **centers** of the medulla oblongata
    - Cardiac centers
      - *Cardioacceleratory center* increases cardiac output
      - *Cardioinhibitory center* reduces cardiac output

21-3 Cardiovascular Regulation

- Vasomotor Center
  - *Control of vasoconstriction*
    - Controlled by *adrenergic* nerves (NE)
    - Stimulates smooth muscle contraction in arteriole walls
  - *Control of vasodilation*

        - Controlled by *cholinergic* nerves (NO)
        - Relaxes smooth muscle
- **Vasomotor Tone**
    - Produced by constant action of sympathetic vasoconstrictor nerves

21-3 Cardiovascular Regulation

- Reflex Control of Cardiovascular Function
    - Cardiovascular centers monitor arterial blood
        - **Baroreceptor reflexes**
            - Respond to changes in blood pressure
        - **Chemoreceptor reflexes**
            - Respond to changes in chemical composition, particularly pH and dissolved gases

21-3 Cardiovascular Regulation

- Baroreceptor Reflexes
    - Stretch receptors in walls of:
        1. **Carotid sinuses** (maintain blood flow to brain)
        2. **Aortic sinuses** (monitor start of systemic circuit)
        3. Right atrium (monitors end of systemic circuit)

21-3 Cardiovascular Regulation

- Baroreceptor Reflexes
    - When blood pressure rises, CV centers:
        - Decrease cardiac output
        - Cause peripheral vasodilation
    - When blood pressure falls, CV centers:
        - Increase cardiac output
        - Cause peripheral vasoconstriction

21-3 Cardiovascular Regulation

- Chemoreceptor Reflexes
    - Peripheral chemoreceptors in **carotid bodies** and **aortic bodies** monitor blood
    - Central chemoreceptors below medulla oblongata
        - Monitor cerebrospinal fluid
        - Control respiratory function
        - Control blood flow to brain

21-3 Cardiovascular Regulation

- Chemoreceptor Reflexes
    - Changes in pH, O_2, and CO_2 concentrations

- Produced by coordinating cardiovascular and respiratory activities

21-3 Cardiovascular Regulation

- CNS Activities and the Cardiovascular Centers
  - Thought processes and emotional states can elevate blood pressure by:
    - Cardiac stimulation and vasoconstriction

21-3 Cardiovascular Regulation

- Hormones and Cardiovascular Regulation
  - Hormones have short-term and long-term effects on cardiovascular regulation
  - For example, E and NE from adrenal medullae stimulate cardiac output and peripheral vasoconstriction

21-3 Cardiovascular Regulation

- *Antidiuretic Hormone* (*ADH*)
  - Released by neurohypophysis (posterior lobe of pituitary)
  - Elevates blood pressure
  - Reduces water loss at kidneys
  - ADH responds to:
    - Low blood volume
    - High plasma osmotic concentration
    - Circulating angiotensin II

21-3 Cardiovascular Regulation

- *Angiotensin II*
  - Responds to fall in renal blood pressure
  - Stimulates:
    - Aldosterone production
    - ADH production
    - Thirst
    - Cardiac output and peripheral vasoconstriction

21-3 Cardiovascular Regulation

- *Erythropoietin* (*EPO*)
  - Released at kidneys
  - Responds to low blood pressure, low O_2 content in blood
  - Stimulates red blood cell production

21-3 Cardiovascular Regulation

- Natriuretic Peptides

- *Atrial natriuretic peptide* (*ANP*)
  - Produced by cells in right atrium
- *Brain natriuretic peptide* (*BNP*)
  - Produced by ventricular muscle cells
- Respond to excessive diastolic stretching
- Lower blood volume and blood pressure
- Reduce stress on heart

21-4 Cardiovascular Adaptation

- Blood, Heart, and Cardiovascular System
  - Work together as unit
  - Respond to physical and physiological changes (for example, exercise and blood loss)
  - Maintain homeostasis

21-4 Cardiovascular Adaptation

- The Cardiovascular Response to Exercise
  - Light Exercise
    - Extensive vasodilation occurs, increasing circulation
    - Venous return increases with muscle contractions
    - Cardiac output rises
      - Venous return (Frank–Starling principle)
      - Atrial stretching

21-4 Cardiovascular Adaptation

- The Cardiovascular Response to Exercise
  - Heavy Exercise
    - Activates sympathetic nervous system
    - Cardiac output increases to maximum
      - About four times resting level
    - Restricts blood flow to “nonessential” organs (e.g., digestive system)
    - Redirects blood flow to skeletal muscles, lungs, and heart
    - Blood supply to brain is unaffected

