Blood & Cardiovascular System

Chapters 10 & 11

Mrs. Joseph
Composition of Blood

• PLASMA – 55%
  – Water (solvent)
  – Salts (electrolytes) – Na\(^+\), K\(^+\), Ca\(^{2+}\), Mg\(^{2+}\), Cl\(^-\), HCO\(_3\)\(^-\)
    $\Rightarrow$ osmotic balance, pH buffering, regulate membrane permeability
  – Plasma Proteins (Albumin, Fibrinogen, Globulins) – osmotic balance, pH buffering, clotting of blood, defense (antibodies) and lipid transport
  – Substances transported by blood – nutrients, waste products, respiratory gases, hormones
## Composition of Blood

- **Formed Elements (Cells) – 45%**

<table>
<thead>
<tr>
<th>CELL TYPE</th>
<th>NUMBER (per mm$^3$ of blood)</th>
<th>FUNCTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erythrocytes (RBC’s)</td>
<td>4-6 million</td>
<td>Transport O$_2$ and help transport CO$_2$</td>
</tr>
<tr>
<td></td>
<td>Lives avg. 100-120 days</td>
<td></td>
</tr>
<tr>
<td>Leukocytes (WBC’s) – basophils, eosinophils, neutrophils, lymphocyte, monocyte</td>
<td>4-11 thousand</td>
<td>Defense &amp; Immunity</td>
</tr>
<tr>
<td>Platelets</td>
<td>250-500 thousand</td>
<td>Blood Clotting</td>
</tr>
</tbody>
</table>
# ABO Blood Groups

<table>
<thead>
<tr>
<th>Blood Group</th>
<th>RBC Antigens</th>
<th>Plasma Antibodies</th>
<th>Blood that can be received</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>A &amp; B</td>
<td>NONE</td>
<td>A, B, AB, O (universal recipient)</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>Anti-A</td>
<td>B, O</td>
</tr>
<tr>
<td>A</td>
<td>A</td>
<td>Anti-B</td>
<td>A, O</td>
</tr>
<tr>
<td>O</td>
<td>NONE</td>
<td>Anti-A &amp; Anti-B</td>
<td>O (universal donor)</td>
</tr>
</tbody>
</table>
**ABO Blood Groups**

- Type A – Genotypes AA & AO
- Type B – Genotypes BB & BO
- Type AB – Genotype AB
- Type O – Genotype OO

SEE Table 10.3 pg. 319
Hematopoiesis (Blood Cell Formation)

- Occurs in RED BONE MARROW (myeloid tissue)
- Stem cell – hemocytoblast $\rightarrow$ lymphoid stem cells OR myeloid stem cells
- Lymphoid stem cells $\rightarrow$ lymphocytes
- Myeloid stem cells $\rightarrow$ erythrocytes, platelets, monocytes, neutrophils, eosinophils, basophils
- See Figures 10.4 & 10.5 in book
Hemostasis

• Blood standing still – stoppage of blood flow
• 3 Major Phases:
  – 1. **Platelet plug forms** – injury causes platelets to adhere and plug opening; fibrin clot with trapped red blood cells forms
  – 2. **Vascular spasms occur** – platelets release serotonin, which causes blood vessels to constrict; vascular spasms occur; platelets release chemicals to attract more platelets
  – 3. **Coagulation events occur** – Thromboplastin released by damaged cells; PF₃ on platelets + Thromboplastin, calcium, and other clotting factors PRODUCE Prothrombin activator: Prothrombin $\rightarrow$ Thrombin $\rightarrow$ Fibrinogen (soluble) $\rightarrow$ Fibrin (insoluble)
  – Blood clots within 3-6 minutes
Blood – Homeostatic Imbalances

- **Anemia** – decrease in oxygen-carrying ability of the blood; lower # of RBC’s, abnormal hemoglobin
- **Sickle-Cell Anemia** – RBC’s are deformed and cannot hold on to oxygen well
- **Leukemia** – cancer of the white blood cells; easier to get infections
- **Undesirable blood clotting** – thrombus (in unbroken vessel) and embolus (thrombus breaks away from wall); cerebral embolus → stroke
- **Bleeding disorders** – thrombocytopenia (insufficient # of platelets); hemophilia (lack factors for clotting)
- **Severe Shock** – when body loses over 30% of blood
The Cardiovascular System

- The CV System consists of the heart, arteries, veins, capillaries, and blood.
- Major Function = transportation of oxygen, nutrients, cell wastes, hormones, etc. through the blood
- Heart beats to move blood through the body.
Anatomy of the Heart

