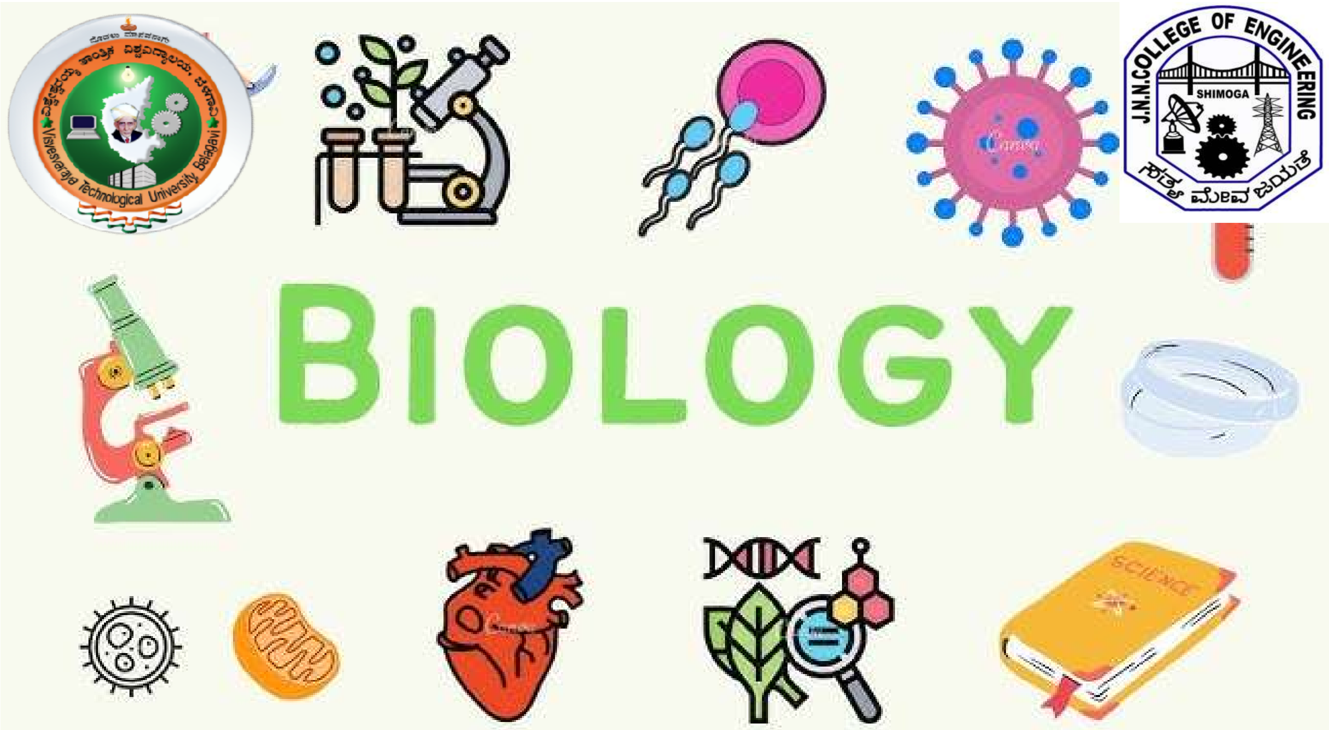


BIOLOGY FOR ENGINEERS
BBOK407

BIOLOGY FOR ENGINEERS		Semester	IV
Course Code	BBOK407	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	3:0:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	3
Examination type (SEE)	Theory		

Course objectives:

- To familiarize the students with the basic biological concepts and their engineering applications.
- To enable the students with an understanding of biodesign principles to create novel devices and structures.
- To provide the students an appreciation of how biological systems can be re-designed as substitute products for natural systems.
- To motivate the students to develop interdisciplinary vision of biological engineering.

Teaching-Learning Process (General Instructions)

These are sample Strategies, which teachers can use to accelerate the attainment of the various course outcomes.

1. Explanation via real life problem, situation modelling, and deliberation of solutions, hands-on sessions, reflective and questioning /inquiry-based teaching.
2. Instructions with interactions in classroom lectures (physical/hybrid).
3. Use of ICT tools, including YouTube videos, related MOOCs, AR/VR/MR tools.
4. Flipped classroom sessions (~10% of the classes).
5. Industrial visits, Guests talks and competitions for learning beyond the syllabus.
6. Students' participation through audio-video based content creation for the syllabus (as assignments).
7. Use of gamification tools (in both physical/hybrid classes) for creative learning outcomes.
8. Students' seminars (in solo or group) /oral presentations.

Module-1 (8 Hours)

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 cell, 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.

Module-2(8 Hours)

BIOMOLECULES AND THEIR APPLICATIONS (QUALITATIVE):

Carbohydrates (cellulose-based water filters, PHA and PLA as bioplastics), Nucleic acids (DNA Vaccine for Rabies and RNA vaccines for Covid19, Forensics – DNA fingerprinting), Proteins (Proteins as food – whey protein and meat analogs, Plant based proteins), lipids (biodiesel, cleaning agents/detergents), Enzymes (glucose-oxidase in biosensors, lignolytic enzyme in bio-bleaching).

Module-3(8 Hours)

HUMAN ORGAN SYSTEMS AND BIO DESIGNS (QUALITATIVE):

Brain as a CPU system (architecture, CNS and Peripheral Nervous System, signal transmission, EEG, Robotic arms for prosthetics. Engineering solutions for Parkinson's disease).Eye as a Camera system (architecture of rod and cone cells, optical corrections, cataract, lens materials, bionic eye). Heart as a pump system (architecture, electrical signalling - ECG monitoring and heart related issues, reasons for blockages of blood vessels, design of stents, pace makers, defibrillators). Lungs as purification system (architecture, gas exchange mechanisms, spirometry, abnormal lung physiology - COPD, Ventilators, Heart-lung machine). Kidney as a filtration system (architecture, mechanism of filtration, CKD, dialysis systems).

Module-4 (8 Hours)

NATURE-BIOINSPIRED MATERIALS AND MECHANISMS (QUALITATIVE):

Echolocation (ultrasonography, sonars), Photosynthesis (photovoltaic cells, bionic leaf). Bird flying (GPS and aircrafts), Lotus leaf effect (Super hydrophobic and self-cleaning surfaces), Plant burrs (Velcro), Shark skin (Friction reducing swim suits), Kingfisher beak (Bullet train). Human Blood substitutes - hemoglobin-based oxygen carriers (HBOCs) and perflourocarbons (PFCs).

Module-5(8 Hours)

TRENDS IN BIOENGINEERING (QUALITATIVE):

Muscular and Skeletal Systems as scaffolds (architecture, mechanisms, bioengineering solutions for muscular dystrophy and osteoporosis), scaffolds and tissue engineering, Bioprinting techniques and materials, 3D printing of ear, bone and skin. 3D printed foods. Electrical tongue and electrical nose in food science, DNA origami and Biocomputing, Bioimaging and Artificial Intelligence for disease diagnosis. Self-healing Bioconcrete (based on bacillus spores, calcium lactate nutrients and biomineralization processes) and Bioremediation and Biomining via microbial surface adsorption (removal of heavy metals like Lead, Cadmium, Mercury, Arsenic).

Course outcome (Course Skill Set)

At the end of the course, the student will be able to :

1. Elucidate the basic biological concepts via relevant industrial applications and case studies.
2. Evaluate the principles of design and development, for exploring novel bioengineering projects.
3. Corroborate the concepts of biomimetics for specific requirements.
4. Think critically towards exploring innovative biobased solutions for socially relevant problems.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 40% of the maximum marks (20 marks out of 50) and for the SEE minimum passing mark is 35% of the maximum marks (18 out of 50 marks). A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation:

- For the Assignment component of the CIE, there are 25 marks and for the Internal Assessment Test component, there are 25 marks.
- The first test will be administered after 40-50% of the syllabus has been covered, and the second test will be administered after 85-90% of the syllabus has been covered
- Any two assignment methods mentioned in the 22OB2.4, if an assignment is project-based then only one assignment for the course shall be planned. The teacher should not conduct two assignments at the end of the semester if two assignments are planned.
- For the course, CIE marks will be based on a scaled-down sum of two tests and other methods of assessment.

Internal Assessment Test question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

Semester-End Examination:

Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the course (**duration 03 hours).**

1. The question paper will have ten questions. Each question is set for 20 marks.
2. There will be 2 questions from each module. Each of the two questions under a module (with a maximum of 2 sub-questions), **should have a mix of topics** under that module.
3. The students have to answer 5 full questions, selecting one full question from each module.
4. Marks scored shall be proportionally reduced to 50 marks

Suggested Learning Resources:

Books

- Biology for Engineers, Rajendra Singh C and Rathnakar Rao N, Rajendra Singh C and Rathnakar Rao N Publishing, Bengaluru, 2023.
- Human Physiology, Stuart Fox, Krista Rompolski, McGraw-Hill eBook. 16th Edition, 2022
- Biology for Engineers, Thyagarajan S., Selvamurugan N., Rajesh M.P., Nazeer R.A., Thilagaraj W., Barathi S., and Jaganthan M.K., Tata McGraw-Hill, New Delhi, 2012.
- Biology for Engineers, Arthur T. Johnson, CRC Press, Taylor and Francis, 2011
- Biomedical Instrumentation, Leslie Cromwell, Prentice Hall 2011.
- Biology for Engineers, Sohini Singh and Tanu Allen, Vayu Education of India, New Delhi, 2014.
- Biomimetics: Nature-Based Innovation, Yoseph Bar-Cohen, 1st edition, 2012, CRC Press.
- Bio-Inspired Artificial Intelligence: Theories, Methods and Technologies, D. Floreano and C. Mattiussi, MIT Press, 2008.
- Bioremediation of heavy metals: bacterial participation, by C R Sunilkumar, N GeethaA C Udayashankar Lambert Academic Publishing, 2019.
- 3D Bioprinting: Fundamentals, Principles and Applications by Ibrahim Ozbolat, Academic Press, 2016.
- Electronic Noses and Tongues in Food Science, Maria Rodriguez Mende, Academic Press, 2016

Web links and Video Lectures (e-Resources):

- https://nptel.ac.in/courses/121106008
- https://freevideolectures.com/course/4877/nptel-biology-engineers-other-non-biologists
- https://ocw.mit.edu/courses/20-020-introduction-to-biological-engineering-design-spring-2009
- https://ocw.mit.edu/courses/20-010j-introduction-to-bioengineering-be-010j-spring-2006
- https://www.coursera.org/courses?query=biology
- https://onlinecourses.nptel.ac.in/noc19_ge31/preview
- https://www.classcentral.com/subject/biology
- https://www.futurelearn.com/courses/biology-basic-concepts

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

- Group Discussion of Case studies
- Model Making and seminar/poster presentations
- Design of novel device/equipment like Cellulose-based water filters, Filtration system

