Cardiovascular System:

Physiology & Regulation
Blood flow

- Aorta
- Arteries
- Arterioles
- Capillaries
- Venules
- Veins
- Vena cava
Overview

• Branching from Aorta to capillaries; Convergence from capillaries to Vena Cava

• Blood Pressure & Velocity $\propto$ to Area (cross sectional)
  - Velocity slows as area increases.
  - Pressure drops as area increases.
Effects of area & distance

- $F \propto \Delta P/R$
  - 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; $\Delta P = 18\text{mm Hg}$**
Effects of diameter & distance

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

- Vascular Resistance
  - Vessel Length & Diameter
    - Longer vessel = more friction; Smaller diameter = more friction; more SA of vessel walls in contact with blood
  - Viscosity; \( R \) caused by interaction of suspended molecules & solutes (stuff sticking together)
  - Turbulence; irregular surfaces, high flow rates, changes in diameter.
BP changes with distance

- From arterioles to capillaries:
  - BP drops quickly
  - $\Delta P$ drops quickly
- Systolic & Diastolic
  - 120/80
- Pulse = difference
- MAP = mean
- Hypertension (140/90) leads to gradual enlargement of ventricle to compensate
Mechanisms of Capillary Exchange

1. Diffusion - *Concentration gradient*
   - Occurs rapidly with: short distances; steep gradients; small particles
   - Avenues of exchange: between endothelial cells & through fenestra; protein channels; cell membranes; major sinuses

2. Filtration - *Hydrostatic pressure*
   - Water and small solutes forced across capillary wall, leaving large solutes & proteins in blood
Capillary Exchange

• About 10 billion capillaries in the body
• Blood pressure (CHP)
  - Forces fluid (but few dissolved solutes) into interstitial space
• Osmotic pressure
  - Fluid (lacking dissolved blood proteins) moves back into capillaries along solute concentration gradient
CHP pushes $\text{H}_2\text{O}$ & solutes OUT

- Large solutes stay in
- Small solutes pass between cells & through pores
Hydrostatic vs. Blood Pressure
Capillary exchange

1. Net movement of fluid out of the capillary into the interstitial space
   - Outward movement of fluid due to blood pressure

2. Inward movement of fluid due to osmosis

3. 1/10 volume to lymphatic capillaries
   - 9/10 volume returns to capillary

Blood flow
- Arterial end
- Venous end

Net movement of fluid into the capillary from the interstitial space
Acronyms

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

• Autoregulation
  - Local vasodilators and vasoconstrictors

• Neural mechanisms
  - Cardiovascular centers
  - Baroreceptors & chemoreceptors measure arterial pressure & dissolved gases

• Endocrine mechanisms
  - Hormones produce both short & long-term changes
Autoregulation: Local control

- **Sphincters** contract or dilate based on concentrations of:
  - **Nutrients** (AA, glucose, fatty acids)
  - **Dissolved gases** ($O_2$, $CO_2$ load, NO)
  - **Wastes** & pH altering ions (lactic acid, $H^+$, $K^+$)
  - **Inflammatory molecules** (histamine, NO)

- **Additional capillaries** infiltrate areas to satisfy increased energy demands.
Neural: Vasomotor

- **Controlled by neurons in Cardiovascular center (brainstem)**
  - **Vasoconstrictors**
    - Release NE; most peripheral blood vessels
    - Constitutively active = Vasomotor tone
  - **Vasodilators**
    - Release ACh; vessels servicing skeletal muscle & brain
- **Allows shunting of blood to/from major regions of body**
Neural: Baroreceptor Reflex

- Carotid sinus & aortic arch baroreceptors
- Increase stretch = increased AP frequency to CaC in MO
  - Stimulates parasymptathetic neurons
  - Inhibits sympathetic neurons
  - Collectively decreases CO & VaT
Summary
Chemoreceptor Reflex

- **Carotid & aortic bodies** have receptors
  - Communicate with MO
- **O₂ or pH drops, or CO₂ increases**
  - Increase AP frequency
  - **CaC & VaC decrease** parasympathetic stimulation & increases sympathetic stimulation of heart
  - Increase CO, VaT
  - Increase BP and blood flow to lungs = MORE O₂
Hormonal

• Adrenal Medullary
  - Mechanisms 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 pathway
- **Stimulus:** BP drops
  1. kidney secretes **Renin** which turns on **Angiotensin**
  2. Angiotensin increase vasoconstriction; **BP rises**
  3. Encourages adrenal medulla to produce **aldosterone**
     - Aldosterone increases Na⁺ and H₂O reclamation @ kidney; **BP rises**
  4. Stimulates secretion of **ADH**, stimulating H₂O reabsorption
  5. Stimulates “thirst” mechanism
Hormonal

- **Vasopressin (ADH) mechanism**
  - **Stimulus**: plasma solute concentration increases or BP decreases
  - **ADH** released from pituitary
  - **ADH** stimulates vasoconstriction & water reclamation at kidney; **BP rises**
• Pulmonary loop
  - Gas exchange
• Systemic loop
  - Nutrient delivery & waste removal