Blood Vessels

- **Anatomy of Blood Vessels – structure of Blood Vessel Walls**
  - **Tunica interna** –
    - Endothelium
    - Basement membrane
    - Internal elastic lamina
  - **Tunica media**
    - Circular smooth muscle
    - Elastic fibers
  - **Tunica externa**
    - Connective tissue
### Blood Vessels

- **Arterial System**

- Elastic or conducting arteries – found closest to the heart, must be able to withstand the high pressures of being close to the ventricles
Blood Vessels

− Medium sized, muscular or distributing arteries, can vary their diameter and alter the distribution of blood throughout the body

− Arterioles, very small arteries that deliver blood to capillaries – play a very important role in regulating blood flow from arteries into capillaries and in altering arterial blood pressure
Blood Vessels

- **Capillaries**
  - microscopic blood vessels through which material are exchanged between blood and tissues
  - Usually connect arterioles and venules
  - Comprised of a single layer of simple squamous epithelium (endothelium) and a basement membrane
  - Branch to form extensive networks
  - Flow of blood through a network is regulated by smooth muscle cells in blood vessels
  - Rings of smooth muscle cells, precapillary sphincters, regulate blood through true capillaries

<table>
<thead>
<tr>
<th>Vessel Type/ Illustration*</th>
<th>Average Lumen Diameter (D) and Wall Thickness (T)</th>
<th>Relative Tissue Makeup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capillary</td>
<td>(D : 9.0 \ \mu m) (T : 0.5 \ \mu m)</td>
<td>Endothelium, Fibrous (Collagenous) Tissues</td>
</tr>
<tr>
<td>Venule</td>
<td>(D : 20.0 \ \mu m) (T : 1.0 \ \mu m)</td>
<td>Elastic Tissues, Smooth Muscles</td>
</tr>
<tr>
<td>Vein</td>
<td>(D : 5.0 \ \text{mm}) (T : 0.5 \ \text{mm})</td>
<td>Fibrous (Collagenous) Tissues</td>
</tr>
</tbody>
</table>
Blood Vessels

- **Types of Capillaries**

(a) Pericyte
    - Red blood cell in lumen
    - Intercellular cleft
    - Endothelial cell
    - Basement membrane
    - Tight junction
    - Endothelial nucleus
    - Pinocytotic vesicles

(b) Pericyte
    - Pinocytotic vesicles
    - Red blood cell in lumen
    - Fenestrations (pores)
    - Intercellular cleft
    - Endothelial cell
    - Basement membrane
    - Tight junction

(c) Pericyte
    - Endothelial cell
    - Red blood cell in lumen
    - Large intercellular cleft
    - Tight junction
    - Incomplete basement membrane
    - Nucleus of endothelial cell
Blood Vessels

• Capillary Beds
Blood Vessels

- **Venous System**
  - Venules – small vessels that are formed from the union of several capillaries, merge to form veins
  - Veins – carry blood back towards the heart – same three layers as arteries with some modifications – possess valves
  - Venous Sinuses – flattened veins with thin walls (only endothelium)
Blood Vessels

• Vascular Anastomoses
  
  – Arterial Anastomoses – provide for multiple routes to supply blood to an organ, collateral channels
  
  – Metarteriole-thoroughfare Channel – shunts blood around capillary beds
  
  – Venous Anastomoses – more common than arterial (look at the back of your hand; implications for bypass surgery?)
Physiology of Circulation

- **Introduction to Blood Flow, Blood Pressure, and Resistance**
  - Blood Flow – volume of blood moving through a structure per unit time
  - Blood Pressure – force per unit area exerted on a vessel; expressed in mm of Hg
  - Resistance – opposition to blood flow; frequently referred to as peripheral resistance
  - Blood Viscosity – stickiness of a fluid
  - Total Blood Vessel Length
  - Blood Vessel Diameter – affects laminar flow

\[ r^4 \]

Assume the radius of a blood vessel doubles

\[ 1/2^4 = 1/16 \]
Physiology of Circulation

- Relationship Between Flow, Pressure and Resistance

\[ F = \frac{\Delta P}{R} \]
Physiology of Circulation

- **Systemic Blood Pressure**

![Diagram showing blood pressure changes through the circulatory system.](image)
Physiology of Circulation

