Cardiovascular System

Blood Vessel anatomy
Physiology & regulation
Path of blood flow

- Aorta
- Arteries
- Arterioles
- Capillaries
- Venules
- Veins
- Vena cava
Vessel anatomy: 3 layers

• **Tunica externa** (*adventitia*): outer layer; dense to loose connective tissue
  – lotsa collagen, bits of elastin, few smooth muscles (veins)

• **Tunica media**: middle layer; concentric rings of smooth muscle within CT framework (thickest layer)
  – **External elastic membrane** in arteries

• **Tunica intima**: inner layer; simple, squamous epithelium (endothelial lining), basement membrane, some elastic fibers
  – **Internal elastic membrane** in arteries
Artery vs. Vein

<table>
<thead>
<tr>
<th>Feature</th>
<th>Typical Artery</th>
<th>Typical Vein</th>
</tr>
</thead>
<tbody>
<tr>
<td>GENERAL APPEARANCE IN SECTIONAL VIEW</td>
<td>Usually round, with relatively thick wall</td>
<td>Usually flattened or collapsed, with relatively thin wall</td>
</tr>
<tr>
<td>TUNICA INTIMA</td>
<td>Usually rippled, due to vessel constriction</td>
<td>Often smooth</td>
</tr>
<tr>
<td>Endothelium</td>
<td>Present</td>
<td>Absent</td>
</tr>
<tr>
<td>Internal elastic membrane</td>
<td>Thick, dominated by smooth muscle cells and elastic fibers</td>
<td>Thin, dominated by smooth muscle cells and collagen fibers</td>
</tr>
<tr>
<td>TUNICA MEDIA</td>
<td>Present</td>
<td>Absent</td>
</tr>
<tr>
<td>External elastic membrane</td>
<td>Collagen and elastic fibers</td>
<td>Collagen and elastic fibers and smooth muscle cells</td>
</tr>
<tr>
<td>TUNICA EXTERNA</td>
<td></td>
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</tbody>
</table>
## Arteries vs. Veins

### Arteries

- **Contractile** (thick, muscular walls) & **elastic**
  - Passive changes in diameter
    - In response to changes in BP
  - Active changes in diameter
    - Vasoconstrict
    - Vasodilate
- **BP maintains unidirectional blood flow**

### Veins

- **Little muscle & little elastic**
  - Passive blood collectors
  - Little diameter change
- **Larger lumen than corresponding arteries**
- **Valves** maintain unidirectional blood flow
Elastic arteries

- Large diameter, *conducing arteries*.
  - Take blood *away* from heart.
  - Ex: Aorta, pulmonary trunk, common carotid, subclavian, & common iliac arteries

- Tunica media has many elastic fibers, few smooth muscle cells
Muscular arteries

- Medium-sized, *distribution arteries*
  - Modify distribution of blood to skeletal muscles & internal organs
  - Ex: external carotid, brachial, mesenteric, femoral
- Muscular (smooth) tunica media, few elastic fibers
Arterioles

- Small arteries, *resistance vessels*
- 1 or 2 layers of smooth muscle; usually incomplete
  - Change diameter in response to *sympathetic* & *hormonal* stimulation (induced by changes in O$_2$, CO$_2$, glucagon concentrations).
    - Alter resistance to blood flow and change BP
Capillaries: exchange vessels

- Simple, squamous epithelial cells + CT layer
- Allows *exchange* between blood & interstitial fluid
- Blood flow regulated by precapillary sphincters
Continuous capillaries

- Widespread
- Limited permeability
  - Permit diffusion of small solutes & lipid soluble material
Fenestrated capillaries

- Limited to areas of absorption or secretion
- **Very permeable**
  - Permit *rapid* diffusion of $\text{H}_2\text{O}$ & large solutes
- Surrounding glands, intestinal tract, filtration areas
  - Hypothalamus, pituitary, thymus, kidneys
Venous return

- **skeletal muscle** contractions provide driving force that moves blood.
- Valves ensure unidirectional flow towards the heart
Pressure and Resistance

• $F \propto \Delta P/R$
  – Increased Pressure = increased Flow
  – Increased Resistance = decreased Flow

• Cardiovascular Pressure
  – Blood Pressure (BP); arterial
    • $\Delta P = 65\text{mm Hg}$
  – Capillary hydrostatic pressure (CHP)
    • $\Delta P = 17\text{mm Hg}$
  – Venous pressure; $\Delta P = 18\text{mm Hg}$

• From arterioles to capillaries, BP and $\Delta P$ drop quickly
Effects of diameter & friction

