Cell

Chapter 10: CELL (1): LIVING UNIT • STRUCTURE

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

- Define a cell as the basic unit of life.
- Explain the concept of organisms as living units.
- Differentiate between unicellular and multicellular organisms.
- Describe the structure and function of major cell organelles.
- Compare and contrast plant and animal cells.
- Understand the organization of cells into tissues, organs, and systems.
- Explain cell theory and its principles.
- Discuss the nature and states of matter in relation to biological processes.
- Describe the processes of diffusion, osmosis, and active transport across the plasma membrane.

10.1 The Cell: The Basic Unit of Life

- **Definition:** The cell is the fundamental structural and functional unit of all known living organisms. It is the smallest unit of life that can replicate independently.
- **Organisms as Living Units:** Every living organism, whether simple or complex, is composed of one or more cells. Cells carry out all the necessary life processes, such as metabolism, growth, response to stimuli, and reproduction.
- **Unicellular Organisms:** Organisms composed of a single cell that performs all life functions.
    - *Examples:* Bacteria, Amoeba, Paramecium, yeast, some algae.
- **Multicellular Organisms:** Organisms composed of many cells that work together, often specialized for different functions.
    - *Examples:* Plants, animals, most fungi, most algae.
    - **Cell Specialization/Differentiation:** In multicellular organisms, cells become specialized in structure and function to perform specific tasks (e.g., muscle cells for contraction, nerve cells for transmitting signals).

10.2 Cell Theory and Structure

- **Cell Theory:** A foundational concept in biology, stating three main principles:
    1. All living organisms are composed of one or more cells.
    2. The cell is the basic unit of structure and organization in organisms.
    3. All cells arise from pre-existing cells (cell division).
- **General Cell Structure (Common to most eukaryotic cells):**
    - **Plasma Membrane (Cell Membrane):**
        - **Structure:** A thin, flexible, selectively permeable boundary surrounding the cytoplasm. Composed primarily of a phospholipid bilayer with embedded proteins (fluid mosaic model).
        - **Function:** Controls the movement of substances into and out of the cell; involved in cell recognition and communication.
    - **Cytoplasm:**
        - **Structure:** The jelly-like substance that fills the cell, enclosed by the plasma membrane. It consists of the **cytosol** (the fluid portion) and various **organelles** suspended within it.
        - **Function:** Site of many metabolic reactions; holds organelles in place.
    - **Nucleus (Eukaryotic Cells):**
        - **Structure:** A large, spherical organelle enclosed by a double membrane (nuclear envelope) with nuclear pores. Contains the cell's genetic material (DNA) organized into chromosomes, and a nucleolus (involved in ribosome synthesis).
        - **Function:** Controls all cell activities; stores genetic information; site of DNA replication and RNA transcription.
    - **Mitochondria:**
        - **Structure:** Oval-shaped organelles with a double membrane; the inner membrane is folded into cristae to increase surface area.
        - **Function:** Powerhouses of the cell; site of aerobic cellular respiration, where glucose is broken down to release ATP (energy).
    - **Ribosomes:**
        - **Structure:** Tiny organelles made of ribosomal RNA and protein. Can be free in the cytoplasm or attached to the endoplasmic reticulum.
        - **Function:** Site of protein synthesis (translation of mRNA into protein).
    - **Endoplasmic Reticulum (ER):**
        - **Structure:** A network of interconnected membranes forming sacs and tubules throughout the cytoplasm.
        - **Types & Function:**
            - **Rough ER (RER):** Studded with ribosomes. Involved in the synthesis, folding, modification, and transport of proteins destined for secretion or insertion into membranes.
            - **Smooth ER (SER):** Lacks ribosomes. Involved in lipid synthesis, detoxification of drugs and poisons, and storage of calcium ions.
    - **Golgi Apparatus (Golgi Complex/Body):**
        - **Structure:** A stack of flattened membrane-bound sacs (cisternae).
        - **Function:** Modifies, sorts, and packages proteins and lipids synthesized in the ER into vesicles for secretion or delivery to other organelles.