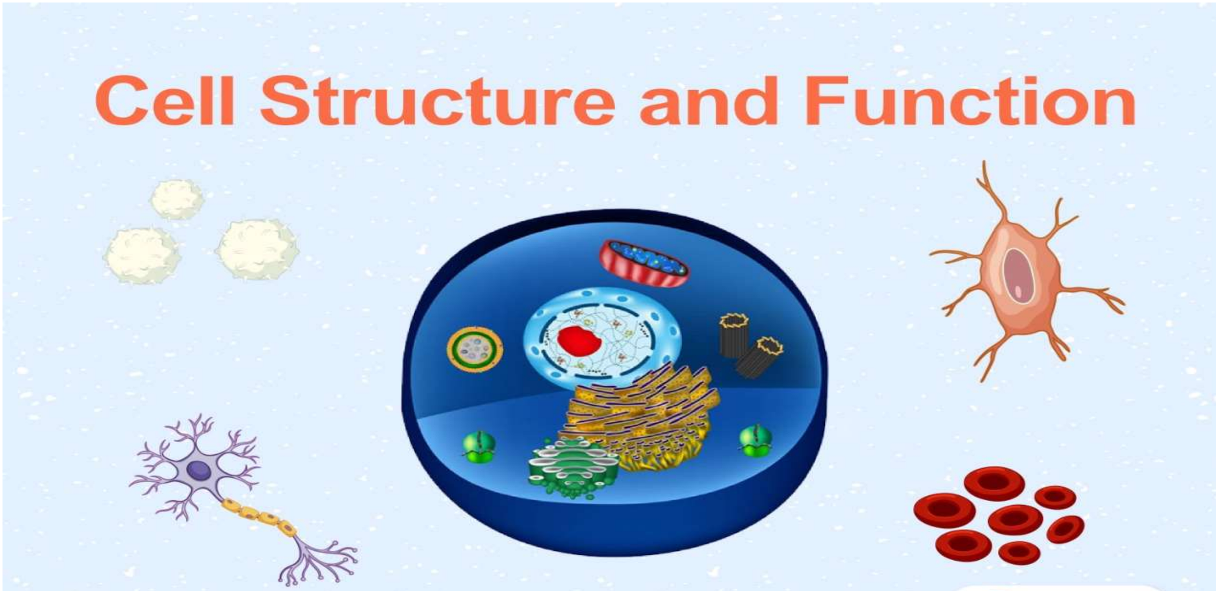
Course Outcomes: After studying this course, a student will be able to	
BBOK407.1	**Define the cells, its structure and function, and Different types of cells including the Classification of Biomolecules, Carbohydrates.**
BBOK407.2	**Explain about the biomolecules and their Industrial applications & explain about bio designs based 0n human physiology.**
BBOK407.3	**Demonstrate the concept of nature-inspired materials and mechanisms including ultrasonography, photovoltaic cells, GPS, Velcro, swim suits, bullet trains, HBOCs, PFCs etc,**
BBOK407.4	**Illustrate the trends in bioengineering involved in bio engineering solutions for muscular dystrophy and osteoporosis, bio-printing techniques, 3D printing solutions, self healing bio-concrete, AI disease diagnosis, and bio remediation,**

CO-PO and CO-PSO Mapping:

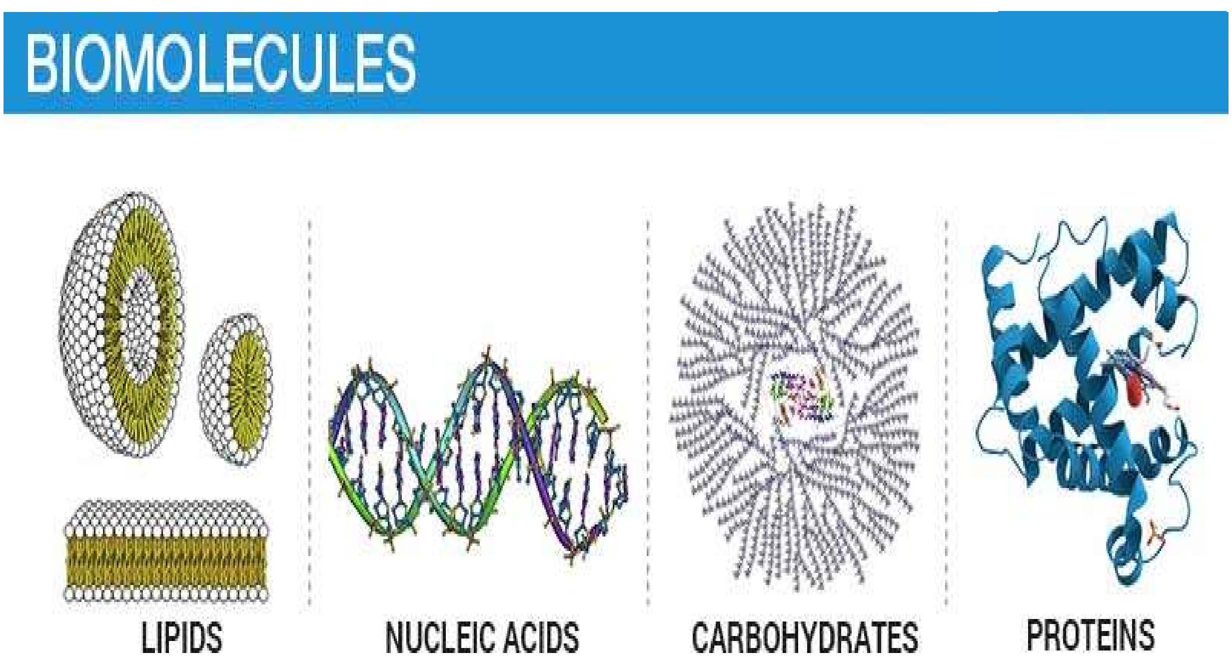
PO/PSO CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2
BBOK407.1	2			2	2	1						1		
BBOK407.2	2		2	2	2	2						1		
BBOK407.3	2	1	2	2	2	2						1		
BBOK407.4	2	1	2	2	2	2						1		
BBOK407	2	1	2	2	2	1.75						1		

Justification:

BCV304.1 To acquire the knowledge of cells structure and function there is a need of knowledge in science, investigation, modern tool usage for societal benefit and lifelong learning.
BCV304.2 The exploration of biomolecules and their application requires engineering knowledge and basic science knowledge to solve, design, investigate using modern tools for society and health.
BCV304.3 Designing and manufacturing of modern anthropogenic tools requires engineering knowledge and basic science knowledge for finding the solutions by investigation through modern tools applications to cater the society and also get the lifelong learning experience.
BCV304.4 Application of bioengineering for manufacturing artificial tools is possible by applying engineering knowledge and basic science knowledge, research investigation, modern tool usage in turn helping the society through lifelong learning.



BIOLOGY FOR ENGINEERS
BBOK407
MODULE : 01



BBOK407 : BIOLOGY FOR ENGINEERS

Module-1 (8 Hours)
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 cell, 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 structural and functional unit of all living organisms. All living organisms, whether unicellular or multicellular, are composed of cells. Cells carry out the essential processes necessary for life and are the building blocks of tissues and organs.

Structure of a Cell:

Cells can be broadly categorized into two types: prokaryotic and eukaryotic.

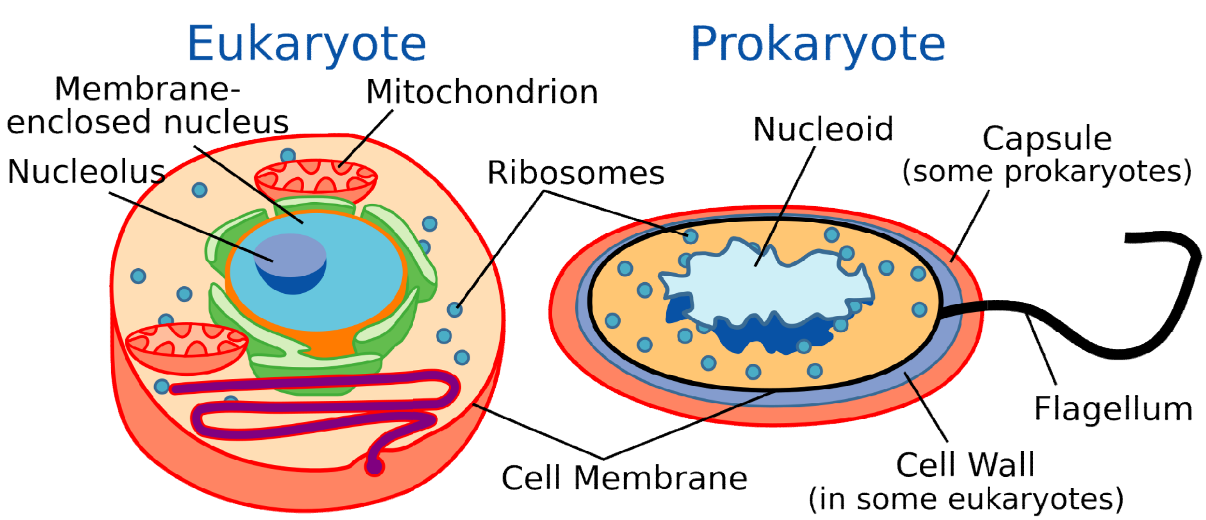


Figure : Prokaryote and Eularyote

1. **Prokaryotic Cells**:
   - No Nucleus: Prokaryotic cells lack a true nucleus. Instead, the genetic material (DNA) is present in a region called the nucleoid.
   - Simple Structure: Prokaryotic cells are generally smaller and simpler in structure than eukaryotic cells.
   - No Membrane-bound Organelles: They lack membrane-bound organelles, such as mitochondria or endoplasmic reticulum.

- Examples: Bacteria and archaea.

2. **Eukaryotic Cells**:
    - True Nucleus: Eukaryotic cells have a well-defined nucleus that houses the genetic material (DNA) enclosed within a nuclear membrane.
    - Complex Structure: Eukaryotic cells are larger and more structurally complex compared to prokaryotic cells.
    - Membrane-bound Organelles: Eukaryotic cells contain various membrane-bound organelles, including the endoplasmic reticulum, Golgi apparatus, mitochondria, and more.
    - Examples: Plant cells, animal cells, fungi cells, and protists.

Common Structures in Eukaryotic Cells:

1. Cell Membrane (Plasma Membrane): It surrounds the cell, regulating the passage of substances in and out of the cell.
2. Nucleus: Contains the genetic material (DNA) and controls cellular activities.
3. Cytoplasm: A gel-like substance within the cell that houses organelles and other cellular structures.
4. Endoplasmic Reticulum (ER): Involved in the synthesis and transport of proteins and lipids.
5. Golgi Apparatus: Modifies, packages, and transports proteins and lipids to their final destinations.
6. Mitochondria: Site of cellular respiration, producing energy in the form of ATP.
7. Ribosomes: Involved in protein synthesis.
8. Lysosomes: Contain enzymes for the breakdown of cellular waste and foreign material.
9. Cytoskeleton: Provides structural support and is involved in cellular movement.

Function of a Cell:

Cells perform various functions to maintain the life of an organism, and these functions can vary based on the type of cell and organism. However, some common functions include:

1. Cellular Respiration: The process by which cells generate energy (ATP) from nutrients.
2. Photosynthesis: In plant cells, the process of converting light energy into chemical energy in the form of glucose.
3. DNA Replication and Cell Division: Ensures the transmission of genetic information to daughter cells during cell division.
4. Protein Synthesis: The assembly of proteins using information encoded in DNA.
5. Transport of Materials: Movement of substances in and out of the cell to maintain homeostasis.
6. Cellular Communication: Cells communicate with each other through various signaling mechanisms.
7. Metabolism: All the chemical reactions that occur within a cell to maintain life.

Understanding the structure and function of cells is fundamental to comprehending the complexity of living organisms and their physiological processes.

PLANT CELL AND ANIMAL CELL :

Plant cells and animal cells are the two primary types of eukaryotic cells, sharing some similarities but also possessing distinct features related to their functions and the environments in which they exist.

