Paper No. VI- Physiology

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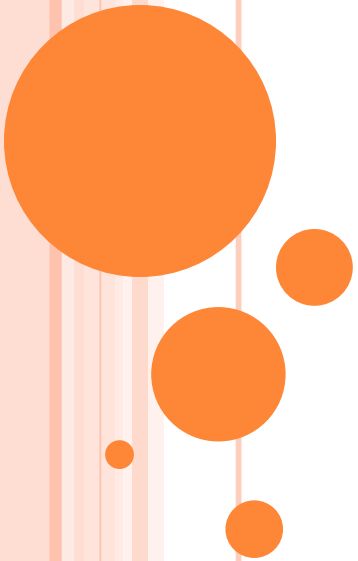
Unit I: Digestion



Digestion:

- Digestion is defined as the process of breaking down large, insoluble molecules of food into smaller, water-soluble molecules which can then be readily absorbed by the body

- Types of Digestion –

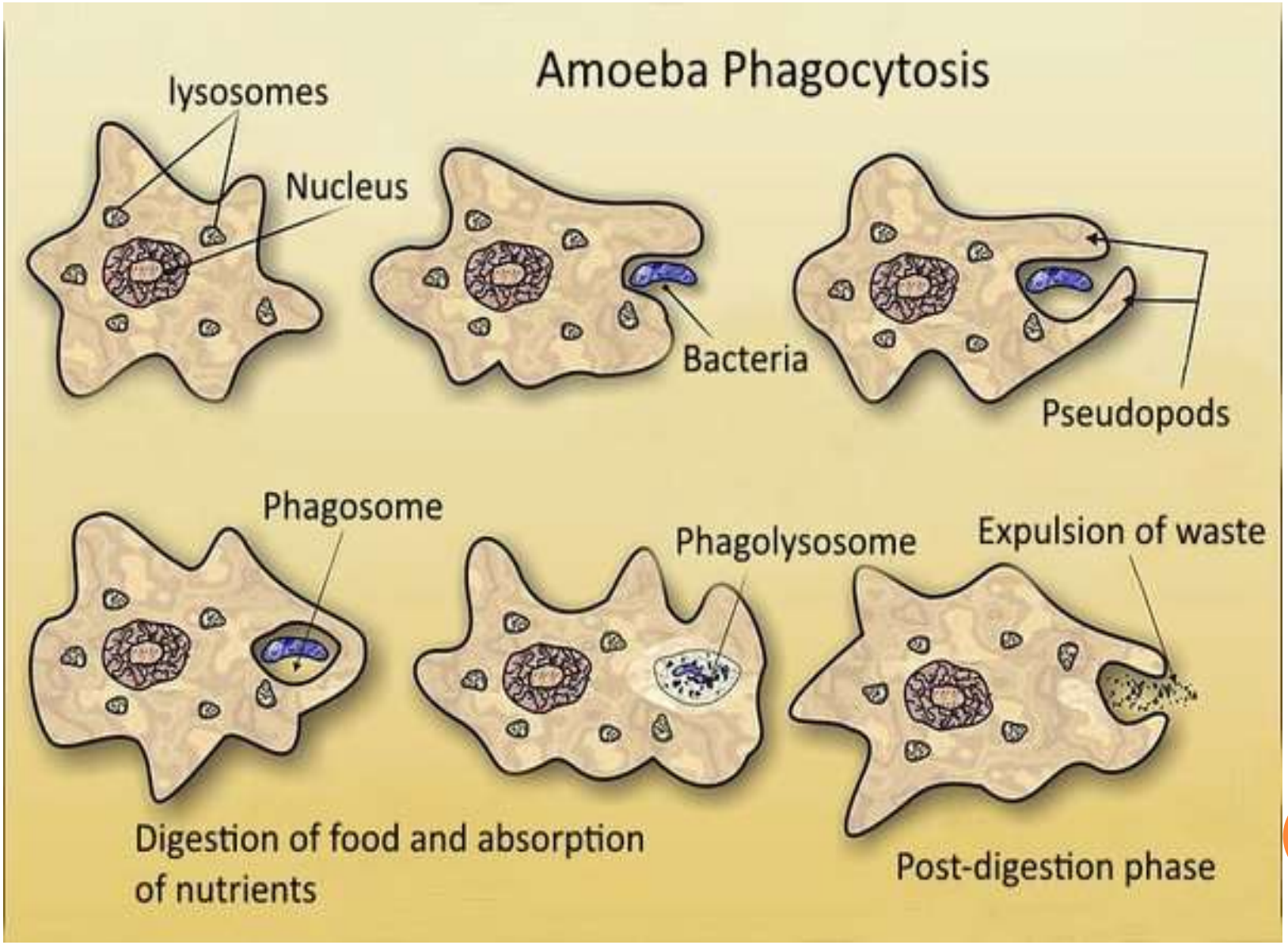
- Intracellular

- Extracellular

Kinds of digestion – Intracellular

- Intracellular digestion is a process in which cells break down complex molecules into simpler ones within their own cytoplasm. This is achieved through the use of enzymes that are contained within organelles called lysosomes.
- **Lysosomes**:
- Lysosomes are membrane-bound organelles filled with hydrolytic enzymes capable of breaking down all types of biological polymers—proteins, nucleic acids, carbohydrates, and

Intracellular Digestion : Eg. Amoeba



Intracellular Digestion Process

1. **Endocytosis**:

A. Phagocytosis:

- Large particles such as bacteria are engulfed by the cell membrane.
- The membrane pinches off to form a phagosome containing the particle.

