Internal Transport, Gas Exchange, and Digestion

~Biology AP~

A Meridian® Study Guide by John Ho, Tim Qi, and Jeff Gu

❖ The Digestive System

➢ Steps of Digestion:

Steps of Digestion		
Step	**Location**	**Description**
Ingestion	Mouth	Process of transporting food into an organism's body
Digestion	Mouth, Stomach, Small Intestine	Process where food is broken down chemically into nutrients
Absorption	Stomach, Small Intestine, Large Intestine	Process where digested food is absorbed into the body and used by individual cells
Elimination	Large Intestine, Anus	Process where undigested material is excreted from the body.

- **Peristalsis:** Contracting motion of muscles that moves food along the digestive tract.

➢ Types of Digestion:

Types of Digestion	
Type	**Function**
Intracellular	Cells consume food through the process of phagocytosis and pinocytosis which are stored in food vacuoles and broken down my Lysosomes.
Extracellular	Digestion occurs in some kind of internal tract. Enzymes are secreted to break down the food. This way, a lot of food can be eaten at once, while the system can slowly digest it.

➢ **Gastrovascular Cavity:** A digestive sac that functions in both digestion and the transport of nutrients to all parts of an animal body through the same opening, which functions are both the mouth and anus. Organisms belonging to two major phyla, the *Cnidaria* and the *Platyhelminthes*, possess gastrovascular cavities. Digestion occurs extra-cellular, then the smaller molecules are directly absorbed by the cell for intracellular digestion.

➢ **Sphincter:** A ring-like muscle that regulates entry/exit of substances into a body passage or tube.

Types of Sphincters		
Name	**Location**	**Description**
Cardiac Sphincter	Stomach	Located at the upper end of the stomach, prevents food from exiting the stomach back into the esophagus
Pyloric Sphincter	Stomach	Regulates entry of chyme (digested food) into the duodenum of the small intestine.

- **Digestive Organs:**

Digestive Organs		
Organ	**Enzymes**	**Description**
1. Mouth	Amylase	Receives the food, primarily responsible for mechanical digestion. Amylase, which digests carbohydrates, is secreted in the saliva. The result (known as "bolus") is transported into the stomach through the esophagus. A flap of cartilage tissue called the epiglottis resides in the pharynx, covers the windpipe during swallowing to prevent food from entering trachea.
2. Stomach	Pepsin HCl	Primary function is to store and digest food, although some water absorption does occur. The stomach contracts to further mechanical digestion. Three types of cells: • *Mucus cells:* Secretes protective mucus • *Chief cells:* Secretes pepsinogen (inactive) • *Parietal:* Secretes HCl Food leaves the stomach as chyme to the small intestine.
3. Small Intestine	Bile (Other enzymes)	Digests and absorbs food. Peristalsis moves substances through the intestine: 1) Duodenum (digestion), 2) Jejunum (absorption), and 3) Ileum (absorption). Absorption occurs though *villi*, projections which maximize surface area.

  - **Pepsin:** Secreted in its inactive form (pepsinogen) by chief cells in order to protect the stomach. It is activated when it comes in contact with HCl, allowing it to digest proteins.

- **Special Digestive Structures:**

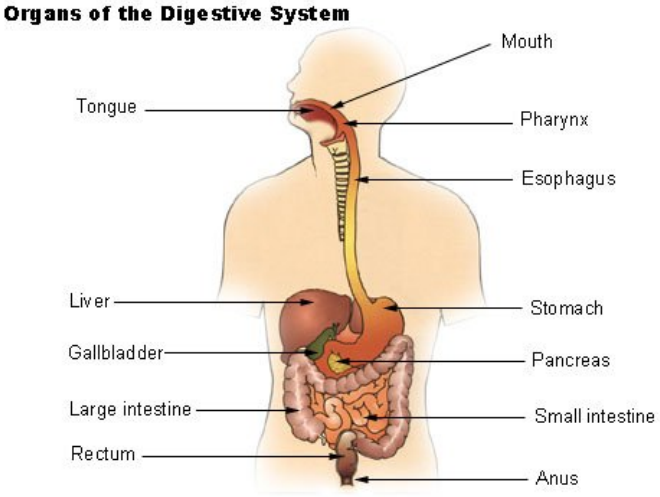
Structure	**Function**	**Examples**
Crop	Store and moisten food	Earthworms, grasshoppers, birds
Gizzard	Contains smooth sand and stone that grinds up the food when the chamber contracts	Earthworms, grasshoppers, birds
Gastric ceca	Elongation of the midgut to lengthen absorption	Grasshoppers