• LOCATION AND SIZE
  • Approximately size of person’s fist
  • Weighs less than 1 lb.
  • Located within bony thorax & flanked on each side by lungs
  • Apex – pointed portion of heart; directed toward left hip and rests on diaphragm; 5th intercostal space (place stethoscope to count heart rate)
  • Base – broader posterosuperior portion; great vessels come from here; points to right shoulder; beneath 2nd rib
Anatomy of the Heart

- COVERINGS AND WALL
  - **Pericardium** – double sac of serous membrane that encloses heart
    - **Visceral pericardium (EPICARDIUM)** – lies directly on heart
    - **Parietal pericardium** – lies on thoracic cavity
    - Pericardial fluid – allows heart to beat without friction
  - **Myocardium** – thick bundles of cardiac muscle twisted in ringlike arrangements; layer that contracts
  - **Endocardium** – thin, glistening sheet of endothelium; continuous with linings of blood vessels
Anatomy of the Heart
Anatomy of the Heart

- HOMEOSTATIC IMBALANCE:
- *Pericarditis* – inflammation of pericardium; decrease amounts of serous fluid; pericardial layers stick together and cause painful adhesions that interfere with heart movements
Anatomy of the Heart

• **CHAMBERS & ASSOCIATED GREAT VESSELS**

• 4 Chambers: 2 Atria and 2 Ventricles

• Superior **atria** are *receiving chambers* (not important for pumping)

• Blood flows into atria under low pressure from veins and then into ventricles.

• Inferior **ventricles** are *discharging chambers* (pumps of heart)

• **Interventricular** or **Interatrial septum** – septum that divides heart longitudinally
Anatomy of the Heart

• PULMONARY CIRCULATION

• Right Side: pulmonary circuit pump; receives O\textsubscript{2} poor blood from veins through superior and inferior venae cavae (vena cava) and pumps out through pulmonary trunk → right and left pulmonary arteries (Arteries go Away from heart) – carry blood to lungs to pick up O\textsubscript{2} and drop off CO\textsubscript{2}

• Left Side: O\textsubscript{2} rich blood leaves lungs and returns to left side through 4 pulmonary veins
Anatomy of the Heart

from the body
superior vena cava
right atrium
from the body
tricuspid valve
LUNGS
pulmonary artery
right ventricle

from the head and the arms
to right lung
pulmonary artery
to left lung
pulmonary vein
from right lung
right atrium
pulmonary valve
tricuspid valve
right ventricle
from trunk and legs
heart muscle (myocardium)
to trunk and legs

left atrium
aortic valve
mitral valve
left ventricle
Anatomy of the Heart

- **SYSTEMIC CIRCULATION**
- Left Side: blood returned to left side is pumped out through the AORTA (all systemic arteries branch from here)
- Right Side: O$_2$ poor blood (from tissues) pumps back to the right atrium via systemic veins; empty into superior or inferior vena cava
- Supplies O$_2$ to body tissues
- Left ventricle: thicker wall since it pumps a longer distance
Anatomy of the Heart

• VALVES (4)
• Allow blood to flow in one direction from atria → ventricles
• Atrioventricular (AV) valves – located between atrial & ventricular chambers on both sides
  – Prevents backflow into atria
  – Left AV valve (Bicuspid or Mitral Valve) – has 2 cusps (flaps) of endocardium
  – Right AV valve (Tricuspid Valve) – has 3 cusps
Anatomy of the Heart

• VALVES (cont.)

• *Chordae tendineae* – “heart strings”; white cords that anchor cusps to walls of ventricles

• Semilunar valves ➔

• **Pulmonary semilunar valve** and **Aortic semilunar valve**

• Guard bases of two large arteries leaving ventricles; 3 cusps

• Prevents arterial blood from reentering heart
Anatomy of the Heart

- AV valves open during heart relaxation
- Semilunar valves open during heart contraction
- Open and close in response to pressure changes in heart
Anatomy of the Heart

- HOMEOSTATIC IMBALANCE:
  - Can function with leaky valves if not too bad
  - *Incompetent valve* – forces heart to pump and repump same blood (does not prevent backflow)
  - *Valvular stenosis* – valve flaps become stiff because of repeated infections (endocarditis); forces heart to contract more vigorously
  - Valves can be replaced with pig valves or synthetic valves
Mitral Valve Replacement With Tissue or Mechanical Valve Option
Anatomy of the Heart