Plant Cell:

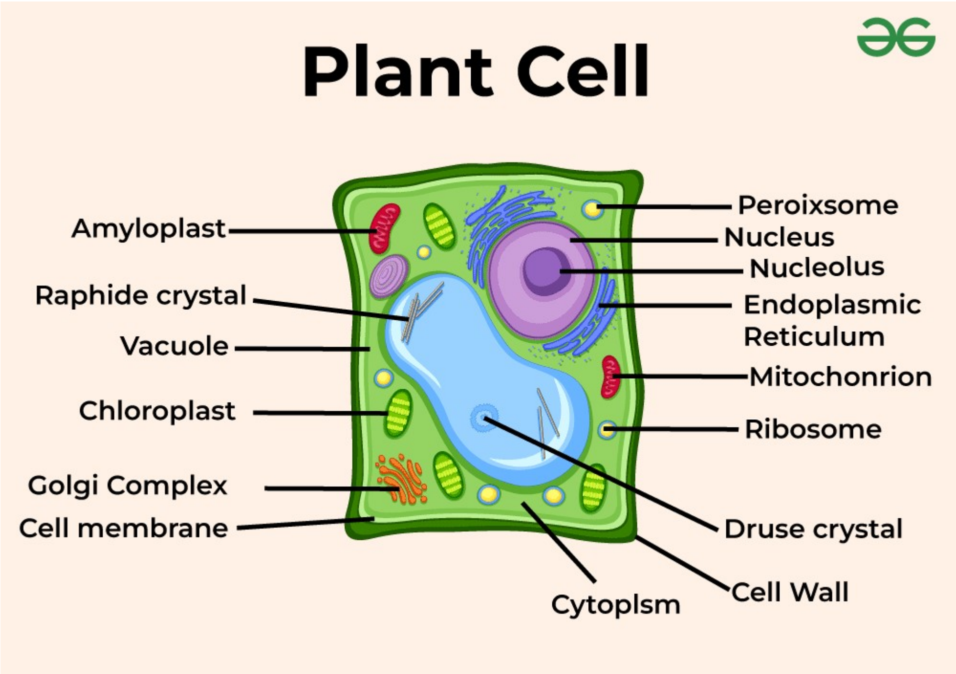


Figure : Plant Cell

1. **Cell Wall**: Plant cells have a rigid cell wall made of cellulose, providing structural support and protection. This feature is absent in animal cells.
2. **Chloroplasts**: Plant cells contain chloroplasts, which are responsible for photosynthesis, the process of converting light energy into chemical energy. Chloroplasts contain the green pigment chlorophyll.
3. **Large Central Vacuole**: Plant cells typically have a large central vacuole filled with sap, which helps maintain turgor pressure, store nutrients, and facilitate waste management. Animal cells may have smaller vacuoles, but they are not as prominent.
4. **Plastids**: Besides chloroplasts, plant cells may contain other types of plastids involved in the storage of pigments, starch, and lipids.
5. **Fixed Shape**: The presence of a rigid cell wall gives plant cells a fixed and defined shape.

Animal Cell:

1. **No Cell Wall**: Animal cells lack a cell wall. Instead, they are surrounded by a flexible cell membrane.
2. **No Chloroplasts**: Animal cells do not contain chloroplasts, and they do not perform photosynthesis. Animals obtain their energy through other means, such as consuming plants or other animals.

3. **Small Vacuoles**: Animal cells may have small, temporary vacuoles for storage, but these are not as prominent as the large central vacuole in plant cells.
4. **Centrioles**: Animal cells contain centrioles, which are involved in the organization of microtubules during cell division. Plant cells generally do not have centrioles.
5. **Irregular Shape**: Without a rigid cell wall, animal cells have a more flexible and variable shape.

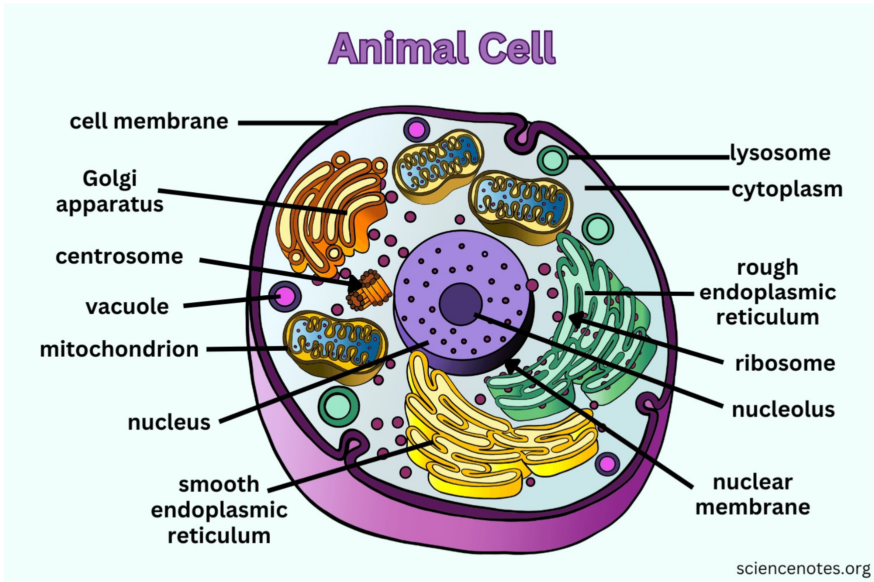


Figure : Animal Cell

Despite these differences, both plant and animal cells share fundamental organelles and structures, including the nucleus, endoplasmic reticulum, Golgi apparatus, mitochondria, and more. These organelles carry out essential cellular functions, such as protein synthesis, energy production, and cellular communication. Additionally, both cell types are crucial components of complex multicellular organisms, contributing to the overall functioning of tissues and organs.

PROKARYOTIC CELLS AND EUKARYOTIC CELLS :

Prokaryotic cells and eukaryotic cells are the two main types of cells that exist in living organisms, each with distinct characteristics related to their structure and organization.

Prokaryotic Cells:

1. **No True Nucleus:** Prokaryotic cells lack a true nucleus. Instead, their genetic material (DNA) is present in a region called the nucleoid, which is not enclosed by a membrane.
2. **Simple Structure:** Prokaryotic cells are generally smaller and simpler in structure compared to eukaryotic cells.
3. **No Membrane-bound Organelles:** Prokaryotic cells lack membrane-bound organelles such as mitochondria, endoplasmic reticulum, Golgi apparatus, and chloroplasts.
4. **Single-Celled Organisms:** Most prokaryotes are unicellular organisms, although there are some exceptions like cyanobacteria that form colonies.
5. **Circular DNA:** The genetic material in prokaryotic cells is usually a single, circular DNA molecule.

6. **Ribosomes:** Prokaryotic cells contain ribosomes, but they are smaller than those found in eukaryotic cells.
7. **Examples:** Bacteria and archaea are examples of organisms with prokaryotic cells.

Eukaryotic Cells:

1. **True Nucleus:** Eukaryotic cells have a well-defined nucleus enclosed by a nuclear membrane, where the genetic material (DNA) is housed.
2. **Complex Structure:** Eukaryotic cells are generally larger and more structurally complex than prokaryotic cells.
3. **Membrane-bound Organelles:** Eukaryotic cells contain membrane-bound organelles such as mitochondria, endoplasmic reticulum, Golgi apparatus, chloroplasts (in plant cells), lysosomes, and more.
4. **Single or Multicellular Organisms:** Eukaryotes can be unicellular, like some protists and yeast, or multicellular, forming complex organisms such as plants, animals, and fungi.
5. **Linear DNA:** The genetic material in eukaryotic cells is organized into multiple linear chromosomes.
6. **Cytoskeleton:** Eukaryotic cells possess a cytoskeleton made up of microtubules, microfilaments, and intermediate filaments, providing structural support and facilitating intracellular transport.
7. **Examples:** Plants, animals, fungi, and protists are examples of organisms with eukaryotic cells.

In summary, the key distinction between prokaryotic and eukaryotic cells lies in the presence of a true nucleus, membrane-bound organelles, and the complexity of the cellular structure. Prokaryotic cells are simpler and lack certain features compared to the more complex and structurally diverse eukaryotic cells.

STEM CELLS AND THEIR APPLICATIONS :

Stem cells are unique cells with the remarkable ability to develop into different cell types in the body. They have the potential to divide and differentiate into specialized cells, contributing to the development, growth, and repair of tissues and organs. There are two primary types of stem cells: embryonic stem cells and adult (or somatic) stem cells.

1. Embryonic Stem Cells (ESCs):

- **Source:** Derived from embryos at the blastocyst stage.
- **Pluripotent:** Have the potential to differentiate into any cell type in the body.
- **Applications:**
  - **Tissue Repair and Regeneration:** ESCs can be directed to differentiate into specific cell types for the repair or replacement of damaged tissues and organs.
  - **Drug Testing and Disease Modeling:** They are used in research to study diseases, test new drugs, and understand cellular development and function.

2. Adult (Somatic) Stem Cells:

- **Source:** Found in various tissues of the body, such as bone marrow, adipose tissue, and the brain.
- **Multipotent or Unipotent:** Multipotent stem cells can differentiate into a limited range of cell types, while unipotent stem cells can differentiate into a single cell type.
- **Applications:**
    - **Tissue Regeneration:** Adult stem cells play a role in natural tissue repair and regeneration by differentiating into specialized cells required for the specific tissue.
    - **Hematopoietic Stem Cell Transplants:** Used in bone marrow transplants for treating certain blood disorders and cancers.
    - **Mesenchymal Stem Cells (MSCs):** These cells have applications in treating conditions like osteoarthritis, heart disease, and autoimmune disorders.

Applications of Stem Cells:

1. **Regenerative Medicine:**
    - Stem cells hold great promise for regenerating tissues and organs damaged by injury, disease, or aging.
    - Treatment of conditions such as spinal cord injuries, heart disease, and neurodegenerative disorders.
2. **Drug Discovery and Testing:**
    - Stem cells are used to model diseases and test the safety and efficacy of new drugs before clinical trials, reducing the need for animal testing.
3. **Tissue Engineering:**
    - Stem cells are employed to create artificial tissues and organs for transplantation, addressing the shortage of donor organs.
4. **Gene Therapy:**
    - Stem cells can be genetically modified to correct or replace defective genes, offering potential treatments for genetic disorders.
5. **Understanding Developmental Biology:**
    - Studying stem cells provides insights into the processes of development, differentiation, and tissue formation.
6. **Treatment of Blood Disorders:**
    - Hematopoietic stem cells are used in bone marrow transplants to treat leukemia, lymphoma, and other blood disorders.
7. **Anti-Aging Therapies:**
    - Stem cell research may contribute to understanding and developing treatments for age-related degenerative diseases.

While the field of stem cell research and applications is promising, ethical considerations, regulatory challenges, and safety concerns must be carefully addressed to ensure responsible and effective use of stem cell technologies.

BIOMOLECULES :

Biomolecule, also called biological molecule, any of numerous substances that are produced by cells and living organisms. Biomolecules include both micromolecules, e.g. amino acids, nitrogenous bases, fatty acids, sugar, etc. and macromolecules, such as carbohydrates, proteins, lipids and nucleic acids.

Biomolecules have a wide range of sizes and structures and perform a vast array of functions. The four major types of biomolecules are carbohydrates, lipids, nucleic acids, and proteins. Among biomolecules, nucleic acids, namely DNA and RNA, have the unique function of storing an organism's genetic code—the sequence of nucleotides that determines the amino acid sequence of proteins, which are of critical importance to life on Earth.