B. **Pinocytosis**:

- Small vesicles containing extracellular fluid and dissolved substances are formed by the invagination of the cell membrane.n

2. **Fusion with Lysosome**:

- The phagosome or pinocytic vesicle fuses with a lysosome, forming a phagolysosome or endolysosome, respectively.

- Lysosomes contain hydrolytic enzymes (shown as small, colored dots) that can break down various macromolecules.

3. **Digestion**:

- Inside the lysosome, hydrolytic enzymes break down macromolecules into their basic building blocks (amino acids, sugars, fatty acids).

- These simpler molecules are then transported out of the lysosome into the cytoplasm for reuse by the cell.

4. Exocytosis:

- Undigested residues are expelled from the cell via exocytosis, where the residual body fuses with the cell membrane and releases its contents outside the cell.

Extracellular digestion:

Extracellular digestion involves the breakdown of complex macromolecules into simpler substances outside the cells.

Mechanism:

- **Secretion of Enzymes**: Cells secrete digestive enzymes into the extracellular environment.
- **Hydrolysis**: Enzymes catalyze the breakdown of macromolecules (proteins, polysaccharides, lipids, and nucleic acids) into their monomeric units (amino acids, monosaccharides, fatty acids, and nucleotides).
- **Absorption**: The resulting small molecules are then absorbed by the cells through the cell membrane.

EXAMPLES:

Extracellular digestion (by fungi)

FUNGI

- Sedentary heterotrophs living in or on food supply
- Saprophytes/parasites
- No internal cavity → release digestive enzymes

Food

↓

Enzymatic hydrolysis outside cells

↓

Absorption by cells across body surface

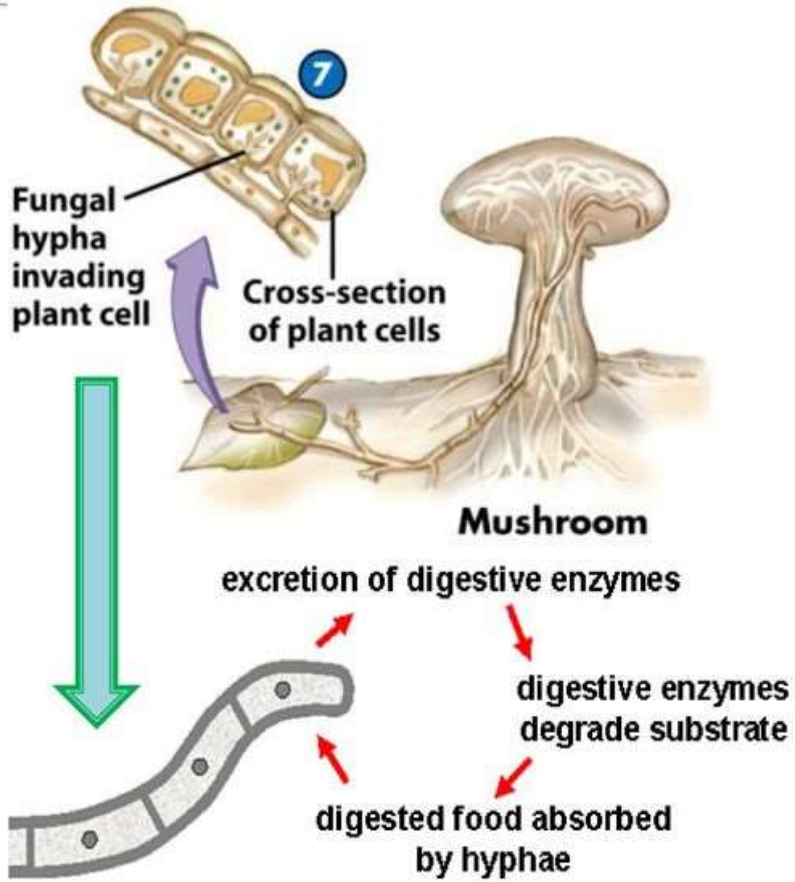


Image from http://www.aber.ac.uk/fungi/graffeg/decomp/digestion-by-hypha.jpg

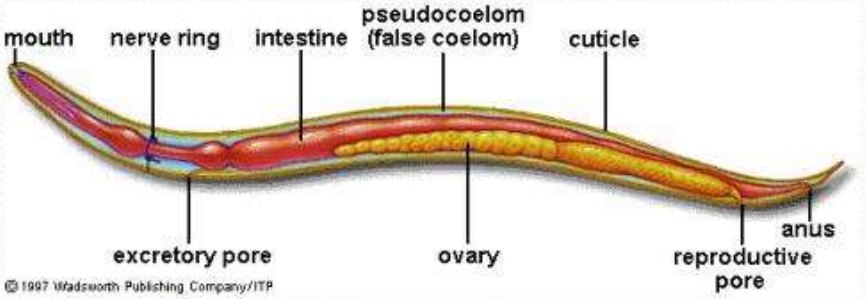
Mechanism:

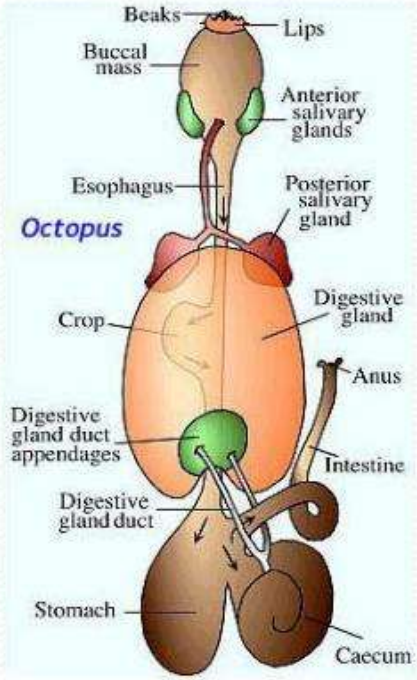
- **Enzyme Secretion**: Fungi release various hydrolytic enzymes, such as proteases, lipases, amylases, and cellulases, into their external environment.
- **Hydrolysis**: These enzymes catalyze the breakdown of macromolecules (proteins, lipids, carbohydrates, and cellulose) into their monomeric units (amino acids, fatty acids, sugars, and glucose).
- **Absorption**: The resulting small molecules are then absorbed through the fungal cell wall and membrane into the cytoplasm where they can be utilized for growth and metabolism.

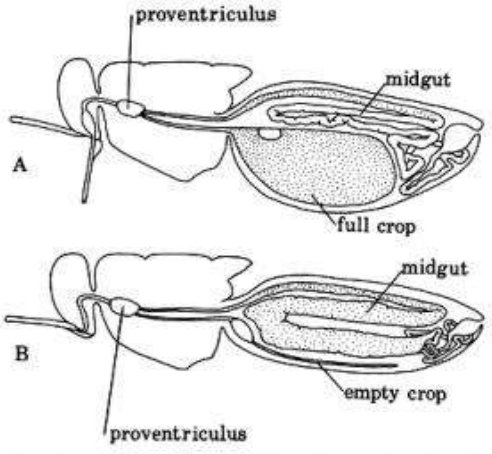
- In **Annelids,**

Digestive Systems

- Complete
  - Annelids, mollusks, arthropods, vertebrates, etc. (most animals)
  - Two openings (mouth & anus)
  - Different regions w/ specialized function
  - Digestion primarily extracellular



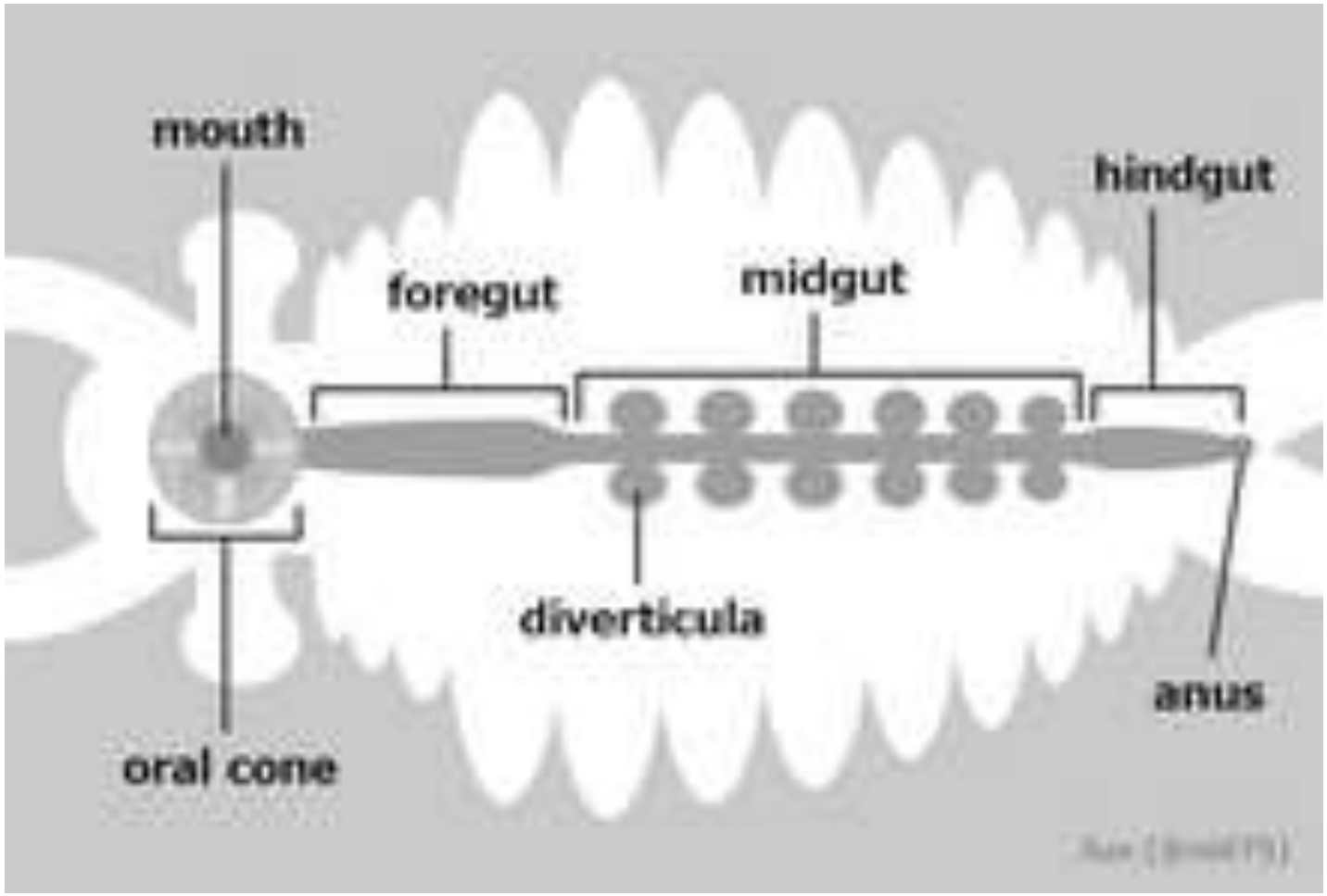




Digestive Process:

- **Ingestion**: Food enters through the mouth and is taken into the pharynx, which acts as a muscular pump.
- **Storage and Grinding**:
  - **Crop**: The food is temporarily stored in the crop.
  - **Gizzard**: The food then moves to the gizzard, where it is mechanically ground into smaller particles with the help of ingested grit and muscular contractions.
- **Chemical Digestion**:
  - **Intestine**: The finely ground food moves into the intestine, where it is mixed with digestive enzymes. These enzymes, secreted by the intestinal walls, break down complex molecules (proteins, carbohydrates, and fats) into simpler, absorbable forms (amino acids, sugars, and fatty acids).
- **Absorption**: The digested nutrients are absorbed through the walls of the intestine into the bloodstream, which distributes them throughout the body.
- **Egestion**: Undigested waste is expelled through the anus as castings.

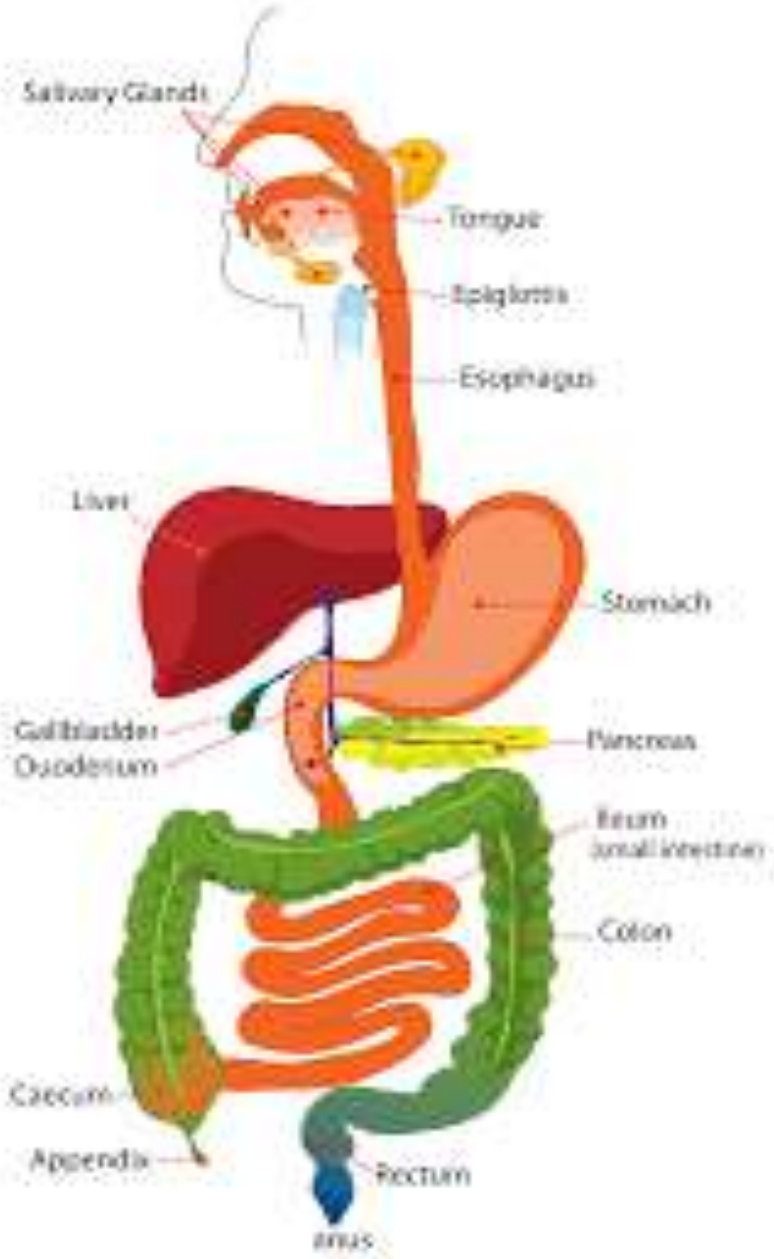
In Arthropods



Digestive Process:

- **Ingestion**: Food is taken in through the mouth.
- **Foregut**:
  - **Mouthparts**: Specialized for different feeding habits (e.g., chewing, sucking, or piercing).
  - **Esophagus**: Food passes through the esophagus to the crop or stomach.
  - **Crop**: Stores food temporarily.
  - **Proventriculus (if present)**: May have grinding functions, similar to a gizzard in other organisms.
- **Midgut**:
  - **Stomach**: Food is mixed with digestive enzymes.
  - **Digestive Enzymes**: Secreted by the midgut walls or associated glands (e.g., salivary glands, hepatopancreas in crustaceans) to break down complex molecules (proteins, carbohydrates, and fats) into simpler, absorbable forms.
- **Hindgut**:
  - **Absorption**: Nutrients absorbed through the walls of the midgut into the hemolymph (the arthropod equivalent of blood).
  - **Waste Formation**: Remaining undigested material moves into the hindgut, where water and salts may be reabsorbed.
  - **Egestion**: Waste is expelled through the anus.

