ENTRANCE TEST MCQs (UHS)

1. Which organelle is bounded by two membranes?
A. Ribosome B. Lysosome C. Mitochondrion D. Nucleolus

2. Fluid mosaic model of plasma membrane states that protein molecules float in a fluid ______ bilayer.
A. Galactose B. Glucose C. Phospholipids D. Carbohydrate

3. Which one of the following cell structure is involved in the synthesis of lipids?
A. Endoplasmic reticulum B. Centriole C. Golgi complex D. Mitochondrion

4. The inner membrane of mitochondria form extensive infoldings called:
A. Cristae B. Lamella C. Cisternae D. Bifidae

5. The basic structure of plasma membrane is provided by:
A. Proteins B. Phospholipids C. Cholesterols D. Cytoskeleton

6. Out of the given option, choose the one which shows the structures found only in plants:
A. Vacuole, chloroplast, ribosomes B. Chloroplast, cell wall, mitochondria
C. Chloroplast, microtubules, peroxisomes D. Chloroplast, cell wall, vacuole

7. Cilia and flagella are absent in:
A. Viruses B. Higher plants C. Bacteria D. Lower animals

8. Ribosome present in prokaryotes are:
A. 80S B. 50S C. 60S D. 70S

9. The enzymes required for Kreb's cycle are found in ______:
A. F_1 particles B. Cytoplasm C. Lysosomes D. Matrix

10. Ribosomes are made up of ______ and ______:
A. Proteins and carbohydrates B. RNA and proteins
C. RNA and lipid D. RNA and carbohydrates

11. These structures are involved in the breakdown of old organelles:
A. Leucoplasts B. Glyoxisomes C. Peroxisome D. Lysosomes

12. The prokaryotes possess small ribosome of size:
A. 40S B. 65S C. 70S D. 60S

13. If 15 µm size object is observed under light microscope using 5X eyepieces and 10X objective, its magnified image size will be:
A. 250µm B. 750µm C. 50µm D. 500µm

14. Smooth endoplasmic reticulum is responsible for the metabolism of:
A. Carbohydrates B. Nucleic acids C. Proteins D. Lipids

15. Site of protein synthesis is:
A. Ribosome B. Golgi body C. Lysosome D. Cisternae

16. Among followings which cellular organelle contains circular DNA similar to those found in bacteria?
A. Ribosome B. Chloroplast C. Lysosome D. Nucleus

17. The structure present in eukaryotic cell but absent in prokaryotic cells is:
A. Nucleus B. Ribosomes C. DNA D. Cell surface membrane

18. The finger like infoldings which are formed by inner membrane of mitochondria are called:
A. Matrix B. Cristae C. Porin D. Ribosomes

19. Which cell organelle is responsible for cell secretion?
A. Mitochondrion B. Ribosome C. Chloroplast D. Golgi body

ANSWERS KEY

1. C	2. C	3. C	4. C	5. B	6. D	7. A	8. D	9. D	10. B	11. D	12. C
13. B	14. D	15. A	16. B	17. A	18. B	19. D					

Chapter 04 MOLECULAR BIOLOGY

Student Learning Outcomes (SLOs)

After studying this chapter, the students will be able to:

- Define biochemistry/molecular biology.
- Describe Briefly the different types of bonds found in biology (hydrogen bonds, covalent bonds, interactions, Ionic, hydrophobic and hydrophilic interactions etc.).
- Distinguish carbohydrates, proteins, lipids and nucleic acids as the four fundamental biological molecules.
- Describe and draw sketches of the condensation synthesis and hydrolysis reactions for making and breaking of macromolecule polymers.
- State the properties of water (high polarity, hydrogen bonding, high specific heat, high heat of vaporization, cohesion, hydrophobic exclusion, ionization and lower density of ice) which allow it to be the medium of life.
- Define carbohydrates and classify them
- Compare and contrast the properties and roles of monosaccharides and write their formulae.
- Compare the isomers and stereoisomers of glucose.
- Distinguish the properties and roles of disaccharides.
- Describe glycosidic bond in disaccharides.
- Describe the structure properties and roles of polysaccharides starch, glycogen, cellulose and chitin.
- Define protein, amino acid and recognized essential amino acid and structural formula of amino acid.
- Outline the synthesis and breakage of peptide linkages.
- Justify the significance of the sequence of amino acids through the example of sickle cell haemoglobin.
- Classify proteins as globular and fibrous proteins.
- List the roles of structural proteins and functional proteins with 3 examples.
- Define lipids.
- Describe the properties and roles of acylglycerols, phospholipids, terpenes and waxes.
- Illustrate the molecular structure (making and breaking) of an acylglycerol, a phospholipid and a terpene.
- Evaluate steroids and prostaglandins as important groups of lipids.
- Describe nucleic acids and molecular structure of nucleotides.
- Distinguish among the nitrogenous bases found in the nucleotides of nucleic acids.
- Outline the examples of a mononucleotide (ATP) and a dinucleotide (NAD).
- Illustrate the formation of phosphodiester bond.
- Explain the double helical structure of DNA as proposed by Watson and Crick.
- Explain the general structure of RNA.
- Distinguish in terms of functions and roles, the three types of RNA.
- Discuss the Central Dogma.
- Define conjugated molecules and describe the roles of common conjugated molecules i.e. glycolipids, glycoproteins, lipoproteins and nucleoproteins.

- Recall **"Levels of Biological Organization"** you have studied in your previous classes. You got a brief introduction about biological molecules in reference of levels of biological organization.
- Now you would get detailed study of **carbohydrates, proteins, lipids and nucleic acids** as well as the importance of water and the role of conjugated molecules.

Recalling

- Life of an organism depends upo[illegible] ceaseless chemical activities in [illegible]
- **Metabolism:** All the chemi[illegible] reactions taking place within [illegible] are collectively called metabo[illegible] The processes in metabolism [illegible] either anabolism or catabolism.
  - **(a) Anabolism:** In which sim[illegible] substances are combine[illegible] to form complex substances.
  - **(b) Catabolism:** In which com[illegible] molecules are broken down into simpler ones.

Biochemistry:

- **Definition:** The study of chemical components and chemical processes, occurring in living organism is called **biochemistry.**
- All structures of living organisms have biochemical organization and all functions occurring in them are due to biochemical processes taking place in this organization.

Importance of Biochemistry in Biology:

- A basic knowledge of biochemistry is helpful to understand **anatomy and physiology** of living orga[illegible]
- **Examples of Biochemistry:** Photosynthesis, respiration, digestion, contraction of muscles etc.

BIOLOGICAL MOLECULES

Macromolecule Importance of Water:

- Life on Earth evolved in **water,** and all life still depends on water.
- **Component of Living Organism:** At least **80%** of the mass of living organisms (protoplasm) is water.
- **Place of Chemical activity:** Almost all chemical reactions of life take place in **aqueous solutions.**

Check Understanding!

1. **Why is biochemistry importa[illegible] understanding biological proce[illegible]**
   A) It helps identify endangered spe[illegible]
   B) It reveals how chemical rea[illegible] sustain life functions
   C) It is used to study the gravita[illegible] pull on organisms
   D) It explains the weather's effe[illegible] wildlife behavior

Organic & Inorganic Molecules:

- The other chemicals that make up living things are mostly organic macromolecules and certain inorganic molecules.
- **Organic Molecules:** The molecules synthesized by cells and containing **carbon** are known as organic molecules. They occur naturally only in the bodies of living organisms or in their products and remains.
- **Examples:** Carbohydrates, proteins, lipids and nucleic acids are important organic molecules in living organisms. They make **93%** of the dry mass of living organisms (Table).
- The remaining **7% comprises** of small organic molecules **(like vitamins)** and **inorganic molecules** (like carbon dioxide, acids, bases, and salts).

- Organic molecules have **carbon based core** with special groups of atoms attached. These groups are called functional groups for example OH, CO, COOH, NH_2 etc.
- **Most biochemical reactions** involve the transfer of a functional group from one molecule to another or breaking of carbon-carbon bond.

Table: %age of major organic molecules in the dry mass of

Group name	% Dry mass
• Proteins	• 50 %
• Nucleic acids	• 18%
• Carbohydrates	• 15%
• Lipids	• 10%

- Most of the organic molecules are large in size and biologists call them macromolecules. Many s are in the form of polymers.
- **Polymer:** A polymer is a molecule consisting of many identical molecular units, called monomers.

Important Macromolecules:

- Carbohydrates, proteins, and nucleic acids are the polymers of simple monomers i.e., sugars, amino acids and nucleotides respectively.

TYPES OF BONDS IN BIOLOGY

- Different types of **bonds and interactions** play vital roles in the structure and function of biological **molecules.**

Check Understanding!

2. How does biochemistry bridge chemistry and biology, and why is it essential for understanding living organisms?

Importance of Carbon:

- Carbon is the basic element of organic molecules.
- **Tetravalent:** It is tetravalent and can react with many other known elements like H, O, N, P and S.
- **C–H Bond As Source of Energy:** Carbon and hydrogen bond (C – H bond) is the potential source of chemical energy for cellular activities.
- **Forms Glyosidic Bond:** Carbon-oxygen association in **glycosidic** linkages provides stability to the complex carbohydrate molecules.
- **Carbon Forms Peptide Bond:** Carbon combines with nitrogen in amino acid linkages to form peptide bonds and forms proteins which are very important due to their diversity in structure and functions.

(i) Covalent Bonds:

- A boqnd formed when two atoms share **electrons** (Figure). Covalent bonds are often found in organic molecules like proteins and nucleic acids, **providing** stability to the molecules.

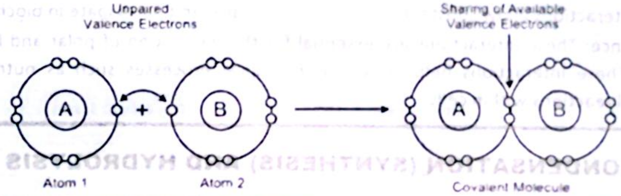


Figure: Covalent bond between two atoms

(ii) Ionic Bonds:

- A bond formed when one atom donates an **electron** (becomes a positive ion, or cation) and another atom accepts the electron (becomes a negative ion, or anion) is called **ionic bond.** (Figure).
- The electrostatic attraction between these **oppositely charged** ions forms the ionic bond.
- Ionic bonds are relatively strong in the solid state and are formed mostly in inorganic molecules like sodium chloride.

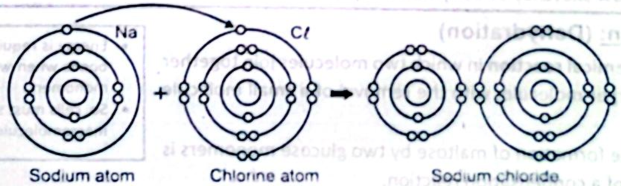


Figure: Ionic bond between sodium and chlorine atoms

(iii) Hydrogen Bonds:

- A weak attractions that occurs between a hydrogen atom and an electronegative atom (such as oxygen or nitrogen) is called hydrogen bond.
- These bonds are **important in maintaining** the structure of large molecules like proteins and nucleic acids, as well as in various biological processes like DNA replication.

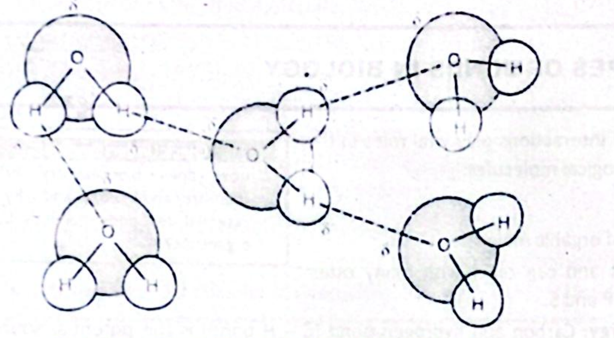


Figure: Hydrogen bond between water molecules

> **Check Understanding!**
> 3. In living organisms, the formation of a peptide bond between amino acids is an example of:
> A) Hydrolysis
> B) Condensation reaction
> C) Ionic bonding
> D) Hydrogen bonding

- **Hydrophobic Interactions:** A type of molecular interaction where **non-polar molecules** come together to avoid contact with water. These interactions help in processes like protein folding and membrane formation.
- **Importance:** This phenomenon is crucial for the folding of proteins and the formation of lipid bilayers in cell membranes.
- **Hydrophilic Interactions:** A type of molecular interaction where polar or charged molecules are attracted to water and interact easily with it.
- These interactions allow substances to dissolve in water and participate in biochemical reactions.
- **Importance:** These interactions are essential for the dissolution of polar and ionic compounds in water. These interactions help in various biological processes such as nutrient transport and chemical reactions within cells.

CONDENSATION (SYNTHESIS) AND HYDROLYSIS

- Proteins, nucleic acids, carbohydrates, and lipids are assembled from different kinds of monomers. All these biomolecules join their monomers by **condensation or dehydration** process.
- During condensation, an **-OH group** is removed from one monomer and an -H atom is removed from another monomer. It is also known as **dehydration synthesis** because the removal of OH and H groups means the removal of a water molecule.

Q. Describe and draw sketches of dehydration synthesis reactions. [Exercise L.Q.]

(1) Condensation: (Dehydration)

- A type of **chemical reaction** in which two molecules join together to form a larger molecule, with the removal of a small molecule like water.
- **Example:** The formation of maltose by two glucose monomers is an example of a condensation reaction.

> - Energy is required to break chemical bonds when water is extracted from monomers.
> - So, cells must supply energy to make macromolecules.