- **Lysosomes (Animal Cells):**
  - **Structure:** Small, membrane-bound sacs containing digestive enzymes.
  - **Function:** Break down waste materials, cellular debris, and foreign invaders (e.g., bacteria); involved in programmed cell death (autolysis).
- **Vacuoles:**
  - **Structure:** Membrane-bound sacs for storage.
  - **Function:**
    - **Large Central Vacuole (Plant Cells):** Stores water, nutrients, waste products; maintains turgor pressure against the cell wall.
    - **Small Vacuoles (Animal Cells):** Involved in temporary storage or transport.
- **Chloroplasts (Plant Cells & some Algae):**
  - **Structure:** Oval-shaped organelles with a double membrane; contain stacks of thylakoids called grana, embedded in a fluid stroma. Contain chlorophyll.
  - **Function:** Site of photosynthesis, converting light energy into chemical energy (glucose).
- **Cell Wall (Plant Cells, Fungi, Bacteria, Algae):**
  - **Structure:** A rigid outer layer outside the plasma membrane. In plants, primarily made of cellulose.
  - **Function:** Provides structural support, protection, and prevents excessive water uptake (bursting).

10.3 Organization of Multicellular Organisms

Multicellular organisms exhibit a hierarchy of organization:

1. **Cells:** The basic units (e.g., muscle cell, nerve cell).
2. **Tissues:** A group of similar cells that work together to perform a specific function (e.g., muscle tissue, nervous tissue, epidermal tissue in plants).
3. **Organs:** A structure made up of different types of tissues that work together to perform a particular function (e.g., heart, stomach, lung, leaf, root).
4. **Organ Systems:** A group of organs that cooperate to perform major functions of the body (e.g., digestive system, circulatory system, respiratory system).
5. **Organism:** A complete living being made up of various organ systems working together.

10.4 Nature and States of Matter

While a chemistry concept, it relates to the environment within and around cells.

- **Matter:** Anything that has mass and takes up space.
- **States of Matter:**
  - **Solid:** Definite shape and volume, particles tightly packed.
  - **Liquid:** Definite volume but takes the shape of its container, particles loosely packed.
  - **Gas:** No definite shape or volume, particles widely spaced and move randomly.
- **Biological Relevance:** Cellular processes occur in an aqueous (liquid) environment. Gases (like oxygen and carbon dioxide) are exchanged, and solids (like nutrients) are transported.

10.5 Transport Across the Plasma Membrane

The plasma membrane is selectively permeable, regulating the movement of substances.

- **1. Diffusion:**
  - **Definition:** The net movement of particles (atoms, ions, molecules) from a region of higher concentration to a region of lower concentration, down a concentration gradient.
  - **Mechanism:** Passive process, requires no energy from the cell. Driven by the random motion of particles. Continues until equilibrium is reached.
  - **Biological Relevance:**
    - Movement of oxygen from the alveoli (lungs) into blood.
    - Movement of carbon dioxide from blood into alveoli.
    - Absorption of digested food molecules (e.g., fatty acids, glycerol) into cells.
    - Uptake of mineral ions by plant roots.
    - Diffusion of water vapor from leaves during transpiration.
  - **Factors Affecting Rate:** Concentration gradient (steeper = faster), temperature (higher = faster), surface area (larger = faster), diffusion distance (shorter = faster), size of molecules (smaller = faster).
- **2. Osmosis:**
  - **Definition:** The net movement of water molecules from a region of higher water potential (more dilute solution) to a region of lower water potential (more concentrated solution) across a selectively permeable membrane.
  - **Mechanism:** Passive process, no energy required. Water moves to equalize solute concentrations.
  - **Biological Relevance:**
    - **Plant Cells:**
      - **Hypotonic Solution:** Water enters the cell, causing the vacuole to swell and the cell membrane to press against the cell wall (turgid). This maintains turgor pressure, providing support to plants.
      - **Isotonic Solution:** No net movement of water; cell remains flaccid.
      - **Hypertonic Solution:** Water leaves the cell, causing the protoplast to shrink away from the cell wall (plasmolysis); plant wilts.
    - **Animal Cells (e.g., Red Blood Cells):**
      - **Hypotonic Solution:** Water enters, cell swells and may burst (hemolysis) due to lack of a cell wall.
      - **Isotonic Solution:** No net movement of water; cell maintains normal shape.
      - **Hypertonic Solution:** Water leaves, cell shrinks and becomes crenated.
  - **Water Potential:** A measure of the potential energy of water in a system. Pure water has the highest water potential (0 kPa). Adding solutes lowers water potential.
- **3. Active Transport:**
  - **Definition:** The movement of particles from a region of lower concentration to a region of higher concentration, *against* a concentration gradient.
  - **Mechanism:** Requires energy (ATP) from the cell, and specific protein carriers (pump proteins) in the plasma membrane.

- **Biological Relevance:**
  - Absorption of mineral ions by plant root hair cells (even when soil concentration is lower).
  - Absorption of glucose and amino acids from the small intestine into the blood (even when blood concentration is higher).
  - Sodium-potassium pump in nerve cells, maintaining membrane potential.
  - Reabsorption of useful substances in kidney tubules.