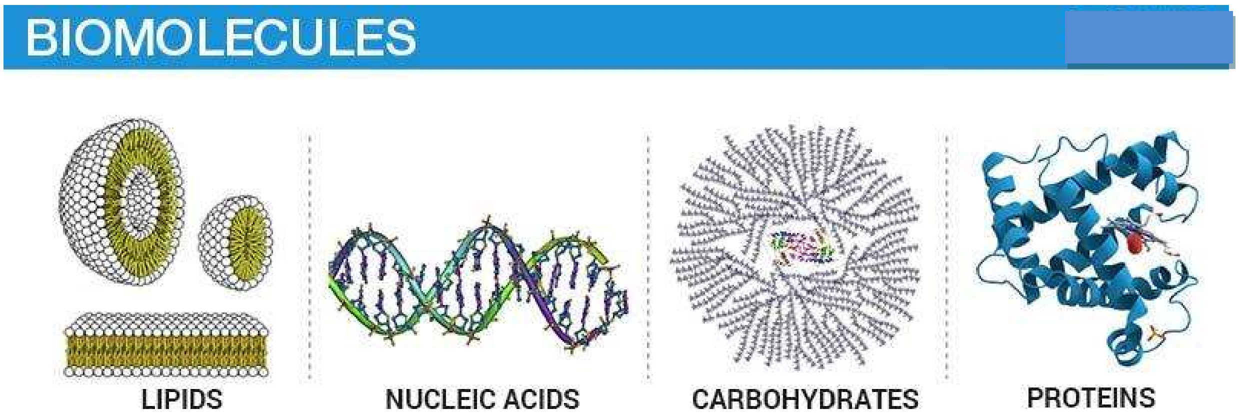


Figure : Types of Biomolecules.

There are 20 different amino acids that can occur within a protein; the order in which they occur plays a fundamental role in determining protein structure and function. Proteins themselves are major structural elements of cells. They also serve as transporters, moving nutrients and other molecules in and out of cells, and as enzymes and catalysts for the vast majority of chemical reactions that take place in living organisms. Proteins also form antibodies and hormones, and they influence gene activity.

Carbohydrates :

Carbohydrates are the most abundant biomolecules on earth. Oxidation of carbohydrates is the central energy-yielding pathway in most non-photosynthetic cells. Definition: Carbohydrates are polyhydroxy aldehydes or ketones, or substances that yield such compounds on hydrolysis. Carbohydrates have the empirical formula (CH2O)n.

There are three major classes of carbohydrates:

1. **Monosaccharides** : Monosaccharides, or simple sugars, consist of a single polyhydroxy aldehyde or ketone unit. The most abundant monosaccharide in nature is the six-carbon sugar Dglucose, sometimes referred to as dextrose.
2. **Oligosaccharides** Oligosaccharides consist of short chains of monosaccharide units, or residues, joined by characteristic linkages called glycosidic bonds. The most abundant are the disaccharides, with two monosaccharide units. Example: sucrose (cane sugar).
3. **Polysaccharides** The polysaccharides are sugar polymers containing more than 20 or so monosaccharide units, and some have hundreds or thousands of units. Example: starch. Polysaccharides are of two types based on their function and composition. Based on function,

polysaccharides are of two types: storage and structural. i) Storage polysaccharide – starch and ii) Structural polysaccharide - cellulose.

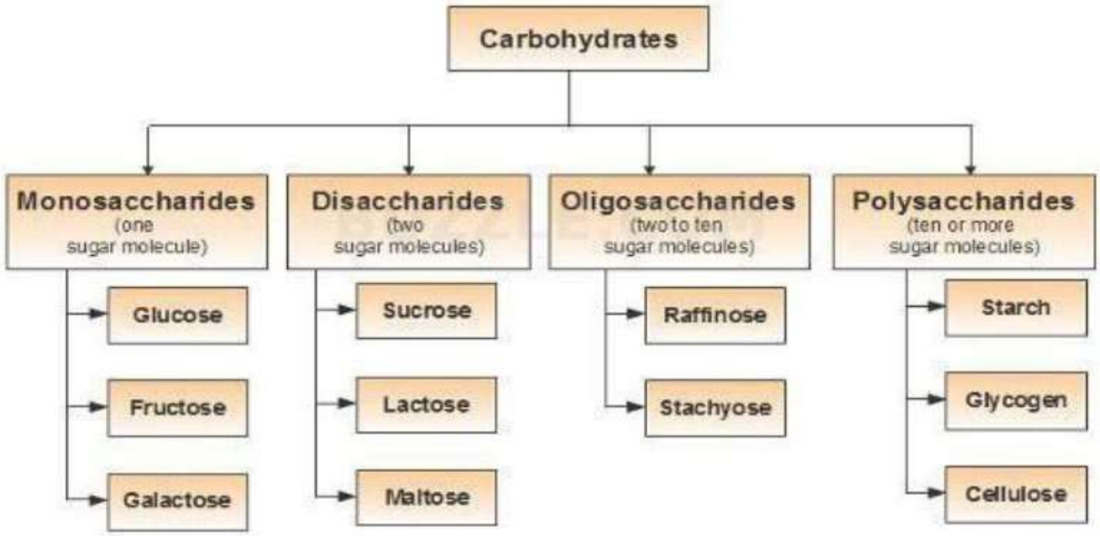


Figure : Classification of Carbohydrates.

General properties of carbohydrates :

- Carbohydrates act as energy reserves, also stores fuels, and metabolic¬ intermediates.
- Ribose and deoxyribose sugars forms the structural frame of the genetic¬ material, RNA and DNA.
- Polysaccharides like cellulose are the structural elements in the cell walls of¬ bacteria and plants.
- Carbohydrates are linked to proteins and lipids that play important roles in¬ cell interactions.
- Carbohydrates are organic compounds, they are aldehydes or ketones with¬ many hydroxyl groups.

Physical Properties of Carbohydrates:

- **Stereoisomerism** - Compound shaving same structural formula but they differ¬ in spatial configuration. Example: Glucose has two isomers with respect to penultimate carbon atom. They are D-glucose and L-glucose.
- **Optical Activity** - It is the rotation of plane polarized light forming (+) glucose¬ and (-) glucose.
- **Diastereoisomerism** - It is the configurational change with respect to C2, C3, or¬ C4 in glucose. Example: Mannose, galactose.
- **Anomerism** - It is the spatial configuration with respect to the first carbon atom¬ in aldoses and second carbon atom in ketoses.

Biological Importance :

- Carbohydrates are chief energy source, in many animals, they are instant ource of energy. Glucose is broken down by glycolysis/ Kreb's cycle to yield ATP.
- Glucose is the source of storage of energy. It is stored as glycogen in animals and starch in plants.
- Stored carbohydrates act as energy source instead of proteins.

- Carbohydrates are intermediates in biosynthesis of fats and proteins.
- Carbohydrates aid in regulation of nerve tissue and as the energy source for brain.
- Carbohydrates get associated with lipids and proteins to form surface¬ antigens, receptor molecules, vitamins and antibiotics.
- They form structural and protective components, like in cell wall of plants and microorganisms.
- In animals they are important constituent of connective tissues.
- They participate in biological transport, cell-cell communication and activation of growth factors.
- Carbohydrates rich in fibre content help to prevent constipation.
- Also they help in modulation of immune system.

NUCLEIC ACIDS :

Nucleic acids are macromolecules that are found in every living cell, either alone or in conjunction with other substances. End-to-end polymerisation of a vast number of units called nucleotides linked by phosphodiester linkages forms these lengthy strands. The word “nucleic acid” is used to describe specific big molecules found in cells.

Properties of Nucleic Acids :

- Nucleotides are the building blocks of nucleic acid.
- These make up all living things’ genetic material.
- In a live cell, deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) are two forms of nucleic acids.
- In 1969, Friedrich Miescher discovered both DNA and RNA.
- A nucleotide is made up of three chemically different components. A heterocyclic base, or nitrogenous base, is one, a monosaccharide pentose sugar is another, and phosphoric acid, or phosphate group, is the third.
- The nitrogenous bases are made up of one or two heterocyclic rings that include nitrogen atoms. Adenine (A), guanine (G), uracil (U), cytosine (C), and thymine (5-methyl uracil) are the five bases (T).
- Adenine and guanine are substituted purines with two heterocyclic rings, whereas uracil, cytosine, and thymine are substituted pyrimidines with three heterocyclic rings (1 heterocyclic ring).
- DNA has the nitrogenous bases A, T, G, and C, whereas RNA has the nitrogenous bases A, U, G, and C.
- Polynucleotides either include beta-ribose sugar (in RNA) or beta 2′ deoxyribose sugar (in DNA) (in DNA).
- Nucleosides: Sugar + Base
- Nucleotides are made up of three parts: base, sugar, and phosphate.
- The backbone of DNA strands is made up of phosphodiester linkages, which are sugar and phosphate residues.
- Due to the presence of phosphate groups, they are acidic and negatively charged.

Functions of Nucleic Acids: Nucleic acids are genetic material for all living cells, meaning they pass on hereditary characteristics from one generation to the next. Nucleic acid can also determine an organism's phenotypic. Some nucleic acids, such as ribozymes, may have enzymatic activity. Nucleic acids play a role in protein production, either directly or indirectly.

Structure of Nucleic Acid : The nucleotide is a tiny unitary structure made up of phosphodiester links that connect nucleic acids. Each nucleotide comprises

- A Nitrogen base
- A Pentose sugar
- Phosphoric acid

An N-glycosidic linkage connects a pentose sugar to a nitrogenous base to form a nucleoside.

Nitrogen base + Pentose sugar = Nucleoside

Nitrogen Bases: The nitrogen bases are the nitrogenous components of the nucleotide. Purine and pyrimidine are two forms of heterocyclic bases that are used to make the five nitrogenous bases.

- Purines have a two-ring structure. Adenine (A) and guanine (G) are the two purine bases found in DNA and RNA (G).
- Pyrimidines are bases with only one ring. Cytosine (C) and thymine (T) are the pyrimidine bases found in DNA molecules, while cytosine (C) and uracil are the pyrimidine bases found in RNA molecules (U).

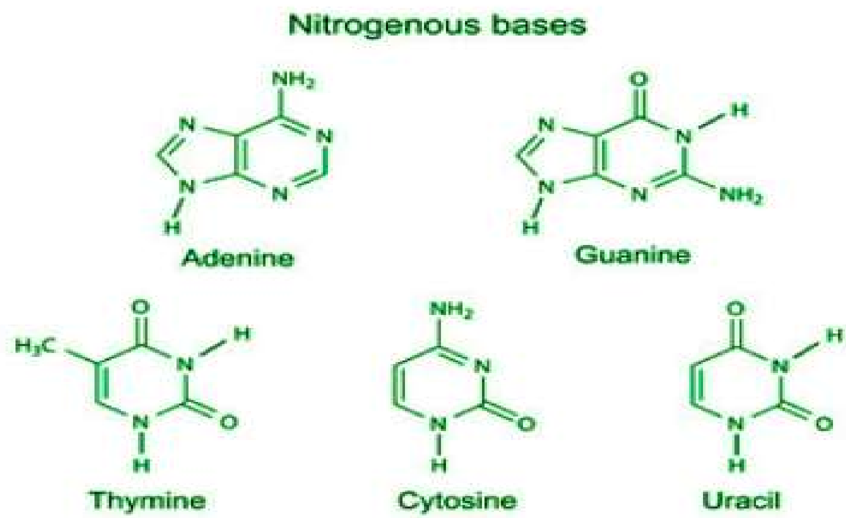


Figure : Structure of Nitrogenous bases Nucleic Acids

Pentose Sugar: Pentose sugar is a sugar molecule or monosaccharide having five carbon atoms. In nucleic acid, the pentose sugar is an aldose sugar. RNA is a nucleic acid that contains ribose sugar, whereas DNA is a nucleic acid that contains a Beta-2'–deoxyribose sugar. Chemically, these two sugars are not the same. Ribose sugar has the chemical formula $C_5H_{10}O_5$, whereas Beta-2'–deoxyribose sugar has the molecular formula $C_5H_{10}O_4$. With OH groups of 5′ and 3′ carbon, these sugars make bonds with phosphate groups, whereas with nitrogenous bases, they form bonds with OH groups of 1′ carbon.