21-4 Cardiovascular Adaptation

- Exercise, Cardiovascular Fitness, and Health
  - Regular moderate exercise
    - Lowers total blood cholesterol levels
  - Intense exercise
    - Can cause severe physiological stress

21-4 Cardiovascular Adaptation

- The Cardiovascular Response to Hemorrhaging
  - Entire cardiovascular system adjusts to:
    - Maintain blood pressure
    - Restore blood volume

21-4 Cardiovascular Adaptation

- Short-Term Elevation of Blood Pressure
  - Carotid and aortic reflexes
    - Increase cardiac output (increasing heart rate)
    - Cause peripheral vasoconstriction
  - Sympathetic nervous system
    - Triggers hypothalamus
    - Further constricts arterioles
    - Venoconstriction improves venous return

21-4 Cardiovascular Adaptation

- Short-Term Elevation of Blood Pressure
  - Hormonal effects
    - Increase cardiac output
    - Increase peripheral vasoconstriction (E, NE, ADH, angiotensin II)

21-4 Cardiovascular Adaptation

- Shock
  - Short-term responses compensate after blood losses of up to 20 percent of total blood volume
  - Failure to restore blood pressure results in *shock*

21-4 Cardiovascular Adaptation

- Long-Term Restoration of Blood Volume
  - Recall of fluids from interstitial spaces
  - Aldosterone and ADH promote fluid retention and reabsorption
  - Thirst increases
  - Erythropoietin stimulates red blood cell production

21-4 Cardiovascular Adaptation

- Vascular Supply to Special Regions
  - Through organs with separate mechanisms to control blood flow
  - Three important examples
    1. Brain
    2. Heart
    3. Lungs

21-4 Cardiovascular Adaptation

- Blood Flow to the Brain
  - Is top priority
  - Brain has high oxygen demand
  - When peripheral vessels constrict, cerebral vessels dilate, normalizing blood flow

21-4 Cardiovascular Adaptation

- *Stroke*
  - Also called *cerebrovascular accident* (*CVA*)
  - Blockage or rupture in a cerebral artery
  - Stops blood flow

21-4 Cardiovascular Adaptation

- Blood Flow to the Heart
  - Through coronary arteries
  - Oxygen demand increases with activity
  - Lactic acid and low O_2 levels
    - Dilate coronary vessels
    - Increase coronary blood flow

21-4 Cardiovascular Adaptation

- Blood Flow to the Heart
  - Epinephrine
    - Dilates coronary vessels
    - Increases heart rate
    - Strengthens contractions

21-4 Cardiovascular Adaptation

- Heart Attack
  - A blockage of coronary blood flow
  - Can cause:
    - Angina (chest pain)
    - Tissue damage
    - Heart failure
    - Death

21-4 Cardiovascular Adaptation

- Blood Flow to the Lungs
  - Regulated by O_2 levels in *alveoli*
  - High O_2 content

        - Vessels *dilate*
    - Low O_2 content
        - Vessels *constrict*

21-5 Pulmonary and Systemic Patterns

- Three General Functional Patterns
    1. Peripheral *artery* and *vein* distribution is the same on right and left, except near the heart
    2. The same vessel may have different names in different locations
    3. Tissues and organs usually have multiple arteries and veins
        - Vessels may be interconnected with anastomoses

21-6 The Pulmonary Circuit

- Deoxygenated Blood Arrives at Heart from Systemic Circuit
    - Passes through right atrium and right ventricle
    - Enters pulmonary trunk
    - At the lungs
        - CO_2 is removed
        - O_2 is added
    - Oxygenated blood
        - Returns to the heart
        - Is distributed to systemic circuit

21-6 The Pulmonary Circuit

- Pulmonary Vessels
    - Pulmonary arteries
        - Carry deoxygenated blood
        - Pulmonary trunk
            - Branches to **left** and **right pulmonary arteries**
        - Pulmonary arteries
            - Branch into *pulmonary arterioles*
        - Pulmonary arterioles
            - Branch into capillary networks that surround *alveoli*

21-6 The Pulmonary Circuit

- Pulmonary Vessels
    - **Pulmonary veins**
        - Carry oxygenated blood
        - Capillary networks around alveoli
            - Join to form venules
        - Venules
            - Join to form four pulmonary veins
        - Pulmonary veins

- Empty into left atrium

21-7 The Systemic Circuit

- The Systemic Circuit
  - Contains 84 percent of blood volume
  - Supplies entire body
    - Except for pulmonary circuit

21-7 The Systemic Circuit

- Systemic Arteries
  - Blood moves from left ventricle
    - Into ascending aorta
  - Coronary arteries
    - Branch from aortic sinus

21-7 The Systemic Circuit

- The Aorta
  - The **ascending aorta**
    - Rises from the left ventricle
    - Curves to form **aortic arch**
    - Turns downward to become *descending aorta*

Figure 21-20 Arteries of the Chest and Upper Limb.