• CARDIAC CIRCULATION
• Blood pumping through heart does not nourish myocardium.
• Right and Left Coronary Arteries: oxygenates & nourishes heart; branch from base of aorta and encircle heart in atrioventricular groove
• Major branches: anterior interventricular artery, anterior marginal artery, posterior interventricular artery, posterior marginal artery (fill when heart is relaxed)
• Cardiac veins – drain myocardium; empty into coronary sinus, which empties into right atrium
Anatomy of the Heart

• HOMEOSTATIC IMBALANCE:
  • Angina pectoris – crushing chest pain caused by deprivation of oxygen to the myocardium. (warning before heart attack)
  • Myocardial infarction – “heart attack” or “coronary”
The heart pushes 6 quarts of blood through blood vessels over 1000 times a day!

Cardiac muscle = spontaneous & involuntary movement

Atrial cells = 60 times per minute

Ventricular cells = 20-40 times per minute

2 control systems to coordinate beating
Physiology of the Heart

- Nerves of AUTONOMIC NERVOUS SYSTEM
  - Act like brakes (decrease) and accelerators (increase)

- INTRISTIC CONDUCTION SYSTEM (nodal system)
  - Built into heart tissue
  - Cross between muscle & nerve tissue
  - Causes heart muscle depolarization from atria to ventricles
  - Enforces contraction rate of 75 beats per minute
Physiology of the Heart

- **INTRISTIC CONDUCTION SYSTEM**

  - **Sinoatrial (SA) Node** – located in the right atrial wall near the superior (cranial) vena cava (starts each heart beat & sets pace) PACEMAKER – discharge 70-80 times per minute
  
  - **Atrioventricular (AV) Node** – located in right atrium near septum where ventricles and atria meet. (picks up impulse from SA Node and sends through atria) – discharge 40-60 times per minute
  
  - **Atrioventricular (AV) Bundle (bundle of His)** - picks up impulse from AV Node through ventricular septum (on both sides) down to the apex of the heart – discharge 20-40 times per minute
  
  - **Right & Left Bundle Branches** – located in interventricular septum (picks up impulse from bundle of His)
  
  - **Purkinje Fibers** – special conductive cells that communicate electrical impulses from the Bundle of His to contractile myocardial cells in the ventricles (ventricular autorhythmic cells) – discharge 20-40 times per minute
Physiology of the Heart

• Spread of the Action Potential
  – Normally originates from the SA node, since it discharges most frequently. (70-80 times/min)
  – Travels through specialized internodal tracts to the AV node.
  – AV node passes the action potential (slowly) from the atria to the ventricles (which are electrically isolated from each other) along the bundles of His. Approximately 0.1 second delay in propagation of the impulses through the AV node.
  – The bundles of His transmit the action potential along the ventricular septum toward the apex.
  – The Perkinje fibers transmit the action potential to the contractile myocardial cells of both ventricles.
  – Action Potential transmitted within 30 milliseconds
Physiology of the Heart

- FORMATION OF THE ACTION POTENTIAL
- Cells of the Intristic Conduction System (specialized conduction system) are specifically modified in a way that gives them autorhythmicity.
- Membranes of these cells are far less permeable (but not impermeable) to K\(^+\) than other excitable cells that we have discussed. They are permeable to Na\(^+\) and Ca\(^{+2}\). Because permeability to K\(^+\) in other excitable cells holds the resting membrane potential at \(\sim -70\text{mV}\), the resting membrane potential in pacemaker cells “wanders” toward threshold (in this case \(-40\text{mV}\)) because of the greater influx of Ca\(^{+2}\) relative to the efflux of K\(^+\).
Physiology of the Heart

- FORMATION OF THE ACTION POTENTIAL

- As Ca\(^{+2}\) enters the cell, voltage gated Ca\(^{+2}\) channels open (at threshold) allowing a more rapid influx of Ca\(^{+2}\) into the cell. The membrane potential at the maximum influx of Ca\(^{+2}\) reaches ~0mV.

- As the membrane potential peaks, the membrane becomes more permeable to K\(^{+}\) and K\(^{+}\) rapidly leaves the cell, reestablishing resting membrane potential.