In Humans,


Salivary Glands
Tongue
Epiglottis
Esophagus
Liver
Stomach
Gallbladder
Duodenum
Pancreas
Ileum
Colon
Caecum
Appendix
Rectum
Anus

Digestive Process:

- **Ingestion**:
  - Food is taken into the mouth where mechanical and chemical digestion begins.
- **Oral Cavity**:
  - **Mechanical Digestion**: Teeth break down food into smaller pieces.
  - **Chemical Digestion**: Salivary glands secrete saliva containing amylase, which begins the breakdown of starch into maltose.
- **Pharynx and Esophagus**:
  - Food is swallowed and transported to the stomach via peristalsis.
- **Stomach**:
  - **Mechanical Digestion**: The stomach churns food, mixing it with gastric juice to form chyme.
  - **Chemical Digestion**: Gastric glands secrete hydrochloric acid (HCl) and pepsinogen (converted to pepsin), which break down proteins into peptides.

- **Small Intestine**:
  - **Duodenum**: Chyme mixes with bile from the liver and digestive enzymes from the pancreas.
    - **Bile**: Emulsifies fats, breaking them into smaller droplets for easier digestion by lipases.
    - **Pancreatic Enzymes**: Include amylase (carbohydrates), lipase (fats), and proteases like trypsin and chymotrypsin (proteins).
  - **Jejunum and Ileum**: Further digestion and nutrient absorption occur. Intestinal enzymes (maltase, sucrase, lactase) complete the breakdown of disaccharides into monosaccharides.
- **Absorption**:
  - Nutrients (amino acids, simple sugars, fatty acids) are absorbed through the intestinal villi into the bloodstream and transported to cells.
- **Large Intestine**:
  - Water and electrolytes are reabsorbed.
  - The remaining undigested material is compacted into feces.
- **Egestion**:
  - Feces are expelled from the body through the rectum and anus.

6. Lungs:

- Two large, spongy organs located in the thoracic cavity.
- The right lung has three lobes, and the left lung has two lobes.
- Each lung is surrounded by a double-layered membrane called the pleura, which reduces friction during breathing.

7. Alveoli:

- Tiny air sacs at the ends of the bronchioles where gas exchange occurs.
- Each alveolus is surrounded by a network of capillaries.
- Oxygen diffuses from the alveoli into the blood, and carbon dioxide diffuses from the blood into the alveoli to be exhaled.

8. Diaphragm and Intercostal Muscles:

- The diaphragm is a dome-shaped muscle at the base of the lungs that plays a crucial role in breathing.

- Intercostal muscles are located between the ribs and assist in expanding and contracting the thoracic cavity during breathing.

Mechanism of Respiration in man

- Respiration in humans involves two main processes: external respiration (breathing) and internal respiration (cellular respiration). Here's a detailed explanation of these mechanisms:

1. External Respiration (Breathing)

External respiration involves the exchange of gases between the atmosphere and the blood. It consists of two phases: inhalation and exhalation.

Inhalation

Inspiration

- **Diaphragm and Intercostal Muscles:** During inhalation, the diaphragm (a dome-shaped muscle at the base of the lungs) contracts and moves downward. The external intercostal muscles (located between the ribs) contract, pulling the ribs upward and outward.
- **Thoracic Cavity Expansion:** The contraction of these muscles increases the volume of the thoracic cavity.
- **Pressure Gradient:** As the thoracic cavity expands, the pressure inside the lungs (intrapulmonary pressure) decreases below the atmospheric pressure. This pressure gradient causes air to flow into the lungs.

Exhalation

Expiration

- **Muscle Relaxation:** During exhalation, the diaphragm and intercostal muscles relax. The diaphragm moves upward to its dome-shaped position, and the ribs move downward and inward.
- **Thoracic Cavity Reduction:** The relaxation of these muscles decreases the volume of the thoracic cavity.
- **Pressure Gradient:** As the thoracic cavity volume decreases, the intrapulmonary pressure increases above atmospheric pressure, causing air to flow out of the lungs.

2. Internal Respiration (Cellular Respiration)

Internal respiration involves the exchange of gases between the blood and the body's cells. It includes two main processes:

Gas Exchange at the Alveoli:

- **Oxygen Transport:** Oxygen from the inhaled air diffuses across the thin walls of the alveoli (tiny air sacs in the lungs) and enters the surrounding capillaries. Hemoglobin in red blood cells binds to the oxygen, forming oxyhemoglobin.
- **Carbon Dioxide Transport:** Carbon dioxide, a waste product of cellular metabolism, diffuses from the blood into the alveoli to be exhaled.

Gas Exchange at the Tissues:

- **Oxygen Delivery:** Oxyhemoglobin travels through the bloodstream to the body's tissues. Oxygen is released from hemoglobin and diffuses into the cells.

- **Carbon Dioxide Removal:** Carbon dioxide produced by cellular respiration diffuses from the cells into the blood. It is transported back to the lungs in various forms, primarily as bicarbonate ions (HCO_3^-).

