

## BIOLOGY FOR ENGINEERS

MODULE I: INTRODUCTION TO BIOLOGY: The cell: the basic unit of life, Structure, and functions of a cell. The Plant Cell and animal cell, Prokaryotic and Eukaryotic cells, Stem cells and their application.

Biomolecules: Properties and functions of Carbohydrates, Nucleic acids, proteins, lipids. Importance of special biomolecules; Enzymes (Classification (with one example each), Properties and functions), vitamins, and hormones.

### THE CELL

The cell is the basic unit of Life. The cell provides minimum requirements to perform essential life properties such as organization, metabolism, responsiveness, movements, and reproduction to live independently. Hence, it ensures

1. Independent existence
2. Performing the vital functions of life.

**Antonie van Leeuwenhoek** a Dutch microbiologist first observed cell. **Robert Brown** later discovered the nucleus. The invention of the microscope and its improvement led to the electron microscope revealing structural details of the cell.

Cells are built from Biomolecules such as carbohydrates, Lipids, Proteins, and Nucleic acids. They exhibit variations in their **size** (In the Human body, the Largest cell is the ovum and the smallest cell is the sperm), **shape** (round, spherical or elongated), life span (white blood cells only live for about 13 days, whereas red blood cells live for about 120 days) and function (Organ specific). Cells that have a similar structure and function form tissues. A cell can form a whole organism as in unicellulars like bacteria, or it may be part of the multicellulars like Humans.

### CELL THE BASIC UNIT OF LIFE:

Cell theory is a scientific theory that states that all living organisms are made of cells.

17<sup>th</sup> century onwards many curious scientists kept on observing diverse groups of organisms. The three major contributions brought a comprehensive understanding that Cells act as a basic unit of life. They are listed as follows

- a. In 1838, **Matthias Schleiden**, a German botanist, examined many plants and observed that all plants are composed of different kinds of cells that form the plant tissues.
- b. **Theodore Schwann** (1839), a British Zoologist, studied different types of animal cells and reported that cells had a thin outer layer which is today known as the 'plasma membrane'.
- c. **Rudolf Virchow** (1855) first explained that cells divide and new cells are formed from pre-existing cells (Omnis cellula-e cellula).

Their discoveries led to the formulation of the 'Cell Theory'.

The three important points of the modified cell theory are as follows:

1. The cell is the basic functional and structural unit of all living organisms.
2. All living organisms are made up of cells.
3. All cells arise from pre-existing cells.

### STRUCTURE AND FUNCTIONS OF A CELL

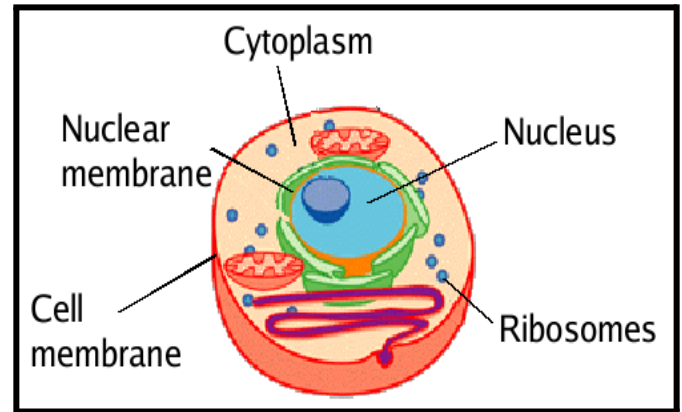
Understanding cell structure and functions is key to understanding life processes.

Structure:

1. Plasma Membrane: Surrounds the cell, regulating the passage of substances.
2. Cytoplasm: Jelly-like substance filling the cell, containing organelles.
3. Nucleus: Houses genetic material (DNA), controlling cell activities.

4. Organelles: Specialized structures:

- a. Endoplasmic Reticulum: Involved in protein and lipid metabolism.
- b. Golgi Apparatus: Modifies, sorts, and packages molecules.
- c. Mitochondria: Generates energy through respiration.
- d. Lysosomes: Break down waste materials.
- e. Ribosomes: Sites of protein synthesis.
- f. Centrioles (in animals): Assist in cell division.
- g. Cytoskeleton: Provides structural support and aids in cell movement.



Functions:

1. Respiration: Converts glucose into ATP for energy.
2. Protein Synthesis: Translates genetic information into proteins.
3. Storage and Processing: Synthesizes, modifies, and transports molecules.
4. Cellular Communication: Signals between cells via various molecules.
5. Waste Management: Breaks down and recycles cellular waste.
6. Cell Division: Replicates cells for growth, repair, and reproduction.
7. Movement: Supports cell movement and shape changes.

## PROKARYOTIC AND EUKARYOTIC CELLS

Prokaryotic and eukaryotic cells are two major types of cells, each with distinct characteristics. Though they perform functions of life, structurally and Evolutionarily they differ. Understanding the differences between prokaryotic and eukaryotic cells is essential in studying the diversity of life and the complexity of cellular organization and functions.

**Prokaryotic Cells:** *Prokaryotic cells*, the ancestral and less evolved cellular form, constitute organisms known as *Prokaryotes*. Examples include **Bacteria, Blue-green algae, Mycoplasma, and PPLO** (Pleuro Pneumonia Like Organisms). They possess several unique characteristics:

**Size and Multiplication Rate:** Prokaryotic cells are generally smaller and replicate more rapidly than eukaryotic cells.

**Cellular Organization:** Despite their diverse shapes and functions, prokaryotes share a fundamental cellular organization. Bacterial shapes range from bacillus (rod-like), coccus (spherical), and vibrio (comma-shaped), to spirillum (spiral).

**Cell Wall:** All prokaryotes except *Mycoplasma* have a cell wall surrounding the cell membrane.

**Cytoplasm:** The fluid matrix within prokaryotic cells is called cytoplasm.

**Nucleus:** Prokaryotes lack a well-defined nucleus; their genetic material is naked, not enclosed within a nuclear membrane.

**Plasmids:** Besides genomic DNA, many bacteria carry small circular DNA molecules called plasmids, conferring unique phenotypic traits like antibiotic resistance.

**Organelles:** Prokaryotic cells lack membrane-bound organelles except for ribosomes, which are associated with the cell's plasma membrane.

**Ribosomes:** Prokaryotic ribosomes are of 70S type, comprising 50S and 30S subunits. They are the sites of protein synthesis and can form chains called polyribosomes or polysomes.

**Reserve Materials:** Prokaryotic cells store reserve materials in inclusion bodies within the cytoplasm, such as phosphate, cyanophycin, and glycogen granules. Gas vacuoles are also present in some photosynthetic bacteria.

**Mesosomes:** A specialized form of cell membrane, mesosomes, are characteristic of prokaryotes. These extensions aid in cell wall formation, DNA replication, distribution to daughter cells, respiration, and secretion processes. In cyanobacteria, chromatophores are membranous extensions containing pigments.

Understanding the unique features of prokaryotic cells provides insight into their functions and evolutionary significance.