- The slow rise toward threshold in these autorhythmic has a definitive periodicity, which is manifested as a relatively constant heart rate. Parasympathetic activity tends to decrease the constancy of heart rate; heart rate varies with respiration and oscillations in blood pressure.
Physiology of the Heart

• HOMEOSTATIC IMBALANCES:
  • Heart block – caused by damage to AV node that releases the ventricles from control of the SA node
  • Ischemia – lack of adequate blood supply causes fibrillation – rapid uncoordinated shuddering of the heart muscle (heart attack)
  • Tachycardia – rapid heart rate (over 100/min)
  • Bradycardia – slower heart rate (under 60/min)
Physiology of the Heart

• **HOMEOSTATIC IMBALANCES:**

• **Loss of a Pacemaker**
  
  – Certain diseases or pathological events (such as myocardial infarction (MI)) can damage or eliminate the pacemaker (SA node). In that case, pacing is taken over by the cells of the AV node. Heart rate will drop accordingly.
  
  – If the heart rate is determined by the cells of the bundles of His or Purkinje fibers, the individual will lose consciousness. This is not due to inefficiency of contraction, but a heart rate that is too slow to maintain adequate blood pressure and, thus, blood flow to the brain.
  
  – A block in the specialized conduction system can result in the atria contracting independently of the ventricles. The atria follow the pace of the SA node and beat at ~70 times per minute while the ventricles beat at ~50 beats per minute.
**Physiology of the Heart**

- **HOMEOSTATIC IMBALANCES:**
- **Ectopic Focus (foci)**
  - Any area of the heart, the specialized conduction system cells or contractile myocardial cells, can become irritable and can take over the pacing function from the SA node. (faster pace)
  - Because all cardiac muscle cells are in communication with each other (within the atria or ventricles), this ectopic focus can cause the heart to contract out of synchrony with the pacing system.
  - If the ectopic focus is located within the ventricles, the resulting beat is referred to as a premature ventricular contraction (PVC).
  - If there are multiple foci, there can be multiple action potentials generated and chaotic contractions can occur. This is often seen in MI and can cause either atrial or ventricular fibrillation.
Physiology of the Heart

- CARDIAC CYCLE & HEART SOUNDS
- **Systole** – heart contraction
- **Diastole** – heart relaxation
- ***Refer to ventricles!!!***
- **Cardiac Cycle** – events of one complete heartbeat, where both atria and ventricles contract and then relax.
- Heart beats ~ 75 times/minute
- Cardiac cycle ~0.8 second
Cardiac Cycle

1. **Mid-to-Late Diastole** – Heart completely relaxed; pressure is low; blood flow is passive into atria and then to ventricles; semilunar valves are closed; AV valves open; atria contract and force remaining blood into ventricles.

2. **Ventricular Systole** – ventricles contract; pressure increases in ventricles; AV valves close; **Semilunar valves open when pressure in ventricles is higher than that in the arteries leaving the heart**; atria are relaxed & filling with blood again.

3. **Early Diastole** – ventricles relax; semilunar valves close; interventricular pressure drops; **AV valves open when pressure is lower than pressure in the atria**; cycle continues.
Cardiac Cycle

The Cardiac Cycle

Diagram showing the heart during the cardiac cycle with labels for various parts including:
- Aorta
- Superior Vena Cava
- Pulmonary Artery
- Pulmonary Veins
- Left Atrium
- Right Atrium
- Left Ventricle
- Right Ventricle
- Inferior Vena Cava

Diastole: Ventricular Relaxation and Filling

Systole: Ventricular Contraction and Ejection
Cardiac Cycle and Heart Sounds

- Use stethoscope to hear heart sounds
- “LUB” and “DUP”
- “LUB” is caused by closing of the AV valves; longer & louder
- “DUP” is caused by closing of the semilunar valves at end of systole; short & sharp
- HOMEOSTATIC IMBALANCES:
  - Heart Murmurs – abnormal heart sounds
Physiology of the Heart

- **CARDIAC OUTPUT (CO)**: amount of blood pumped out by each side of the heart (each ventricle) in 1 minute.
- CO = Heart Rate(HR) x Stroke Volume(SV)
- **Stroke volume** – volume of blood pumped out by a ventricle with each heartbeat.
- SV↑ as Force of ventricular contraction↑
- Avg. adult: CO = HR (75 beats/min) x SV (70mL/beat)
- CO = 5250 mL/min
- Normal blood volume = 5000 mL SO, entire blood supply passes through body once each minute.
Physiology of the Heart

REGULATION OF STROKE VOLUME

Healthy heart pumps out about 60% of blood present in its ventricles. (70 mL/heartbeat)

Starling’s Law of the Heart – main factor for controlling SV is how much cardiac muscle cells are stretched before they contract.