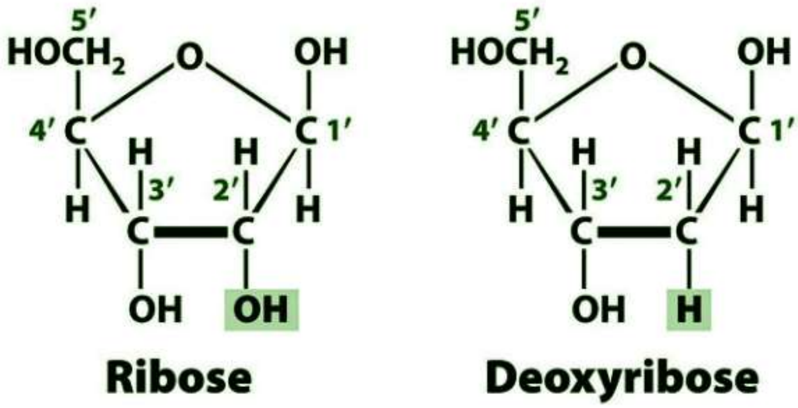


Figure : Pentose Sugar

- **Phosphoric Acid:** H_3PO_4 is the formula. Three reactive -OH groups can be found in phosphoric acid. Two of these are involved in the formation of a sugar-phosphate backbone using phosphodiester bonds.

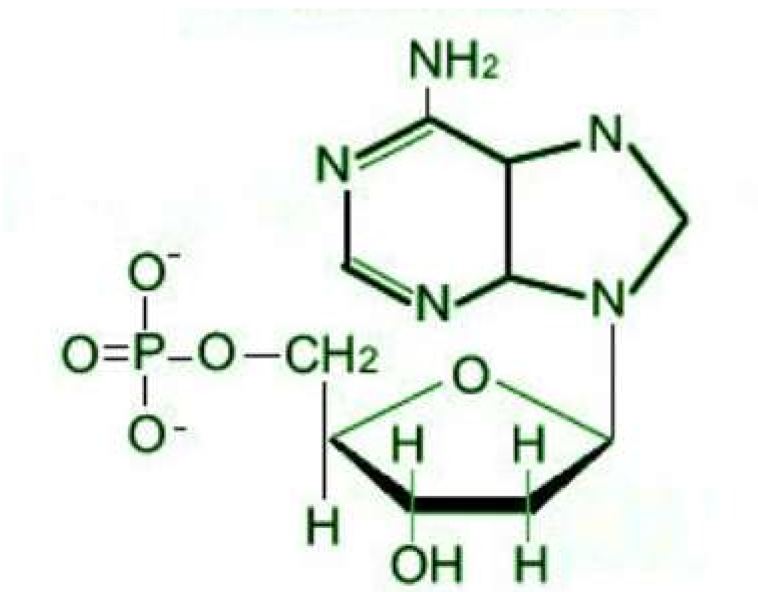


Figure : Phosphoric Acid

Bonds between Different Units of Nucleotides :

The following types of linkage or bond can be found in a nucleotide unit's components:

1. **N–glycosidic linkage:** To generate a nucleoside, a nitrogenous base is attached to the pentose sugar via a N– glycosidic linkage. Purine nucleosides feature a 1'–9′ glycosidic bond (sugar carbon 1′, A/G nitrogen 9′). The 1'–1′ linkage (sugar carbon 1′ and 1′ nitrogen of T/C) is found in pyrimidine nucleosides.
2. **Phosphoester linkage:** A matching nucleotide is generated when a phosphate group is attached to the 5′–OH of a pentose sugar of a nucleoside via phosphodiester linkage. A dinucleotide is made up of two nucleotides joined together by a 3′–5′ phosphodiester bond.

Types of Nucleic Acids

Nucleic acids are of two types:

1. Deoxyribonucleic acid (DNA)
2. Ribonucleic Acid (RNA)

DNA

All living species have DNA as their primary genetic material. It's a nucleic acid molecule with two strands.

Occurrence: DNA is mostly present in the chromosomes of plant and animal cells' nuclei. It's found in mitochondria and chloroplasts as well. It's found in circular and supercoiled chromosomes in prokaryotes' cytoplasm. However, it is found in eukaryotes with proteins such as histones and protamine.

Structure: Watson and Crick's double-stranded double-helical model is the most widely accepted structural model of DNA (1953). The structure of DNA, according to the model, is as follows:

- A right-handed helical spiral is formed by each chain of DNA, and two chains coil around each other to form a double helix.
- The phosphodiester bond is the link between the sugar and phosphate molecules, and the bases project inside.
- The chains run in antiparallel directions, with one strand coming from the 5'→3′ direction and the other coming from the 3'→5′ direction.
- The nitrogenous bases on one strand form hydrogen bonds with the bases on the other strand. Adenine forms 2H -bonds with thymine (A-T), and guanine forms 3H -bonds with cytosine (G-C). The helical structure is stabilised by this coupling.
- The chains are complementary because, for every adenine in one chain, there will be thymine in the other; for every guanine in one chain, there will be cytosine in the other, and so on.
- DNA has a 2nm consistent thickness.
- The pitch of the helix is 3.4nm for each round of the double helix.
- Each turn comprises around 10 base pairs. The distance between two neighbouring base pairs is about 0.34 nanometers.
- The helix's backbone is made up of sugar and phosphate, with bases aligned along the axis.

RNA :

RNA is a single-stranded nucleic acid found in a few viruses, such as retroviruses and viroids, as genetic material.

Occurrence: The majority of RNA is located in the cytoplasm of cells. The nucleolus and nucleoplasm both contain it. Except for a few viruses that have double-stranded RNA, it is generally found as a single-stranded polynucleotide.

Structure:

1. The single RNA strand is folded back on itself, generating hairpin-like structures fully or in parts.
2. In some plant viruses, the genetic material is double-stranded but non-helical RNA.
3. Each strand of RNA is made up of a large number of ribonucleotides that are bonded together by phosphodiester linkages.
4. Adenine and uracil (A-U) form a pair, and guanine and cytosine form a pair (G-C).
5. Messenger RNA, ribosomal RNA, and transfer RNA are the three kinds of RNA.

Difference between DNA and RNA

DNA	RNA
It contains deoxyribose sugar.	It contains ribose sugar.
It can be present in the nucleus, mitochondria, and chloroplast chromosomes.	It is related to chromosomes and can be found in the cytoplasm, nucleolus, and nucleoplasm.
Double-stranded structure.	Single-stranded structures generally except a few viruses.
Adenine, guanine, cytosine, and thymine are the nitrogenous bases found.	Adenine, guanine, cytosine, and uracil are the nitrogenous bases found.
A long molecule with high molecular weight.	A relatively short molecule with low molecular weight.
Purines and pyrimidines occur in equal proportion	Purines and pyrimidines do not occur in equal proportion.
DNA is the hereditary material.	Only a few viruses and viroids have RNA as their genetic material.

PROTEINS :

Proteins are macromolecules made up of monomers called amino acids. Amino acids are the building block of all proteins. Proteins are highly complex macromolecules consisting of one or more long chains of amino acids linked together by peptide bonds.

- A protein is a macronutrient that is present in all living beings and is directly involved in various metabolic pathways.

- Proteins are species-specific and are unique to each organism. Similarly, these are also organ-specific in that the proteins of the brain are different from those in the muscles.
- Proteins are made up of 20 different amino acids, and the property of a protein molecule is a function of the amino acids present.
- Plants are capable of synthesizing all amino acids necessary to make proteins, whereas animals cannot.
- Amino acids in proteins are linked together by peptide bonds that are formed between the NH2 group of one amino acid to the COOH group of another amino acid.
- Proteins are also termed polypeptides, as they are long chains of amino acids connected by peptide bonds.

Properties of Proteins :

1. **Amino Acid Composition**: Proteins are composed of amino acids linked together by peptide bonds. There are 20 different amino acids that can be combined in various sequences to form proteins.
2. **Structure**: Proteins have a complex three-dimensional structure that can be categorized into four levels:
    - **Primary Structure**: Sequence of amino acids
    - **Secondary Structure**: Alpha-helices and beta-sheets formed by hydrogen bonding
    - **Tertiary Structure**: Overall three-dimensional shape
    - **Quaternary Structure**: Arrangement of multiple protein subunits, if applicable
3. **Solubility**: Proteins can be soluble in water (hydrophilic) or insoluble (hydrophobic) depending on their amino acid composition and environment.
4. **Denaturation**: Proteins can be denatured or unfolded by heat, pH changes, or chemicals, which can affect their function.

Functions of Proteins:

1. **Enzymatic Activity**: Many proteins act as enzymes, catalyzing biochemical reactions in the body by speeding up chemical reactions.
2. **Structural Support**: Proteins like collagen and keratin provide structural support to tissues and organs.
3. **Transport**: Proteins like hemoglobin transport molecules such as oxygen and carbon dioxide in the blood.
4. **Hormones**: Proteins like insulin and growth hormone act as chemical messengers to regulate various physiological processes.
5. **Immune Response**: Antibodies are proteins produced by the immune system to recognize and neutralize pathogens.
6. **Cell Signaling**: Proteins participate in cell signaling pathways to regulate cellular activities like growth, differentiation, and apoptosis.
7. **Muscle Contraction**: Proteins like actin and myosin are essential for muscle contraction and movement.
8. **Nutrient Storage**: Proteins can act as nutrient reserves, especially in seeds (e.g., albumin in egg whites).
9. **pH Balance**: Some proteins act as buffers to maintain pH balance in body fluids.

10. **Gene Expression**: Proteins like histones play a role in DNA packaging and gene regulation. Understanding the properties and functions of proteins is essential for studying biology, medicine, and biochemistry. The versatility of proteins allows them to perform a wide range of roles that are crucial for life.

Protein Structures :

- Because protein is a complex macromolecule, its structure has been described using four basic structural levels of the organization.
- These structural levels are often referred to as primary, secondary, tertiary, and quarternary.
- Three of these structural levels (primary, secondary, and tertiary) can exist in molecules composed of a single polypeptide chain. In contrast, the fourth (quarternary) involves interactions of polypeptides within a multi chained protein molecule.