- **Arterial Blood Pressure** – 120/80
  - Systolic = 120
  - Diastolic = 80

\[ \text{MAP} = \text{dP} + \frac{1}{3} \text{PP} \]

- **Capillary Blood Pressure**
  - Beginning of beds 40 mmHg at end 20 mmHg – low for good reasons
    - Capillaries delicate
    - Capillaries very permeable allowing for exchange
Physiology of Circulation

- Venous Blood Pressure
  - Relatively constant
  - Approximately 20 mmHg
  - Venous return
    - Muscular Pump
    - Respiratory Pump
Physiology of Circulation

• Maintaining Blood Pressure

\[ F = \Delta P/R \text{ or } CO = \Delta P/R \text{ or } \Delta P = CO \times R \]

– Major Factors Determining CO
Physiology of Circulation

- **Short-Term Mechanisms: Neural Controls** – provides for altering blood flow to organs as needed and maintaining adequate MAP – does so via reflexes regulated by baroreceptors and chemoreceptors

- **Baroreceptors**

- **Chemoreceptors** – sense $O_2$, $CO_2$ and pH – more when we discuss the respiratory system

- **Higher Brain Centers** – fight or flight (emotions)
Physiology of Circulation

- Short-Term Mechanisms: Chemical Controls
  
  - Adrenal Medulla Hormones
    
    - Norepinephrine
    - Epinephrine
  
  - Atrial Natriuretic Peptide (ANP) – antagonizes aldosterone, and causes vasodilation
  
  - ADH
  
  - Angiotensin II
    
    - Vasoconstrictor
    - Release of aldosterone (more in a bit)
  
  - Endothelium-Derived Factors
    
    - Endothelin – vasoconstrictor (stimulated by angiotensin II and ADH)
    
    - Nitric Oxide (NO) – vasodilator (stimulated by acetylcholine, bradykinin, nitroglycerine)
Physiology of Circulation

• Inflammatory Chemicals – potent vasodilators
  – Histamine
  – Kinins
  – Other chemicals released during allergic reactions

• Alcohol
  – Decreases BP
  – Inhibits ADH
  – Promotes vasodilation in the skin
Physiology of Circulation

- Long-Term Mechanisms: Renal Regulation

Key:
- Initial stimulus
- Physiological response
- Result

Decreased arterial pressure

Baroreceptors

Sympathetic stimulation promotes renin release
catalyzes cascade, resulting in formation of

Kidney

Renin release

Less filtrate formed, more filtrate retained

Angiotensin II

ADH release by posterior pituitary

Vasoconstriction (decreased diameter of blood vessels)

Aldosterone secretion by adrenal cortex

Increased sodium reabsorption by kidneys

Increased water reabsorption by kidneys

Increased blood volume

Increased arterial pressure
Physiology of Circulation

Renal activity

Conservation of Na⁺ and water

Increased blood volume

Increased venous return

Increased stroke volume

Increased heart rate

Increased cardiac output

Decreased blood volume, decreased blood pressure

Decreased release of ANP

Increased activity of muscular pump and respiratory pump

Reflex activation of vasomotor and cardiac acceleratory centers

Baroreceptors

Chemoreceptors

Blood pH and O₂ level decreased, blood CO₂ level increased

Hemorrhage, excessive sweating, inflammation

Crisis stressors (exercise, physical or emotional trauma, increased body temperature)

Increased body size, obesity

Increased blood vessel length

Dehydration, high hematocrit

Bloodborne chemicals (norepinephrine [NE], epinephrine, antidiuretic hormone [ADH], angiotensin II) generated by renin release by kidneys, endothelin (secreted by endothelial cells); reduced release of NO by endothelial cells

Decreased diameter of blood vessels

Increased blood viscosity

Increased peripheral resistance

Increased mean systemic arterial blood pressure

Key:
- Initial stimulus
- Physiological response
- Result
Physiology of Circulation