More they are stretched = stronger contraction

Venous Return – main factor for stretching heart muscles (amount of blood entering heart and entering ventricle)

↑ volume or speed of venous return = ↑ SV
Physiology of the Heart

• REGULATION OF HEART RATE
• IF SV ↓, CO is maintained by a faster heartbeat
• Rate can be changed temporarily by the AUTONOMIC NERVES
• Rate is also changed by chemicals, hormones, and ions.
Regulation of Heart Rate

- SYMPATHETIC
- During times of physical or emotional stress.
- Nerves stimulate the SA and AV nodes and the cardiac muscle $\rightarrow$ heart beats rapidly
- More $O_2$ and glucose made available to cells
Regulation of Heart Rate

- PARASYMPATHETIC
- When calming down; normal conditions
- Mainly VAGUS NERVES
- Slow down and steady heartbeat
- Give heart time to rest
- *Digitalis* – drug given to patients with congestive heart failure; acts like vagus nerves to slow down and steady heartbeat (makes it stronger)
Hormones & Ions that Affect HR

- **Epinephrine** – mimics effects of sympathetic nerves; used to increase heart rate
- **Thyroxine** – increases heart rate
- Reduced levels in blood Ca\(^{2+}\) can depress the heart. Too much Ca\(^{2+}\) causes prolonged contractions (heart may stop).
- Deficit of K\(^+\) in blood causes heart to beat abnormally.
Physical Factors that Affect HR

• Age, gender, exercise, body temperature, etc. can affect HR
• Resting HR is fastest in fetus = 140-160 bt/min
• Avg. HR faster in females
• Heat increases HR by boosting metabolic rate of heart cells (fast heartbeat during exercise)
• Exercise (sympathetic nervous) increases HR and increases SV
Homeostatic Imbalance

• Congestive Heart Failure (CHF) – a progressive condition that reflects weakening of the heart by:
  – Coronary atherosclerosis
  – Persistent high blood pressure
  – Multiple myocardial infarcts
• If LEFT heart fails, PULMONARY CONGESTION occurs (pulmonary edema)
• If RIGHT heart fails, PERIPHERAL CONGESTION occurs (edema at extremities)
Cardiovascular System: Blood Vessels

- Vascular system = closed transport system
- Heart → Arteries → Arterioles (smaller arteries) → Capillary Beds (in tissues) → Venules (smaller veins) → Veins → Heart
- ARTERIES = carry blood AWAY from heart
- VEINS = carry blood TOWARD heart
Microscopic Anatomy of Blood Vessels

- **TUNICS** = coats on blood vessels
- **Tunica Interna** = lines the lumen or interior of vessels
- **Tunica Media** = bulky middle coat
- **Tunica Externa** = outermost tunic; support and protect vessels
Differences in Arteries, Veins, and Capillaries

- Walls of arteries are THICKER than walls of veins (tunica media is heavier)
- Arteries = closer to heart pump; must be able to expand and recoil
- Veins = far from heart pump; lower pressure; lumens are larger; valves to prevent backflow; skeletal muscle moves blood through veins; respiratory pump (drop in pressure in thorax causes large veins to expand and fill)
Differences in Arteries, Veins, and Capillaries

- Capillaries = walls are only 1 cell layer thick (tunica interna); exchanges made between blood and tissue; form capillary beds
- Microcirculation = flow of blood from arteriole to venule
- Capillary Bed:
  - 1. vascular shunt = vessel that directly connects the arteriole and venule at opposite ends of the bed
  - 2. true capillaries = actual exchange vessels
Differences in Arteries, Veins, and Capillaries

- Precapillary sphincter is a cuff of smooth muscle that surrounds the root of each true capillary.
- It acts as a valve to regulate flow of blood into capillary.
- When precapillary sphincters are relaxed (open) – blood flows through true capillaries (exchange with tissues)
- When precapillary sphincters are closed – blood bypasses tissues by flowing through shunts.
Differences in Arteries, Veins, and Capillaries

- **HOMEOSTATIC IMBALANCE:**
  - **Varicose veins** – pooling of blood in feet and legs and inefficient venous return; **overworked valves give way** → veins become twisted and dilated
  - **Thrombophlebitis** – complication of varicose veins where a clot forms → blood must go through pulmonary circulation, so pulmonary embolism can occur
Gross Anatomy of the Blood Vessels

- **MAJOR ARTERIES of SYSTEMIC CIRCULATION:**

- **Aorta** – largest artery of body; leaves left ventricle of heart
  - *Ascending aorta* – upward portion leaving left ventricle
  - *Aortic arch* – arches to left
  - *Thoracic aorta* – portion going through thorax following spine
  - *Abdominal aorta* – after passing through diaphragm into abdominopelvic cavity
Major Arteries of the Systemic Circulation

- Name of artery normally tells you which region or organ it is serving or bone it follows.