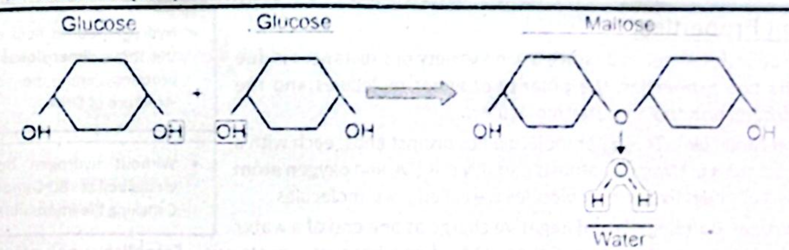


Figure: Making of macromolecules (Dehydration synthesis)

(2) Hydrolysis:

- Hydrolysis is a **chemical process** in which macromolecule (polymer) is broken down into smaller fragments by the addition of water molecules.
- **Reverse of Dehydration Synthesis:** Along with making polymers by combining their monomers, cells keep on breaking polymers too. It is the reverse of dehydration synthesis.
- Cells break bonds between monomers by adding water to them.
- In this process, OH group from a water molecule joins to one monomer and hydrogen joins to the second monomer.
- **Example:** Breakdown of maltose into two glucose monomers by the addition of a water molecule is an example of hydrolysis.

> **Importance of Hydrolysis**
> - The breakdown of macromolecules is essential in various biological processes, such as digestion and cellular respiration, where smaller molecules are needed for energy production.

> **Check Understanding!**
> 4. Why is hydrolysis critical for digestion and cellular metabolism?

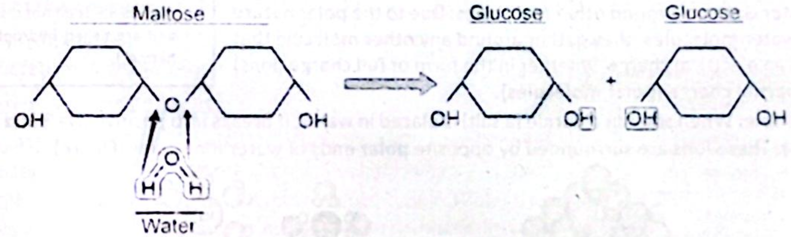


Figure: Breaking of macromolecules (Hydrolysis)

IMPORTANCE OF WATER

- **Chemical Formula:** An oxide of hydrogen, water has the **chemical formula H_2O**. This seemingly simple molecule has many surprising properties, which give it the status of "the medium of life".
- About two third of our **bodies** are composed of water and we cannot exist without it.
- In fact, it is the most abundant compound found in all organisms.
- Its concentration varies from 65 to 89 percent in different organisms.
- In multicellular organisms, its concentration varies from tissue to tissue.
- **Example:** Bone cells are made up of about **20 percent water** and brain cells contain **85 percent water.**
- Water plays important roles in making and **maintaining** the matter of life (protoplasm) and in establishing suitable environment, necessary for the working of life.

Q. Explain how the properties of water make it the medium of life. [Exercise L.Q.3]

➤ **Properties of Water:**

- Water has many important properties which make it essential for life.

(1) Solvent Properties:

- The ability of water to dissolve a wide variety of substances is due to its two properties, the polarity of water molecules and the hydrogen bonding in water molecules.
- **Polar Molecules:** The water molecule has distinct ends, each with a partial charge. Hydrogen atom is partially positive and oxygen atom is partially negative, such molecules are called polar molecules.
- **Hydrogen Bonding: Partial negative charge at one end of a water** molecule is attracted to partial positive of another water molecule. Establish weak attraction among water molecules called a **hydrogen bond**. Water forms a network of such bonds.
- Many of the properties of water are due to hydrogen bonds in water.

> - Hydrogen bonds help in maintaining the three-dimensional structures of proteins and the double helix structure of DNA.

> - Without hydrogen bonding water would boil at - 80°C and freeze at -100 C making life impossible.

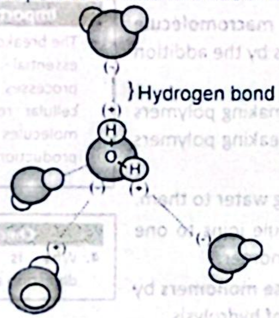


Figure: Hydrogen bonds among water molecules

> **Check Understanding!**
> 5. Why is water called the "universal solvent"?
> A) It dissolves nonpolar molecules easily
> B) It has a neutral pH
> C) It can dissolve a wide range of polar and ionic substances
> D) It is only found in living organisms

> - **Charged or polar molecules** such as salts, sugars, amino acids dissolve readily in water and so are called **hydrophilic** ("water loving")
> - **Uncharged or non-polar molecules** such as lipids do not dissolve in water and are called **hydrophobic** ("water hating").

- **Water Gathers Around other Molecules:** Due to the polar nature of water molecules, they gather around any other molecule that has an electrical charge, whether in the form of **full charge (ions)** or **partial charge (polar molecules).**
- **Example:** When sodium chloride (a salt) is placed in water, it breaks into positive (Na^+) and negative ions (Cl^-). These ions are surrounded by opposite polar ends of water molecules (Figure).

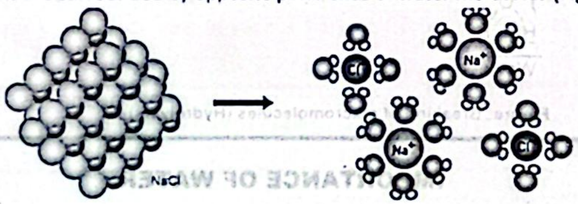


Figure: Water as a solvent of inorganic molecules (NaCl)

- Similarly, when a glucose is placed in water, the molecules of water form **hydrogen bonds** with polar hydroxyl groups of glucose molecules. In this way, glucose dissolves in water (Figure). It means that **charged or polar molecules are soluble in water. In the state of solution, ions and molecules** can react with each other easily. So, water provides a medium for chemical reactions **i.e., metabolism of cells.**

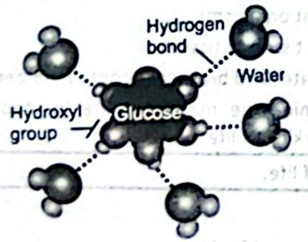


Figure: Water as a solvent of organic molecules (glucose)

> **Check Understanding!**
> 6. How does water's high heat of vaporization aid in cooling the human body?

- **Conclusive Sentence:** So, charged or polar molecules are soluble in water. In the state of solution, **ions and molecules can react with each other easily. So, water provides a medium for metabolism (chemical** reactions in cells).

(2) Hydrophobic Exclusion:

- Non-polar or uncharged molecules are insoluble in water because water molecules do not make **hydrogen** bonds with them. When they are placed in water, water molecules move **them out.**
- The insoluble molecules make hydrophobic associations with **one another.**
- **Example:** Lipids molecules are insoluble in water. When they are excluded from water, they make strong associations among themselves. Therefore, lipids help to maintain membranes of cells

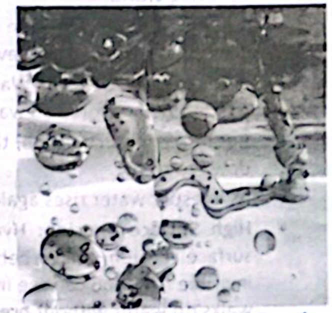


Figure: Hydrophobic association of oil (lipid) with water molecules

(3) Heat Capacity:

- The number of calories (amount of heat) required to raise the temperature of 1 gram of a substance water from **15°C to 16°C** (i.e., **1°C**) is called heat capacity.
- **High Heat Capacity of Water:** Water has a high specific heat capacity i.e., 4.184 Joules.
- It means that water has **great ability to absorb and releasing heat with minimum change** in its own temperature.
- Most of the **heat energy** absorbed by water is used to break hydrogen bonds between its molecules.
- Due to this breakage of hydrogen bonds, individual water molecules start moving more freely and **temperature of water rises.**

> - Specific heat of water is twice than that of most carbon compounds and is nine times more than that of iron.

➤ **Importance of Heat Capacity:**

- **Acts as Temperature Stabilizer:** Due to high specific heat capacity, water heats up **more slowly**. Similarly, when it is given a cooler environment, it holds its temperature longer. Water thus works as temperature stabilizer not only for organisms' internal environment but also for their external environment.

> **Check Understanding!**
> 7. Why is ionization of water important in cells?
> A) It helps form hydrophobic layers
> B) It provides energy for reactions
> C) It maintains pH balance for enzymes
> D) It raises cell temperature

(4) Heat of Vaporization:

- The amount of heat required to change a liquid to gas is called heat of vaporization.
- Water has high heat of vaporization. So, it absorbs much heat while changing from liquid state to gas. Its heat of vaporization is **547 Kcal/kg** which means a considerable amount of heat energy (574 Kcal) is required to change **1 kg of liquid water into vapours.**

> - Evaporation of **2 ml** of water out of **1 litre** lowers the temperature of the **remaining 998 ml water by 1°C.**

➤ **Importance of Heat of Vaporization:**

- Due to this property, Earth's temperature is kept moderate.
- **Cooling Effect:** It also provides cooling effects to plants and animals when they transpire and perspire (sweat). Every gram of water that evaporates from plant or animals' body surface removes **574 calories** of heat from the body.

(5) Cohesion:

- A type of attraction between same type of molecules is called **cohesion.**
- Hydrogen bonds among water molecules enable them to "stick together".

➤ **Importance of Cohesion:**

- Inside water, molecules have **high cohesion**, this cohesion of water is important for living world.
- Plants depend on cohesion among water molecules for the transport of water and nutrients from roots to leaves.
- **Exert Pulling Force for Water Transport:** The evaporation of water from a leaf exerts a pulling force on water within xylem vessels of the leaf.
- Because of this cohesion, the force is relayed through xylem vessels all the way down to roots.
- As a result, water rises **against the force of gravity.**
- **High Surface Tension: Hydrogen** bonds also give water high surface tension. Water behaves as if it were coated with some invisible film. You can see in **Figure 4.10,** the insect water strider walks on water without **breaking surface.**

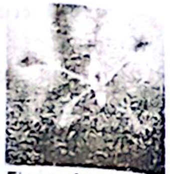


Figure: A water strider walking on the surface of water

- Acids combine with OH^- ions, leaving H^+ ions in medium and make medium acidic.
- Similarly bases combine with H^+ ions, leaving OH^- ions in medium, and make medium basic.

➲ Ionization of Water:

- When the covalent bonds among the atoms of water molecule break, water is ionized to form hydrogen ions (H^+) and **hydroxyl ions (OH^-).** At normal conditions, this reaction is reversible and equilibrium is maintained.
- At room temperature **(25°C)** in a litre of water one molecule out of each **550 million** is ionized and thus the concentration of each of H^+ and OH^- in pure water remains at 10^{-7} moles/litre.
- H^+ and OH^- ions take part in many chemical reactions in the cells e.g., hydrolysis of macromolecules. Relative concentrations of H^+ and OH^- ions determine the **acidity and alkalinity** of medium i.e., pH of medium. The pH affects the biochemical reactions. Enzymes work best at **specific** pH.

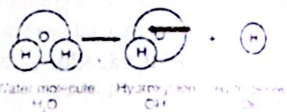


Figure: Ionization of water

Check Understanding!

8. How does the density anomaly of water at 4°C support seasonal mixing in lakes?

(7) Maximum Density at 4°C:

- Water exhibits its maximum **density at 4°C.** Its density decreases when the **temperature** lowers it is because of the **hydrogen bonds** which keep water molecules relatively far apart.
- **Ice Floats on Water:** When temperature **falls to 0°C**, water freezes but the resulting ice is less dense than liquid water, because at this temperature, hydrogen bonding keeps water molecules further apart than in liquid water.
- In rivers, streams or lakes, **ice** is formed on the surface water due to falling of temperature. As ice is less dense than water, it floats on surface.
- **Importance:** It acts as an **insulator and does not** allow heat to escape from the water beneath it. In this way aquatic organisms are protected.

Table: Properties of water and benefits to life

Properties	Bonding	Benefits to life
• Best solvent	• Polarity	• Provides medium for chemical reactions
• Maximum heat capacity	• Hydrogen bonding	• Keeps temperature constant internally and externally for organism
• Maximum density at 4°C	• Change in hydrogen bonding	• Ice floats on water
• High heat of vaporization	• Hydrogen bonding	• Moderates Earth's temperature
• Ionization	• Covalent bond breaks	• Determine the acidity and alkalinity of medium
• Cohesion	• Polarity, Hydrogen bonding	• Water and nutrients are transported from roots to leaves

CARBOHYDRATES

- The word **"carbohydrate"** literally means "hydrated carbon".
- Carbohydrate are naturally occurring organic compounds, which are synthesized as the primary **products of photosynthesis**
- During photosynthesis, when reduction of **CO_2 occurs,** the resulting carbohydrate molecule contains carbon, hydrogen and oxygen in the molar ratio of 1:2:1. Their empirical formula is **$C(H_2O)n$** where 'n' is the number of **carbon atoms.**

➲ Classification of Carbohydrates:

- Carbohydrates are also known as "**Saccharides**" (Latin: "**Saccharum**" meaning sugar) and are classified into three groups after this name:

  (1) Monosaccharides (2) Disaccharides (3) Polysaccharides.