- \( F \propto \Delta P/R \)
  - Increased Resistance = decreased Flow

- Vascular Resistance: Forces that oppose blood flow
  - Viscosity; \( R \) due to interaction of suspended molecules & solutes
  - Turbulence; \( R \) due to irregular surfaces, high flow rates, changes in diameter.
  - Friction as mediated by Total cross-sectional Area; \( R \propto 1/r^4 \)
    - From one large artery to thousands of small capillaries
Capillary exchange

• About 10 billion capillaries in the body

• Blood pressure
  – Forces fluid (and some dissolved solutes) into interstitial space

• Osmosis
  – Fluid (lacking dissolved blood proteins) moves back into capillaries along solute concentration gradient
Fluid exchange in capillaries

- **Blood pressure** forces fluid, small solutes & gases *out* of capillaries.
- **Osmotic pressure** (large solutes) draw fluid back *into* capillaries.
Capillary bed function

- Alters blood flow and BP via **sphincter muscles** (smooth)
- Contract or dilate based on signals that indicate deficiencies in nutrients, increases in waste, or local damage
- Additional capillaries infiltrate areas to satisfy increased energy demands
Cardioregulatory mechanisms

- 3 mechanisms to maintain $O_2$ and nutrient delivery to, and waste removal from tissues.
  - *Autoregulation*: immediate, localized adjustments in blood flow in response to changes in chemical concentrations
  - *Neural*: Systemic response to changes in BP and gas concentration @ specific sites
  - *Hormonal/Endocrine*: enhance short term changes; direct long term changes
Autoregulation

• Local vasodilators dilate due to:
  – Low concentrations of **nutrients** (AA, glucose, fatty acids)
  – Dissolved **gases** (low $O_2$, high or $CO_2$)
  – Increased **wastes** & pH altering ions (lactic acid, $H^+$, $K^+$)
  – Increased **inflammatory molecules** (histamine, NO)
  – Elevated temp.

• Local vasoconstrictors contract due to:
  – Chemical signals of local damage or bleeding
Neural Regulation

- Controlled by vasomotor center (pons & MO)
- *Stimulation* of sympathetic nerves causes vasoconstriction of arterioles via release of NE
- *Inhibition* of sympathetic nerves causes vasodilation via release of NO
- Allows shunting of blood to/from major regions of body
Neural Regulation

• **Baroreceptor** reflex
  – Stretch receptors; autonomic control

• **Chemoreceptor** reflex
  – Stimulated by change in CO₂, O₂ or pH; autonomic control

• **Hormonal** control
  – Adrenal Medullary; Renin-Angiotensin-Aldosterone (RAA); Vasopressin; Atrial Natiuretic; autonomic control
Acronyms

- Heart rate (HR)
- Blood Pressure (BP)
- Stroke Volume (SV)
- Medulla oblongata (MO)
- Vasomotor Center (VaC)
- Cardiovascular Center (CaC)
- Vasomotor Tone (VaT)
Baroreceptor Reflex

- Carotid body & aortic arch baroreceptors
- Increase stretch = increased AP frequency to VaC & CaC
  - Decrease HR, SV, VaT
  - Decreases BP
- Decrease stretch = decreased AP freq. to MO
Chemoreceptor reflex

- **Carotid & aortic** body chemoreceptors
- O$_2$ decrease; OR CO$_2$ or pH increase
  - Increase AP frequency
  - CaC & VaC *decrease* parasympathetic stimulation & *increases* sympathetic stimulation of heart
  - Increase HR, SV, VaT
  - Increase BP and blood flow to lungs = MORE O$_2$
Hormonal

• Adrenal Medullary
  – Signals that increase *sympathetic* stimulation of heart & vessels, also stimulate adrenal medulla
  – Adrenal medulla releases **epinephrine**
  – Epinephrine **increases** HR, SV; causes **vasoconstriction of** blood vessels in skin & viscera; **vasodilation** of blood vessels in skeletal & cardiac muscle
Hormonal

- RAA
- BP drops
  1. kidney secretes **renin** which turns on **angiotensin**
  2. Angiotensin increase vasoconstriction; **BP rises**
  3. Angiotensin encourages adrenal medulla to produce **aldosterone**.
  4. Aldosterone increases Na\(^+\) and H\(_2\)O reclamation @ kidney; **BP rises**
Hormonal

• Vasopressin (ADH)
  – plasma solute concentration increases or BP decreases
  – ADH released from pituitary
  – ADH stimulates vasoconstriction & water reclamation at kidney; BP rises
Response to Exercise

• Extensive vasodilation
• Increased venous return
  – Skeletal muscle contractions
• CO increases
  – Starling law & atrial reflex