21-7 The Systemic Circuit

- Branches of the Aortic Arch
  - Deliver blood to head, neck, shoulders, and upper limbs
    1. **Brachiocephalic trunk**
    2. **Left common carotid artery**
    3. **Left subclavian artery**

21-7 The Systemic Circuit

- The Subclavian Arteries
  - Leaving the thoracic cavity:
    - Become **axillary artery** in arm
    - And **brachial artery** distally

21-7 The Systemic Circuit

- The Brachial Artery
  - Divides at coronoid fossa of humerus

        - Into **radial artery** and **ulnar artery**
            - Fuse at wrist to form:
                - **Superficial** and **deep palmar arches**
                - Which supply **digital arteries**

21-7 The Systemic Circuit

- The Common Carotid Arteries
    - Each common carotid divides into:
        - **External carotid artery** – supplies blood to structures of the neck, lower jaw, and face
        - **Internal carotid artery** – enters skull and delivers blood to brain
            - Divides into three branches
                1. **Ophthalmic artery**
                2. **Anterior cerebral artery**
                3. **Middle cerebral artery**

21-7 The Systemic Circuit

- The Vertebral Arteries
    - Also supply brain with blood
    - Left and right vertebral arteries
        - Arise from subclavian arteries
        - Enter cranium through foramen magnum
        - Fuse to form **basilar artery**
            - Branches to form **posterior cerebral arteries**
            - Posterior cerebral arteries
                - Become **posterior communicating arteries**

21-7 The Systemic Circuit

- Anastomoses
    - The **cerebral arterial circle** (or *circle of Willis*) interconnects:
        - The internal carotid arteries
        - And the basilar artery

21-7 The Systemic Circuit

- The **Descending Aorta**
    - **Thoracic aorta**
        - Supplies organs of the chest
            - Bronchial arteries
            - Pericardial arteries
            - Esophageal arteries
            - Mediastinal arteries
        - Supplies chest wall

    - Intercostal arteries
    - Superior phrenic arteries

21-7 The Systemic Circuit

- The Descending Aorta
    - **Abdominal Aorta**
        - Divides at terminal segment of the aorta into:
            - *Left common iliac artery*
            - *Right common iliac artery*
        - Unpaired branches
            - Major branches to visceral organs
        - Paired branches
            - To body wall
            - Kidneys
            - Urinary bladder
            - Structures outside abdominopelvic cavity

21-7 The Systemic Circuit

- Arteries of the Pelvis and Lower Limbs
    - Femoral artery
        - **Deep femoral artery**
    - Becomes popliteal artery
        - Posterior to knee
        - Branches to form:
            - **Posterior** and **anterior tibial arteries**
            - Posterior gives rise to **fibular artery**

21-7 The Systemic Circuit

- Systemic Veins
    - Complementary Arteries and Veins
        - Run side by side
        - Branching patterns of peripheral veins are more variable
    - In neck and limbs
        - One set of arteries (deep)
        - Two sets of veins (one deep, one superficial)
    - Venous system controls body temperature

21-7 The Systemic Circuit

- The **Superior Vena Cava** (**SVC**)
    - Receives blood from the tissues and organs of:
        - Head
        - Neck
        - Chest

        - Shoulders
        - Upper limbs

21-7 The Systemic Circuit

- The Dural Sinuses
    - Superficial cerebral veins and small veins of the brain stem
        - Empty into network of dural sinuses
            - **Superior** and **inferior sagittal sinuses**
            - *Petrosal sinuses*
            - *Occipital sinus*
            - *Left and right transverse sinuses*
            - **Straight sinus**

21-7 The Systemic Circuit

- Cerebral Veins
    - **Great cerebral vein**
        - Drains to **straight sinus**
    - Other cerebral veins
        - Drain to **cavernous sinus**
        - Which drains to petrosal sinus
- Vertebral Veins
    - Empty into *brachiocephalic veins* of chest

21-7 The Systemic Circuit

- Superficial Veins of the Head and Neck
    - Converge to form:
        - **Temporal**, **facial**, and **maxillary veins**
            - Temporal and maxillary veins
                - Drain to **external jugular vein**
            - Facial vein
                - Drains to **internal jugular vein**

