Systemic 1[C]

Chapter 14: NEED FOR A TRANSPORT SYSTEM • MECHANISMS

Learning Objectives: Upon completion of this chapter, students should be able to:

- Explain the need for transport systems in multicellular organisms.
- Differentiate between unicellular and multicellular transport mechanisms.
- Describe open and closed circulatory systems in animals.
- Detail the structure and function of the human circulatory system (heart, blood vessels, blood).
- Explain blood as a transport medium.
- Outline mammalian double circulation.
- Discuss transport in plants (xylem, phloem).
- Describe the processes of transpiration and translocation.

14.1 Need for a Transport System

- **Unicellular and Simple Multicellular Organisms:**
  - In single-celled organisms (e.g., *Amoeba*, *Paramecium*, bacteria, yeast) and very simple multicellular organisms (e.g., *Hydra*, flatworms), transport of substances (nutrients, gases, waste) occurs primarily by **diffusion** and **active transport** directly across the cell surface or through simple internal cavities.
  - This is efficient because these organisms have a large surface area to volume ratio and a short diffusion distance to all cells.
- **Complex Multicellular Organisms:**
  - As organisms become larger and more complex, their cells are not in direct contact with the external environment.
  - The surface area to volume ratio becomes too small for simple diffusion to meet the needs of all cells.
  - Therefore, specialized internal **transport systems** (circulatory systems in animals, vascular tissues in plants) are required to efficiently deliver nutrients and oxygen to, and remove waste products from, all cells in the body.

14.2 Transport in Animals: Circulatory Systems

- **A. Open Circulatory System:**
  - **Description:** Blood (more accurately, hemolymph) is pumped by a heart into body cavities (sinuses) where it directly bathes the organs and tissues.

- **No Capillaries:** There are no fine capillaries connecting arteries and veins; blood is not always contained within vessels.
- **Examples:** Most invertebrates like arthropods (insects, crustaceans) and molluscs.
- **Advantages:** Less energy required, lower pressure.
- **Disadvantages:** Less efficient at delivering oxygen and nutrients rapidly, slower flow.

- **B. Closed Circulatory System:**
  - **Description:** Blood is always confined within a continuous network of vessels (arteries, capillaries, veins) and is pumped by a heart.
  - **No Direct Contact:** Blood does not directly bathe the organs; substances diffuse between blood and tissue fluid across capillary walls.
  - **Examples:** All vertebrates (fish, amphibians, reptiles, birds, mammals) and some invertebrates (e.g., earthworms, squids, octopuses).
  - **Advantages:** More efficient at delivering oxygen and nutrients rapidly, higher pressure, faster flow, precise control of blood flow to different organs.
  - **Disadvantages:** Requires more energy to maintain high pressure.
- **C. Human Circulatory System (Mammalian Double Circulation):**
  - **Type:** Closed and double circulatory system.
  - **Double Circulation:** Blood passes through the heart twice in one complete circuit of the body.
    1. **Pulmonary Circulation:** Carries deoxygenated blood from the heart to the lungs and oxygenated blood back to the heart.
    2. **Systemic Circulation:** Carries oxygenated blood from the heart to all body tissues and deoxygenated blood back to the heart.
  - **Advantages of Double Circulation:**
    - Maintains high pressure to deliver oxygenated blood efficiently to all body parts.
    - Separates oxygenated and deoxygenated blood, preventing mixing and maximizing oxygen delivery.
- **D. Components of the Human Circulatory System:**
  1. **Heart:** A muscular, four-chambered pump (two atria, two ventricles) that drives blood through the vessels.
     - **Function:** Pumps deoxygenated blood to the lungs and oxygenated blood to the rest of the body.
  2. **Blood Vessels:**
     - **Arteries:** Carry oxygenated blood *away* from the heart to the body (except pulmonary artery which carries deoxygenated blood to lungs).
       - **Characteristics:** Thick, muscular, elastic walls to withstand high pressure.
       - **Arterioles:** Smaller arteries leading to capillaries.
     - **Capillaries:** Microscopic, thin-walled vessels (one cell thick) forming networks within tissues.
       - **Function:** Site of exchange of gases, nutrients, hormones, and waste products between blood and tissue cells.
       - **Characteristics:** Very narrow lumen, large total surface area for efficient exchange.
     - **Veins:** Carry deoxygenated blood *back* to the heart from the body (except pulmonary vein which carries oxygenated blood from lungs).

