Cell

Chapter 11: CELL (2): PROPERTIES AND FUNCTIONS

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

- Explain the fundamental properties and functions common to all cells.
- Describe cellular requirements for nutrition, including inorganic and organic nutrients.
- Differentiate between aerobic and anaerobic respiration (catabolism).
- Explain the process of excretion in cells.
- Discuss the concept of growth and cell division (mitosis).
- Understand the importance of irritability/response to external stimuli.
- Describe different types of movement in cells.
- Explain asexual and sexual reproduction at the cellular level.
- Outline the processes of budding, vegetative propagation, and meiosis.

11.1 Fundamental Properties and Functions of Cells

Despite their diversity, all living cells share fundamental properties:

1. **Nutrition:** The process of obtaining and utilizing nutrients for energy and raw materials.
2. **Respiration:** The process of breaking down organic molecules to release energy (ATP).
3. **Excretion:** The removal of metabolic waste products.
4. **Growth:** An irreversible increase in size and complexity.
5. **Reproduction:** The ability to produce new individuals.
6. **Irritability/Sensitivity:** The ability to detect and respond to changes in the environment (stimuli).
7. **Movement:** The ability to change position or shape, either of the entire cell or internal components.

11.2 Cellular Nutritional Requirements

Cells require various nutrients to survive and function:

- **Inorganic Nutrients:**
    - **Water (H_2O):** Universal solvent, medium for reactions, transport.
    - **Mineral Salts:** Ions like calcium (Ca^{2+}), potassium (K^+), sodium (Na^+), phosphate (PO_4^{3-}), nitrate (NO_3^-), iron (Fe^{2+}), etc., essential for various metabolic processes, structural components, and enzyme cofactors.
    - **Carbon Dioxide (CO_2):** Raw material for photosynthesis in autotrophic cells.

- **Organic Nutrients:**
    - **Carbohydrates:** Primary energy source (e.g., glucose).
    - **Proteins:** Building blocks (amino acids) for enzymes, structural components, transport.
    - **Fats/Lipids:** Energy storage, membrane components, insulation.
    - **Vitamins:** Organic compounds required in small amounts for specific metabolic functions.

11.3 Cellular Respiration (Catabolism)

Respiration is the process by which cells break down organic molecules (like glucose) to release energy in the form of ATP (Adenosine Triphosphate). This is a catabolic (breaking down) process.

- **A. Aerobic Respiration:**
    - **Definition:** Respiration that requires oxygen. It is the most efficient form of energy release.
    - **Location:** Begins in the cytoplasm, completed in the mitochondria.
    - **Word Equation:** Glucose + Oxygen \rightarrow Carbon Dioxide + Water + Large amount of Energy (ATP)
    - **Chemical Equation:** C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy (30-32 ATP)}
    - **Stages (Briefly):**
        1. **Glycolysis:** Glucose is broken down into pyruvate in the cytoplasm (anaerobic stage).
        2. **Krebs Cycle (Citric Acid Cycle):** Pyruvate derivatives are completely oxidized in the mitochondrial matrix.
        3. **Oxidative Phosphorylation (Electron Transport Chain):** Most ATP is generated using oxygen as the final electron acceptor on the inner mitochondrial membrane.
    - **Relevance:** Occurs in most eukaryotic cells and many prokaryotes, providing energy for all life activities.
- **B. Anaerobic Respiration (Fermentation):**
    - **Definition:** Respiration that occurs in the absence of oxygen. It is less efficient in energy release.
    - **Location:** Cytoplasm only.
    - **Products & Energy:** Varies depending on the organism.
        1. **In Animals (e.g., in muscle cells during strenuous exercise):** Glucose \rightarrow Lactic Acid + Small amount of Energy (ATP) C_6H_{12}O_6 \rightarrow 2C_3H_6O_3 + \text{Energy (2 ATP)} *Lactic acid causes muscle fatigue and oxygen debt.*
        2. **In Yeast and Some Bacteria (Alcoholic Fermentation):** Glucose \rightarrow Ethanol + Carbon Dioxide + Small amount of Energy (ATP) C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 + \text{Energy (2 ATP)}
    - **Relevance:** Used by some microorganisms (e.g., yeast in brewing, bacteria in food production), and by muscle cells when oxygen supply is insufficient.

11.4 Excretion

- **Definition:** The process by which metabolic waste products are removed from the body or cell. These wastes are often toxic if allowed to accumulate.
- **Examples of Cellular Waste Products:**
    - **Carbon Dioxide (CO_2):** From respiration, diffuses out of cells.
    - **Urea/Ammonia:** From protein metabolism, diffuse out or are transported away.
    - **Excess Water:** May be removed by contractile vacuoles in some unicellular organisms or excreted by kidneys in multicellular organisms.
    - **Heat:** A by-product of metabolic reactions.
- **Mechanism (Unicellular Organisms):** Waste products simply diffuse across the cell membrane into the surrounding environment. Contractile vacuoles in fresh-water protozoa pump out excess water.