Q. Distinguish the properties and roles of monosaccharides and classify them. **[Exercise L.O.4]**

(1) Monosaccharides:

General Characteristics:

- Monosaccharides (simple sugars) are made of single sugar molecule.
- **Solubility:** They are easily **soluble** in water.
- **Most common Monosaccharides:** Pentoses and hexoses are most common and found in all living organisms.
- They may have 3-7 carbon atoms. They are further classified into subgroups on the basis of number of carbon atoms. Hexoses play central role in energy storage.
- **Primary Source of Energy:** The primary energy-storage molecule is glucose with seven energy-storing CH bonds.
- Its empirical formula is **$C_6H_{12}O_6$ or (CH_2O_6)**

Check Understanding!

9. **A six-membered ring form of glucose is called:**
A) Furanose B) Hexose
C) Pyranose D) Pentose

Table: Classification of monosaccharides

Mon osaccharides	Carbon atoms	Formula	Examples
i. Trioses	3	$C_3H_6O_3$	Glyceraldehyde, Dihydroxyacetone
ii. Tetroses	4	$C_4H_{10}O_4$	Erythrose, Erythrulose (intermediate in photosynthesis in bacteria)
iii. Pentoses	5	$C_5H_{10}O_5$	Ribose, Deoxyribose ($C_5H_{10}O_4$) Ribulose
iv. Hexoses	6	$C_6H_{12}O_6$	Glucose, Fructose, Galactose
v. Heptoses	7	$C_7H_{14}O_7$	Rare in nature (intermediate in photosynthesis)

Q. Compare the structural isomers and stereoisomers of glucose. **[Exercise L.O.5]**

➤ **Isomers of Monosaccharides:**

- The molecules which have the same number of atoms (same molecular formula) but differ in how the atoms are arranged (different structural formula) are called **Isomers of each other.**
- **Example:** Glucose is not the only monosaccharide with the formula $C_6H_{12}O_6$. Fructose and galactose also have the same **molecular formula** but their structural formulas are different. The structural and orientation differences have important consequences in the making of polymers.

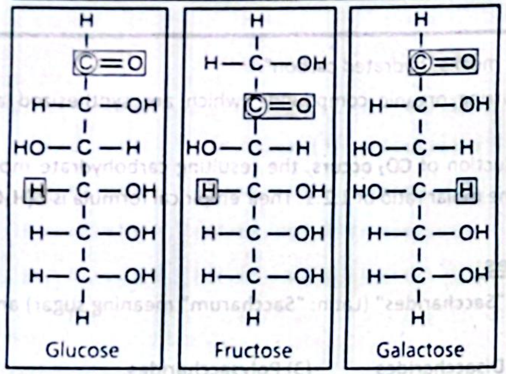


Figure: Structural and stereoisomers of glucose

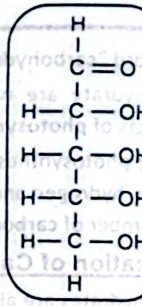


Figure: Structure of Ribose

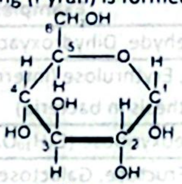
- In fructose, the **double-bonded oxygen** is attached to an internal carbon (no. 2) rather than to a terminal one
- In other words, glucose and fructose are structural isomers Glucose and galactose have a difference in the orientation of one hydroxyl (OH) group at carbon no. 4 (Figure). It means that glucose and galactose are stereoisomers.
- Common Five-Carbon or Pentose Sugars **Ribose and Deoxyribose** (found in nucleic acids and ATP) and ribulose (which occurs as a precursor in photosynthesis).

Check Understanding!
10. How does the Haworth projection represent the ring form of monosaccharides?

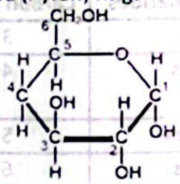
Ring Structures of Monosaccharides:

- In solution form most of the **monosaccharides** form ring structures.
- Ring structure is formed when an **oxygen-bridge develops between two carbon** atoms of the same sugar molecule (Figure).

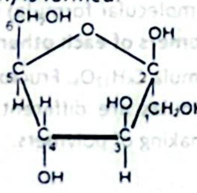
Pyran Ring: (Pyranose)
- In case of glucose, oxygen-bridge develops between carbon number 1 and 5. So, a six cornered ring (Pyran) is formed.



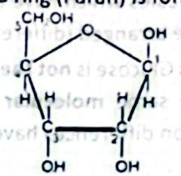
Pyran Ring: (Pyranose)
- In galactose too, oxygen-bridge is formed between carbon number 1 and 5. It again gives a six cornered (Pyran) ring.



Furan Ring: (Furanose)
- In fructose, oxygen-bridge is formed between carbon number 2 and 5. So, a five cornered ring (Furan) is formed.



Furan Ring: Furanose)
- When ribose goes in solution, oxygen-bridge develops between carbon number 1 and 4. So, a five cornered ring (Furan) is formed.



Forms of D–Glucsoe: There are two forms of **D-glucose** i.e., (i) Alpha-D-glucose (ii) Beta-D-glucose.
- **They differ only in** the direction of OH groups on **carbon 1.**
- **The** α-D-glucose has OH group on the lower side while the β-D-glucose has OH - on above side.
- When many alpha-D-glucose molecules join together, they form a polymer called starch. When many beta-D-glucose molecules join together, they form a polymer called cellulose.

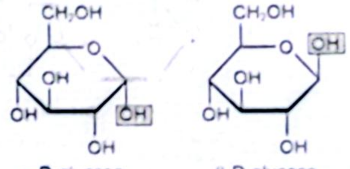


Figure: Ring structures of glucose, galactose, fructose, and ribose

➤ Fischer & Haworth Projections:

- Fischer and Haworth projections are two ways to represent the **structure of sugar molecules.**
- **Fischer Projection:** It was devised by German chemist Emil Fischer in 1891, In a Fischer projection the carbohydrate is shown in its open chain form, rather than a cyclical one.
- **Haworth Projection:** It is named after British chemist **Sir Norman Haworth.** It shows sugars in their **cyclic forms.**

Check Understanding!
11. How does the Haworth projection differ from the Fischer projection?
A) It shows only linear structures
B) It displays the 3D ring structure of monosaccharides
C) It is used for fats and oils
D) It does not represent any stereochemistry

Q. Distinguish the properties and roles of disaccharides. [Exercise L.Q.]

(2) Disaccharides:

- The carbohydrates made up of two monosaccharides by the process of **dehydration synthesis** are called disaccharide.
- The covalent bond between two monosaccharides is called **glycosidic bond,** on hydrolysis they yield monosaccharide monomers, of which they are made.
- **Less Soluble in Water:** As compared to monosaccharides, they are less soluble in water. Physiologically important disaccharides are:

(a) Maltose (Malt Sugar):
- **Composition:** It is made up of two glucose monomers. The glucose molecules are attached by 1,4 glycosidic bond between carbon 1 of one and carbon 4 of the other glucose.
- **Occurrence:** It is found in many cereals (wheat, corn etc.) and is also formed (as an intermediate product) during the digestion of starch (Figure).

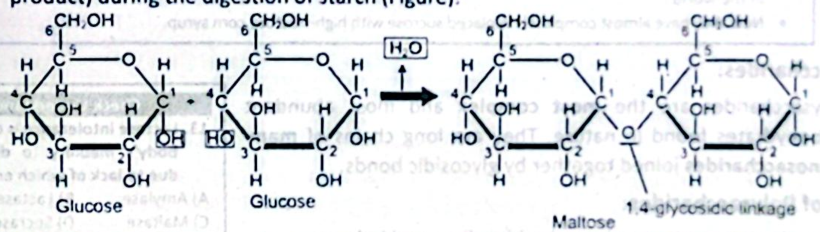


Figure: Dehydration synthesis of one maltose by the condensation of two glucose

(b) Lactose (Milk Sugar):
- **Composition:** It is made up of one glucose and one galactose subunit i.e., it is galactose 1-4 glucose
- **Occurrence:** It is found only in mammalian milk, and is the main source of energy for infant mammals.

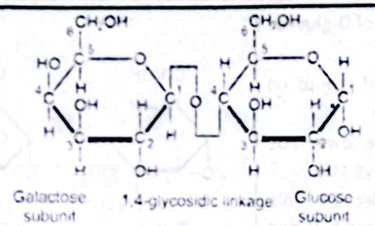


Figure : Structure of lactose

> **Check Understanding!**
> 12. How does the body utilize disaccharides like maltose, lactose, and sucrose?

(c) Sucrose (Cane or Table Sugar):

- **Composition:** It is made up of one glucose and one fructose subunits i.e., it is glucose 1-2 fructose. It is the most familiar disaccharide and is also known as **table sugar.**
- It acts as a **sweetener** in our food. Its molecular formula is ($C_{11}H_{22}O_{11}$).
- **Transport Disaccharide in Plants:** It is also found in phloem vessels of higher plants where it acts as a transport product for the conduction of glucose to and from different parts of plant. That is why it is also known as **transport disaccharide.**

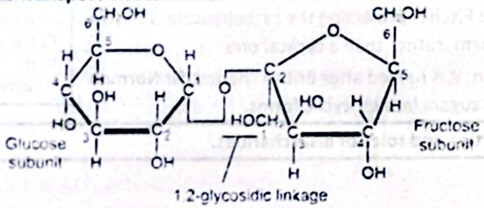


Figure : Structure of sucrose

> **Important To Know**
> - By 1950, food sweeteners were taken from sucrose extracted from sugarcane and beet.
> - In a small part of market, sweeteners were obtained by breaking down the starch of corn into glucose monomers. Because glucose is only half as sweet as sucrose, this method was not a serious rival to cane and beet sugar.
> - In 1980s, a method was developed to convert the glucose, obtained from corn starch, into its isomer i.e., fructose.
> - Fructose is even sweeter than sucrose. The resulting high-fructose corn syrup is inexpensive and has replaced sucrose in many prepared foods. The manufacturers of soft drinks "Cola", were the largest commercial users of sucrose in the world.
> - Now they have almost completely replaced sucrose with high-fructose corn syrup.
>
> 

(3) Polysaccharides:

- Polysaccharides are the **most complex** and **most abundant** carbohydrates found in nature. They are long chains of **many monosaccharides joined together by glycosidic bonds.**

> **Check Understanding!**
> 13. Lactose intolerance is caused by the body's inability to digest lactose due to lack of which enzyme?
> A) Amylase B) Lactase
> C) Maltase D) Sucrase

➤ **Types of Polysaccharides:**

There are three important polysaccharides discussed below.

(a) Starch: It is the plant storage polysaccharide.

- It is insoluble and forms starch granules inside many **plant cells.**
- It is insoluble in water, so it does not change water potential of **plant cells.** So, it does not cause the cells to take up water by osmosis.
- **Components of Starch:** Starch is not a pure substance, but is a mixture of amylose and amylopectin (Figure).

(i) **Amylose Starch:** It is a chain made of glucose monomers (with **1,4-glycosidic** linkages). It is straight and unbranched. However, it tends to coil up into a helix.

(ii) **Amylopectin Starch:** It is also a chain of glucose monomers (with 1,4-glycosidic linkages). It also has branches (with 1,6-glycosidic linkages). In this way, it has more ends that can be broken more quickly by amylase enzymes.

- **Both amylase and amylopectin** are broken down by the enzyme amylase into maltose, though at different rates.

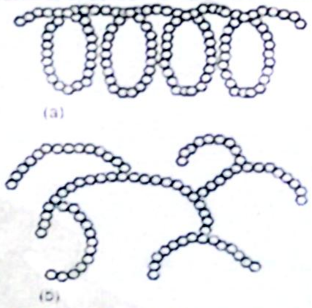


Figure : (a) amylose, (b) amylopectin

(b) Glycogen:

- It is similar in **structure** to amylopectin.
- It is a chain of glucose monomers (with **1,4-glycosidic** linkages) with branches (with 1,6-glycosidic linkages).
- It is made by animals as their storage polysaccharide, and is found mainly in muscles and liver. Because it is so highly branched, it can be broken down to glucose very quickly.

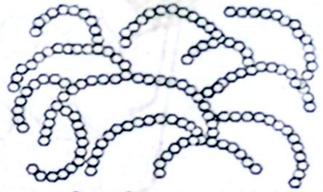


Figure: Glycogen

(c) Cellulose:

- It is only **found in plants,** where it is the main component of cell walls.
- It is a chain of glucose monomers (with 1,4-glycosidic linkages), but with a **different isomers** of glucose.
- Starch and glycogen contain **alpha-glucose,** in which OH group on carbon 1 sticks down from the ring, while **cellulose contains beta-glucose,** in which OH group on carbon 1 sticks up. This means that in cellulose, alternate glucose molecules are **inverted** (Figure).

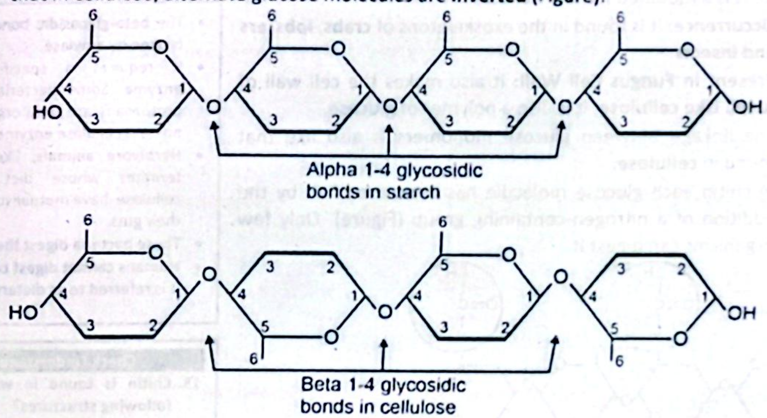


Figure: Difference between starch and cellulose

- This apparently tiny difference makes a huge difference in structure and properties. The alpha 1-4 glucose polymer in starch coils up to form granules. On the other hand, the beta **1-4 glucose polymer** in cellulose forms straight chains.