- ASCENDING AORTA:
  - Right coronary artery
  - Left coronary artery (these serve the heart)

- AORTIC ARCH:
  - Brachiocephalic artery

R. COMMON CAROTID ARTERY
R. SUBCLAVIAN ARTERY
Major Arteries of the Systemic Circulation

- **AORTIC ARCH:**
- **Left Common Carotid Artery** (second branch off of arch)
  - L. INTERNAL CAROTID (brain)
  - L. EXTERNAL CAROTID (skin & muscles of head and neck)
- **Left Subclavian Artery** (3rd branch off of arch) – these branches are for both R & L subclavian
Major Arteries of the Systemic Circulation

- **THORACIC AORTA:**
  - Intercostal arteries (10 pairs) – supply muscles of thorax wall
  - Bronchial arteries – supply lungs
  - Esophageal arteries – supply esophagus
  - Phrenic arteries – supply diaphragm
Major Arteries of the Systemic Circulation

- **ABDOMINAL AORTA:**
  - **Celiac Trunk** (3 branches)
    - **LEFT GASTRIC ARTERY** – supplies stomach
    - **SPLENIC ARTERY** – supplies spleen
    - **COMMON HEPATIC ARTERY** – supplies liver
  - **Superior Mesenteric Artery** (unpaired) – supplies most of small intestine and first half of large intestine (colon)
- **Right and Left Renal Arteries** – supply kidneys
- **Right and Left Gonadal Arteries** – supply gonads
  - **Ovarian arteries** in females and **Testicular arteries** in males
Major Arteries of the Systemic Circulation

- **ABDOMINAL AORTA:**
  - Lumbar arteries (several pairs) – supply muscles of abdomen and trunk walls
  - Inferior Mesenteric Artery (small, unpaired) – supplies second half of large intestine

- **Right and Left Common Iliac Arteries** (final branch of aorta)

  - **INTERNAL ILIAC ARTERY** – supplies bladder, rectum, etc.
  - **EXTERNAL ILIAC ARTERY**
Major Arteries of the Systemic Circulation

- **Femoral Artery**
  - **Popliteal Artery (at knee)**
    - **Anterior Tibial Artery** – supply leg and foot
    - **Posterior Tibial Artery** – supply leg and foot
    - **Dorsalis Pedis Artery** – supplies dorsum of foot
    - **Arcuate Artery** – supplies toes
Major Veins of the Systemic Circulation

- Veins are more superficial than arteries. The few deep veins follow the same course as arteries.
- **SUPERIOR VENA CAVA** – where veins from head and arms empty into
- **INFERIOR VENA CAVA** – where veins from lower body empty into
Major Veins of the Systemic Circulation

- **Superior Vena Cava**
  - **Radial vein**
  - **Ulnar vein**
  - **Cephalic vein** (lateral)
  - **Basilic vein** (medial)
  - **Median cubital vein** (connects Cephalic vein and Basilic vein at elbow)
  - **Subclavian vein**

  ![Diagram of Major Veins of the Systemic Circulation]

- **Brachial vein**
- **Axillary vein**
- **External jugular vein**
- **Axillary vein**
Major Veins of the Systemic Circulation

- Superior vena cava
  - **Vertebral vein** (drains posterior part of head) → Right and Left Brachiocephalic veins
  - **Internal jugular vein** (drains dural sinuses of brain) → Right and Left Brachiocephalic veins
  - **Subclavian vein** → Right & Left Brachiocephalic veins → Superior Vena Cava
  - **Azygos vein** (drains thorax) → Superior Vena Cava
Veins draining into Superior Vena Cava
Major Veins of the Systemic Circulation

- Inferior vena cava (from everything below diaphragm)
  - Anterior & Posterior tibial veins → Popliteal vein (at knee) → Femoral vein (at thigh) → External iliac vein (when entering pelvis)
  - Great saphenous veins (longest) [begin at dorsal venous arch in foot] → Femoral vein
  - Internal & External iliac veins → Common iliac vein → Inferior vena cava
  - Right gonadal vein (drains right ovary or testicle)
  - Left gonadal vein (drains left ovary or testicle)
  - Renal veins (drain kidneys)
  - Hepatic portal vein (drains digestive tract → liver)
  - Right and Left hepatic veins (drain liver)
Special Circulations: The Brain & Circle of Willis