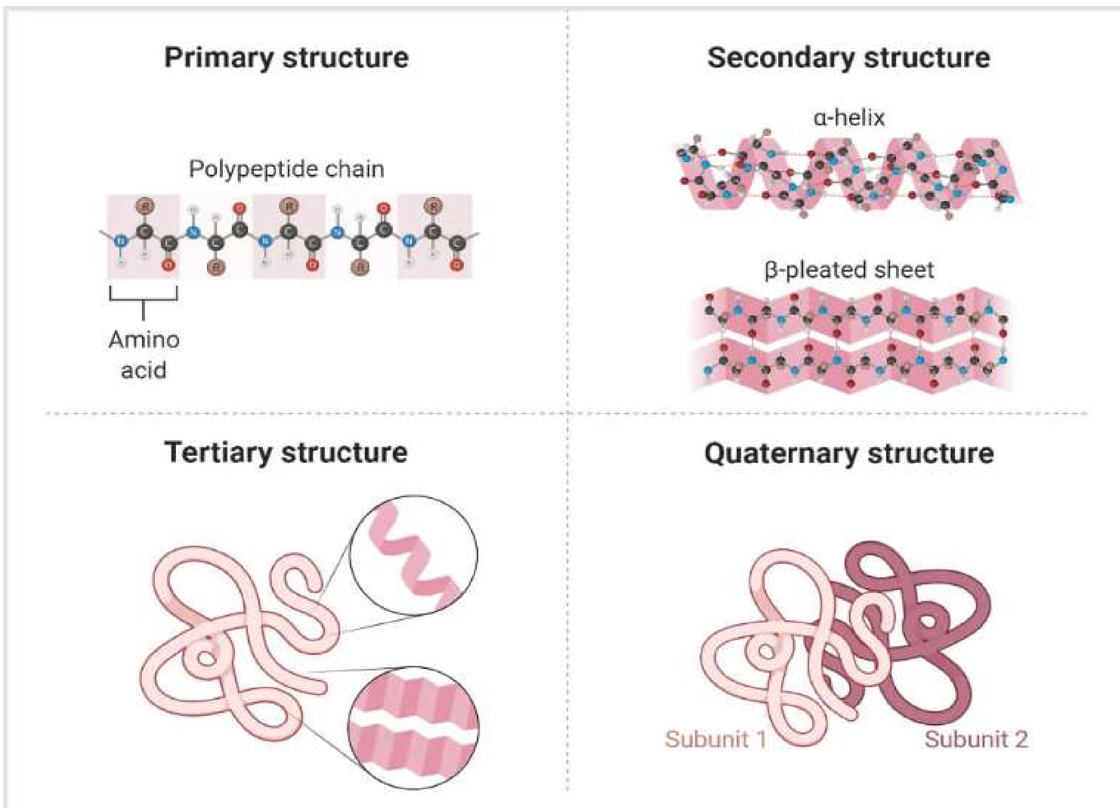


Figure : Protein Structure

1. Primary structure

- The basic primary structure of a protein is relatively simple and consists of one or more linear chains of a number of amino acid units.
- The primary structure of a protein indicates the number and sequence of amino acids which form the constituent units of the polypeptide chain.
- The primary bond between the amino acids in proteins is the peptide bond which links the α-carboxyl group of one amino acid residue to the α-amino group of the adjacent amino acid. The proteins may consist either of one or more polypeptide chains.

- A partial double bond is created between carbon and nitrogen of the amide bond, which aids in the stabilization the peptide bond.
- A resonance effect is created as the nitrogen involved in the bond donates its lone pair to the carbonyl group.
- The resonance mechanism is highly stabilizing as the electrons can be delocalized over multiple atoms generating a resonance structure which is stable than the native structure.
- The resonance structure thus created stabilizes the bond but also limits the rotation of the amide bond due to the partial double bond.
- Peptide bonds create a planar configuration that undergoes minimal movement around the C-N bond but the other single bonds on either side of C-N bond exhibit a high degree of rotational motion.

2. Secondary structure

- The linear, unfolded primary structure of the polypeptide chain often assumes a helical shape to produce the secondary structure.
- The secondary structure of proteins refers to the steric or spatial relationship of amino acids that are near to each other in the amino acid sequence.
- The folding of the chain is mainly due to the presence of hydrogen bonds which can either be intramolecular or intermolecular.
- The folding and hydrogen bonding between neighboring amino acids results in the formation of a rigid and tubular structure called a helix.
- Secondary structures in proteins are of two types depending on the nature of the hydrogen bonding; α-helix and β-pleated sheet.

a. Alpha-helix structure

- The alpha-helix structure is formed when the CO group of each amino acid is hydrogen-bonded to the NH group of the amino acid that is present four residues ahead in the linear sequence.
- The α-helical structure depends on the intramolecular hydrogen bonding between the NH and CO groups of peptide bonds.

b. Beta-pleated structure

- The β-pleated sheet structure is formed by the parallel alignment of a number of polypeptide chains, with hydrogen bonds between the >C = O and N-H groups of adjacent chains.
- The R groups of the constituent amino acids in one polypeptide chain alternately project above and below the plane of the sheet.
- The formation of β-pleated sheets depends on intermolecular hydrogen bonding, although intramolecular hydrogen bonds are also present.

3. Tertiary structure

- The tertiary structure of the protein molecule is a three-dimensional structure of protein formed by the folding of secondary structure in certain specific patterns.
- The tertiary structure is generally stabilized by outside polar hydrophilic hydrogen and ionic bond interactions, and internal hydrophobic interactions between nonpolar amino acid side chains.
- Based upon their tertiary structure, proteins are often divided into globular or fibrous types.

a. Fibrous proteins

- Fibrous proteins have elongated rope-like structures that are strong and hydrophobic and usually consist mainly of a single type of secondary structure.

- The structures that provide support, shape, and external protection to vertebrates are made of fibrous proteins like α-keratin.

b. Globular proteins

- Globular proteins often contain several types of secondary structure and are more spherical and hydrophilic.
- Thus, most enzymes and regulatory proteins like immunoglobulins are globular proteins.

4. Quaternary structure

- The three-dimensional arrangement of protein subunits in proteins containing two or more identical or different polypeptide chains, or subunits is the quaternary structure.
- The subunits are held together by noncovalent forces between complementary surface hydrophobic and hydrophilic regions on the polypeptide subunits.
- These forces allow the polypeptide chains to undergo rapid conformational changes that affect the biological activity of the proteins.

Classification of Proteins :

Based on the chemical nature, structure, shape, and solubility, proteins are classified as:

1. **Simple proteins**: They are composed of only amino acid residue. On hydrolysis, these proteins yield only constituent amino acids. It is further divided into:
    - Fibrous protein: Keratin, Elastin, Collagen
    - Globular protein: Albumin, Globulin, Glutelin, Histones
2. **Conjugated proteins**: They are combined with non-protein moiety. Eg. Nucleoprotein, Phosphoprotein, Lipoprotein, Metalloprotein, etc.
3. **Derived proteins**: They are derivatives or degraded products of simple and conjugated proteins. They may be :
    - Primary derived protein: Proteans, Metaproteins, Coagulated proteins
    - Secondary derived proteins: Proteosesn or albunoses, peptones, peptides.

LIPIDS :

- Lipids are a heterogeneous group of organic compounds that are insoluble in water and soluble in non-polar organic solvents.
- They naturally occur in most plants, animals, microorganisms and are used as cell membrane components, energy storage molecules, insulation, and hormones.

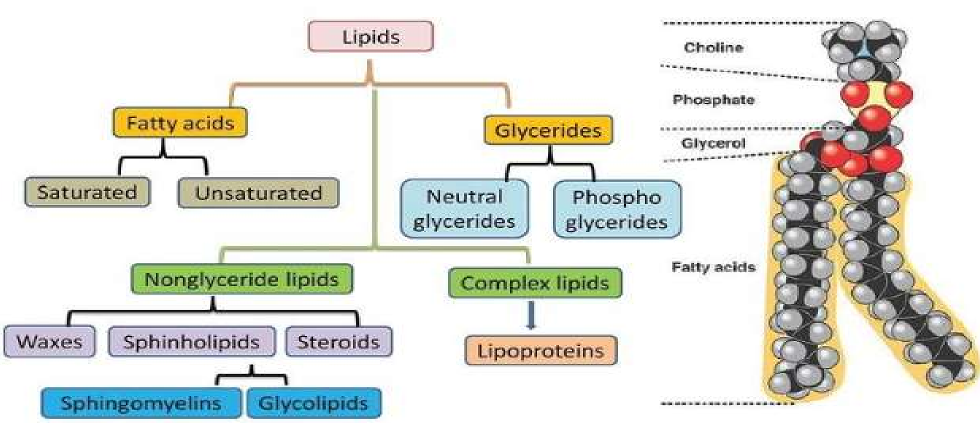


Figure : Lipids

Properties of Lipids :

- Lipids may be either liquids or non-crystalline solids at room temperature.
- Pure fats and oils are colorless, odorless, and tasteless.
- They are energy-rich organic molecules
- Insoluble in water
- Soluble in organic solvents like alcohol, chloroform, acetone, benzene, etc.
- No ionic charges
- Solid triglycerols (Fats) have high proportions of saturated fatty acids.
- Liquid triglycerols (Oils) have high proportions of unsaturated fatty acids.

1. Hydrolysis of triglycerols: Triglycerols like any other esters react with water to form their carboxylic acid and alcohol– a process known as hydrolysis.
2. Saponification: Triacylglycerols may be hydrolyzed by several procedures, the most common of which utilizes alkali or enzymes called lipases. Alkaline hydrolysis is termed saponification because one of the products of the hydrolysis is a soap, generally sodium or potassium salts of fatty acids.
3. Hydrogenation : The carbon-carbon double bonds in unsaturated fatty acids can be hydrogenated by reacting with hydrogen to produce saturated fatty acids.
4. Halogenation : Unsaturated fatty acids, whether they are free or combined as esters in fats and oils, react with halogens by addition at the double bond(s). The reaction results in the decolorization of the halogen solution.
5. Rancidity: The term rancid is applied to any fat or oil that develops a disagreeable odor. Hydrolysis and oxidation reactions are responsible for causing rancidity. Oxidative rancidity occurs in triacylglycerols containing unsaturated fatty acids.

Structure of Lipids :

- Lipids are made of the elements Carbon, Hydrogen and Oxygen, but have a much lower proportion of water than other molecules such as carbohydrates.
- Unlike polysaccharides and proteins, lipids are not polymers—they lack a repeating monomeric unit.
- They are made from two molecules: Glycerol and Fatty Acids.
- A glycerol molecule is made up of three carbon atoms with a hydroxyl group attached to it and hydrogen atoms occupying the remaining positions.
- Fatty acids consist of an acid group at one end of the molecule and a hydrocarbon chain, which is usually denoted by the letter ‘R’.
- They may be saturated or unsaturated.
- A fatty acid is saturated if every possible bond is made with a Hydrogen atom, such that there exist no C=C bonds.
- Unsaturated fatty acids, on the other hand, do contain C=C bonds. Monounsaturated fatty acids have one C=C bond, and polyunsaturated have more than one C=C bond.

Structure of Triglycerides :

- Triglycerides are lipids consisting of one glycerol molecule bonded with three fatty acid molecules.
- The bonds between the molecules are covalent and are called Ester bonds.
- They are formed during a condensation reaction.
- The charges are evenly distributed around the molecule so hydrogen bonds to not form with water molecules making them insoluble in water.

Classification of Lipids :

Lipids can be classified according to their hydrolysis products and according to similarities in their molecular structures. Three major subclasses are recognized:

1. Simple lipids :

(a) Fats and oils which yield fatty acids and glycerol upon hydrolysis.
(b) Waxes, which yield fatty acids and long-chain alcohols upon hydrolysis.

Fats and Oils:

- Both types of compounds are called triacylglycerols because they are esters composed of three fatty acids joined to glycerol, trihydroxy alcohol.
- The difference is on the basis of their physical states at room temperature. It is customary to call a lipid a fat if it is solid at 25°C, and oil if it is a liquid at the same temperature.
- These differences in melting points reflect differences in the degree of unsaturation of the constituent fatty acids.