> **Check Understanding!**
> 14. How is glycogen metabolism regulated in the body?

- **Cellulose Microfibrels:** Hundreds of these chains are linked together by hydrogen bonds to form cellulose microfibrils. These microfibrils make **cellulose fibrils** (Figure). They are very strong and rigid, and give strength to plant cells, and therefore to young plants and also to materials such as paper, cotton etc.

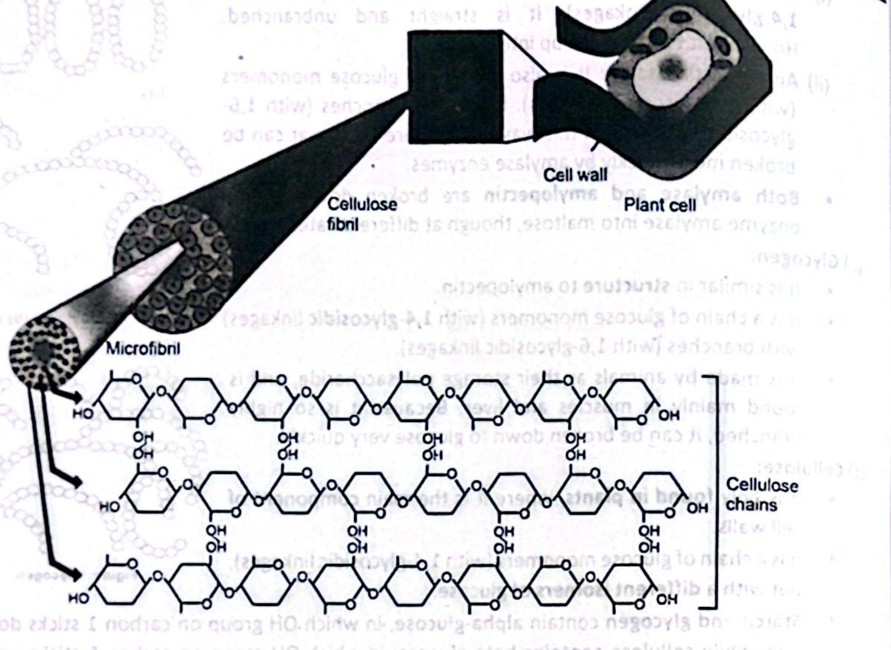


Figure: Cellulose fibrils in plant cell wall

(d) Chitin: It is a modified form of cellulose.

- **Occurrence:** It is found in the exoskeletons of **crabs, lobsters** and insects.
- **Present in Fungus Cell Wall:** It also makes the cell wall of fungi. Like cellulose, it is also a polymer of glucose.
- The linkage between glucose monomers is also like that found in cellulose.
- In chitin each glucose molecule has been modified by the addition of a nitrogen-containing group (Figure). Only few organisms can digest it.

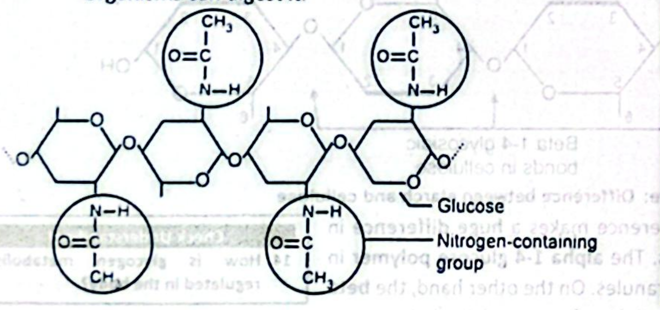


Figure: A part of the chitin molecule

> - The beta-glycosidic bond cannot be broken by amylase.
> - It requires a specific cellulase enzyme. Some bacteria and some protozoans are only organisms that possess cellulase enzyme.
> - **Herbivore animals**, like cows and termites whose diet is mainly cellulose, have mutualistic bacteria in their guts.
> - These bacteria digest their cellulose.
> - Humans cannot digest cellulose, and it is referred to as dietary fibre

> **Check Understanding!**
>
> **15. Chitin is found in which of the following structures?**
>
> A) Plant cell walls
> B) Animal blood vessels
> C) Insect exoskeletons and fungal cell walls
> D) Human bones

(e) Pectin and Lignin: They are also the **polysaccharides used as building material. They are present in the cell walls of plant cells.**

(f) Agar: It is found in the cell walls of red algae. It is used as a thickener in foods. It is also used as a medium on which bacteria and fungi are grown in laboratories.

(g) Murein: It is a sugar-peptide polymer and is found in the cell walls of prokaryotes.

PROTEINS

- The polymers of amino acids Proteins are regarded as the principal compounds of cells are called **proteins.**
- Proteins are most abundant organic compounds in cell.
- **J. Berzelius (in 1938) coined the term "protein" (Greek "Proteios")** molecules of the first rank) to emphasize the importance of this group of macromolecules.
- Proteins are important for the structures of cells and organisms and participate in everything they do. In this way, they act as the **building blocks of life.**

> - The diversity in biological world is the reflection of the diversity of structure and function that exists in proteins.

Structure of Proteins:

- Proteins are the polymers formed by the inter-linkage of monomers called amino acids.
- Different proteins may have a few to **3000 amino acids** in their make-up (e.g., Insulin has **51 amino acids**, Haemoglobin has **574 amino acids**).

> **Check Understanding!**
>
> **16. What is a peptide bond and why is it important in biology?**

Amino acid:

- Amino acid is the basic **structural unit** of proteins.
- It is an organic molecule, in which **four groups**; an amino group (NH_2), a carboxyl group **(COOH)**, a hydrogen group (H) and a side group (R); are attached to the same carbon atom (alpha carbon).
- **No. of Amino Acids in Living Cells:** Although many different amino acids occur in nature, about **170 types** of amino acids have been reported to occur in living organisms (in cells and tissues). Of these, **about 25 types** of amino acids may take part as building units of proteins.
- **Most of the proteins are, however, made of 20 types of amino acids.**
- The identity and unique chemical properties of each amino acid are determined by the nature of its side group (R), covalently bonded to alpha carbon.
- **Example:** R may be a hydrogen atom as in **glycine**, or CH_3 as in **alanine**, or any other group. (Figure).

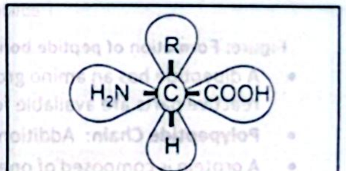


Figure: Structure of an amino acid

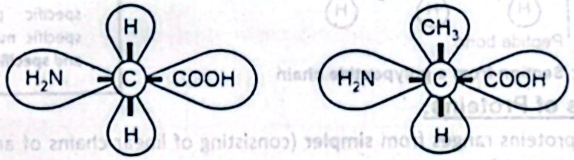


Figure: General structures of glycine and alanine

Essential and Non-essential Amino Acids:

Non Essential Amino Acids: Out of 20 amino acids, our bodies can make eleven amino acids, which are called non essential amino acids.

- **Examples:** Alanine, arginine, asparagine, aspartic acid, cysteine, glutamic acid, glutamine, glycine, proline, serine, and tyrosine.
- **Essential Amino Acid:** The nine amino acids be which cannot make our bodies on its own and must obtain these amino acids by eating various foods are called **essential amino acid.**
- **Examples:** Methionine, valine, tryptophan, isoleucine, leucine, lysine, threonine, phenylalanine and histidine (necessary only for babies).

> - Like disaccharide, the production of a dipeptide is dehydration synthesis.

Q. Define proteins and amino acids and outline the synthesis and breakage of peptide linkages. (Exercise L.Q.)

- **Peptide Bond:** A covalent bond that links two amino acids is known as a peptide bond. Note that each amino acid has an amino group at one end and a carboxyl group at the other end.
- **Synthesis and Breakage:** When two amino acids are brought closer, dehydration synthesis occurs between the amino group of one and the carboxyl group of second amino acid. It results in the release of a molecule of water and formation of a peptide bond between "N" and "C" of adjacent amino acids.
- **Peptides:** The amino acids, which are linked by peptide bond, are called peptides.
- **Dipeptide:** A dipeptide is formed by the linkage of two amino acids.
- **Example:** Glycylalanine (a dipeptide) is formed by the linking of glycine and alanine (Figure).

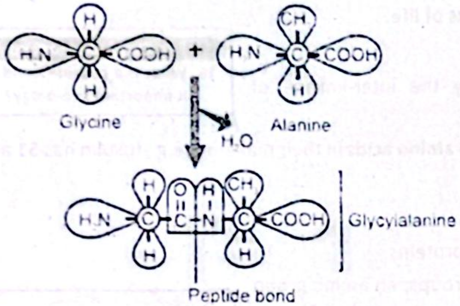


Figure: Formation of peptide bond between glycine and alanine

Check Understanding!
17. Why is the amino acid sequence in a protein critical to its function?
A) It determines the rate of metabolism
B) It defines the protein's solubility only
C) It dictates the folding and final shape of the protein
D) It has no effect on protein activity

- A dipeptide has an amino group at one end and a carboxyl group at the other end of molecule. So, both reactive parts are available for further peptide bonds.
- **Polypeptide Chain:** Addition of many amino acids ultimately leads to form polypeptide chains (Figure).
- A protein is composed of one or more polypeptide chains, e.g., insulin protein contains two polypeptide chains while haemoglobin protein has four polypeptide chains.
- Polypeptide chains assume different shapes on the basis of number, types and sequence of amino acids. It gives different levels of structure to proteins.

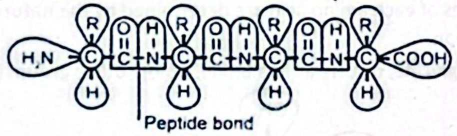


Figure: Section from a polypeptide chain

Proteins in Human Body
- These are over 10,000 proteins in human body and each of these has its specific primary structure, i.e. specific number, specific sequence and specific types of amino acids

➲ Structural Levels of Proteins:

- The diversity of proteins ranges from **simpler** (consisting of linear chains of amino acids) to complex proteins (structural modifications in linear chains).
- **Levels of Protein:**
  The following are different levels at which proteins are built (Figure).

(i) Primary Structure:

- A level of protein molecule which is formed by the linear arrangement of amino acids is called **primary structure.**
- **Primary Structure:** represents the number and sequence of amino acid molecules in a amino acids polypeptide chain. All protein molecules (whether simple or complex) have specific primary structures.
- **Primary Structure of Muslin:** The primary structure of insulin reveals that it is composed of two polypeptide chains.
- **α + β Chains:** The smaller alpha chain has **21 amino acids** while the longer beta chain is made of 30 amino acids (Figure).

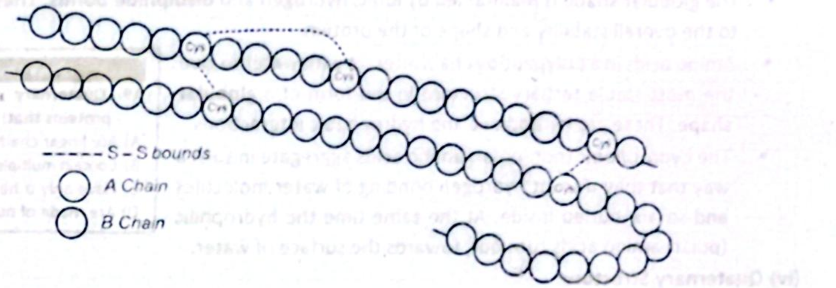


Figure: Chains of insulin

- **Primary Structure of Haemoglobin:** The primary structure of haemoglobin shows that it is made of four polypeptide chains i.e.,
  (a) Two alpha 141 amino acids in each chain. (b) Two beta chains 146 amino acids in each chain.

Q. Justify the significance of the sequence of amino acids through the example of sickle cell haemoglobin. (Exercise L.Q.8)

➤ **Importance of Sequence of Amino Acids:**

- The number, sequence and types of amino acids is highly specific in the primary structure of a protein, for its proper functioning. This specificity in primary structure is determined by the order of nucleotides in DNA.
- Any change in the primary structure results in abnormal protein that fails to carry out its **normal** function.
- **Example:** Sickle cell haemoglobin is formed by **a mistake** in the arrangement of only one amino acid in position six in each beta chain. In sickle cell haemoglobin, **amino acid valine** is present in the place of **glutamic acid.**
- Due to sickle cell haemoglobin, red blood cells get sickle shapes and abnormal **haemoglobin** cannot transport sufficient oxygen. This disease is known as sickle cell anaemia (Figure).

Check Understanding!
18. What are the features of the secondary structure of proteins?