**Eukaryotic Cells:** Eukaryotic cells are more complex than prokaryotic cells and are found in organisms belonging to the domain Eukarya which includes all the protists, plants, animals and fungi. Here's an account of their structure:

1. **Nucleus:** Enclosed within a double membrane called the nuclear envelope. Contains genetic material (DNA) organized into linear chromosomes. The nucleolus within the nucleus is the site of ribosome synthesis. Nuclear Pores are openings in the nuclear envelope that control the passage of molecules between the nucleus and cytoplasm.
2. **Cell Membrane:** Surrounds the cell, regulating the passage of substances in and out of the cell. Composed of a phospholipid bilayer embedded with proteins.
3. **Cytoplasm:** Jelly-like substance filling the cell, containing organelles and cytosol.
4. **Organelles:**
  - **Endoplasmic Reticulum (ER):**
    - Rough ER studded with ribosomes involved in protein synthesis.
    - Smooth ER is involved in lipid metabolism and detoxification.
  - **Golgi Apparatus:** Modifies, sorts, and packages proteins and lipids for secretion or delivery to other parts of the cell.
  - **Mitochondria:** Powerhouse of the cell, generating energy through cellular respiration.
  - **Lysosomes:** Contain enzymes for intracellular digestion and waste removal.
  - **Ribosomes:** Site of protein synthesis, found free in the cytoplasm or attached to the endoplasmic reticulum. They are of 80S type; made of two subunits - 60S and 40S units.
  - **Chloroplasts** (in plant cells): Site of photosynthesis, containing chlorophyll.
  - **Vacuoles** (in plant and fungal cells): Store water, nutrients, and waste products.
5. **Cytoskeleton:** Network of protein filaments providing structural support, aiding in cell movement, and facilitating intracellular transport.
6. **Cell Wall** (in plant, fungal, and some protist cells): Rigid structure outside the cell membrane, providing support and protection.
7. **Centrioles** (in animal cells): Involved in cell division, forming the spindle fibers during mitosis.

8. **Flagella and Cilia:** Extensions of the cell membrane involved in cell movement or the movement of the surrounding fluid.

9. **Inclusions:** Storage granules containing reserve materials such as starch, glycogen, or lipids.

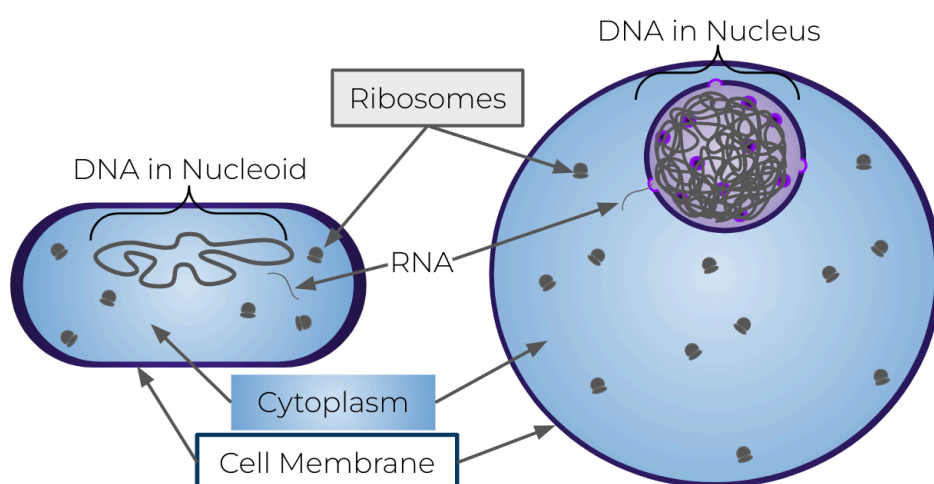
10. **Specialized Junctions** (in animal cells): Tight junctions, desmosomes, and gap junctions facilitate cell-to-cell adhesion and communication.

Eukaryotic cell structure is highly organized and compartmentalized, allowing for diverse and specialized functions necessary for the survival and functioning of complex multicellular organisms.

### Differences between Prokaryotic and Eukaryotic cells

#### Prokaryotic Cell

#### Eukaryotic Cell



Feature	Prokaryotic Cell	Eukaryotic Cell
Nucleus	Absent	Present
Genetic Material	Naked DNA dispersed in the cytoplasm (nucleoid region)	Enclosed within a nuclear envelope
Organelles	Lack membrane-bound organelles	Contain membrane-bound organelles
Size	Generally smaller and simpler	Larger and more complex
Examples	Bacteria, Archaea	Plants, Animals, Fungi, Protists
Ribosomes	70S type	80S type
Cell Wall	Present in most, except Mycoplasma	Present in plants, fungi, and some protists
Membrane Structure	Simple lipid bilayer	Complex lipid bilayer with embedded proteins

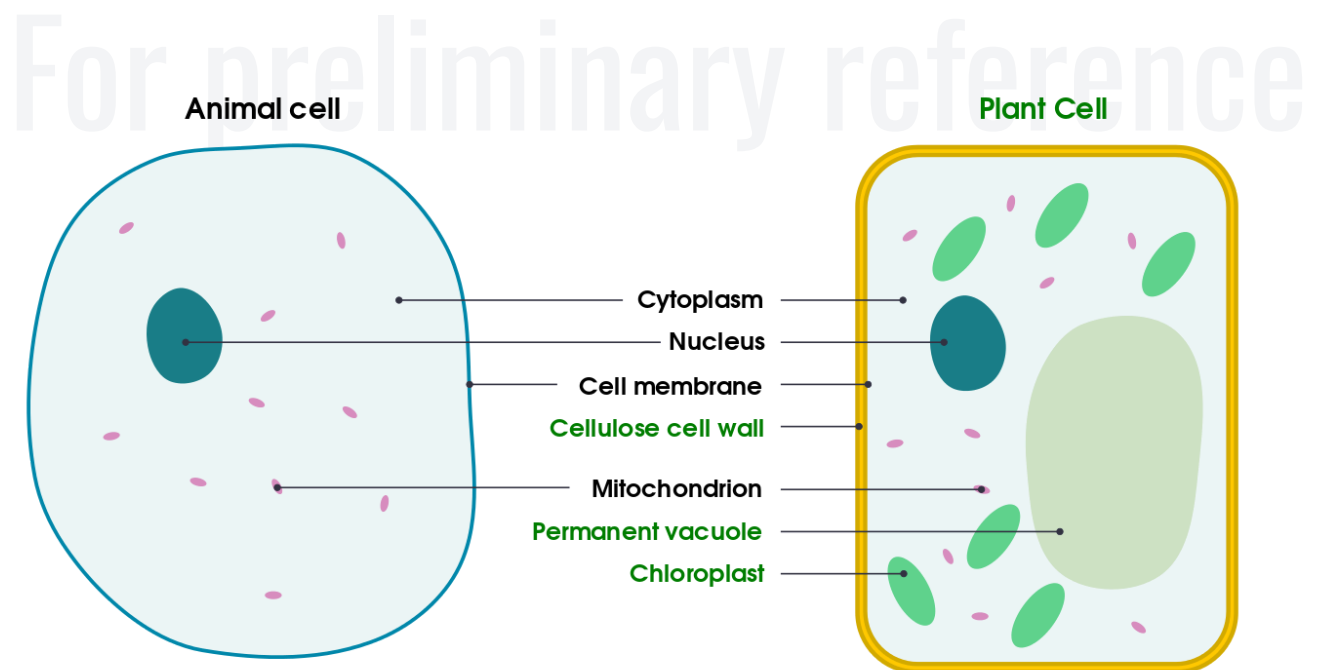
Division	Binary fission	Mitosis (for somatic cells) or meiosis (for gametes)
Reproduction	Asexual reproduction through binary fission	Asexual (e.g., budding in yeast) or sexual reproduction
Cytoskeleton	Absent or simpler	Present, providing structural support and cell shape
Examples of Shapes	Bacillus (rod), Coccus (spherical), Spirillum (spiral)	More diverse shapes, including spherical, elongated, etc.