- It is very important to have a continuous blood supply to the brain!
- Supplied by 2 pairs of arteries: **Internal carotid arteries** & **Vertebral arteries**
- **Common carotid artery** → **Internal carotid arteries** (enter through temporal bone)

[Diagram showing blood circulation through the brain with labels for Middle cerebral artery, Anterior cerebral artery, and other key arteries.]
Special Circulations: The Brain & Circle of Willis

- Subclavian arteries → Vertebral arteries join from each side to form → Basilar artery (serves brain stem & cerebellum) divides → Posterior cerebral arteries (supply posterior part of cerebrum)

- Anterior & Posterior blood supplies connect by communicating arterial branches – forms circle (Circle of Willis) – protects brain (provides more than one route for blood to get to brain)
Special Circulations: The Brain & Circle of Willis

The Circle of Willis

- Frontal lobe
- Optic chiasma
- Middle cerebral artery
- Internal carotid artery
- Pituitary gland
- Temporal lobe
- Pons
- Occipital lobe

Anterior communicating artery
Anterior cerebral artery
Posterior communicating artery
Posterior cerebral artery
Basilar artery
Vertebral artery
Cerebellum

Internal carotid artery
Middle cerebral artery
Circle of Willis
Basilar artery
Bottom view of brain
Special Circulations: Hepatic Portal

- Veins drain digestive organs, spleen, and pancreas (hepatic portal vein) → liver
- Liver is very important in maintaining proper levels of glucose, fat, and protein in blood.
- Blood flows SLOWLY through liver so that nutrients can be sorted.
Special Circulations: Hepatic Portal

- **Hepatic veins** → **Inferior vena cava**
- **Inferior mesenteric vein** (drains large intestine) → **Splenic vein** (drains spleen, pancreas & left side of stomach) + **Superior mesenteric vein** (drains small intestine & 1st part of colon) → **Hepatic portal vein**

**Left gastric vein** (drains right side of stomach) → **Hepatic portal vein**
Special Circulations: Fetal Circulation

- Remember that lungs and digestive systems are not functioning in a fetus. So, all nutrient, excretory, and gas exchanges have to occur across the placenta.
- Nutrients go from mother → placenta → fetus
- Wastes go from fetus → placenta → mother
- Umbilical cord: umbilical vein (very large) – carries nutrients to fetus, 2 umbilical arteries (smaller) – carry wastes to mother (ARTERIES go AWAY from fetus)
- Ductus venosus – allows blood to bypass immature liver in fetus (enters into inferior vena cava)
- To bypass lungs:
  - 1) Blood entering R atrium bypasses to L atrium directly by foramen ovale (fossa ovalis in adult)
  - 2) If blood makes it into the R ventricle, it is pumped out through pulmonary trunk where it comes in contact with ductus arteriosus (ligamentum arteriosum in adult) – connects pulmonary trunk to aorta → sends blood to system rather than to lungs
Physiology of Circulation

- Measurements to test circulation: arterial pulse & blood pressure (VITAL SIGNS – also includes respiratory rate & body temp.)
- ARTERIAL PULSE: pulse created by expansion & recoil of artery after left ventricle has made a pressure wave
- Normally pulse rate = heart rate
- Avg. pulse rate = 70-76 beats/min (resting)
- Feel pulse by pressing artery against tissue – good pulse point is where radial artery surfaces at the wrist (radial pulse)
- **Pressure Points** = points where you can feel pulse & compress to stop too much blood loss
Pressure Points

- Temporal artery
- Facial artery
- Carotid artery
- Brachial artery
- Radial artery
- Femoral artery
- Popliteal artery
- Posterior tibial artery
- Dorsalis pedis artery
Blood Pressure

- The closer to the pump, the higher the pressure.
- **Blood pressure** = pressure the blood exerts against the inner walls of the blood vessels (force that keeps blood circulating). [assumed to be in major arteries near heart]
- Pressure is highest in arteries that leave the heart and drops the further it gets from the pump. (Reaches 0 at venae cavae)
- Flows along a pressure gradient (high to low)
- Low pressure by the time blood gets to VEINS, so veins must have larger lumens, skeletal muscle surrounding, and pressure changes in thorax to push blood through.
- Cutting vein: even flow of blood  Cutting artery: spurts of blood
- It is important that arteries’ walls stretch further so they can recoil more and push the blood further.
Blood Pressure