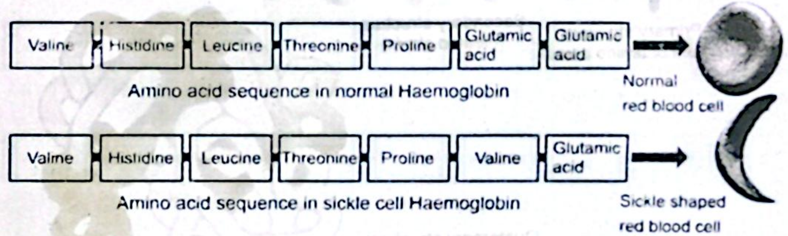


Figure. Difference in amino acid sequence in normal and sickle cell haemoglobin

(ii) Secondary Structure:

- The folding or coiling patterns occur within a polypeptide is called **secondary structure of proteins.**
- Coiling of a polypeptide chain results in alpha helix while folding makes a pleated sheet, both these structures are maintained by hydrogen bonds between amino and carboxyl groups of nearby amino acids in the chain.

Q. If no. of Amino Acids in beta chains of haemoglobin are unchanged a person still develop circle cell amino.
- Chain if no. of Amino Acid in beta chains of hemoglobin are unchanged.
- Why might a person still develop sickle cell anemia.

(iii) Tertiary Structure:

- When the secondary structure further folds up and gets a complicated globular shape, it is called the tertiary structure of protein. These are more complex proteins.

- The globular shape is maintained by ionic, hydrogen and **disulphide bonds.** These bonds contribute to the overall stability and shape of the protein.
- Amino acids in a polypeptide chain interact with water to give the most stable tertiary structure in the form of a globular shape. These are hydrophilic and hydrophobic interactions.
- The hydrophobic (non-polar) amino acids aggregate in such a way that they disrupt hydrogen bonding of water molecules and so are buried inside. At the same time the hydrophilic (polar) amino acids turn out, towards the surface of water.

Check Understanding!

19. Quaternary structure is found in proteins that:
A) Are linear chains of amino acids
B) Contain multiple polypeptide subunits
C) Have only α-helices
D) Are made of nucleotides

(iv) Quaternary Structure:

- **When two or more polypeptide chains with tertiary structures are held together by hydrophobic interactions**, hydrogen bonds and ionic bonds, they form most complex proteins. The **aggregation** of tertiary structures forms the **quaternary structure** of protein.

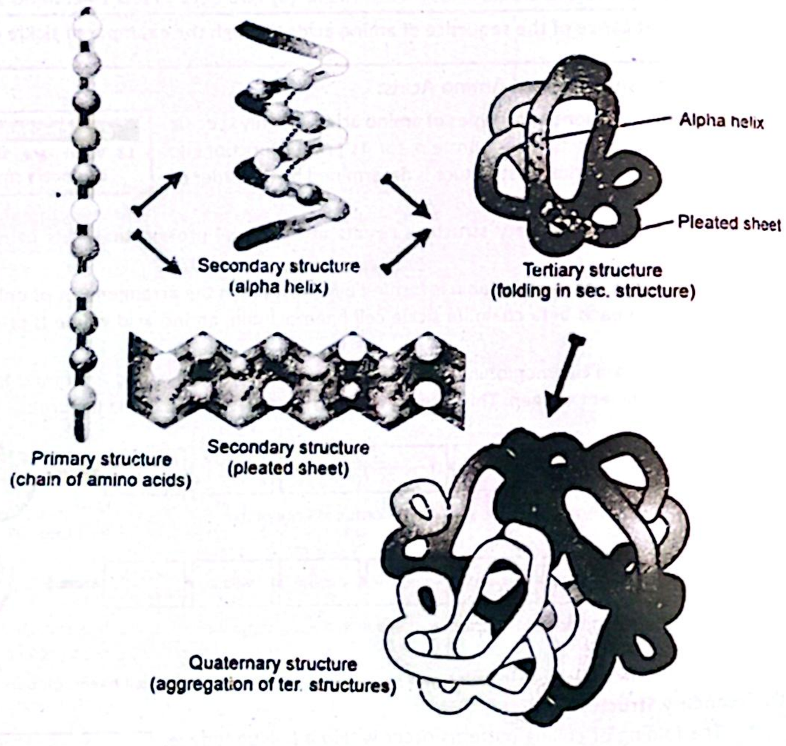


Figure: Levels of protein structure

Classification of Proteins:

- Proteins make a **very diverse group** of organic compounds in living organisms.
- They can be classified on basis of their role in living organisms:
  (a) Structural Proteins **(b) Functional Proteins**
- The recommended classification of proteins is based on their structure.
- In this classification proteins are classified as **"fibrous proteins"** and **"globular proteins"**. We can describe the characteristics of both these classes by a comparison in table.

Table: Characteristics of Fibrous and Globular Proteins

Characteristics	Fibrous proteins	Globular proteins
• Shape	• In the form of fibrils	• Spherical or ellipsoidal
• Structure	• Primary or secondary	• Tertiary or quaternary
• Role	• Structural	• Functional
• Crystallization	• Non crystalline and elastic	• Can be crystallized
• Solubility	• Insoluble	• Soluble in salt, acid or base solutions and in aqueous alcohol
• Disorganization	• Do not disorganize easily	• Disorganized with changes in environment
• Examples	• Silk fibre-form the webs of silk worm and spider Actin in muscle cells Fibrin - in blood clots Keratin - in nails, hairs, beak, skin etc. Collagen - in matrix of connective tissues	• Enzymes - biocatalyst Antibodies - active against invading antigens Some hormones - regulate body's activities Haemoglobin - oxygen carrying protein

Role of Proteins in life:

- Proteins carry out **almost all activities of living organisms.** Some of their remarkable structural and functional roles are given below.
- **Component of Plasma Membrane (Sodium + Potassium):** Proteins are an important part of the composition of all plasma membranes.
- **Controls Movement of Materials:** Channel proteins in the membranes of cells control the movement of materials in and out of cells. For example, proteins make sodium potassium pump in the cell membrane of neurons. This pump controls the movement of Na^+ and K^+ ions in and out of nerve cell.

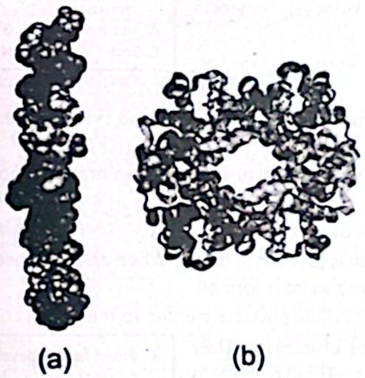


Figure: (a) Collagen – a fibrous protein,
(b) haemoglobin – a globular protein

Check Understanding!

20. What makes globular proteins suitable for dynamic functions in the cell?

- **Example of Fibrous Proteins:** Collagen and keratin make almost whole structures of cartilage and hair, nails respectively.
- **Acts As Enzyme: Enzymes** are a class of proteins that catalyse the metabolism of cells. They are a much diverse class of proteins.
- **Example:** Proteases catalyse the breakdown of proteins, polymerases catalyse the synthesis of polymers.

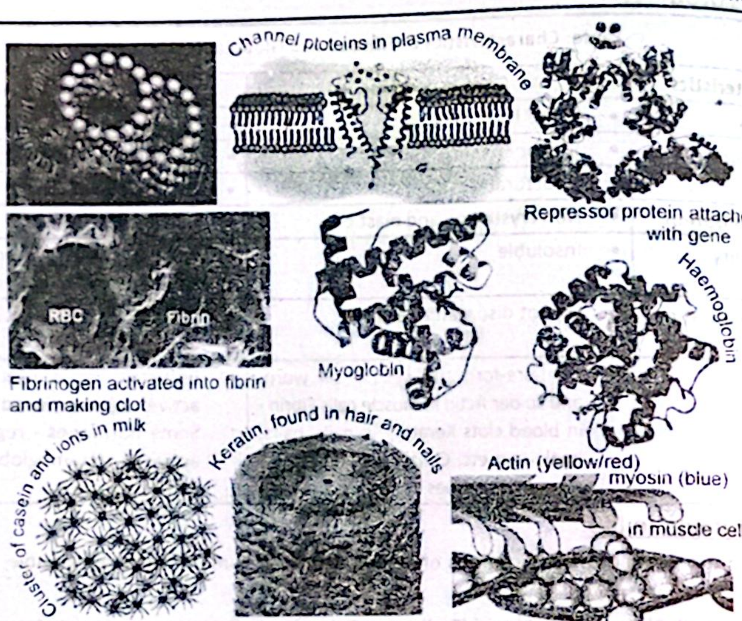


Figure: Different proteins of human body

- **Proteins As Hormones:** Some very important hormones of animals are proteins or peptides in nature.
- **Example:** Insulin (controls blood glucose level), antidiuretic hormone (increases water retention by kidneys), oxytocin (regulates milk production).

> **Check Understanding!**
> 21. Which protein type is more lik[illegible] contain active sites for e[illegible] function?
> A. Fibrous B. Globular
> C. Both D. Neither

- **Transport Gases:** Some globular proteins work to transport different materials throughout the body.
- **Example:** Haemoglobin and myoglobin transport O_2 and some CO_2, and cytochromeswork in ele[illegible] transport chain as electron carriers.
- **Maintains Osmotic Balance of Blood Albumin:** Is a blood protein that maintains osmotic concen[illegible] of blood and keeps its ability to flow.
- Blood clotting is important to prevent the loss of blood after an injury.
- **Blood Clotting After Injury:** Fibrinogen protein is present in blood. When an injury occurs, fibrino[illegible] activated into fibrin. The fibrin makes fibres and a clot is formed.
- **Contraction of Body:** All types of contractions in living matter are due to the actions of proteins
- **Example:** Actin and myosin are main proteins of muscles. They are responsible for **muscular contractions.** Tubulin protein makes spindle fibres.

> - **Blood ferritin levels** are measur[illegible] patients as a diagnostic to[illegible] anaemia.
> - **If ferritin** is high there is [illegible] excess. If ferritin is low there i[illegible] for lack of iron which sooner o[illegible] could lead to anaemia.

- **Prevent From Germ Attack:** Antibodies are important proteins. They recognize and combine with foreign substances (antigens) and convert them into harmless products.
- **Stores Ion:** Some ion-binding proteins store ions in different parts of body. For example, ferritin is the main intracellular iron storage protein.
- **Stores Calcium + Potassium:** Casein is a milk protein that stores potassium and calcium ions.
- **Repressors** are the proteins that regulate gene action by preventing the synthesis of RNA. These p[illegible] allow genes to work where and when required.

LIPIDS

Q. Describe the properties and roles of acylglycerols, phospholipids, terpenes and waxes. (Exercise L.Q.9)

- A group of non-polar heterogeneous molecules that are **insoluble** in water but soluble in organic solvents (e.g., ether, alcohol, etc.) are called **lipids.**
- **Classification of Lipids:** They are a diverse group of molecules and are classified as acylglycerols, waxes, phospholipids, terpenes, steroids and prostaglandins.

(1) Acylglycerols: (Fats and Oils)

> - **Ester:** An ester is the compound produced as the result of a chemical reaction of an alcohol with an acid and a water molecule is released.

- **Sub-units of acylglycerols:** (a) Glycerol (b) Fatty acid
- **Oils:** The acylglycerols which are liquid at room temperature, are called oils.
- **Fats:** The acylglycerols which are solid at room temperature, are called fats.
- In animals, most acylglycerols are fats. In plants, most acylglycerols are oils.
- **Example:** Peanut oil, corn oil, castor oil etc.
- **Chemcial Nature:** Acylglycerols are the esters of fatty acids and alcohol. They are synthesized through dehydration synthesis (OH is released from alcohol and H from an acid) as shown below.

$$C_2H_5OH + HOOCCH_3 \rightarrow C_2H_5OCOCH_3 + H_2O$$

Alcohol acetic acid an ester

- **Neutral Lipids:** The most widely found acylglycerols are triacylglycerol (triglycerides), also called neutral lipids. In triacylglycerols, three molecules of fatty acid (same or different) are joined to a **single glycerol backbone.**

> **Check Understanding!**
> 22. How do proteins function in movement within the body?

➤ **Sub-units of Acylyglycerole:**

(a) Glycero:

- It is a 3C alcohol and each of its carbon bears a hydroxyl group. The 3 carbons of glycerol form the backbone of acylglycerol molecule, to which three fatty acids are attached.

(b) Fatty acids:

- These are responsible for all the characteristics of acylglycerols. Fatty acids are long hydrocarbon chains (with carbon in even number 4 - 30), ending in a carboxyl (-COOH) group. They vary in length and may be as straight chains (in animals) or branched or ringed (in plants).

➤ **Types of Fatty Acids:**

They are of two types:

> - If a fatty acid has one double bond it is called **mono-unsaturated** and if there are more than one double bond, it is called **poly-unsaturated.**

(i) Saturated Fatty Acids:

- The fatty acids which contain **no double bond** in their hydrocarbon chain.
- In saturated fatty acids, all internal carbon atoms possess hydrogen sidegroups. These fatty acids make straight chains, and have a high melting point.

(ii) Unsaturated Fatty Acids:

- The fatty acids which have **double bonds (6 maximum)** between one or more pairs of carbon atoms.
- The double bonds **replace some** of the hydrogen atoms so, unsaturated fatty acids contain fewer than the **maximum** number of hydrogen atoms.
- These fatty acids form **bent chains,** and have a **low melting point.**

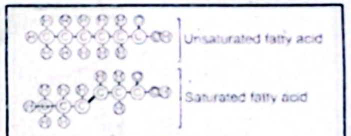


Figure: Fatty acids

➤ **Properties:**

- **Solubility + Melting Point:** Solubility of fatty acids (in organic solvents) and their melting points increase with increasing number of carbon atoms in their chains.
- **Efficient Energy Storage Molecules:** Acylglycerols are efficient energy-storage molecules due to higher number of C – H bonds in them.

Check Understanding!