## THE PLANT CELL AND ANIMAL CELL

Both plant and Animal cells are Eukaryotic cells. Their comparative analysis is as follows

Organelle	Function	Plant Cell	Animal Cell
Cell Membrane	Regulates passage of substances in and out	Present	Present
Cell Wall	Provides structural support and protection	Present (made of cellulose)	Absent
Nucleus	Stores genetic information and controls activity	Present	Present
Chloroplasts	Site of photosynthesis	Present	Absent
Central Vacuole	Stores water, nutrients, and waste products	Present (large and permanent)	Small or absent
Mitochondria	Generates energy through cellular respiration	Present	Present
Endoplasmic Reticulum (ER)	Involved in protein and lipid metabolism	Present (rough&smooth ER)	Present (rough & smooth ER)
Golgi Apparatus	Modifies, sorts, and packages proteins and lipids	Present	Present
Lysosomes	Contains enzymes for intracellular digestion	Rarely present	Commonly present
Ribosomes	Site of protein synthesis	Present	Present

Peroxisomes	Breaks down fatty acids and detoxifies harmful substances	Present	Present
Cytoskeleton	Provides structural support and facilitates cell movement	Present (microtubules, microfilaments)	Present (microtubules, microfilaments)
Centrioles	Involved in cell division	Absent	Present
Vacuoles	Stores water, nutrients, and waste products	Present (small membrane-bound sacs)	Present (small membrane-bound sacs)
Plasmodesmata	Facilitates cell-to-cell communication	Present	Absent
Gap Junctions	Channels between animal cells	Absent	Present
Tight Junctions	Forms impermeable barriers between cells	Absent	Present



#### Differences between Plant and Animal Cells

Feature	Plant Cell	Animal Cell
Cell Wall	Present, composed of cellulose	Absent
Chloroplasts	Present, site of photosynthesis	Absent

Central Vacuole	Present, large and permanent	Small or absent
Shape	Often rectangular or polygonal	Variable, round or irregular in shape
Centrioles	Absent	Present, involved in cell division
Storage Organelles	Often contain starch granules or plastids	May contain glycogen granules or lipid droplets
Lysosomes	Rarely present	Commonly present
Movement Structures	Plant cells may have flagella or cilia	Animal cells have flagella or cilia
Specialized Organelles	Plasmodesmata facilitate cell-to-cell communication	Gap junctions or tight junctions facilitate cell-to-cell communication

## STEM CELLS AND THEIR APPLICATION

**Stem Cells:** Stem cells are undifferentiated cells with the remarkable ability to differentiate into specialized cell types. They possess two main characteristics:

1. **Self-Renewal:** The ability to divide and produce more stem cells, maintaining a renewable source for further differentiation.
2. **Differentiation:** The potential to differentiate into various cell types depending on their environment and the signals they receive.

Stem cells are classified based on their potency or potential to differentiate into different cell types:

1. **Totipotent:** Can differentiate into all cell types, including embryonic and extraembryonic tissues. Examples include cells in the early embryo.
2. **Pluripotent:** Can differentiate into cells of all three germ layers: ectoderm, endoderm, and mesoderm. Examples include embryonic stem cells (ESCs).
3. **Multipotent:** Can differentiate into a limited range of cell types within a particular lineage or tissue. Examples include adult stem cells.

**Applications of Stem Cells:**

Stem cells hold immense potential for engineering applications due to their unique properties. Here's how stem cells are utilized in engineering:

Application	Description
Tissue Engineering	Stem cells combined with biomaterials can engineer tissues and organs for transplantation. This approach holds promise for creating replacement tissues and organs, addressing the shortage of donor organs, and reducing the risk of rejection.
Biomaterial Integration	Stem cells can be integrated into various biomaterial scaffolds, providing a platform for tissue regeneration and repair. Engineers



	design and optimize these scaffolds to mimic the natural microenvironment and guide stem cell differentiation.
Bioprinting	Stem cell-based bioprinting involves the precise deposition of stem cells and biomaterials to create complex three-dimensional structures. This technology enables the fabrication of tissue constructs with defined architectures, suitable for transplantation.
Drug Screening and Development	Stem cell-based models can be used for drug screening and development, providing a more accurate representation of human biology than traditional cell lines. Engineers develop high-throughput platforms for screening potential drugs and assessing their safety and efficacy.
Gene Therapy	Engineers design stem cell-based gene delivery systems for gene therapy applications. Stem cells can serve as vectors for delivering therapeutic genes to target tissues, offering potential treatments for genetic disorders and other diseases.
Disease Modeling	Stem cells are used to model diseases in the laboratory, providing insights into disease mechanisms and testing personalized therapies. Engineers develop sophisticated platforms for culturing and analyzing stem cells, facilitating disease modeling and drug discovery.

Stem cells exist in embryonic tissues as well as adult or fetal tissues such as bone marrow (bone marrow stem cells, BMSCs), fat (adipose-derived stem cells, ADSCs), dental pulp (dental pulp stem cells, DPSCs), blood (hematopoietic stem cells, HSCs), amniotic fluid (amniotic fluid stem cells, AFSCs), umbilical cord (umbilical cord stem cells, UCSCs) and even other tissues. Stem cells are a class of undifferentiated cells with high potential for self-renewal, proliferation, and mono- or multidirectional differentiation. A totipotent stem cell (a single fertilized egg) can develop into more than 250 cell types (depending on the definition of cell types) throughout human or animal life.

Organisms persist as a result of cell-cell renewal and continuous growth through the division of stem cells. Human stem cells can spontaneously (or be induced to) cause regeneration in the case of injury, aging, and deletion to maintain the function of tissues and organs and thus maintain the regular operation of the entire organism.

Regenerative medicine using stem cells is one of the most remarkable fields in the life sciences of the 21st century. Stem cells have great scientific significance and excellent practical application prospects in medical technology innovation. The study of stem cell proliferation, differentiation, migration, and signal transduction can contribute to the trauma repair and regeneration of body tissues, leading to the discovery of new ways to promote the self-repair and renewal of patients. Ultimately, the use of stem cells to build new tissues and organs for restorative treatment of organ injury and diseases has been achieved.



In addition to drugs and surgery, regenerative medicine, with stem cell therapy as the core technology, is becoming a new disease treatment option. The field of regenerative medicine using stem cells needs to be advanced by fundamental knowledge of molecular biology, cell biology, developmental biology, information science, and systems biology. What factors initiate the regeneration of tissues? What factors inhibit regeneration? Where do stem cells come from? How do stem cells proliferate, migrate to a specified location, and differentiate into specific tissue cells? How are these mechanisms different from those of fibrosis? Regenerative medicine explores these regenerative mechanisms to treat tissue damage, stimulate functional regeneration, and repair tissues and organs that cannot spontaneously regenerate or have low regenerative capacity.

The repair and reconstruction of missing or dysfunctional tissues and organs are still significant problems in biomedicine. The clinical approach is mainly to use surgery for organ transplantation. Although autologous transplantation is not immunogenic, such organ transplantation surgeries are costly and essentially repair damage at the cost of further injury. Allogeneic transplantation is immunogenic and there is a limited organ source. The immune response to xenografts is high, and xenogenic tissues and organs are at risk of carrying viruses or other pathogenic microorganisms.

Artificial alternatives made of mechanical, electronic, and physical materials also have significant defects, such as poor biocompatibility and short lifespan. Artificial tissues and organs regenerated by tissue engineering techniques using stem cells, which have structures and functions similar to those of natural tissues and organs, may solve these problems to a large extent. Therefore, it is possible for stem cell tissue engineering to promote the transformation of organ transplantation technology in the future.