- **The Small Intestine:**
  - **Digestion:** Occurs in duodenum

Organ	**Functions**
Duodenum Lining	Secretes various digestive enzymes
Pancreas	Pancreatic amylase – Breaks down carbohydrates Pancreatic lipase – Breaks down lipids Pancreatic nuclease – Breaks down nucleic acids Trypsin – Breaks down proteins Bicarbonate solution – neutralize the acidic chime
Liver	Produces bile – Bile breaks up fat into tiny molecules called micelles.
Gallbladder	Stores bile

- **Absorption:** Occurs in jejunum and ileum

Vessel	Functions
Capillaries	Carbohydrate, proteins, nucleic acids, and water are all absorbed into the capillaries in the villi. The capillaries in the villi lead to the hepatic portal vessel which goes into the liver, converting many nutrients into various forms.
Lacteal	Only lipid molecules are absorbed into the lacteals in the villi. The lacteals in the small intestines join up with bigger lymphatic vessels, which will transport the fat to thoracic duct and eventually into veins.



- **The Large Intestine (also "Colon"):**
  - Final part of the digestive tract that is responsible for the absorption of water from the remaining chyme.
  - Bacteria (such as E. coli) live on the lining of the large intestine and synthesizes vitamins B and K
  - The remaining digested material, which is now called feces, moved into the rectum and expelled through the anus.

Organ	Function
Rumen	Microbes in the rumen begin the digestion by breaking down cellulose. Products are fatty acids and partly digested food, which is regurgitated and rechewed.
Reticulum	Controls whether or not the food need to be regurgitated or moved on to the next stage of digestion.
Omasum	Main function is the absorption of water, magnesium, and fermentation acids.
Abomasum	This final stomach is somewhat similar to the normal stomach in human as it is mainly responsible for breaking down proteins.

- **Control of the Digestive System:**

Digestive System Hormones			
Hormone	**Source**	**Target**	**Description**
Gastrin	Stomach	Proteins	Gastrin stimulates stomach to increase secretion of HCl and pepsin. It also stimulates stomach movement.
CCK	Small Intestine	Fat and Protein	Secreted by the duodenum, the hormone stimulates release of bile and pancreatic juices.
Secretin	Small Intestine	Low pH	The hormone stimulates the secretion of bicarbonate, which helps neutralize the products entering the duodenum from the stomach.

❖ Circulatory System

- **Types of Systems:**

Types of Circulatory Systems	
Open	Blood and interstitial fluid (fluid found in the lymphatic system) are not differentiated. Generally, the system is much simpler and contains only two types of tubes: • Sinuses: Tubes part of the central system • Ostia: Tubes open to the outside enviroment
Closed	Blood in the closed system is confined in tubes. High blood pressure must be maintained through a system of complex arteries, which included: • Arteries: Large vessels that carry blood from heart • Veins: Large vessels that carry blood towards the heart • Capillaries: Thin walled vessels where molecules diffuse in/out