23. Which lipid class contains phosphate group and is a major component of cell membranes?
A) Steroids B) Phospholipids
C) Waxes D) Terpenes

- **Insoluble in Water:** They are insoluble, because of their **non-polar structure**. Therefore, they can be deposited at specific storage locations within organism.
- **Fats Have More Energy Than Oils:** Animal fats contain more energy than do plant oils, because they contain saturated fatty acids and so contain more **C – H bonds**. On the other hand, plant oils have unsaturated fatty acids and contain comparatively lesser number of C – H bonds.
- When organisms have to store glucose for long periods, they usually convert it into fats or oils.

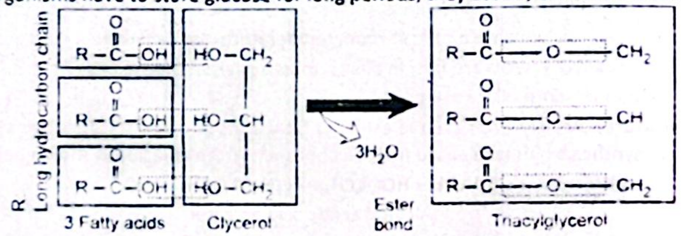


Figure: Dehydration synthesis of a triacylglycerol

(2) Waxes:

- Waxed are derived from acylglycerols.

➤ **Properties of Waxes:**

- **Chemical Nature:** Waxes do not have any well-defined structure and composition. They are mixtures of long chain alkanes (with carbon atoms in odd number; 25-35), alcohols (other than glycerol), ketones and long chain fatty acids.

- **Natural Wax:** Honeybees produce waxes and use it to make six sided (hexagonal) chambers of the combs, where honey is stored. In humans, wax is secreted by glands in the outer ear canal.

- **High Melting Point:** They have high melting points, because of large number of –C–atoms and so are solid at room temperature.
- **Inert + Strong Hydrophobic:** Waxes are chemically inert. Like other lipids, waxes are strongly hydrophobic. So, they act as protective coverings and water barriers for living organisms.

➤ **Uses/Importance of Wax:**

- **As Protective Coating:** Waxes are widespread as protective coatings on fruits and leaves. Some animals like insects, birds, sheep etc. also secrete waxes over their skin.
- **Water Proof Cover:** Waxes are used to waterproof paper and cards.
- **Use in Polish:** Waxes are also used in wax polishes for furniture, footwear and vehicles.
- **Candles Making:** Waxes are also used to make candles.
- **Crayons Making:** Waxes with coloured pigments are used in making crayons and coloured pencils.

Wax on cuticle of leaves | Candles made of wax | Wax crayons | Waxy polish

Figure: Some uses of waxes

(1) Phospholipids:

➤ **Properties of Phospholipids:**

- **Chemical Nature:** Chemically they are the derivatives of phosphatidic acid Phosphatidic acid is composed of one glycerol, two fatty acids and one phosphoric acid (phosphate). Any nitrogenous base e.g., choline, ethanolamine or serine attaches with its phosphoric acid and makes phospholipid.

Check Understanding!

24. What is the biological significance of prostaglandins in the human body?

- **Common Examples:** Phosphatidyl choline (lecithin), phosphatidyl ethanolamine and phosphatidyl serine. Phosphatidyl choline (Figure 4.35) forms lipid bilayer in plasma membranes.

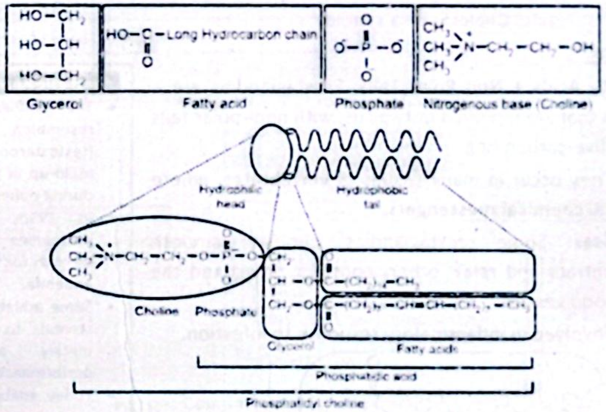


Figure: Phosphatidyl choline – a phospholipid

- **Have Two Parts:** Phospholipids have two parts of their molecules i.e., (a) Head (b) Tail
  (a) Head: It is polar and contains nitrogenous base and phosphate group.
  (b) Tail: It is non polar and contains the two fatty acids.
- Phospholipids play important structural roles in making plasma membranes.

(2) Terpenes:

➤ **Properties of Terpenes:**

- **Large + Diverse Group:** It is a very large and diverse group of lipids. All terpenes are made of isoprene units.
- **Isoprene Unit:** An isoprene unit is a branched unsaturated hydrocarbon chain with the formula $CH_2 = C(CH_3) - CH = CH_2$ is called isoprene unit.
- **Importance Uses:** Terpenes form many biologically important pigments, such as chlorophyll in plants and retinal pigments in eyes. Vitamin A and rubber are also terpenes.

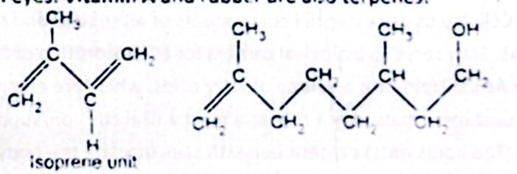


Figure: Structure of terpenes

(3) Steroids:

- Steroids are lipids whose carbon skeleton is bent to form **four fused rings**.
- **Importance/Uses:** All steroids have the same ring pattern i.e., three 6 -cornored rings and one 5 - cornored ring. Cholesterol is a common steroid in animal cell membranes. Animal cells also use it for making other steroids.

- **Examples:** Male and female sex hormones.

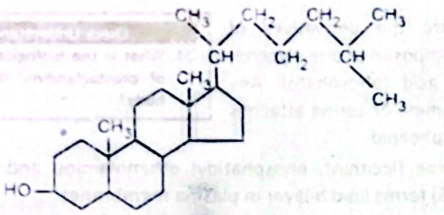


Figure: Cholesterol: a steroid

Check Understanding

25. Which nitrogenous base is present in RNA but not in DNA?
A) Adenine B) Cytosine
C) Uracil D) Thymine

(4) Prostaglandins:

- **Modified Fatty Acids + Non Polar Tails:** Prostaglandins are a group of lipids that are modified fatty acids, with non-polar tails attached to a five-carbon ring.
- **Occurrence:** They occur in many tissues of vertebrates, where they act as local chemical messengers.
- **Importance/Uses:** Some prostaglandins stimulate smooth muscles to contract and relax; others constrict or expand the diameter of blood vessels.
- They are also involved in inflammatory response to infection.

Synthetic Anabolic Steroids & Its Uses

- The synthesized anabolic steroids resemble male sex hormone (testosterone) and cause general build-up in muscles and bone mass during puberty in males.
- In 1950s some pharmaceutical companies produced anabolic steroids for the treatment of general anaemia.
- Some athletes began using anabolic steroids to build-up their muscles quickly and enhance their performance.
- Today, anabolic steroids are banned.
- Anabolic steroids can cause serious physical and mental problems e.g. deep depression, liver damage etc.

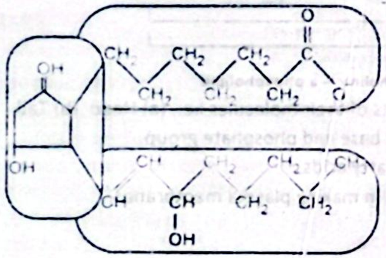


Figure: A prostaglandin

- Aspirin is a prostaglandin inhibitor and that is why it reduces inflammation, pain, and fever.

Role of lipids in life:

- **Rich Source of Energy:** Lipids are important sources of energy (ATP). In fact, lipids are the most energy rich of all nutrients. One gram of lipids provides 9.5 kilocalories of energy. The same amount of protein provides 5.6 kilocalories while that of carbohydrate provides 4.1 kilocalories.
- **Component of Cell:** Lipids are essential components of all cellular and subcellular membranes.
- **Absorb Vitamins:** They serve as biological carriers for the absorption of fat-soluble vitamins A, D, E and K.
- **Source of Fatty Acids:** Lipids are a source of fatty acids, which are essential for various metabolisms.
- **As Mechanical Cushion:** Lipids play a role as a mechanical cushion/support for vital body organs.
- **Act As Insulate:** The lipids (fats) present beneath skin, insulate the body from extreme temperatures.
- **Role of Steroids:** Steroids perform a wide range of important biological functions.
- **Maintains Membrane:** Cholesterol is involved in the maintenance of membranes. It also helps in lipid transport. It as a precursor of vitamin D, bile acids, and steroid hormones (androgens, oestrogens), adrenal hormones and corticosteroids.

NUCLEIC ACIDS

- **Definition:** The polymers of nucleotide units is called **nucleic acid**.

Check Understanding

26. Explain the importance of ribosomal RNA (rRNA) in the cell.

Types of Nucleic Acid:

- There are two main types of nucleic acids i.e.,
  (i) Deoxyribonucleic acid (DNA) **(ii) Ribonucleic acid (RNA)**
- DNA is found mainly in chromosomes, with small amounts in mitochondria and chloroplasts.
- RNA is found in nucleolus, ribosomes and cytosol.

Q. Describe the molecular level structure of nucleotide. **(Exercise L.Q.10)**

- **Nucleotide:** It is made up of a nucleoside and phosphoric acid.
- **Nucleoside:** It is made of a nitrogen base and a pentose sugar (Figure).

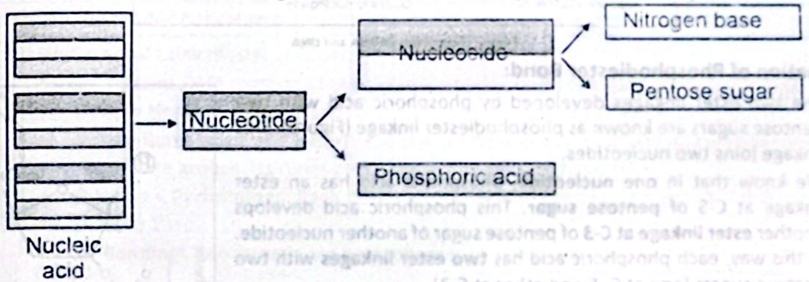


Figure: Components of nucleic acids

Components of Nucleic Acid:

- Nucleic acid has three components:
  (i) Pentose Sugar **(ii) Nitrogenous Base** **(iii) Phosphoric Acid**

(i) Pentose sugars:
- RNA contains ribose while DNA contains deoxyribose as their pentoses.

(ii) Nitrogenous bases:
- There are two types of nitrogenous bases in nucleic acids i.e.,
  (a) Pyrimidine Bases (b) Purine Bases

(a) Pyrimidine Bases:
- Pyrimidine is a single ringed nitrogenous base.
- There are three pyrimidine bases in nucleic acids.
- Cytosine (C) is present in both DNA and RNA, thymine (T) is present only in DNA, and uracil (U) is present only in RNA.
- Purine is a double ring nitrogenous base.

(b) Purine Bases:
- Both DNA & RNA contain two purine bases Adenine (A) guanine (G).
- One nitrogenous base is attached with carbon 1 of pentose sugar and makes a nucleoside.

(iii) Phosphoric acid:
- A nucleoside develops **ester linkage** with a phosphoric acid and becomes nucleotide. In this ester linkage, phosphoric acid is linked with **C-5 of pentose sugar.**
- The backbone of the structure of nucleic acids is made of sugars and phosphates (Figure).

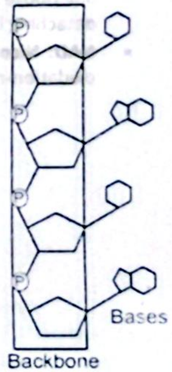


Figure: Sugar-phosphate backbone of nucleic acids

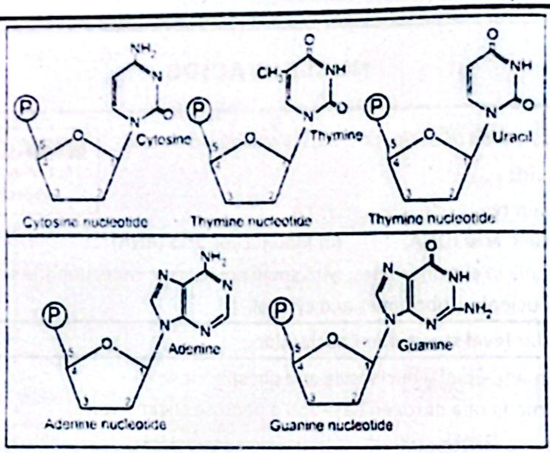


Figure: Nucleotides of RNA and DNA

- **Formation of Phosphodiester Bond:**
  - The two ester linkages developed by phosphoric acid with two pentose sugars are known as phosphodiester linkage (Figure). This linkage joins two nucleotides.
  - We know that **in one nucleotide,** phosphoric acid has an ester linkage at **C-5 of pentose sugar.** This phosphoric acid develops **another ester linkage at C-3** of pentose sugar of another nucleotide. In this way, each phosphoric acid has **two ester linkages** with two pentose sugars (one at C–5 and other at C-3).
  - **Ribonucleotides:** The nucleotides of RNA are known as ribonucleotides.
  - **Deoxyribonucleotide:** The nucleotides of DNA are known as deoxyribonucleotides.
  - **Naming of Nucleotides:** Nucleotides are named after the type of nitrogenous base.