Stem cells are currently the ideal seeding cells for tissue engineering. Stem cells can theoretically induce, differentiate, and grow into any kind of human cell, tissue, or organ under artificial conditions through histological engineering techniques. With the increasing maturity of stem cell transplantation technology, the use of stem cells in vivo will surely advance regenerative medicine and the regeneration and repair of tissues and organs.

## **BIOMOLECULES**

Biomolecules, also known as biological molecules, are chemical compounds found in living organisms that are essential for the survival of living cells and all life processes. They are the building blocks of life and perform important functions in living organisms, such as reproduction, growth, and sustenance. Biomolecules include large macromolecules such as proteins, carbohydrates, lipids, and nucleic acids, as well as small molecules such as vitamins and hormones.

## **CARBOHYDRATES**

Carbohydrates are a class of organic compounds that serve as essential macronutrients and biomolecules in living organisms. They consist of carbon, hydrogen, and oxygen atoms, typically in a ratio of 1:2:1, respectively. The term "carbohydrate" originates from the chemical formula  $C_n(H_2O)_n$ , reflecting this composition.

Carbohydrates play diverse roles in biological systems. They serve as a primary source of energy, providing fuel for cellular processes through processes like glycolysis and cellular respiration. Additionally, carbohydrates contribute to structural support in organisms, forming components of cell walls, exoskeletons, and connective tissues.

These molecules vary in complexity, ranging from simple sugars such as glucose and fructose to complex polysaccharides like starch and cellulose. Monosaccharides, the simplest form of carbohydrates, can combine to form disaccharides and polysaccharides through dehydration synthesis reactions.

In addition to their roles in energy metabolism and structure, carbohydrates play crucial roles in cell signalling, recognition, and adhesion processes. For example, they serve as recognition markers on cell surfaces and participate in the immune response.

Overall, carbohydrates are fundamental to life, contributing to various biological functions and serving as key components of the diet in both plants and animals.

### Properties of Carbohydrates

Property	Description
Chemical Composition	Composed of carbon, hydrogen, and oxygen atoms in a ratio of 1:2:1, respectively.
Structure	Consists of chains or rings of sugar molecules.
Types	Divided into three main groups: monosaccharides, disaccharides, and polysaccharides.
Solubility	Most carbohydrates are soluble in water due to their hydrophilic nature, except for some larger polysaccharides.
Sweetness	Monosaccharides and disaccharides are generally sweet-tasting, while polysaccharides are not.
Energy Source	The primary source of energy for living organisms, providing 4 calories per gram upon digestion.
Storage	Stored as glycogen in animals and as starch in plants for energy reserves.
Structural Function	Act as building blocks for cell walls in plants (cellulose) and exoskeletons in arthropods (chitin).
Biological Significance	Essential for cellular processes such as metabolism, cell signalling, and immune system functioning.

### Functions of Carbohydrates

Function	Description
Energy Source	Carbohydrates serve as the primary source of energy for the body, providing fuel for various physiological processes. Glucose, derived from carbohydrates, is particularly vital for brain function and muscle activity.

Structural Support	In organisms, carbohydrates play a crucial role in providing structural support. For instance, cellulose, a complex carbohydrate found in plant cell walls, offers rigidity and strength, contributing to the overall structural integrity of plants.
Storage of Energy	Carbohydrates are stored in the body as glycogen in the liver and muscles. When energy demand increases, glycogen is broken down into glucose to meet the energy requirements, maintaining blood glucose levels within a normal range.
Facilitate Digestion	Dietary fibers, a type of carbohydrate found in plant-based foods, aid in digestion by promoting regular bowel movements, preventing constipation, and supporting a healthy digestive system.
Cellular Communication	Carbohydrates on cell surfaces play a crucial role in cell recognition and communication. They help cells identify and interact with each other, facilitating various physiological processes such as immune responses and tissue development.
Flavor and Texture	Carbohydrates contribute to the taste, texture, and appearance of foods. They enhance the flavor of foods, provide sweetness, and contribute to the texture of baked goods, making them palatable and appealing to consumers.
Metabolic Regulation	Carbohydrates participate in metabolic regulation by influencing insulin secretion and blood glucose levels. Maintaining proper carbohydrate intake and metabolism is essential for preventing metabolic disorders such as diabetes.
Fuel for Exercise	During physical activity, carbohydrates provide the necessary energy to sustain muscle contractions and endurance. Athletes often rely on carbohydrate-rich foods to fuel their performance and enhance recovery after exercise.

## NUCLEIC ACIDS

**Nucleic acids**, including DNA and RNA, play diverse and fundamental roles in the functioning of living organisms. As the carriers of genetic information, DNA molecules encode the instructions required for the development, growth, and reproduction of organisms, while RNA molecules participate in protein synthesis and gene expression regulation. Beyond their roles in genetic processes, nucleic acids also contribute to energy transfer through molecules like ATP, catalyze biochemical reactions as ribozymes, and participate in immune responses and chemical signaling pathways within cells. Understanding the multifaceted functions of nucleic acids provides insights into their significance in biological systems and their implications for health and disease.

Nucleic acids possess distinctive properties that contribute to their structural stability, functional specificity, and biochemical behavior. The polarity of nucleic acid molecules, characterized by 5' and 3' ends, influences their orientation and interactions with other molecules. The double helix structure of DNA provides a stable framework for genetic information storage and transmission, facilitated by specific base pairing rules and hydrogen bonding between complementary nucleotide bases. The acidic nature of nucleic acids, stemming from phosphate groups, affects their overall charge and molecular interactions. Additionally, nucleic acids exhibit unique absorbance properties in the UV range, allowing for their detection and analysis in biochemical assays. Understanding these properties is essential for elucidating the structure-function relationships of nucleic acids and their roles in biological processes.

### Properties of Nucleic Acids

Property	Description
Polarity	Nucleic acids exhibit polarity, with distinct 5' (five-prime) and 3' (three-prime) ends. This polarity arises from the orientation of the sugar-phosphate backbone, where the 5' end contains a phosphate group attached to the 5' carbon of the sugar molecule, and the 3' end terminates with a hydroxyl group on the 3' carbon.
Double Helix Structure	DNA molecules possess a double helix structure, characterized by two complementary polynucleotide strands winding around each other in a right-handed manner. This structure provides stability and protection to the genetic information encoded within the DNA molecule and facilitates replication and transcription processes.
Base Pairing	Nucleic acids exhibit specific base pairing rules, where adenine (A) pairs with thymine (T) in DNA or uracil (U) in RNA via hydrogen bonds, and cytosine (C) pairs with guanine (G). This complementary base pairing ensures the accurate replication and transmission of genetic information during cellular processes.
Hydrogen Bonding	Hydrogen bonding plays a crucial role in stabilizing the structure of nucleic acids. Within the double helix of DNA, hydrogen bonds form between complementary base pairs, contributing to the structural integrity and specificity of the molecule. These bonds are relatively weak individually but collectively provide stability to the DNA double helix.
Acidic Nature	Nucleic acids are acidic molecules due to the presence of phosphate groups in their structure. The negatively charged phosphate groups confer an overall negative charge to the nucleic acid molecule, influencing its interactions with other molecules and its behavior in biochemical processes.