Waxes :

- Wax is an ester of long-chain alcohol (usually mono-hydroxy) and a fatty acid.
- The acids and alcohols normally found in waxes have chains of the order of 12-34 carbon atoms in length.

2. Compound lipids :

(a) Phospholipids, which yield fatty acids, glycerol, amino alcohol sphingosine, phosphoric acid and nitrogen-containing alcohol upon hydrolysis. They may be **glycerophospholipids** or **sphingophospholipid** depending upon the alcohol group present (glycerol or sphingosine).
(b) **Glycolipids,** which yield fatty acids, sphingosine or glycerol, and a carbohydrate upon hydrolysis. They may also be **glyceroglycolipids** or **sphingoglycolipid** depending upon the alcohol group present (glycerol or sphingosine).

3. Derived lipids:

Hydrolysis product of simple and compound lipids is called derived lipids. They include fatty acid, glycerol, sphingosine and steroid derivatives. Steroid derivatives are phenanthrene structures that are quite different from lipids made up of fatty acids.

Functions of Lipids :

It is established that lipids play extremely important roles in the normal functions of a cell. Not only do lipids serve as highly reduced storage forms of energy, but they also play an intimate role in the structure of cell membrane and organellar membranes. Lipids perform many functions, such as:

1. Energy Storage
2. Making Biological Membranes
3. Insulation
4. Protection – e.g. protecting plant leaves from drying up
5. Buoyancy 6. Acting as hormones
7. Act as the structural component of the body and provide the hydrophobic barrier that permits partitioning of the aqueous contents of the cell and subcellular structures.
8. Lipids are major sources of energy in animals and high lipid-containing seeds.
9. Activators of enzymes eg. glucose-6-phosphatase, stearyl CoA desaturase and ω-monooxygenase, and β-hydroxybutyric dehydrogenase (a mitochondrial enzyme) require phosphatidylcholine micelles for activation.

ENZYMES :

Enzymes, are biological catalysts. While they hasten or speed up a process, they are actually providing an alternative pathway for the process. But, in the process, the structure or composition of the enzymes remain unaltered.

Enzymes are actually made up of 1000s of amino acids that are linked in a specific way to form different enzymes. The enzyme chains fold over to form unique shapes and it is these shapes that provide the enzyme with its characteristic chemical potential. Most enzymes also contain a non-protein component known as the *co-facto*r.

Structure of Enzymes :

Primary Structure :: Amino acids are joined together in a linear chain by amide (peptide) bonds to form enzymes. This is the most important part of the building. Polypeptide or protein refers to the amino acid chain that results. The DNA sequence of the relevant gene specifies the exact order of amino acids in the protein

Secondary Structure :: Each amino acid's hydrogen in the amino group (NH2) and oxygen in the carboxyl group (COOH) can form a hydrogen bond, allowing amino acids in the same chain to interact. As a result, the protein chain can fold in two directions, yielding two secondary structures: the α-helix and the β -sheet

Tertiary Structure : The protein can fold up further and obtain a three-dimensional structure as a result of the secondary structure folding up the 2D linear chain. The tertiary structure of the organism is as follows.

Properties of Enzymes :

- Physical Properties
- Chemical Properties
- General Properties

Physical Properties

- In terms of physical qualities, enzymes are similar to colloids or high-molecular-weight compounds
- Enzymes are damaged or inactivated at temperatures below the boiling point of water
- At 60 degrees Celsius, most enzymes in liquid medium become inactive
- Temperatures of 100 to 120 degrees Celsius, and even higher, can be tolerated by dried enzyme extracts. As a result, enzymes are thermostable
- For optimum action, each enzyme requires a specific temperature range, which is usually between 25 and 45 degrees Celsius. Enzymes become inactive when the temperature hits 37 degrees Celsius, and when the temperature reaches 60 degrees Celsius, enzymes become inactive

Chemical Properties

- Catalytic Properties : Enzymes are biological catalysts with catalytic characteristics. The higher quantities of chemicals are catalyzed by a small number of enzymes. It signifies that enzymes have a great capacity for converting large amounts of substrate to product. Enzymes accelerate reactions while remaining unaffected by the reactions they catalyse
- Enzyme specificity : Enzymes are extremely specific in nature, meaning that only one enzyme can catalyze a single process. Enzyme sucrase, for example, can exclusively catalyse sucrose hydrolysis

General Properties

- Enzymes are proteins that start and speed up biological reactions
- The acidity of the media affects enzyme activity (pH specific). At a certain pH, each catalyst is most active. For example, pepsin has a pH of 2 whereas trypsin has a pH of 8.5. The pH of most internal enzymes is close to neutral
- Enzymes have the ability to speed up a reaction in either way
- All enzymes have active sites, which are engaged in biological activities
- Enzymes are extremely unstable molecules that can only be dissolved in dilute glycerol, NaCl, and dilute alcohol
- Enzymes are active when the temperature is just perfect
- Enzymes are proteins in nature, although not all proteins are enzymes
- Enzymes lower the amount of energy needed to activate a substance molecule, allowing the biochemical reaction to take place at body temperature, which is 37°C

<u>Some other Important Properties of Enzymes</u>

- **Catalytic Property**

  - Enzymes have exceptional catalytic abilities.
  - They are only active in extremely little amounts.
  - It only takes a minimal amount of enzyme to convert a big number of substrates.
  - After the reaction, the enzymes are unaffected.

- **Specificity**
  - In nature, enzymes are incredibly specialised.
  - Only a specific substrate is acted upon by a certain enzyme.
  - Enzymes are also unique to a specific reaction type.
  - In some rare instances, the specificity may be insufficient.
  - Specificity of Bonds: It's sometimes referred to as relative specificity. The enzyme is looking for a specific bond in this case. Peptidase, for example, is a Peptide Bond Specific enzyme
  - Absolute specificity is also known as substrate specificity
  - Only one substrate is acted upon by the enzyme
  - Structure specificity is another term for group specificity. The enzyme is specific to a subset of bacteria
  - Stereospecificity is another term for optical specificity. This is an enzyme's maximum level of specificity. Not only is the enzyme particular to the substrate, but it is also specific to its optical configuration

- **Reversibility**
  - The majority of enzyme-catalyzed reactions can be reversed.
  - The reaction's reversibility is determined by the cell.
  - There are separate enzymes for forward and reverse reactions in some circumstances.

- **Sensitiveness to Heat and Temperature**
  - Heat and temperature have a significant impact on enzymes.
  - At room temperature, an enzyme's maximum activity occurs.
  - At very low temperatures, enzymes become inactive.

<u>Types of Enzymes:</u>

The biochemical reactions occurring in the body are basically of 6 types and the enzymes that bring about these reactions are named accordingly:

- **Oxidoreductases:** These enzymes bring about oxidation and reduction reactions and hence are called oxidoreductases. In these reactions, electrons in the form of hydride ions or hydrogen atoms are transferred. When a substrate is being oxidized, these enzymes act as the hydrogen donor. These enzymes are called dehydrogenases or reductases. When the oxygen atom is the acceptor, these enzymes are called oxidases.
- **Transferases:** These enzymes are responsible for transferring functional groups from one molecule to another. Example: alanine aminotransferase which shuffles the alpha-amino group between alanine and aspartate etc. Some transferases also transfer phosphate groups between ATP and other compounds, sugar residues to form disaccharides such as hexokinase in glycolysis.
- **Hydrolases:** These enzymes catalyze reactions that involve the process of hydrolysis.They break single bonds by adding water. Some hydrolases function as digestive enzymes because they break the peptide bonds in proteins. Hydrolases can also be a type of transferases as they transfer the water molecule from one compound to another. Example: Glucose-6-phosphatase that removes the phosphate group from glucose-6-phosphate, leaving glucose and H_3PO_4.

- **Lyases:** These enzymes catalyze reactions where functional groups are added to break double bonds in molecules or where double bonds are formed by the removal of functional groups. Example: Pyruvate decarboxylase is a lyase that removes CO_2 from pyruvate. Other examples include deaminases and dehydratases.
- **Isomerases:** These enzymes catalyze the reactions where a functional group is moved to another position within the same molecule such that the resulting molecule is actually an isomer of the earlier molecule. Example: triosephosphate isomerase and phosphoglucose isomerase for converting glucose 6-phosphate to fructose 6-phosphate.
- **Ligases:** These enzymes perform a function that is opposite to that of the hydrolases. Where hydrolases break bonds by adding water, ligases form bonds by removal of the water component. There are different subclasses of ligases which involve the synthesis of ATP.

CLASSIFICATION OF ENZYMES

Group of Enzyme	Reaction Catalysed	Examples
1. Oxidoreductases	Transfer of hydrogen and oxygen atoms or electrons from one substrate to another.	Dehydrogenases Oxidases
2. Transferases	Transfer of a specific group (a phosphate or methyl etc.) from one substrate to another.	Transaminase Kinases
3. Hydrolases	Hydrolysis of a substrate.	Estrases Digestive enzymes
4. Isomerases	Change of the molecular form of the substrate.	Phospho hexo isomerase, Fumarase
5. Lyases	Nonhydrolytic removal of a group or addition of a group to a substrate.	Decarboxylases Aldolases
6. Ligases (Synthetases)	Joining of two molecules by the formation of new bonds.	Citric acid synthetase

Figure : Classification of Enzymes

Functions of Enzymes :

For any reaction to occur in the universe, there is an energy requirement. In cases where there is no activation energy provided, a catalyst plays an important role to reduce the activation energy and carried forward the reaction. This works in animals and plants as well. Enzymes help reduce the activation energy of the complex molecules in the reaction. The following steps simplify how an enzyme works to speed up a reaction:

Step 1: Each enzyme has an ‘active site’ which is where one of the substrate molecules can bind to. Thus, an enzyme- substrate complex is formed.

Step 2: This enzyme-substrate molecule now reacts with the second substrate to form the product and the enzyme is liberated as the second product.

There are many theories that explain how enzymes work. But, there are two important theories that we will discuss here.

Theory 1 : Lock and Key Hypothesis :

This is the most accepted of the theories of enzyme action. This theory states that the substrate fits exactly into the active site of the enzyme to form an enzyme-substrate complex. This model also describes why enzymes are so specific in their action because they are specific to the substrate molecules.

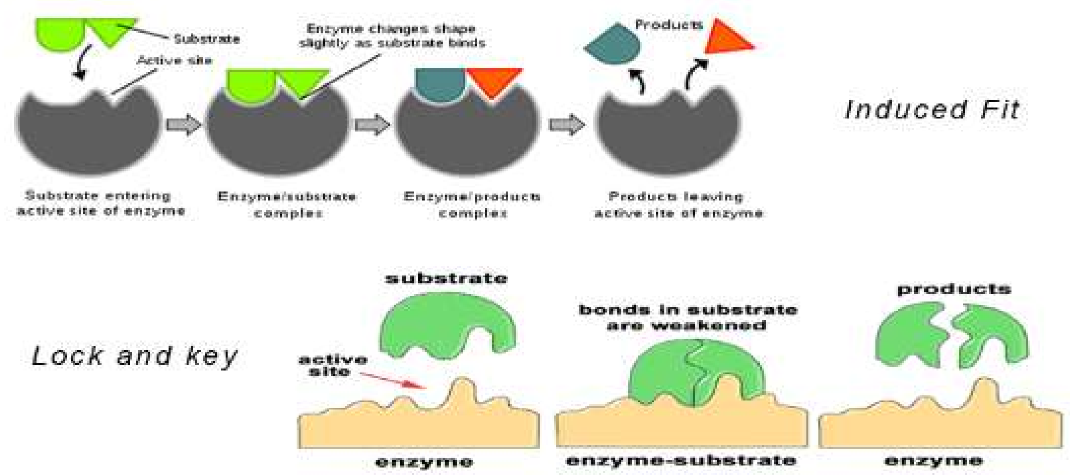


Figure : Lock and Key Hypothesis.