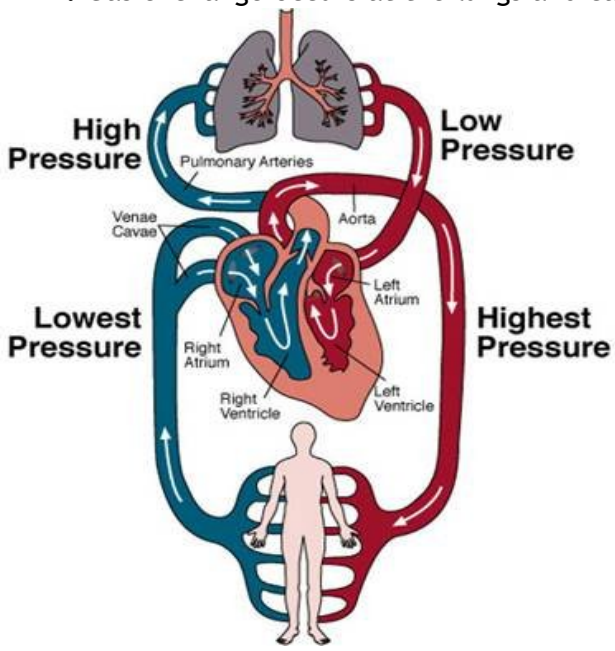
- **Vertebrate Circulatory Systems:**

Vertebrate Circulation				
Type	**Separation**	**Circulation**	**Chambers**	**Description**
Fish	Separate	Single	2	Linear route, gas exchange occurs in gills
Amphibian	Mixed	Double	3	Both skin and lungs are used for exchange; O_2 rich and O_2 poor blood is mixed due to the 3-chambered heart.
Reptile	Mixed	Double	3	Ventricles not fully separated, reptiles are able to regulate flow in order to control body temperature.
Mammal/Bird	Separate	Double	4	Blood is fully separated by muscular wall in the center.

- **Human Circulatory System:**
  - **The Heart:** Four-chambered heart, contains several valves to regulate flow of blood:

Heart Valves		
Name	**Location**	**Description**
Atrioventricular Valves (AV)	Between Atrium + Ventricle	Function to prevent backflow. Includes two valves: • Tricuspid: Between R. atrium and R. ventricle • Bicuspid: Between L. atrium and L. ventricle
Semi-lunar Valves	Exits of the heart	One located at the left ventricle controlling exit to the aorta (to body), second at the right ventricle regulating flow to the pulmonary artery (to lungs).

- **Pathway of Blood:** Gas exchange occurs at the lungs and capillaries.



- **Producing the Heartbeat:** SA node releases an electrical signal, causing the aria to contract, which is received by the AV node; the signal is transferred to the Bundle of His after a delay. It is then relayed to the Purkenje fibers, which ultimately causes the ventricles to contract.

Nodes	
Sinoatrial (SA)	Responsible as the “pacemaker”. Generates the electrical impulse to cause atria to contract.
Atrioventricular (AV)	Transfers impulse after a delay to the Purkenje fibers, which causes both ventricles to contract.

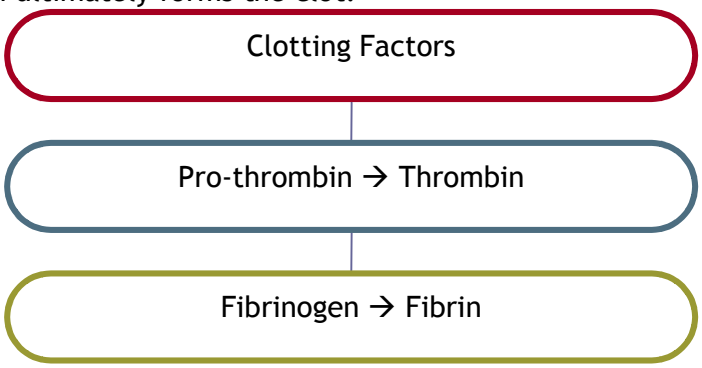
- **Blood Pressure:** Measure of force applied to cell walls.

Blood Pressure		
Type	**Phase**	**Description**
Systole	Contraction	Highest blood pressure, heart is contracting and pushes blood along the circulatory tract.
Diastole	Relaxation	Lowest blood pressure, period when blood is filling heart after contraction.

- **Circulation Control:**

Blood Pressure		
Control	**Aspect**	**Description**
Nerve impulse	Heart rate	The nervous system controls the SA and AV nodes which set the pace of the heart.
Oxygen level	Heart rate	Low oxygen levels increases heart rate to compensate for decrease on oxygen.
Lymphatic system	Blood pressure	Maintains fluid levels to ensure constant pressure. It filters substances before they enter the circulatory system.

- **Blood Clotting:** Platelets bind to the damaged blood vessel wall. Clotting factors, which include platelets and damaged cells, activate enzymes which react to form a clot. Fibrin ultimately forms the clot.