## Functions of Nucleic Acids

Function	Description
Genetic Information Storage	Nucleic acids, particularly DNA (deoxyribonucleic acid), serve as the primary carrier of genetic information in living organisms. DNA contains the instructions necessary for the development, growth, functioning, and reproduction of organisms.
Protein Synthesis	Nucleic acids, specifically RNA (ribonucleic acid), play a crucial role in protein synthesis. RNA molecules, including messenger RNA (mRNA), transfer RNA (tRNA), and ribosomal RNA (rRNA), are involved in various stages of protein production, from transcription to translation.
Gene Expression Regulation	Nucleic acids participate in the regulation of gene expression, controlling when and how genes are turned on or off. This regulatory role is essential for orchestrating the precise timing and levels of protein production required for various cellular processes.
Energy Transfer	Nucleic acids, particularly adenosine triphosphate (ATP), function as carriers of chemical energy within cells. ATP molecules store and transfer energy generated during cellular metabolism, providing the necessary energy for cellular activities such as muscle contraction, biosynthesis, and transport processes.
Catalysis	Some nucleic acids, such as ribozymes, exhibit catalytic activity, enabling them to facilitate specific biochemical reactions within cells. Ribozymes participate in processes such as RNA splicing, peptide bond formation, and RNA cleavage, demonstrating the diverse functional capabilities of nucleic acids beyond their roles in information storage and transfer.
Immune Response	Nucleic acids, both DNA and RNA, can trigger immune responses when recognized as foreign molecules by the immune system. This immune recognition serves as a defense mechanism against viral infections and other pathogens, highlighting the dual role of nucleic acids in both genetic information storage and host defense.
Chemical Signaling	Certain nucleic acids, such as small non-coding RNAs, are involved in chemical signalling pathways within cells. These regulatory RNAs modulate gene expression by interacting with specific target molecules, thereby influencing various cellular processes, including development, differentiation, and response to environmental stimuli.

## PROTEINS

**Proteins** are versatile biomolecules with diverse structural, functional, and chemical properties that underlie their roles in biological systems. Their hierarchical structure encompasses primary, secondary, tertiary, and quaternary levels of organization, dictating their overall shape and function. Composed of amino acids, proteins exhibit a wide range of functionalities, including enzymatic catalysis, structural support, molecular recognition, and cellular signaling. The folding of proteins into their native conformations is essential for their biological activity, with denaturation representing a reversible or irreversible structural disruption. Protein solubility, stability, and behavior are influenced by various factors, providing insights into their physiological function and biochemical properties. Understanding the properties of proteins is crucial for elucidating their roles in health, disease, and biotechnological applications.

Proteins are indispensable macromolecules that fulfill many essential functions in living organisms. As enzymes, they catalyze biochemical reactions, driving metabolic processes and maintaining cellular homeostasis. Additionally, proteins provide structural support to cells and tissues, ensuring the integrity and mechanical strength of biological structures. Through their role in transport, proteins facilitate the movement of molecules across biological membranes and within the circulatory system, ensuring the delivery of nutrients and signaling molecules to target sites. Moreover, proteins participate in cellular signaling pathways, regulating gene expression, cell growth, and responses to extracellular stimuli. In the immune system, proteins contribute to defense mechanisms by recognizing and neutralizing pathogens. Hormonal proteins and receptors coordinate physiological processes, while contractile proteins enable muscle contraction and movement. The diverse functions of proteins underscore their indispensability in biological systems and highlight their significance in health, disease, and biotechnological applications.

### Properties of Proteins

Property	Description
Structure	Proteins exhibit a hierarchical structure, consisting of primary, secondary, tertiary, and quaternary levels of organization. The primary structure refers to the linear sequence of amino acids linked by peptide bonds. Secondary structure involves folding patterns such as alpha helices and beta sheets, while tertiary structure refers to the three-dimensional arrangement of the entire polypeptide chain. Quaternary structure arises when multiple polypeptide chains assemble to form a functional protein complex.
Amino Acid Composition	Proteins are composed of amino acids, which are organic molecules containing an amino group, a carboxyl group, and a variable side chain. There are 20 standard amino acids, each with a unique side chain that imparts specific chemical and structural properties to the protein. The sequence and composition of amino acids determine the structure and function of the protein molecule.

Functional Diversity	Proteins exhibit remarkable functional diversity, serving as enzymes, structural components, transporters, receptors, antibodies, hormones, and molecular motors, among other roles. Enzymes catalyze biochemical reactions, while structural proteins provide support and stability to cells and tissues. Transport proteins facilitate the movement of molecules across biological membranes, and receptors mediate cellular signaling pathways. The diverse functions of proteins reflect their versatility and importance in biological systems.
Folding and Stability	Proteins undergo folding into their native three-dimensional structures, driven by interactions between amino acid side chains and the surrounding environment. The folding process is crucial for protein function, as it determines the specific binding sites and active sites necessary for interactions with other molecules. Proteins can also exhibit different levels of stability, influenced by factors such as temperature, pH, and the presence of cofactors or ligands.
Denaturation	Proteins can undergo denaturation, a process in which their native structure is disrupted, leading to loss of function. Denaturation can be induced by various factors, including heat, pH extremes, organic solvents, and chaotropic agents. While denatured proteins may lose their biological activity, they often retain their primary structure, allowing for the possibility of renaturation under favorable conditions.
Solubility	The solubility of proteins varies depending on their amino acid composition and the surrounding environment. Some proteins are soluble in water, while others are insoluble and may form aggregates or precipitates. Protein solubility is influenced by factors such as pH, temperature, ionic strength, and the presence of denaturing agents or binding partners. Understanding the solubility behavior of proteins is essential for their purification, characterization, and functional studies.

### Functions of Proteins

Function	Description
Enzymatic Activity	Proteins serve as enzymes, catalyzing biochemical reactions within cells and organisms. Enzymes facilitate the conversion of substrates into products by lowering the activation energy of reactions, thereby accelerating metabolic processes essential for life.
Structural Support	Proteins provide structural support to cells, tissues, and organs in living organisms. Structural proteins such as collagen, elastin, and keratin contribute to the mechanical strength, elasticity, and integrity of various biological structures, including bones, skin, hair, and connective tissues.



Transport	Proteins function as carriers and transporters, facilitating the movement of molecules across biological membranes and within the circulatory system. Transport proteins, such as hemoglobin, transport gases like oxygen and carbon dioxide in the blood, while membrane transporters regulate the passage of ions and molecules across cell membranes.
Signaling	Proteins play crucial roles in cellular signaling pathways, transmitting and modulating signals that regulate various physiological processes. Signaling proteins, such as receptors, transducers, and kinases, relay information from extracellular stimuli to intracellular effectors, controlling cell growth, differentiation, and responses to environmental cues.
Immune Response	Proteins are essential components of the immune system, participating in the recognition, response, and defense against pathogens and foreign substances. Antibodies, also known as immunoglobulins, are proteins produced by the immune system that bind to specific antigens, marking them for destruction by immune cells.
Hormonal Regulation	Proteins serve as hormones and hormone receptors, regulating numerous physiological processes and maintaining homeostasis in the body. Hormones, such as insulin, glucagon, and growth hormone, are signaling proteins that coordinate metabolism, growth, reproduction, and other functions by binding to specific receptors on target cells.
Muscle Contraction	Proteins play a central role in muscle contraction, enabling movement and locomotion in animals. Contractile proteins, including actin and myosin, interact to generate the force required for muscle contraction and movement. The coordinated action of these proteins underlies processes such as muscle contraction, relaxation, and control of motor functions.