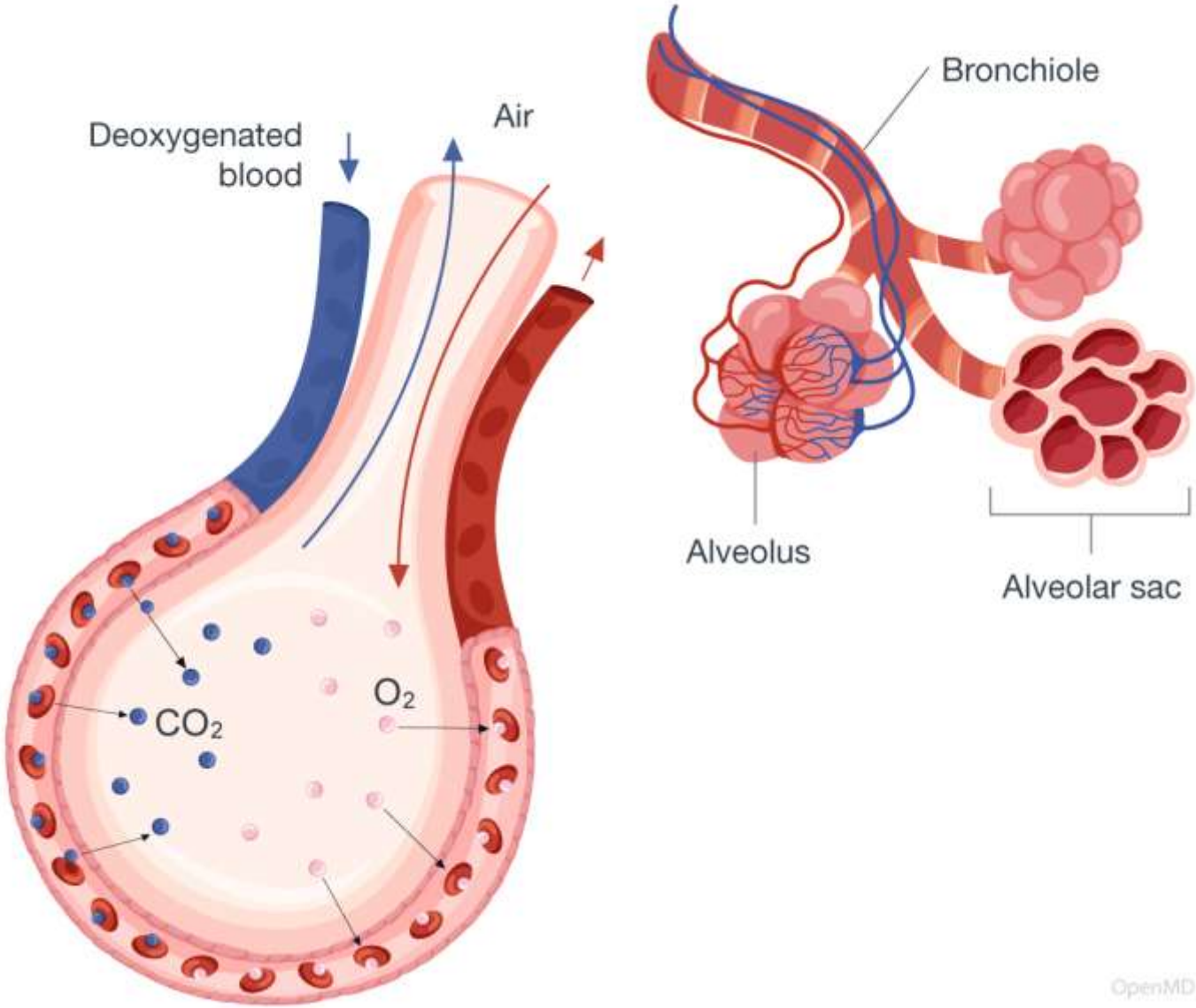
Control of Respiration

- Respiration is controlled by the respiratory centers in the brainstem (medulla oblongata and pons), which respond to changes in blood levels of carbon dioxide, oxygen, and pH. Chemoreceptors in the aortic and carotid bodies also detect changes in blood gases and send signals to the brainstem to adjust the rate and depth of breathing accordingly.
- This coordination ensures that the body maintains proper levels of oxygen and carbon dioxide, enabling efficient cellular function and energy production.

Transport of O2 and CO2

1. Oxygen Uptake in the Lungs:

- **Alveolar Gas Exchange:** Oxygen from inhaled air diffuses across the thin alveolar walls and into the pulmonary capillaries due to the concentration gradient (high oxygen concentration in the alveoli, low in the blood).
- **Hemoglobin Binding:** Once in the blood, oxygen binds to hemoglobin molecules within red blood cells. Hemoglobin consists of four heme groups, each capable of binding one oxygen molecule, forming oxyhemoglobin (HbO_2).