21-7 The Systemic Circuit

- Veins of the Hand
    - **Digital veins**
        - Empty into **superficial** and **deep palmar veins**
        - Which interconnect to form **palmar venous arches**

21-7 The Systemic Circuit

- Veins of the Hand
    - Superficial arch empties into:

        - **Cephalic vein**
        - **Median antebrachial vein**
        - **Basilic vein**
        - **Median cubital vein**
    - Deep palmar veins drain into:
        - **Radial** and **ulnar** veins
        - Which fuse above elbow to form **brachial vein**

21-7 The Systemic Circuit

- The Brachial Vein
    - Merges with basilic vein
    - To become **axillary vein**
        - Cephalic vein joins axillary vein
            - To form **subclavian vein**
            - Merges with external and internal jugular veins
                - To form **brachiocephalic vein**
                - Which enters thoracic cavity

21-7 The Systemic Circuit

- Veins of the Thoracic Cavity
    - **Brachiocephalic vein** receives blood from:
        - **Vertebral vein**
        - **Internal thoracic vein**
- The Left and Right Brachiocephalic Veins
    - Merge to form the superior vena cava (SVC)

21-7 The Systemic Circuit

- Tributaries of the Superior Vena Cava
    - **Azygos** vein and **hemiazygos vein**, which receive blood from:
        - **Intercostal veins**
        - **Esophageal veins**
        - Veins of other mediastinal structures

21-7 The Systemic Circuit

- The **Inferior Vena Cava** (**IVC**)
    - Collects blood from organs inferior to the diaphragm

21-7 The Systemic Circuit

- Veins of the Foot
    - Capillaries of the sole
        - Drain into a network of **plantar veins**

        - Which supply the **plantar venous arch**
        - Drain into deep veins of leg:
            - **Anterior tibial vein**
            - **Posterior tibial vein**
            - **Fibular vein**
                - All three join to become **popliteal vein**

21-7 The Systemic Circuit

- The Dorsal Venous Arch
    - Collects blood from:
        - Superior surface of foot
        - **Digital veins**
    - Drains into two superficial veins
        1. **Great saphenous vein** (drains into femoral vein)
        2. **Small saphenous vein** (drains into popliteal vein)

21-7 The Systemic Circuit

- The Popliteal Vein
    - Becomes the **femoral vein**
        - Before entering abdominal wall, receives blood from:
            - **Great saphenous vein**
            - **Deep femoral vein**
            - **Femoral circumflex vein**
        - Inside the pelvic cavity
            - Becomes the **external iliac vein**

21-7 The Systemic Circuit

- The External Iliac Veins
    - Are joined by **internal iliac veins**
        - To form right and left **common iliac veins**
            - The right and left common iliac veins
                - Merge to form the inferior vena cava

21-7 The Systemic Circuit

- Major Tributaries of the Abdominal Inferior Vena Cava
    1. **Lumbar veins**
    2. **Gonadal veins**
    3. **Hepatic veins**
    4. **Renal veins**
    5. **Adrenal veins**
    6. **Phrenic veins**

21-7 The Systemic Circuit

- The **Hepatic Portal System**
  - Connects two capillary beds
  - Delivers nutrient-laden blood
    - From capillaries of digestive organs
    - To liver sinusoids for processing

21-7 The Systemic Circuit

- Tributaries of the **Hepatic Portal Vein**
  1. **Inferior mesenteric vein**
     - Drains part of large intestine
  2. **Splenic vein**
     - Drains spleen, part of stomach, and pancreas
  3. **Superior mesenteric vein**
     - Drains part of stomach, small intestine, and part of large intestine
  4. Left and right **gastric veins**
     - Drain part of stomach
  5. **Cystic vein**
     - Drains gallbladder

21-7 The Systemic Circuit

- Blood Processed in Liver
  - After processing in liver sinusoids (exchange vessels):
    - Blood collects in hepatic veins and empties into inferior vena cava

21-8 Fetal and Maternal Circulation

- Fetal and Maternal Cardiovascular Systems Promote the Exchange of Materials
  - Embryonic lungs and digestive tract nonfunctional
  - Respiratory functions and nutrition provided by placenta

21-8 Fetal and Maternal Circulation

- Placental Blood Supply
  - Blood flows to the placenta
    - Through a pair of **umbilical arteries** that arise from internal iliac arteries
    - Enters umbilical cord
  - Blood returns from placenta
    - In a single **umbilical vein** that drains into **ductus venosus**
  - Ductus venosus
    - Empties into inferior vena cava