## LIPIDS

**Lipids** encompass a diverse group of biomolecules with essential roles in cellular structure, energy metabolism, and signaling pathways. As a concentrated source of energy, lipids serve as a reservoir of metabolic fuel, providing energy for cellular processes and physical activity. In addition to their role in energy storage, lipids contribute to the structural integrity of cell membranes, ensuring the compartmentalization and protection of cellular contents. Moreover, lipids act as insulators, helping to maintain body temperature and protect vital organs from external stressors. Lipids also play a critical role in hormone regulation, serving as precursors for steroid hormones involved in metabolic, reproductive, and stress-related processes. Furthermore, lipids function as signaling molecules, mediating cellular responses to environmental cues and modulating inflammatory and immune responses. Finally, lipids facilitate the absorption and transport of fat-soluble vitamins and other hydrophobic nutrients in the digestive system, ensuring their efficient uptake and utilization by the

body. Overall, the multifaceted functions of lipids underscore their importance in maintaining cellular homeostasis and supporting various physiological processes in organisms.

Lipids exhibit several characteristic properties that distinguish them from other classes of biomolecules. Their hydrophobic nature renders them insoluble in water but soluble in nonpolar solvents, reflecting the predominance of nonpolar hydrocarbon chains in their structure. Lipids display structural diversity, encompassing various classes such as fatty acids, triglycerides, phospholipids, and sterols, each with distinct chemical compositions and functions in biological systems. Some lipids exhibit amphipathic properties, containing both hydrophilic and hydrophobic regions within the same molecule, enabling them to form structures like lipid bilayers in aqueous environments. Functionally, lipids serve as efficient energy storage molecules, insulation against temperature fluctuations, and lubricants that reduce friction between tissues. Understanding the properties of lipids are essential for elucidating their roles in cellular structure, energy metabolism, and physiological function in living organisms.

### Properties of Lipids

Property	Description
Hydrophobicity	Lipids are characterized by their hydrophobic nature, meaning they are insoluble in water but soluble in nonpolar solvents such as chloroform, ether, or benzene. This property arises from the nonpolar hydrocarbon chains of fatty acids and the hydrophobic regions of other lipid molecules, making them inherently repellant to water molecules.
Structural Diversity	Lipids exhibit structural diversity, encompassing a wide range of molecules with distinct chemical compositions and functions. Common lipid classes include fatty acids, triglycerides, phospholipids, sterols, and sphingolipids, each with unique molecular structures and properties that contribute to their biological functions.
Amphipathicity	Some lipids display amphipathic properties, containing both hydrophilic (water-attracting) and hydrophobic (water-repelling) regions within the same molecule. Phospholipids, for example, have hydrophilic phosphate heads and hydrophobic fatty acid tails, allowing them to form lipid bilayers in aqueous environments such as cell membranes.
Energy Storage	Lipids serve as efficient energy storage molecules, storing energy in the form of chemical bonds within their hydrocarbon chains. Triglycerides, the primary storage form of lipids, accumulate in adipose tissue and can be mobilized and oxidized to generate ATP, providing a long-term reservoir of energy for cellular metabolism and physical activity.
Insulation	Lipids act as insulators, helping to maintain body temperature and protect vital organs from temperature fluctuations and mechanical damage. Adipose tissue,

	composed primarily of fat cells, serves as an insulating layer beneath the skin, providing thermal insulation and cushioning for organs.
Lubrication	Certain lipids, such as waxes and oils, possess lubricating properties that reduce friction and facilitate movement in biological systems. Lipid-based lubricants coat surfaces, preventing them from drying out and reducing wear and tear caused by friction between tissues, such as in joints or between skin surfaces.

### Functions of Lipids

Function	Description
Energy Storage	Lipids serve as a concentrated energy reserve in the body, providing more than twice the energy per gram compared to carbohydrates or proteins. Triglycerides, the most common form of dietary fat, are stored in adipose tissue and can be mobilized and oxidized to generate ATP, the primary energy currency of cells.
Structural Role	Lipids contribute to the structural integrity of cell membranes, forming a lipid bilayer that encloses and protects the contents of cells. Phospholipids, cholesterol, and glycolipids are key components of cell membranes, regulating membrane fluidity, permeability, and signaling processes essential for cellular function and communication.
Insulation	Lipids act as insulators, helping to maintain body temperature and protect vital organs from temperature fluctuations and mechanical damage. Adipose tissue, composed primarily of fat cells, serves as an insulating layer beneath the skin, providing thermal insulation and cushioning for organs.
Hormone Regulation	Lipids play a crucial role in hormone synthesis and regulation, serving as precursors for steroid hormones such as estrogen, testosterone, and cortisol. These hormones regulate various physiological processes, including metabolism, growth, reproduction, and stress responses, exerting widespread effects on the body's functions.
Cell Signaling	Lipids function as signaling molecules in intercellular communication pathways, modulating cellular responses to environmental cues and stimuli. Lipid-derived signaling molecules, such as prostaglandins, leukotrienes, and sphingolipids, mediate inflammatory responses, immune function, and neuronal signaling, influencing diverse physiological processes.
Absorption of Nutrients	Lipids facilitate the absorption and transport of fat-soluble vitamins (A, D, E, and K) and other hydrophobic nutrients in the digestive system. Bile acids and lipases emulsify and break down dietary fats into absorbable forms, allowing for the

	efficient uptake of essential nutrients across the intestinal epithelium and into the bloodstream.
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## ENZYMES

**Enzymes** are biological catalysts that accelerate biochemical reactions by lowering the activation energy required for the conversion of substrates into products. They are classified into six main classes based on the type of reaction they catalyze and the nature of their substrates. Oxidoreductases catalyze oxidation-reduction reactions by transferring electrons between substrates, as exemplified by lactate dehydrogenase, which converts lactate to pyruvate during cellular respiration. Transferases facilitate the transfer of functional groups between substrates, such as the conversion of alanine to pyruvate by alanine transaminase (ALT) in amino acid metabolism. Hydrolases catalyze hydrolysis reactions, breaking chemical bonds by adding water molecules, as demonstrated by the action of lipase in the digestion of dietary fats. Lyases catalyze the addition or removal of groups to double bonds or the cleavage of bonds without hydrolysis or oxidation-reduction, such as carbonic anhydrase, which converts carbon dioxide into bicarbonate ions. Isomerases catalyze the rearrangement of atoms within a molecule, exemplified by triose phosphate isomerase (TIM), which interconverts dihydroxyacetone phosphate and glyceraldehyde-3-phosphate in glycolysis. Ligases, also known as synthetases, catalyze the formation of bonds between molecules, often using energy from ATP hydrolysis, as seen in DNA ligase, which joins DNA strands during DNA replication and repair. These examples illustrate the diverse functions of enzymes and their critical roles in biological processes.

### Classification of Enzymes

Enzyme Class	Description	Example
Oxidoreductases	Oxidoreductases catalyze oxidation-reduction reactions, involving the transfer of electrons between substrates. These enzymes typically utilize cofactors such as NAD <sup>+</sup> or FAD as electron carriers.	Lactate dehydrogenase
Transferases	Transferases facilitate the transfer of functional groups, such as methyl, acetyl, or phosphate groups, between substrates. These enzymes play essential roles in metabolic pathways and signal transduction.	Alanine transaminase (ALT)
Hydrolases	Hydrolases catalyze hydrolysis reactions, cleaving chemical bonds by adding water molecules. These enzymes are involved in the breakdown of macromolecules such as proteins, carbohydrates, and lipids.	Lipase
Lyases	Lyases catalyze the addition or removal of groups to double bonds or the cleavage of bonds without	Carbonic anhydrase

	hydrolysis or oxidation-reduction. These enzymes participate in diverse metabolic pathways and biosynthesis.	
Isomerases	Isomerases catalyze the rearrangement of atoms within a molecule, resulting in the conversion between isomeric forms. These enzymes play crucial roles in maintaining metabolic equilibrium and generating biological diversity.	Triose phosphate isomerase (TIM)
Ligases (Synthetases)	Ligases, also known as synthetases, catalyze the formation of bonds between molecules, often using energy from ATP hydrolysis. These enzymes are involved in DNA replication, RNA synthesis, and protein synthesis.	DNA ligase

### Properties of Enzymes

Enzymes possess several distinctive properties that contribute to their essential roles in biological systems. One of the key properties of enzymes is their specificity, both in substrate recognition and catalytic activity. Enzymes interact selectively with specific substrates, binding to them at their active sites and facilitating particular biochemical reactions. This specificity arises from the precise arrangement of amino acid residues within the enzyme's active site, which complements the structure and chemical properties of the substrate molecule.