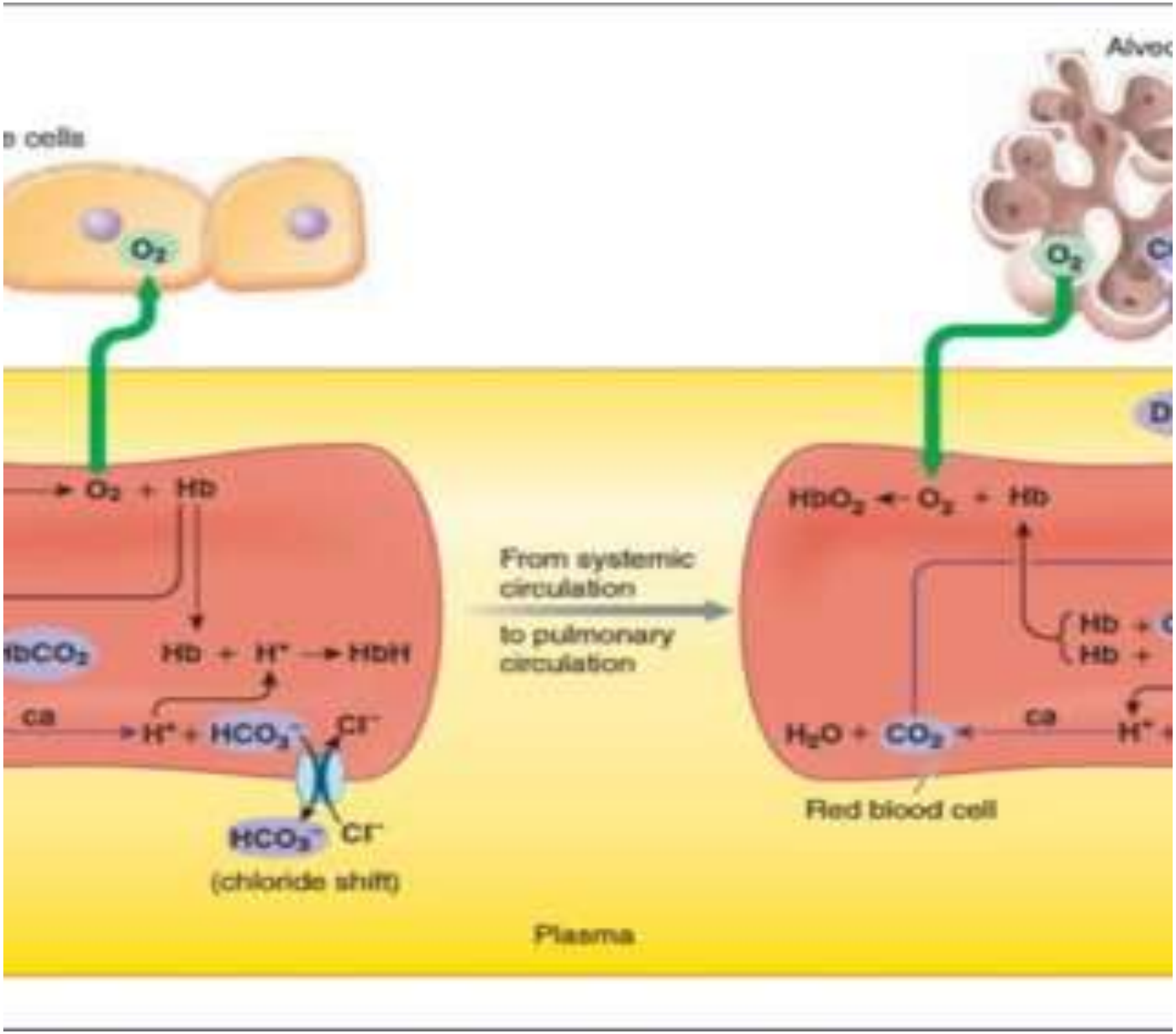

Deoxygenated blood
Air
CO_2
O_2
Bronchiole
Alveolus
Alveolar sac
OpenMD

2. Oxygen Transport in the Blood:

- **Oxyhemoglobin:** About 98.5% of oxygen is transported bound to hemoglobin. This binding is reversible, allowing oxygen to be released where it is needed.
- **Dissolved Oxygen:** A small amount (about 1.5%) of oxygen is transported dissolved in the plasma.

3. Oxygen Delivery to Tissues:

- **Release from Hemoglobin:** As blood circulates through the body's tissues, the lower partial pressure of oxygen in the tissues causes hemoglobin to release its bound oxygen.
- **Diffusion into Cells:** Oxygen diffuses from the blood into the interstitial fluid and then into cells, where it is used for cellular respiration to produce energy (ATP).


cells
O_2
O_2 + Hb
HbCO$_2$
Hb + H^+ → HbH
ca
H^+ + HCO_3^-
Cl^-
HCO_3^-
Cl^-
(chloride shift)
From systemic circulation
to pulmonary circulation
HbO_2 ← O_2 + Hb
Hb +
Hb +
H_2O + CO_2 ←
ca
H^+
Red blood cell
Plasma

Transport of Carbon Dioxide

Carbon Dioxide Production in Tissues:

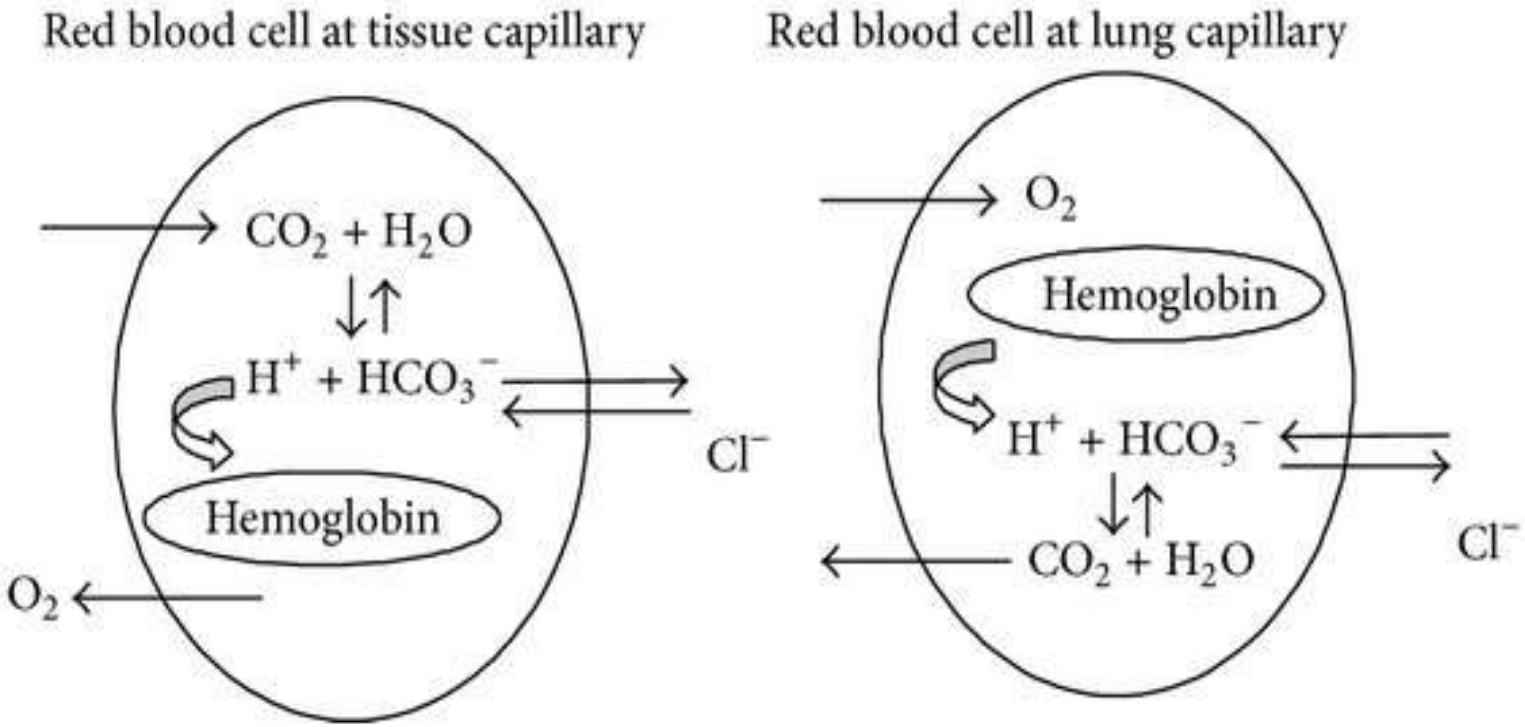
- **Cellular Respiration:** Carbon dioxide is produced as a waste product of cellular respiration, primarily in the mitochondria of cells.

2. Carbon Dioxide Transport in the Blood:

- **Dissolved in Plasma:** About 7-10% of carbon dioxide is transported dissolved in the plasma.
- **Bound to Hemoglobin:** Approximately 20-23% of carbon dioxide binds to hemoglobin, forming carbaminohemoglobin ($HbCO_2$). This binding is different from the oxygen-binding site.
- **As Bicarbonate Ions:** The majority (about 70%) of carbon dioxide is transported as bicarbonate ions (HCO_3^-). This occurs through the following reaction in red blood cells, catalyzed by the enzyme carbonic anhydrase:
- $CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow HCO_3^- + H^+$
  - Carbon dioxide diffuses into red blood cells and reacts with water to form carbonic acid (H_2CO_3), which quickly dissociates into bicarbonate ions and hydrogen ions (H^+).
  - Bicarbonate ions are then transported out of red blood cells into the plasma, while chloride ions (Cl^-) move into red blood cells to maintain electrical neutrality (chloride shift).

3. Carbon Dioxide Release in the Lungs:

- **Reverse Chloride Shift:** In the pulmonary capillaries, bicarbonate ions re-enter red blood cells and recombine with hydrogen ions to form carbonic acid, which is then converted back into carbon dioxide and water.
- **Diffusion into Alveoli:** Carbon dioxide diffuses from the blood into the alveoli due to the concentration gradient (high carbon dioxide concentration in the blood, low in the alveoli) and is then exhaled.


Red blood cell at tissue capillary
$CO_2 + H_2O$
$H^+ + HCO_3^-$
Cl^-
Hemoglobin
O_2
Red blood cell at lung capillary
O_2
Hemoglobin
$H^+ + HCO_3^-$
Cl^-
$CO_2 + H_2O$

Summary

- **Oxygen** is primarily transported bound to hemoglobin as oxyhemoglobin, with a small amount dissolved in plasma. It is released from hemoglobin and diffuses into tissues for cellular respiration.
- **Carbon Dioxide** is transported dissolved in plasma, bound to hemoglobin as carbaminohemoglobin, and primarily as bicarbonate ions. It is converted back to carbon dioxide in the lungs and exhaled.

This efficient transport system ensures that oxygen is delivered to tissues for energy production, and carbon dioxide, a metabolic waste product, is removed from the body.

THANK YOU