21-8 Fetal and Maternal Circulation

- Before Birth
  - Fetal lungs are collapsed
  - O_2 provided by placental circulation

21-8 Fetal and Maternal Circulation

- Fetal Pulmonary Circulation Bypasses
  - **Foramen ovale**
    - *Interatrial opening*
    - Covered by valve-like flap
    - Directs blood from right to left atrium
  - **Ductus arteriosus**
    - Short vessel
    - Connects pulmonary and aortic trunks

21-8 Fetal and Maternal Circulation

- Cardiovascular Changes at Birth
  - Newborn breathes air
  - Lungs expand
    - Pulmonary vessels expand
    - Reduced resistance allows blood flow
    - Rising O_2 causes ductus arteriosus constriction
    - Rising left atrium pressure closes foramen ovale
  - Pulmonary circulation provides O_2

21-8 Fetal and Maternal Circulation

- Patent Foramen Ovale and Patent Ductus Arteriosus
  - In patent (open) foramen ovale blood recirculates through pulmonary circuit instead of entering left ventricle
    - The movement, driven by relatively high systemic pressure, is a “left-to-right shunt”
    - Arterial oxygen content is normal, but left ventricle must work much harder than usual to provide adequate blood flow through systemic circuit

21-8 Fetal and Maternal Circulation

- Patent Foramen Ovale and Patent Ductus Arteriosus
  - Pressures rise in the pulmonary circuit
    - If pulmonary pressures rise enough, they may force blood into systemic circuit through ductus arteriosus
    - A patent ductus arteriosus creates a “right-to-left shunt”
    - Because circulating blood is not adequately oxygenated, it develops

deep red color
    - Skin develops blue tones typical of cyanosis and infant is known as a “blue baby”

21-8 Fetal and Maternal Circulation

- Tetralogy of Fallot
    - Complex group of heart and circulatory defects that affect 0.10 percent of newborn infants
        1. Pulmonary trunk is abnormally narrow (pulmonary stenosis)
        2. Interventricular septum is incomplete
        3. Aorta originates where interventricular septum normally ends
        4. Right ventricle is enlarged and both ventricles thicken in response to increased workload

21-8 Fetal and Maternal Circulation

- Ventricular Septal Defect
    - Openings in interventricular septum that separate right and left ventricles
    - The most common congenital heart problems, affecting 0.12 percent of newborns
    - Opening between the two ventricles has an effect similar to a connection between the atria
        - When more powerful left ventricle beats, it ejects blood into right ventricle and pulmonary circuit

21-8 Fetal and Maternal Circulation

- Atrioventricular Septal Defect
    - Both the atria and ventricles are incompletely separated
        - Results are quite variable, depending on extent of defect and effects on atrioventricular valves
        - This type of defect most commonly affects infants with Down’s syndrome, a disorder caused by the presence of an extra copy of chromosome 21

21-8 Fetal and Maternal Circulation

- Transposition of Great Vessels
    - The aorta is connected to right ventricle instead of to left ventricle
    - The pulmonary artery is connected to left ventricle instead of right ventricle
    - This malformation affects 0.05 percent of newborn infants

21-9 Effects of Aging and the Cardiovascular System

- Cardiovascular Capabilities Decline with Age
- Age-related changes occur in:

- Blood
- Heart
- Blood vessels

21-9 Effects of Aging and the Cardiovascular System

- Three **Age-Related Changes in Blood**
  1. Decreased hematocrit
  2. Peripheral blockage by blood clot (*thrombus*)
  3. Pooling of blood in legs
     - Due to venous valve deterioration

21-9 Effects of Aging and the Cardiovascular System

- Five **Age-Related Changes in the Heart**
  1. Reduced maximum cardiac output
  2. Changes in nodal and conducting cells
  3. Reduced elasticity of cardiac (fibrous) skeleton
  4. Progressive atherosclerosis
  5. Replacement of damaged cardiac muscle cells by scar tissue

21-9 Effects of Aging and the Cardiovascular System

- Three Age-Related Changes in Blood Vessels
  1. Arteries become less elastic
     - Pressure change can cause aneurysm
  2. Calcium deposits on vessel walls
     - Can cause stroke or infarction
  3. Thrombi can form
     - At atherosclerotic plaques

21-9 Cardiovascular System Integration

- Many Categories of Cardiovascular Disorders
  - Disorders may:
    - Affect all cells and systems
    - Be structural or functional
    - Result from disease or trauma