Theory 2: Induced Fit Hypothesis

This is similar to the lock and key hypothesis. It says that the shape of the enzyme molecule changes as it gets closer to the substrate molecule in such a way that the substrate molecule fits exactly into the active site of the enzyme.

VITAMINS :

Vitamins are organic compounds that are essential for normal growth, development, and overall health. They are required in small amounts but play crucial roles in various physiological processes. Vitamins are classified into two main groups based on their solubility: fat-soluble vitamins (A, D, E, and K) and water-soluble vitamins (B-complex vitamins and vitamin C). Here are the properties and functions of vitamins:

Properties of Vitamins:

1. **Organic Compounds**: Vitamins are organic molecules containing carbon, which distinguishes them from minerals.
2. **Essential Nutrients**: Vitamins cannot be synthesized in sufficient quantities by the body and must be obtained from the diet or supplements.
3. **Solubility**:
   - **Fat-Soluble Vitamins**: These vitamins are soluble in fats and oils but not in water. They are stored in the liver and fatty tissues.

- **Water-Soluble Vitamins**: These vitamins are soluble in water and are not stored in large amounts in the body. They are excreted through urine, and excess intake is generally not stored.

4. **Coenzymes or Precursors**: Many vitamins serve as coenzymes or precursors for coenzymes that are necessary for enzymatic reactions in the body.

Functions and Types of Vitamins:

Fat-Soluble Vitamins:

1. **Vitamin A**:
   - **Function**: Essential for vision, immune function, and cellular communication.
   - **Sources**: Liver, carrots, sweet potatoes, spinach.
2. **Vitamin D**:
   - **Function**: Promotes calcium absorption and bone health.
   - **Sources**: Sunlight, fatty fish, fortified dairy products.
3. **Vitamin E**:
   - **Function**: Antioxidant that protects cells from damage; supports immune function.
   - **Sources**: Nuts, seeds, vegetable oils.
4. **Vitamin K**:
   - **Function**: Essential for blood clotting and bone health.
   - **Sources**: Leafy green vegetables, liver, egg yolks.

Water-Soluble Vitamins:

1. **Vitamin B1 (Thiamine)**:
   - **Function**: Energy metabolism, nerve function.
   - **Sources**: Whole grains, pork, nuts.
2. **Vitamin B2 (Riboflavin)**:
   - **Function**: Energy production, antioxidant function.
   - **Sources**: Dairy products, leafy green vegetables, lean meats.
3. **Vitamin B3 (Niacin)**:
   - **Function**: Energy metabolism, DNA repair.
   - **Sources**: Meat, fish, whole grains.
4. **Vitamin B6**:
   - **Function**: Amino acid metabolism, neurotransmitter synthesis.
   - **Sources**: Meat, fish, fruits, vegetables.
5. **Vitamin B12**:
   - **Function**: DNA synthesis, nerve function, red blood cell formation.
   - **Sources**: Meat, fish, dairy products; also available in fortified foods and supplements.
6. **Folate (Vitamin B9)**:
   - **Function**: DNA synthesis, cell division, red blood cell formation.
   - **Sources**: Leafy green vegetables, legumes, fortified grains.
7. **Vitamin C**:
   - **Function**: Antioxidant, collagen synthesis, immune function.
   - **Sources**: Citrus fruits, strawberries, bell peppers, broccoli.

Understanding the properties and functions of vitamins is essential for maintaining optimal health. While vitamins are necessary for various physiological processes, it's important to obtain them through a balanced diet rather than relying solely on supplements, unless advised by a healthcare professional. Excessive intake of certain vitamins can be harmful, so it's essential to follow recommended dietary guidelines.

HORMONES :

Hormones are various chemicals released within the human body that regulate and control the activities of multiple organs. The introduction of hormones to the blood takes place via endocrine glands.

Our body contains two different kinds of glands.

a. **Endocrine Glands:** These glands, such as the pituitary and adrenal glands, do not have ducts and deliver their secretions through the blood straight to the site of action.

b. **Exocrine Glands:** These glands have ducts by which their secretions are transported. Example: sweat and liver,

Endocrine glands secrete “Hormones”.

Functions of Hormones :

Hormones act as a messenger which is released into the blood. Blood transmits them to various organs and tissues of the human body. After reaching a target site, hormones bind to the receptors. Once this process is complete, hormones then transmit the message which causes an organ or tissue to perform a specific action.

The following are some important functions of hormones:

- Regulating mood and cognitive functions
- Growth and development
- Food metabolism
- Maintaining body temperature
- Controlling thirst and hunger
- Initiating and maintaining sexual development and reproduction

Hormone Regulation

Hormones may be regulated by glands and organs, by a negative feedback mechanism, or by other hormones. Hormones that regulate the release of other hormones are defined as tropic hormones, which are secreted by the anterior pituitary in the brain.

Hormones During Pregnancy

Many hormone levels are affected in the body during pregnancy. Several hormones play major roles during pregnancy such as Estrogen, Progesterone, human chorionic gonadotropin hormone (hCG), and Human placental lactogen (hPL).

Chemical Nature of Hormones

Hormones may be chemically classified as either proteins or steroids. All of the hormones in the human body, except the sex hormones and those from the adrenal cortex, are proteins or protein derivatives.

Properties of Hormones :

The significant properties of hormones are –

1. They have a low molecular weight; thus, they can easily pass through capillaries.
2. Hormones always act in low concentration.
3. They are soluble in water so that they can be transported via blood.
4. The importance of hormones is that they are non-antigenic. They are organic catalysts. Hormones act as coenzymes of other enzymes in the human body.
5. Hormones, in their first action, cause a limited number of reactions and do not influence any metabolic activities of a cell directly.
6. A significant characteristic of hormones is that, after their function is over, they are readily destroyed, excreted or inactivated.
7. Hormonal activities are not hereditary.

Characteristics of Hormones :

Hormones possess the following characteristics:

- Endocrine cells release hormones into the body.
- Circulating in bodily fluids, hormones are chemical messengers.
- They act on one portion of the body after being secreted in another.
- Unlike enzymes, hormones do not catalyse any reactions.
- They are not stored beforehand and are only secreted in minute amounts when necessary.
- The nervous system uses the feedback effect to control hormone secretion.
- The majority of the time, hormones have long-lasting impacts such as altered behaviour, growth, etc.

Classification of Hormones :

The hormones produced in the human body are classified based on their chemical structure and nature as follows:

a. Peptide/Protein Hormones:

These hormones are made of polypeptide chains—linked chains of amino acids. The secretory vesicles serve as both a place for peptide hormone synthesis and storage. They are located in the membrane of the cell and are expelled from the parent cell through exocytosis. After being stored in vesicles, the substance is released when a stimulus causes a reaction, such as when high blood glucose levels cause the release of insulin. These hormones are water soluble but not fat soluble. The cell membrane comprises a phospholipid bilayer that prevents any fat-insoluble compounds from diffusing into the cell, preventing peptide hormones from passing through the membrane. Since the peptide hormones are unable to pass through the cell's plasma membrane, the receptors are present on the target's cell surface.

ADH (antidiuretic hormone), which is produced in the brain and released into the circulation by the posterior pituitary gland, is one example along with oxytocin and vasopressin

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b. Steroid Hormones:

These hormones are lipid-derived hormones that are obtained from cholesterol. On-demand, they are synthesised from precursors and released from the parent cell by a simple diffusion process. These hormones typically have the goal response of inducing the synthesis of new proteins because they bind to proteins while being transported through the blood. Steroid hormones, in contrast to peptide hormones, are fat-soluble and may pass through the cell membranes. Steroid hormones comprise sex hormones including progesterone, estrogen, and testosterone.

Functions of Hormones :

The following are a few important functions that hormones perform:

- Metabolism of food.
- Development and growth.
- Controlling hunger and thirst.
- Preserving one's body's temperature.
- Maintain Homeostasis
- Regulating sleep and wake cycle
- Regulating mental and emotional functions.
- Establishing and sustaining sexual development and reproduction

Important Hormones of the human body

- **Melatonin:** It primarily controls the circadian rhythm or sleep cycles.
- **Estrogen**: This is the main sex hormone present in women which bring about puberty, prepares the uterus and body for pregnancy and even regulates the menstrual cycle. Estrogen level changes during menopause because of which women experience many uncomfortable symptoms.
- **Cortisol**: It has been named the "stress hormone" as it helps the body in responding to stress. This is done by increasing the heart rate, elevating blood sugar levels etc.
- **Progesterone:** It is a female sex hormone also responsible for the menstrual cycle, pregnancy and embryogenesis.
- **Testosterone**: This is the most important sex hormone synthesized in men, which cause puberty, muscle mass growth, and strengthen the bones and muscles, increase bone density and controls facial hair growth.

Some hormones, such as serotonin and dopamine, also function as neurotransmitters, which are chemicals that relay messages between nerve cells in the brain and from neurons to muscles.

Types of Hormones :

Even though there are several types of hormones in a human body, they are primarily classified into three categories based on their chemical structure. These are –

1. Lipid-Derived Hormones

Lipid-derived hormones are primarily derived from cholesterol, and they share a similarity in terms of their structure. Steroid hormones are the primary lipid hormones in the human body, and chemically they are either ketones or alcohols. Examples of steroid hormones are cortisol and aldosterone.

2. Amino Acid-Derived Hormones

These classes of hormones originate from amino acids, tyrosine and tryptohan. Examples of such hormones as norepinephrine and epinephrine. The medulla section of the adrenal glands produces these. Moreover, the pineal gland in the brain synthesizes melatonin, which controls the sleep cycle.

3. Peptide Hormones

The structure of the peptide hormone is similar to that of the polypeptide chain (chain of amino acids). A popular example of peptide hormone is insulin produced by the pancreas.

Name of Hormones and Their Functions

Here is a list of some important hormones and their functions –

- **Insulin:** Produced by the pancreas, this hormone helps the human body to synthesize glucose from food intake for energy. Additionally, it controls the blood sugar level in the human body.
- **Cortisol:** It is a steroid hormone synthesized in the cortex of adrenal glands. Furthermore, this hormone is also called stress hormone as it helps the human body to deal with any pressure.
- **Melatonin:** The pineal gland in the human brain produces this hormone. It primarily controls the sleep cycle.
- **Progesterone:** This female hormone is responsible for embryogenesis, menstrual cycle, and pregnancy. It is produced in the corpus luteum section of the ovary.

Examples of Hormones

- Insulin is a hormone that's made by the beta cells in the pancreas. When it is released into the blood, insulin helps regulate how the cells of the body use glucose (a type of sugar) for energy.
- Androgens are responsible for male sex characteristics. Testosterone, the sex hormone produced by the testicles, is an androgen.
- Estrogens are the group of hormones responsible for female sexual development. They are produced primarily by the ovaries and in small amounts by the adrenal glands.
- The thyroid gland secretes two main hormones, thyroxine and triiodothyronine, into the bloodstream. These thyroid hormones stimulate all the cells in the body and control biological processes such as growth, reproduction, development, and metabolism.

**********END OF MODULE 1*********