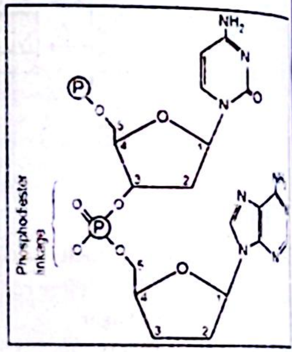


Figure: A dinucleotide

- **Importance of Nucleotides:**

Nucleotides also play other critical roles in the life of cell.

- **ATP:** ATP is a **triphosphate nucleotide of adenine.** In ATP, three phosphate groups are attached with one ribose sugar. You know that ATP is the **"energy currency"** of cell. **It provides energy** by successively detaching its two phosphate groups and changing to ADP and AMP. Similarly,
- **NAD: Nicotinamide Adenine Dinucleotide (NAD)** is a co-enzyme. It acts as a hydrogen acceptor in oxidation-reduction reactions in cell.

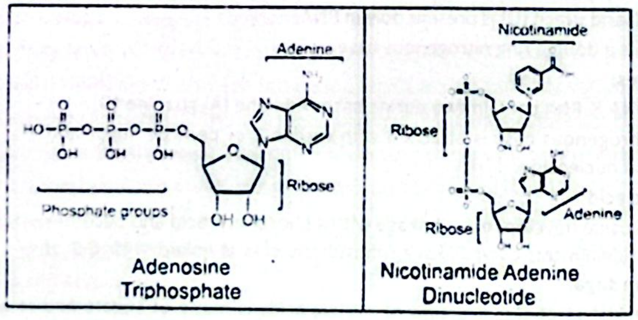


Figure: ATP and NAD

- **Polypeptide Chain:** Nucleotides join together through **phosphodiester linkages** to form long polynucleotide chains. In a polynucleotide chain, phosphate group at **5′** end and **OH group at 3′** are always free. RNA is made of a single polynucleotide chain. On the other hand, DNA is a double helix and is made of two polynucleotide chains.

(1) Deoxyribonucleic Acid (DNA):

- **Contribution of Scientists to Describe the DNA Structure:**
  - **(a) Rosalind Franklin (1953) and Maurice Wilkins (1967):** They studied the molecular architecture of DNA.
  - **(b) James D. Watson and Francis Crick:** In 1953 they put forward the model of DNA.
  - **(c) Chargaff:** The observation by Chargaff was also of basic importance in working out the structure of DNA. In 1951 Erwin Chargaff provided an informative data and it was found that adenine and thymine are equal in ratio in DNA and so are guanine and cytosine following points:
  - Watson and Crick's Model of DNA suggests the in 1950.
  - **Linus Pauling** concluded that DNA is a fibrous substance and the fibre is coiled into a helix.

Q. Explain the double helical structure of DNA as proposed by Watson and Crick. (Exercise L.Q.11)

- **Watson and Crick model of DNA:**
  - Two chains DNA is made of two polynucleotide chains or strands.
  - **Double Helix:** The two strands are coiled around each other and make a double helix.
  - **Pole + Rung (Step of Ladder):** The double helix is like a ladder. Its poles are made of sugars and phosphate groups. Its rungs are made of nitrogenous base pairs.
  - **Purines + Pyrimidines:** Each base pair (rung) is made of one purine (A or G) and one pyrimidine (C or T) base.
  - **H–Bonding:** Two strands are held together by weak hydrogen bonds between their bases.

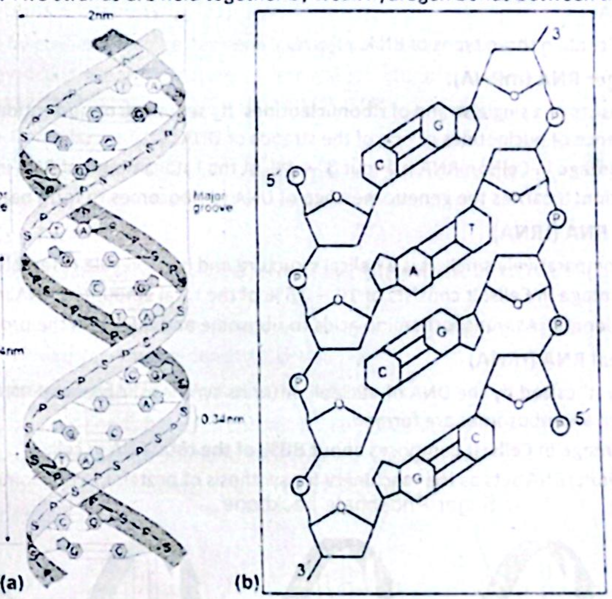


Figure: (a) Watson and Crick model of DNA (b) The detailed structure of DNA

- **A = T, G ≡ C:** Adenine in one chain makes two hydrogen bonds with thymine in second chain, or vice versa. Guanine in one chain makes three hydrogen bonds with cytosine in second chain, or vice versa. There are two hydrogen bonds between A and T pair and three hydrogen bonds between G and C pair.

- **Antiparallel:** Two strands are not in the same direction with respect to their phosphodiester linkages, but are anti-parallel to each other.

➢ **Location of DNA in Cell & Viruses:**

- **In Eukaryotes:** DNA is the fundamental part of chromosomes and so is located **inside nucleus** in eukaryotes.
- **In Prokaryotes:** As there is no distinct nucleus in prokaryotes, their DNA is **present in cytoplasm**.
- **In viruses:** The DNA is located as a core molecule, covered by a protein coat.

> **Recalling**
> - In eukaryotes, small amount (about 2%) of DNA are also present in mitochondria and chloroplasts.

➢ **Importance of DNA:**

- DNA is the hereditary material for all organisms (except some viruses).
- DNA contains the "program" that ultimately directs all cellular activities. The program in DNA is in the form of genes.
- **Gene:** A gene is a sequence of nucleotides of DNA, which codes for the formation of a polypeptide. When a gene is turned "ON", the sequence of DNA nucleotides is transcribed into RNA and then translated into specific proteins. In this way DNA controls the properties and activities of a cell.

> - In the chromosome of bacterium *E. coli*, each strand of DNA contains about **5 million bases** arranged in a particular linear order. It has genes, each consisting of several hundred bases.

Q. Explain the general structure of RNA and differentiate between the three types of RNA. **(Exercise L.O.17)**

(2) Ribonucleic Acid RNA:

RNA: It is composed by ribonucleotides. RNA is synthesized by joining **ribonucleotides** in front of deoxyribonucleotides of DNA **by transcription process**.

➢ **Types of RNA:**

All living cells contain three types of RNA.

(i) Messenger RNA (mRNA):

- It consists of a single strand of **ribonucleotides**. Its sequence of nucleotides is complimentary to the sequence of nucleotides of one of the strands of DNA.
- **Percentage in Cells:** mRNA is about **3 − 4%** of the total amount of RNA in cell.
- **Fucntion:** It carries the genetic message of DNA to ribosomes to form particular protein.

(ii) Transfer RNA (tRNA)

- It is comparatively small. It is a helical structure and its molecule resembles a clover leaf.
- **Percentage in Cells:** It consists of **10 − 15%** of the total amount of RNA in cell.
- **Function:** tRNAs transport amino acids to ribosome and mRNA, in the process of protein synthesis

(iii) Ribosomal RNA (rRNA)

- It is synthesized by the DNA of nucleoli. After its synthesis, ribosomal RNA is joined with ribosomal protein and ribosomes are formed.
- **Percentage in Cells:** It comprises about **80% of the total RNA in cell**.
- **Function:** rRNA acts as the machinery for synthesis of proteins in ribosomes.

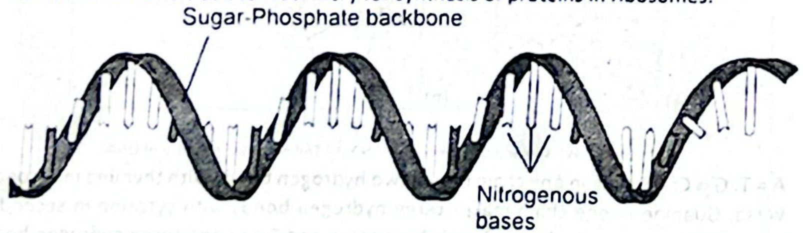


Figure: A model of RNA structure

Central Dogma

- All the organisms have the same basic mechanism of gene reading and expressing is called to as central dogma.
- We can divide central dogma in to two main steps.
  - **(a) First Step (Transcription):** The first step of **central dogma** is the transfer of information from DNA to RNA, which occurs when an RNA copy of the **gene is produced.**
  - **(b) Second Step: (Translation):** The process is called transcription. The second step of the central dogma is the transfer of information from **RNA to proteins,** which occurs when the information contained in the RNA is used to direct the synthesis of proteins. This process is called translation.

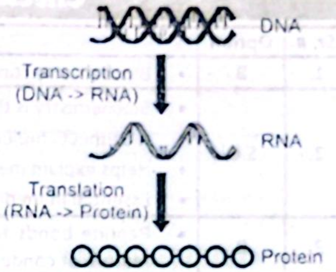


Figure: Flow sheet of Central dogma

- In this way DNA controls the properties and activities of a cell.

CONJUGATED MOLECULES

Q. Define conjugated molecules and describe the roles of common conjugated molecules. **(Exercise L.O.13)**

- The molecules which are formed by the **combination of two or more molecules** belonging to different categories are called **conjugated molecules.**
- Some important conjugated molecules are as follows.

(i) Glycoproteins (Proteins + Carbohydrates):

- They are formed by covalent linkage between a **protein and a carbohydrate polymer.**
- **Occurrence:** They occur widely in nature as integral structural component of membranes; in blood serum; as cellular secretions; and in cartilage, eyes, skin etc.

(ii) Glycolipids (Lipid + Carbohydrates):

- They are formed by a covalent linkage between a lipid and a carbohydrate.
- **Occurrence:** They are an integral structural component of membranes.

(iii) Lipoproteins (Lipids + Proteins):

- They are a class of biomolecules which are formed by **hydrophobic** interactions (not covalent or ionic bonds) between lipids and proteins.
- **Occurrence:** Lipoproteins are the basic structural framework of all types of plasma membranes. Lipids are transported in blood as very low-density lipoproteins.

(iv) Nucleoproteins (Chromosomal DNA + Proteins):

- They are formed by ionic bonds between chromosomal DNA and proteins.
- **Occurrence:** Histone proteins are bound to DNA to form nucleosomes.
- **Function:** They stabilize chromosomal structure in eukaryotes and also play an important role in the regulation of gene expression.

Check Understanding (Solutions)

Sr. #	Option	Explanation
1.	B	• Biochemistry connects chemistry to biology, showing how cells work and life continues.
2.	S.Q	• Biochemistry is the study of chemical processes in living organisms. • It connects molecular chemistry with biological functions. • Helps explain metabolism, enzyme activity, and genetic control. • Essential in medical research, biotechnology, and drug development.
3.	B	• Peptide bonds form when two amino acids join and release a water molecule—a key feature of condensation (or dehydration synthesis).
4.	S.Q	• Hydrolysis breaks covalent bonds by adding water to split molecules. • It helps digest complex food molecules into absorbable units (e.g., proteins into amino acids). • Enzymes catalyze hydrolysis in metabolic pathways. • This reaction provides energy and raw materials for cellular processes.
5.	C	• Water's polarity allows it to surround and dissolve polar and charged (ionic) molecules.
6.	S.Q	• It takes a large amount of heat to evaporate sweat from the skin. • As sweat evaporates, it removes excess body heat. • This cooling mechanism helps prevent overheating. • It's vital for temperature regulation in humans.
7.	C	• Ionization keeps pH within a narrow range for proper enzyme and cellular function.
8.	S.Q	• In spring and autumn, water layers reach 4°C and mix due to equal density. • This seasonal turnover brings oxygen to deeper layers and nutrients to the surface. • It maintains ecological balance and supports aquatic life. • It's vital for nutrient cycling in freshwater ecosystems.
9.	C	• The six-membered ring structure formed by glucose is referred to as a pyranose due to its similarity to the chemical pyran.
10.	S.Q	• The Haworth projection is a cyclic representation that shows how a monosaccharide's ring forms in solution. • It indicates alpha (α) or beta (β) anomers based on the position of the hydroxyl group on the anomeric carbon. • It helps visualize ring closure and stereochemistry of cyclic sugars.
11.	B	• The Haworth projection represents cyclic (ring) forms of monosaccharides, while Fischer projection shows them in linear form.
12.	S.Q	• Each disaccharide is hydrolyzed into monosaccharides by specific enzymes (maltase, lactase, sucrase) in the digestive tract. • The resulting sugars—glucose, galactose, and fructose—are absorbed and used for energy production via cellular respiration. • Efficient digestion of disaccharides is essential for nutrient absorption and metabolism.
13.	B	• Lactase is the enzyme responsible for breaking down lactose into glucose and galactose. Its deficiency leads to lactose intolerance.
14.	S.Q	• Glycogen synthesis and breakdown are controlled by hormones like insulin and glucagon. • Insulin promotes glycogen formation after meals, while glucagon stimulates breakdown during fasting. • This ensures blood glucose homeostasis is maintained in various physiological states.
15.	C	• Chitin is a major component of arthropod exoskeletons and fungal cell walls, providing strength and flexibility.