Furthermore, enzymes are highly efficient catalysts that significantly accelerate the rates of biochemical reactions. By lowering the activation energy barrier required for substrate conversion, enzymes enable reactions to proceed more rapidly and efficiently, allowing cells to carry out essential metabolic processes at biologically relevant rates.

Enzyme activity is tightly regulated to ensure that metabolic pathways are coordinated and responsive to changing physiological conditions. Factors such as substrate concentration, pH, temperature, and the presence of regulatory molecules can modulate enzyme activity, allowing cells to fine-tune metabolic flux and maintain homeostasis.

Moreover, enzymes are reusable catalysts that can catalyze multiple rounds of substrate conversion without being consumed in the reaction. After facilitating a reaction, enzymes remain unchanged and available to catalyze subsequent reactions, making them highly economical and efficient components of cellular metabolism.

Despite their efficiency, enzymes are sensitive to changes in environmental conditions, such as temperature and pH. Small deviations from optimal conditions can significantly impact enzyme activity and, consequently, metabolic pathways and cellular function. Understanding the properties of enzymes is crucial for elucidating their roles in biological processes and their potential as targets for therapeutic intervention.

## Properties of Enzymes

Property	Description
Specificity	Enzymes exhibit specificity in substrate recognition and catalytic activity, interacting with specific substrates to facilitate particular biochemical reactions. This specificity arises from the complementary shapes and chemical properties of the enzyme's active site and the substrate molecule.
Catalytic	Enzymes are catalysts that accelerate biochemical reactions by lowering the activation energy required for the conversion of substrates into products. By stabilizing the transition state of the reaction, enzymes facilitate the formation of product molecules more rapidly and efficiently.
Efficiency	Enzymes are highly efficient catalysts, often capable of increasing reaction rates by millions to billions of times compared to uncatalyzed reactions. This high efficiency allows cells to carry out metabolic processes at rates compatible with life despite relatively mild physiological conditions.
Regulation	Enzyme activity is regulated by various factors, including substrate concentration, pH, temperature, and the presence of inhibitors or activators. These regulatory mechanisms ensure that enzyme activity is finely tuned to meet the changing metabolic demands of cells and maintain homeostasis.
Reusability	Enzymes are reusable catalysts that can catalyze multiple rounds of substrate conversion without being consumed in the reaction. After facilitating a reaction, enzymes remain unchanged and available to catalyze subsequent reactions, making them highly economical and efficient components of cellular metabolism.
Sensitivity	Enzyme activity is sensitive to changes in environmental conditions, such as temperature and pH, which can influence enzyme structure and function. Small deviations from optimal conditions can significantly affect enzyme activity, leading to alterations in metabolic pathways and cellular function.

## Functions of Enzymes

Enzymes are essential biological molecules that perform a wide range of functions critical for life processes. As catalysts, enzymes accelerate chemical reactions by lowering the activation energy barrier, enabling reactions to occur at physiological conditions. Their specificity ensures that enzymes selectively bind to specific substrates, leading to precise control over metabolic pathways and cellular processes. Enzyme activity is tightly regulated through various mechanisms to maintain metabolic homeostasis and respond to environmental cues. Enzymes participate in metabolic pathways, DNA replication, and repair processes, ensuring the efficient synthesis, degradation, and maintenance of biomolecules and genetic material. Additionally, enzymes play roles in signal transduction pathways, translating extracellular signals into intracellular responses, and facilitate the

breakdown of macromolecules during digestion, enabling nutrient absorption and energy production. These diverse functions highlight the central importance of enzymes in biological systems and their indispensable roles in maintaining cellular function and organismal viability.

Function	Description
Catalysis	Enzymes serve as biological catalysts, accelerating chemical reactions by lowering the activation energy required for the conversion of substrates into products. By facilitating the formation of transition states and stabilizing reaction intermediates, enzymes enhance the rate of reactions without being consumed in the process.
Specificity	Enzymes exhibit high specificity for their substrates, recognizing and binding to specific molecules or chemical groups through complementary interactions at the enzyme's active site. This substrate specificity ensures that enzymes selectively catalyze particular reactions, leading to precise control over metabolic pathways and cellular processes.
Regulation	Enzyme activity is tightly regulated to maintain metabolic homeostasis and respond to changing environmental conditions. Regulation may occur through various mechanisms, including allosteric regulation, covalent modification, and feedback inhibition, which modulate enzyme activity in response to signals such as substrate availability, cellular energy levels, or hormonal signals.
Metabolic Pathways	Enzymes participate in metabolic pathways, sequences of interconnected biochemical reactions that convert substrates into products. Within these pathways, enzymes catalyze specific steps, regulating the flow of metabolites and ensuring the coordinated synthesis, degradation, and interconversion of biomolecules essential for cellular function and survival.
Signal Transduction	Enzymes play key roles in signal transduction pathways, transmitting extracellular signals into intracellular responses that regulate various cellular processes. For example, protein kinases and phosphatases catalyze the phosphorylation and dephosphorylation of target proteins, respectively, thereby modulating their activity and mediating cellular responses to stimuli.
DNA Replication and Repair	Enzymes are involved in DNA replication and repair processes, ensuring the faithful transmission of genetic information and maintaining genomic stability. DNA polymerases catalyze the synthesis of new DNA strands during replication, while DNA repair enzymes correct errors and lesions in the DNA sequence, minimizing mutations and preserving genetic integrity.



Digestion	Enzymes facilitate the breakdown of macromolecules into smaller, more readily absorbable units during the process of digestion. Digestive enzymes, such as proteases, lipases, and carbohydrases, hydrolyze proteins, fats, and carbohydrates, respectively, into amino acids, fatty acids, and sugars that can be absorbed and utilized by the body for energy and growth.
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## VITAMINS

**Vitamins** are essential micronutrients that play diverse roles in maintaining health and supporting various physiological functions in the body. They are classified into two categories: fat-soluble vitamins (A, D, E, and K) and water-soluble vitamins (B vitamins and vitamin C). Fat-soluble vitamins are absorbed along with fats in the diet and are stored in the body's fatty tissues, while water-soluble vitamins dissolve in water and are excreted in urine when consumed in excess. Each vitamin has a specific chemical name and description, along with plant and animal food sources that provide significant amounts of the vitamin. Plant sources include fruits, vegetables, nuts, seeds, and grains, while animal sources include meat, poultry, fish, dairy products, and eggs. Consuming a balanced diet that includes a variety of foods rich in vitamins is essential for meeting the body's nutritional needs and maintaining optimal health.