11.5 Growth and Cell Division (Mitosis)

- **Growth:** An irreversible increase in the size, mass, and complexity of an organism, resulting from an increase in the number and/or size of its cells.
- **Cell Division:** The process by which a parent cell divides into two or more daughter cells. It is essential for growth, repair, and reproduction.
- **Mitosis:**
    - **Definition:** A type of cell division that results in two genetically identical daughter cells, each with the same number of chromosomes as the parent cell.
    - **Location:** Occurs in somatic (body) cells for growth and repair.
    - **Process (Simplified):**
        1. **Interphase:** Cell grows, DNA replicates, organelles duplicate.
        2. **Prophase:** Chromosomes condense, nuclear envelope breaks down.
        3. **Metaphase:** Chromosomes align at the metaphase plate (equator of the cell).
        4. **Anaphase:** Sister chromatids separate and move to opposite poles.
        5. **Telophase:** Chromosomes decondense, nuclear envelopes reform around two new nuclei.
        6. **Cytokinesis:** Cytoplasm divides, forming two separate daughter cells.
    - **Importance:**
        - **Growth:** Increases the number of cells in a multicellular organism.
        - **Repair and Replacement:** Replaces damaged or worn-out cells (e.g., skin cells, blood cells).
        - **Asexual Reproduction:** The basis for asexual reproduction in many unicellular and some multicellular organisms.

11.6 Irritability (Response to External Stimuli)

- **Definition:** The ability of an organism or cell to detect and respond to changes (stimuli) in its internal or external environment. This allows organisms to adapt and survive.
- **Stimuli Examples:** Light, temperature, touch, chemicals, gravity, water.
- **Response Examples:**
    - **Unicellular:** *Amoeba* moving away from a harmful chemical, *Euglena* moving towards light (phototaxis).

- **Multicellular (cellular level):** Nerve cells transmitting signals, muscle cells contracting in response to nerve impulses, plant cells growing towards light (phototropism).

11.7 Movement

- **Definition:** The ability to change position or shape. Can be of the entire organism/cell or internal cellular components.
- **Types of Cellular Movement:**
  - **Amoeboid Movement:** Characterized by the extension and retraction of pseudopods ("false feet") formed by the flowing cytoplasm.
    - *Example: Amoeba*, white blood cells (phagocytosis).
  - **Cilia:** Short, hair-like structures that beat in a coordinated rhythm to propel the cell or move substances across its surface.
    - *Examples: Paramecium* (for movement), ciliated cells lining the human trachea (to sweep mucus).
  - **Flagella:** Long, whip-like appendages that propel the cell through a liquid medium.
    - *Examples:* Bacteria, sperm cells, *Euglena*.
  - **Cytoplasmic Streaming (Cyclosis):** The movement of cytoplasm within a cell, helping to circulate nutrients and organelles.
    - *Example:* Occurs in many plant cells.
  - **Movement of Chromosomes:** During cell division, chromosomes are moved by spindle fibers.

11.8 Reproduction at the Cellular Level

Reproduction is the process by which living organisms produce new individuals of their own kind.

- **A. Asexual Reproduction:**
  - **Definition:** Involves a single parent producing genetically identical offspring (clones) without the fusion of gametes.
  - **Advantages:** Rapid population growth, only one parent needed, efficient in stable environments.
  - **Disadvantages:** Lack of genetic variation, making populations vulnerable to environmental changes.
  - **Types:**
    1. **Binary Fission:** A single parent cell divides into two approximately equal-sized daughter cells.
       - *Examples:* Bacteria, Amoeba, Paramecium.
    2. **Budding:** A new organism develops from an outgrowth or bud due to cell division at one particular site. The bud eventually separates from the parent.
       - *Examples:* Yeast, *Hydra*.
    3. **Spore Formation:** Reproductive cells (spores) are produced and dispersed, each capable of developing into a new individual.
       - *Examples:* Fungi, ferns, mosses.
    4. **Vegetative Propagation (in Plants):** Asexual reproduction from vegetative parts of a plant (roots, stems, leaves) rather than seeds or spores. Produces genetically identical plants.

        - *Examples:*
            - **Stem:** Runners (strawberries), rhizomes (ginger), tubers (potatoes), bulbs (onions), corms (gladioli).
            - **Leaf:** Bryophyllum.
            - **Root:** Sweet potato.
        - *Artificial Methods:* Cuttings, layering, grafting, tissue culture.
- **B. Sexual Reproduction:**
    - **Definition:** Involves the fusion of two specialized reproductive cells (gametes – sperm and egg), usually from two different parents, to form a zygote. This results in genetically diverse offspring.
    - **Advantages:** Genetic variation (increases adaptability to changing environments), allows for evolution.
    - **Disadvantages:** Requires two parents, slower process, requires more energy.
    - **Meiosis:**
        - **Definition:** A type of cell division that reduces the number of chromosomes by half, producing four haploid gametes (sex cells) from a single diploid parent cell.
        - **Location:** Occurs in germline cells to produce gametes (sperm and egg).
        - **Process (Simplified):** Involves two rounds of division (Meiosis I and Meiosis II), resulting in genetic recombination (crossing over) and independent assortment of chromosomes, leading to genetic variation.
        - **Importance:** Ensures genetic diversity in sexually reproducing organisms; maintains a constant chromosome number across generations after fertilization.