        - **Characteristics:** Thinner, less muscular walls than arteries, contain valves to prevent backflow of blood due to lower pressure.
        - **Venules:** Small veins collecting blood from capillaries.
    3. **Blood:** A specialized connective tissue acting as the transport medium.
        - **Components and Functions:**
            - **Plasma (55%):** Liquid matrix; transports water, dissolved nutrients (glucose, amino acids, fatty acids), hormones, antibodies, salts, and waste products (urea, CO_2).
            - **Red Blood Cells (Erythrocytes):** Biconcave discs, no nucleus in mature cells, contain hemoglobin.
                - **Function:** Transport oxygen (bound to hemoglobin) from lungs to tissues; also transport some carbon dioxide.
            - **White Blood Cells (Leukocytes):** Larger than red blood cells, have a nucleus involved in the immune system.
                - **Function:** Defend the body against pathogens (e.g., phagocytosis by neutrophils and macrophages, antibody production by lymphocytes).
            - **Platelets (Thrombocytes):** Cell fragments.
                - **Function:** Involved in blood clotting to prevent blood loss.

14.3 Transport in Plants: Vascular Tissues

Plants have specialized vascular tissues for long-distance transport of water, minerals, and manufactured food.

- **A. Xylem:**
    - **Structure:** Composed mainly of dead cells (xylem vessels and tracheids) that form continuous tubes. Walls are lignified (thickened with lignin) for strength.
    - **Function:** Transports **water and dissolved mineral salts** from the roots, through the stem, to the leaves. Provides mechanical support to the plant.
    - **Direction of Flow:** Unidirectional (upwards only).
- **B. Phloem:**
    - **Structure:** Composed of living cells (sieve tubes, companion cells). Sieve tubes have perforated end walls (sieve plates).
    - **Function:** Transports manufactured food (sugars, primarily sucrose) from the leaves (sites of photosynthesis) to other parts of the plant where it is needed for growth or storage (e.g., roots, fruits, growing tips).
    - **Direction of Flow:** Bidirectional (up and down).
- **C. Mechanisms of Transport in Plants:**
    1. **Transpiration:**
        - **Definition:** The loss of water vapor from the aerial parts of a plant, primarily through the stomata on leaves.
        - **Mechanism:** Water evaporates from the moist surfaces of mesophyll cells in the leaves, creating a transpiration pull (tension). This pull, along with cohesion (water molecules sticking together) and adhesion (water sticking to xylem walls), draws water upwards through the xylem vessels from the roots.
        - **Importance:**
            - Pulls water and dissolved minerals from roots to leaves.
            - Cools the plant through evaporative cooling.

        - Maintains turgor pressure in cells.
    - **Factors Affecting Rate:** Temperature (higher = faster), humidity (lower = faster), wind speed (higher = faster), light intensity (higher = faster, due to stomata opening).
2. **Translocation:**
    - **Definition:** The transport of manufactured food (sucrose) from the leaves (source) to other parts of the plant where it is needed (sink) via the phloem.
    - **Mechanism (Pressure Flow Hypothesis):** Sugars are actively loaded into sieve tubes at the source, increasing solute concentration and drawing water in by osmosis. This creates high pressure. At the sink, sugars are unloaded, reducing pressure, and water moves out. The pressure gradient drives the mass flow of sap.
    - **Importance:** Distributes energy and building blocks throughout the plant.

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