- Monitoring Circulatory Efficiency
  - Taking a Pulse
  - Measuring Blood Pressure

- Alterations in Blood Pressure
  - Hypotension
  - Hypertension
    - Primary, Essential, or Idiopathic – numerous risk factors
    - Secondary – excessive renin, atherosclerosis, hyperthyroidism
Physiology of Circulation

- **Blood Flow Through Body Tissues: Tissue Perfusion**
  - Transport to and from tissues
  - Gas exchange in lungs
  - Absorption of nutrients from GI tract
  - Production of urine
  - Distribution – varies depending upon activity
Physiology of Circulation

- Velocity of Blood Flow

Relative cross-sectional area of different vessels of the vascular bed

<table>
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<tr>
<th>Total area $^2$ (cm$^2$) of the vascular bed</th>
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<td>Velocity of blood flow (cm/s)</td>
</tr>
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Aorta | Arteries | Arterioles | Capillaries | Venules | Veins | Venae cavae
Physiology of Circulation

- Autoregulation - local automatic adjustment of blood flow to meet particular needs of a tissue
  
  • Metabolic Controls
    
    - NO along with O₂ from lungs
    
    - H⁺ and lactic acid
  
  • Myogenic Controls
    
    - Vascular smooth muscle, when stretched results in reflexive constriction
  
  • Long-Term Autoregulation – over long periods of time angiogenesis may occur
Physiology of Circulation

- **Blood Flow to Special Areas**
  - Skeletal Muscle – varies with activity
  - Brain – remains relatively constant
  - Skin – varies
  - Lungs
    - Pressure much lower in capillaries than at other areas of the body (24/8 vs 120/80)
    - Autoregulation opposite of other capillaries
Physiology of Circulation

- Blood Flow Through Capillaries and Capillary Dynamics
• Capillary Exchange

USE NORMAL PLUS THREE ABNORMAL EXAMPLES
Physiology of Circulation

- Circulatory Shock – too little blood in vessels to supply organs
  - Hypovolemic Shock
  - Vascular Shock
    - Anaphylaxis
    - Septicemia
  - Cardiogenic
Physiology of Circulation

Acute bleeding (or other events leading to blood volume loss)

leads to

1. Inadequate tissue perfusion → ↓O₂ and nutrients to cells
2. Cells begin to metabolize anaerobically (without O₂) → lactic acid accumulates
3. Water leaves tissue cells → moves into blood → cells dehydrate

Compensatory mechanisms activated

Chemoreceptors activated (by ↓ in blood pH)

major effect
Activation of respiratory centers
↑ Rate and depth of breathing
CO₂ blown off; blood pH rises

minor effect
Cardioacceleratory and vasomotor centers activated
↑ Heart rate

Baroreceptors firing reduced (by ↓ in blood volume and blood pressure)

Sympathetic nervous system activated
Intense vasoconstriction (only heart and brain spared)

Hypothalamus activated (by ↓pH and ↓ blood volume)

Thirst

Blood pressure maintained

Restlessness (early sign)

ADH released

Kidney

Coma (late sign)

Blood pressure restored

Renal blood flow

Renin released

Angiotensin II produced in the blood

Kidneys retain salt and water

↓ Urine output

Increased blood volume

Central nervous system depressed

Neurons depressed by ↓pH

If fluid volume continues to decrease, blood pressure ultimately drops. ↓ Blood pressure is a late sign.

Aldosterone released

Skin becomes cold, clammy, and cyanotic

Kidneys retain salt and water

↓ Urine output

Water retention

Kidney
Blood Vessels

- Signs and Symptoms of Shock

  - Systolic BP < 90
  - Resting tachycardia
  - Weak pulse
  - Cool, pale, clammy skin
  - Altered mental state, confused
  - Reduced urine formation
  - Thirsty
  - Acidosis (lactic acid build up)
  - Nausea (reduced blood flow to digestive tract)
Blood Vessels

- Using a flow diagram you should be able to trace a drop of blood from one region (organ) of the body to another. In so doing you should be able to name all of the blood vessels, chambers of the heart, heart valves and organs that drop of blood may pass through.