- Measuring blood pressure:
  - Systolic pressure – pressure in arteries at peak of VENTRICULAR CONTRACTION
  - Diastolic pressure – pressure when VENTRICLES RELAX
  - Given in mmHg (millimeters of mercury)
  - Systolic/Diastolic = Normal: 120/80
  - Auscultatory method – measure pressure on brachial artery of arm
Blood Pressure
Effects of Factors on Blood Pressure

- Blood pressure is DIRECTLY related to cardiac output and peripheral resistance.
- **Peripheral resistance** – amount of friction encountered by blood as it flows through the blood vessels.
  - Increased by constriction of vessels (arterioles) – sympathetic nervous system or atherosclerosis
  - Increased by increased blood volume or blood viscosity (thickness)
- ↑Cardiac output (↑peripheral resistance) = ↑Blood Pressure
Effects of Factors on Blood Pressure

1) Neural factors: AUTONOMIC NERVOUS SYSTEM – parasympathetic division has little effect on blood pressure; sympathetic division causes vasoconstriction (narrowing of blood vessels) → increases blood pressure

- Sympathetic activated in various circumstances: Standing up suddenly (gravity causes blood to pool in feet and blood pressure drops → activates pressoreceptors in large arteries of neck and chest → cause vasoconstriction to increase blood pressure)
Effects of Factors on Blood Pressure

1) continued

If blood volume decreases (hemorrhage), then blood pressure drops. Heart will beat more rapidly to make up for this. But venous return is reduced by blood loss, so the heart beats weakly. Sympathetic nervous system tries to increase blood pressure to hopefully increase venous return.

Exercise: sympathetic nervous system – generalized vasoconstriction EXCEPT in the skeletal muscles; vessels of skeletal muscles dilate to increase blood flow in working muscles

NOTE: sympathetic nerves NEVER cause vasoconstriction of blood vessels in heart or brain
2) Renal Factors: THE KIDNEYS – alter blood volume

- If blood pressure increases too much, kidneys will allow more water to leave body in urine. (Most water comes out of the blood, so blood volume will decrease.)
- If blood pressure is too low, kidneys will retain body water in hopes to increase blood volume, which will increase blood pressure.
- If blood pressure is too low, kidney cells release renin, an enzyme that triggers a series of reactions that lead to formation of angiotensin II – vasoconstrictor chemical
Effects of Factors on Blood Pressure

3) TEMPERATURE: Cold temperature = vasoconstricting
   - Good to put ice on bruised area to prevent swelling

   Hot temperature = vasodilating
   - Good to put heat on area to speed circulation to inflamed area
4) CHEMICALS:
- Epinephrine – increases blood pressure and HR
- Nicotine – increases blood pressure (vasoconstriction)
- Alcohol – decrease blood pressure (vasodilation)
  - Skin vessels become dilated and cause flushed look
- Histamine – decrease blood pressure
Effects of Factors on Blood Pressure

5) DIET:

- Low in salt, saturated fat, and cholesterol = prevents hypertension (high blood pressure)
Variations in Blood Pressure

- Normal adults: SYSTOLIC 110 – 140 & DIASTOLIC 75 – 80
- Blood pressure varies with age, weight, race, mood, physical activity, and posture.
- HOMEOSTATIC IMBALANCE: Orthostatic hypotension – found in elderly people; low blood pressure causing dizziness (sympathetic nervous system acts slowly)
- Hypotension = low blood pressure (systolic below 100 mmHg) – normal for physically active people
- Chronic hypotension may be due to poor nutrition.
- Acute hypotension is warning of circulatory shock (most common cause is blood loss).
- Hypertension = high blood pressure (140/90 or higher)
Capillary Exchange

- Substances diffuse across membranes in capillary beds. (move according to concentration gradients – down the gradient)

- 4 Routes that Substances can take:
  1) DIFFUSE DIRECTLY ACROSS MEMBRANE (lipid soluble)
  2) MOVE THROUGH VESICLES (lipid insoluble – endocytosis and exocytosis)
  3) INTERCELLULAR CLEFTS (gaps in membrane that allow small solutes through – not in brain capillaries)
  4) FENESTRATED CAPILLARIES (free passage of small solutes and fluids – found where absorption is necessary [intestinal capillaries] or where filtration is necessary [kidney])

- READ DEVELOPMENTAL ASPECTS pg. 360