Vitamin	Chemical Name	Description	Plant Source	Animal Source
Vitamin A	Retinol	Essential for vision, immune function, mucous membranes, maintaining healthy skin, and cell growth and differentiation.	Carrots, sweet potatoes, spinach, kale, broccoli	Liver, fish oil, eggs, dairy products
Vitamin B <sub>1</sub>	Thiamine	Energy metabolism, nerve function, and carbohydrate metabolism.	Whole grains, legumes, nuts, seeds	Pork, beef, organ meats, whole grains
Vitamin B <sub>2</sub>	Riboflavin	Energy production, metabolism of fats, carbohydrates, and proteins, and maintenance of healthy skin and vision; acts as an antioxidant.	Dairy products, leafy greens, almonds, mushrooms	Meat, poultry, fish, eggs, dairy products
Vitamin B <sub>3</sub>	Niacin	Energy metabolism, DNA repair, and cell signaling.	Meat, poultry, fish, peanuts, whole grains	Legumes, seeds, nuts, dairy products
Vitamin B <sub>5</sub>	Pantothenic acid	Energy metabolism, fatty acid synthesis, and the synthesis of cholesterol, hormones, & neurotransmitters.	Avocado, mushrooms, broccoli, sweet potatoes	Chicken, beef, liver, whole grains

Vitamin B <sub>6</sub>	Pyridoxine	Amino acid metabolism, neurotransmitter synthesis, and the production of red blood cells. It plays a crucial role in brain development and function, immune health, and the regulation of homocysteine levels.	Chickpeas, potatoes, bananas, poultry	Fish, beef liver, poultry, nuts, seeds
Vitamin B <sub>7</sub>	Biotin	Essential for carbohydrate, fat, and protein metabolism.	Nuts, seeds, sweet potatoes, avocado	Eggs, liver, salmon, pork
Vitamin B <sub>9</sub>	Folate Folic acid	Crucial for DNA synthesis, cell division, and the formation of red blood cells. It plays a vital role in fetal development, preventing birth defects.	Leafy greens, asparagus, citrus fruits, beans	Liver, eggs, fortified grains, lentils
Vitamin B <sub>12</sub>	Cobalamin	DNA synthesis, red blood cell formation, and neurological function. It plays a critical role in maintaining nerve cells' health and preventing a type of anemia called megaloblastic anemia.	Meat, fish, poultry, dairy products	Fortified cereals, nutritional yeast, algae
Vitamin C	Ascorbic acid	Antioxidant that supports immune function, collagen synthesis, wound healing, and the absorption of iron.	Citrus fruits, strawberries, bell peppers, broccoli	Citrus fruits, kiwi, strawberries, bell peppers
Vitamin D	Cholecalciferol	Essential for calcium absorption, bone health, and immune function. It helps regulate calcium and phosphorus levels in the blood and supports the growth and maintenance of strong bones and teeth.	Sunlight (UV exposure), fortified dairy products	Fatty fish (salmon, tuna, mackerel), egg yolks
Vitamin E	Tocopherol	An antioxidant that protects cell membranes from oxidative damage. It plays a role in immune function, skin health,	Nuts, seeds, vegetable oils, leafy greens	Vegetable oils, nuts, seeds, avocado

		and gene expression regulation. Vitamin E also supports cardiovascular health and may reduce the risk of chronic diseases.		
Vitamin K	Phylloquinone	Essential for blood clotting, bone metabolism, and heart health. It plays a crucial role in the synthesis of clotting factors and the regulation of calcium in bones and blood vessels.	Leafy greens (kale, spinach, collard greens)	Liver, egg yolks, cheese, fermented foods

## HORMONES

**Hormones** are chemical messengers produced by endocrine glands or tissues in the body that regulate various physiological processes and maintain homeostasis. Each hormone has specific functions and targets, exerting effects on cells and tissues throughout the body. Insulin, for example, regulates blood glucose levels by promoting glucose uptake and storage, while testosterone influences male sexual development and secondary sexual characteristics. Estrogen plays a central role in female reproductive health and bone metabolism, while thyroxine regulates metabolism and growth. Cortisol helps the body respond to stress and modulates metabolism, inflammation, and immune function. Growth hormone stimulates growth and tissue repair, while progesterone supports pregnancy and embryonic development. Adrenaline triggers the fight-or-flight response, preparing the body for action during stressful situations. These hormones work in concert to regulate physiological processes and ensure the body's overall health and well-being.

Hormone	Function	Origin	Target
Insulin	Regulates blood glucose levels by facilitating glucose uptake, promoting glycogen synthesis, and inhibiting gluconeogenesis. It plays a crucial role in carbohydrate metabolism and helps maintain blood glucose within a narrow range.	Pancreas (specifically beta cells in the islets of Langerhans)	Liver, muscle, adipose tissue
Testosterone	Development of male reproductive tissues and secondary sexual characteristics. It influences libido, muscle mass, bone density, facial hair growth, mood regulation, and energy levels.	Testes (in males), ovaries and adrenal glands (in females)	Reproductive organs, muscle, bone, brain

Estrogen	Development and function of female reproductive organs, including the uterus, ovaries, and breasts. Regulates menstrual cycle, maintains bone density, and supports cardiovascular health. Estrogen also affects mood, cognition, and skin health.	Ovaries (mainly), adrenal glands, adipose tissue	Reproductive organs, bone, brain, cardiovascular system
Thyroxine (T4)	Regulates metabolism, growth, and development throughout the body. It influences cellular energy production, protein synthesis, organs & tissue function. Thyroxine levels are crucial for maintaining metabolic balance and overall health.	Thyroid gland	Cells throughout the body
Cortisol	Body's stress response, increases blood sugar levels, suppressing the immune system, and modulating metabolism. It also regulates inflammation, blood pressure, and the sleep-wake cycle. Cortisol helps the body cope with stress and maintain physiological equilibrium.	Adrenal glands (specifically the adrenal cortex)	Liver, muscle, immune cells
Growth Hormone	Growth hormone stimulates growth, cell reproduction, and regeneration. It promotes the growth of bones, muscles, and other tissues, as well as supporting protein synthesis, fat metabolism, and the utilization of nutrients for energy production. Growth hormone is crucial for growth and maintenance of tissues throughout life.	Anterior pituitary gland	Bones, muscles, and tissues throughout the body
Progesterone	Critical role in the menstrual cycle, pregnancy, and embryonic development. It prepares the uterus for implantation and maintains the uterine lining during pregnancy, supporting fetal growth and development. Progesterone is essential for reproductive health and successful pregnancy.	Ovaries (mainly), adrenal glands, placenta (during pregnancy)	Reproductive organs, uterus, placenta (during pregnancy)
Auxins	Auxins regulate plant growth and development, including cell elongation, apical dominance, and root formation. They also influence tropic	Shoot apical meristems, young	Various plant tissues, including

	responses such as phototropism and gravitropism.	leaves, seeds	stems, roots, and leaves
Gibberellins	Gibberellins promote stem elongation, seed germination, and flowering in plants. They also regulate fruit and leaf growth and influence responses to environmental stimuli such as light and temperature changes.	Shoot apical meristems, young leaves, seeds	Stem and leaf tissues, seeds, and fruit
Cytokinins	Cytokinins regulate cell division and differentiation in plants, promoting shoot and root growth, and delaying senescence. They also influence apical dominance, leaf expansion, and nutrient uptake.	Root apical meristems, developing seeds, young fruits	Shoot and root meristems, leaves, and developing organs
Absciscic acid	Absciscic acid (ABA) regulates plant responses to environmental stressors such as drought, salinity, and cold temperatures. It promotes stomatal closure, inhibits seed germination, and induces dormancy in buds and seeds.	Leaves, stems, roots, and seeds	Guard cells, seeds, and buds
Ethylene	Ethylene is involved in various aspects of plant growth and development, including fruit ripening, leaf senescence, and abscission (shedding of leaves and fruits). It also regulates responses to mechanical stress.	Ripening fruits, aging leaves, and nodes of stems	Various plant tissues, including fruit, leaves, and roots