- **Cardiovascular Diseases:** *Atherosclerosis* occurs when plaque build up in arteries. This occurs when excessive amounts of Low Density Lipids (LDL) are consumed. High Density Lipids (HDL) can counter the effect.

❖ Respiratory System

- **Respiratory Medium:**

Substances for Respiratory Medium		
Water	*Advantages*	No problem keeping plasma membranes moist due to abundance of water
	Disadvantage	Oxygen levels are lower in water, and water is denser than air, requiring more energy to ventilate it. Also, as water becomes warmer and saltier, oxygen levels decrease.
Air	*Advantages*	Higher oxygen concentration than water. Less ventilation required.
	Disadvantages	Respiratory surfaces and plasma membranes must be kept moist, which is harder since water is lost through evaporation.

- **Countercurrent Exchange:** Blood and new air flow in opposite directions. This allows for blood to always be exposed to fresh air, making gas exchange more efficient. This is mostly found in fishes.

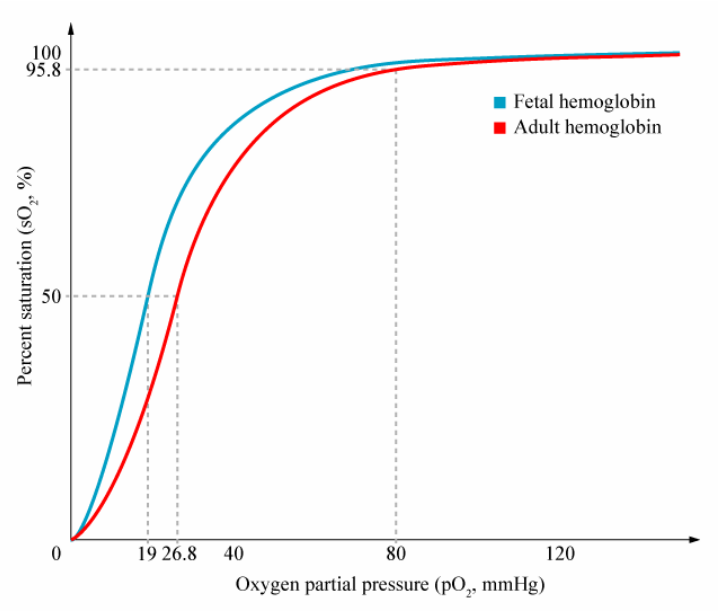
- **Hemoglobin:** Acts as a transport, each unit can carry 4 molecules of O_2. It capacity it changed by the pH of blood.
  - **Buffer capacity:** CO_2 is absorbed in bloodstream and reacts with water.

    $$CO_2 + H_2O \rightarrow H_2CO_3$$

    The molecule breaks down into hydrogen and carbon dioxide units, which lowers the pH of blood.

    $$H_2CO_3 \rightarrow H^+ + CO_2$$

    Hemoglobin takes on the H^+ ion, raising the pH.
  - **Myoglobin:** An oxygen storing protein structurally similar to hemoglobin. It has a significantly larger affinity for O_2 than hemoglobin.



  - **The Bohr Effect:** High CO_2 concentrations in blood cause hemoglobin to bind with less affinity to O_2. CO_2 is normally transported in the plasma as bicarbonate (HCO_3^-).

Bohr Effect		
pH Level	**Response**	**Description**
Low pH	O_2 release	Hemoglobin balances high CO_2 levels by releasing O_2 molecules into the plasma, raising pH.
High pH	O_2 bind	Hemoglobin binds to O_2 to remove excess molecule levels

- **Breathing:**

Breathing		
Action	**Diaphragm**	**Description**
Inhale	Contracts	The diaphragm contracts, that is, moves downwards building negative pressure in lungs which air fills.
Exhale	Relaxes	The diaphragm relaxes and moves back up; positive pressure and decreased volume of the chest cavity force air out

  - Breathing is controlled by the medulla oblongata, and the pons. They receive feedback from sensors in the aorta and carotid arteries which check for oxygen, and CO_2 concentration, and work in sync with the circulatory system.