16.	S.Q	• A peptide bond is a covalent bond formed between the carboxyl group of one amino acid and the amino group of another. • It forms through a dehydration reaction, releasing water. • Peptide bonds are essential for creating polypeptides and proteins, which carry out structural and enzymatic roles in cells.
17.	C	• The amino acid sequence determines how the protein folds, which directly influences its biological function.
18.	S.Q	• Secondary structure arises from hydrogen bonding between backbone atoms, forming α-helices or β-pleated sheets. • These structures provide local stability and folding patterns in the polypeptide. • They are found in many structural and functional proteins like keratin and silk fibroin.
19.	B	• Quaternary structure exists in proteins composed of more than one polypeptide chain (e.g., hemoglobin).
20.	S.Q	• Globular proteins are spherical, compact, and water-soluble due to their hydrophilic outer regions. • They perform dynamic roles like enzymatic activity, transport, and immune responses. • Examples include hemoglobin, insulin, and antibodies. • Their complex folding allows formation of active sites for specific functions.
21.	B	• Globular proteins are compact and folded, allowing formation of specific active sites essential for enzymatic and regulatory functions in the cell.
22.	S.Q	• Proteins like actin and myosin are responsible for muscle contraction. • They convert chemical energy into mechanical movement. • They are also involved in intracellular transport and cytoskeleton structure. • These proteins are essential for mobility and organ function.
23.	B	• Phospholipids have hydrophilic phosphate heads and hydrophobic fatty acid tails, essential for membrane structure.
24.	S.Q	• Prostaglandins are lipid-based local signaling molecules. • Regulate inflammation, blood flow, and blood clotting. • Act near their synthesis site, not via bloodstream. • Play roles in immune response and pain sensation.
25.	C	• RNA uses uracil instead of thymine found in DNA, which pairs with adenine during base pairing.
26.	S.Q	• rRNA is a major component of ribosomes. • It catalyzes peptide bond formation between amino acids. • rRNA also provides structural support for ribosome assembly and function.

Exercise

Exercise **MULTIPLE CHOICE QUESTIONS (MCQs)** Section 01

1. **Which characteristic of water molecules is responsible for most of the unique properties of water?**
(a) Small in size (b) Held together by covalent bonds
(c) Can easily separate from one another (d) Stick together
2. **To which group of lipids, the human sex hormones belong?**
(a) Steroid (b) Waxes (c) Prostaglandins (d) Phospholipids
3. **Which of the following is NOT a protein?**
(a) Haemoglobin (b) Cholesterol (c) Pepsin (d) Antibody
4. **Which one is the largest carbohydrate?**
(a) Cellulose (b) Ribose (c) Glyceraldehyde (d) Glucose
5. **What compound would be manufactured difficultly when soil has a shortage of phosphorous?**
(a) DNA (b) Fatty acids (c) Proteins (d) Cellulose
6. **A compound whose chemical composition is most closely related to maltose is;**
(a) Starch (b) Protein (c) ATP (d) RNA
7. **Which group is found in all fatty acids?**
(a) PO_4 (b) SO_4 (c) C – N (d) COOH
8. **Haemoglobin has:**
(a) Primary structure (b) Secondary structure (c) Tertiary structure (d) Quaternary structure
9. **Which process produces peptide bonds?**
(a) Digestion (b) Dehydration synthesis (c) Hydrolysis (d) Enzyme deactivation

Answer Key with Explanations

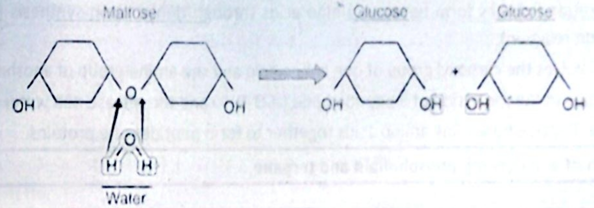
Sr.No.	Option	Answer	Explanations
1.	(b)	Stick together	• Water molecules are polar and form hydrogen bonds with each other. This cohesion causes them to "stick together," leading to surface tension and other unique properties.
2.	(a)	Steroid	• Human sex hormones like estrogen and testosterone are derived from cholesterol, which classifies them as steroids—a type of lipid with a four-ring structure.
3.	(b)	Cholesterol	• Cholesterol is a lipid, not a protein. The other options—haemoglobin, pepsin, and antibodies—are all proteins with specific functions in the body.
4.	(a)	Cellulose	• Cellulose is a large, complex carbohydrate made of long chains of glucose. It is the primary structural component of plant cell walls.
5.	(a)	DNA	• DNA requires phosphorus for the formation of its sugar-phosphate backbone. A deficiency in phosphorus would hinder DNA synthesis and cell division.
6.	(a)	Starch	• Starch and maltose are both carbohydrates. Starch is a polysaccharide made of glucose units, just like maltose, which is a disaccharide.
7.	(d)	COOH	• All fatty acids contain a carboxylic acid group (–COOH) at one end, which gives them their acidic nature and name.
8.	(d)	Quaternary structure	• Hemoglobin is made of four polypeptide chains, giving it a quaternary structure. This arrangement allows it to carry oxygen efficiently.
9.	(b)	Dehydration synthesis	• Peptide bonds are formed during dehydration synthesis, where a water molecule is removed to link two amino acids together.

Exercise **SHORT ANSWER QUESTIONS** Section 02

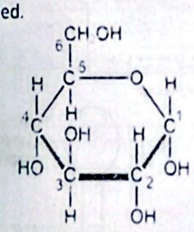
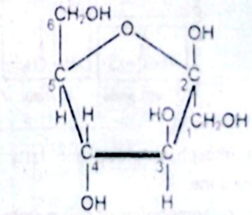
Q.1 Draw a sketch of hydrolysis reactions.

Ans. Hydrolysis:

- Hydrolysis is a chemical process in which macromolecule (polymer) is broken down into smaller fragments by the addition of water molecules.
- **Reverse of Dehydration Synthesis:** Along with making polymers by combining their monomers, cells keep on breaking polymers too. It is the reverse of dehydration synthesis.
- Cells break bonds between monomers by adding water to them.
- In this process, OH group from a water molecule joins to one monomer and hydrogen joins to the second monomer.
- **Example:** Breakdown of maltose into two glucose monomers by the addition of a water molecule is an example of hydrolysis.



Q.2 Draw the ring structure of glucose and fructose.

Ans.	Pyran Ring: (Pyranose)	Furan Ring: (Furanose)
	• In case of glucose, oxygen-bridge develops between carbon number 1 and 5. So, a six cornered ring (Pyran) is formed.  Glucose	• In fructose, oxygen-bridge is formed between carbon number 2 and 5. So, a five cornered ring (Furan) is formed.  Fructose

Q.3 Define isomers and stereoisomers.

Ans. Isomers:

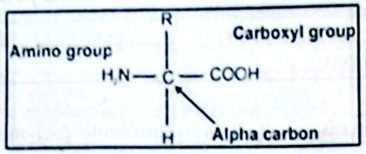
- Compounds with the same molecular formula but different structural formulas.
- Can be classified into structural isomers and stereoisomers.

Stereoisomers:

- Isomers that differ in the spatial arrangement of atoms.
- Include enantiomers (non-superimposable mirror images) and diastereomers (not mirror images).
- Have the same molecular formula and sequence of bonded atoms but differ in their three-dimensional structure.

Q.4 Draw the sketch of amino acid.

Ans.



- **General Structure:** NH2-CHR-COOH, where R is the side chain.

Components:

- Amino group (-NH2)
- Carboxyl group (-COOH)
- Side chain (R group), which varies among different amino acids.
- **Importance:** Amino acids are the building blocks of proteins, and their sequence determines the structure and function of proteins.

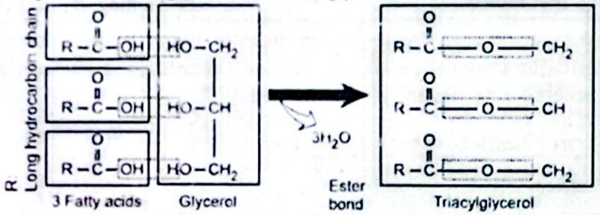
Q.5 Outline the synthesis of peptide linkages.

Ans.
- **Process:** Peptide linkages form between amino acids through dehydration synthesis (also known as condensation reaction).
- **Reaction:** Involves the carboxyl group of one amino acid and the amino group of another.
- **Result:** Results in the formation of a peptide bond (-CO-NH-) and the release of a water molecule.
- **Importance:** Peptide bonds link amino acids together to form peptides and proteins.

Q.6 Draw the sketch of acylglycerol, phospholipid and terpene.

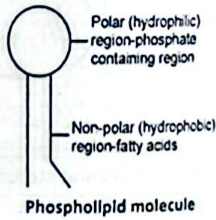
Ans. Acylglycerol:

- Glycerol esterified with one, two, or three fatty acid chains.
- Can be monoacylglycerol, diacylglycerol, or triacylglycerol.



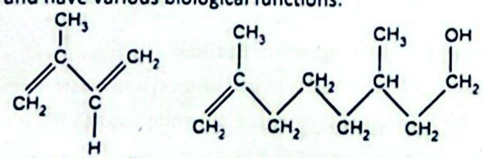
Phospholipid:

- Contains a phosphate group and fatty acids attached to a glycerol backbone.
- Forms a major component of cell membranes, contributing to their structure and function.



Terpene:

- Hydrocarbon derived from isoprene units (C_5H_8).
- Can be classified based on the number of isoprene units: monoterpenes (C_{10}), sesquiterpenes (C_{15}), etc.
- Found in essential oils and have various biological functions.



Isoprene unit

Q.7 Differentiate between nucleoside and nucleotide.

Ans. Nucleoside:

- Consists of a nitrogenous base and a sugar (ribose or deoxyribose).
- Does not contain phosphate groups.

Nucleotide:

- Consists of a nucleoside and one or more phosphate groups.
- The phosphate group is attached to the sugar.
- Nucleotides are the building blocks of nucleic acids (DNA and RNA).

Q.8 Illustrate the formation of phosphodiester bond.

Ans.
- **Process:** Phosphodiester bond forms between the phosphate group of one nucleotide and the sugar of another.
- **Reaction:** Occurs during DNA and RNA synthesis, where nucleotides are linked together.
- **Result:** Links nucleotides together in a polynucleotide chain, forming the backbone of DNA and RNA.
- **Importance:** Essential for the structure and replication of genetic material.

Q.9 State the central dogma of gene expression.

Ans.
- **Overview:** The central dogma outlines the flow of genetic information from DNA to proteins.

Steps:

1. **Transcription:** DNA is transcribed into RNA.
2. **Translation:** RNA is translated into protein.

- **Importance:** Describes how genetic information is used to synthesize proteins, which perform various functions in the cell.

Exercise

LONG ANSWER QUESTIONS

Section 03

Q.1 Distinguish carbohydrates, proteins, lipids and nucleic acids as the four fundamental biological molecules.

Ans.

Property	Carbohydrates	Proteins	Lipids	Nucleic Acids
Basic Unit (Monomer)	Monosaccharides (e.g., glucose)	Amino acids	Fatty acids & glycerol	Nucleotides
Main Elements	C, H, O	C, H, O, N (sometimes S)	C, H, O	C, H, O, N, P
Function	Quick energy source, structural support	Enzymes, transport, structural components	Energy storage, insulation, membrane structure	Store and transmit genetic information
Solubility in Water	Generally soluble	Depends on structure (some are, some aren't)	Mostly insoluble (hydrophobic)	Soluble (especially RNA); DNA less soluble
Examples	Starch, cellulose, glucose	Hemoglobin, enzymes, keratin	Fats, oils, phospholipids, steroids	DNA, RNA

Q.2 Describe and draw sketches of dehydration synthesis reactions.

Ans. See Page No. (116)

Q.3 Explain how the properties of water make it the medium of life.

Ans. See Page No. (117)

Q.4 Distinguish the properties and roles of monosaccharides and classify them.

Ans. See Page No. (121)

Q.5 Compare the structural isomers and stereoisomers of glucose.

Ans. See Page No. (121)

Q.6 Distinguish the properties and roles of disaccharides.

Ans. See Page No. (123)

Q.7 Define proteins and amino acids and outline the synthesis and breakage of peptide linkages.

Ans. See Page No. (128)

Q.8 Justify the significance of the sequence of amino acids through the example of sickle cell haemoglobin.

Ans. See Page No. (129)

Q.9 Describe the properties and roles of acylglycerols, phospholipids, terpenes and waxes.

Ans. See Page No. (133)

Q.10 Describe the molecular level structure of nucleus.

Ans. See Page No. (137)

Q.11 Explain the double helical structure of DNA as proposed by Watson and Crick.

Ans. See Page No. (139)

Q.12 Explain the general structure of RNA and differentiate between the three types of RNA.

Ans. See Page No. (140)

Q.13 Define conjugated molecules and describe the roles of common conjugated molecules.

Ans. See Page No. (141)

Exercise

INQUISITIVE ANSWER QUESTIONS

Q.1 What happens if even one amino acid is substituted for another in a polypeptide chain? Provide a specific example.

Ans. **Effect of Substituting One Amino Acid in a Polypeptide Chain:**

- Even a single amino acid substitution can drastically affect a protein's structure and function.
- The primary structure determines how the protein folds into its final shape; a change may disrupt secondary, tertiary, or quaternary structure.
- A classic example is sickle cell anemia, where valine replaces glutamic acid in the β-chain of hemoglobin.
- This substitution causes hemoglobin molecules to stick together, forming rigid, sickle-shaped red blood cells.
- These cells block capillaries, reducing oxygen delivery and causing pain and fatigue.
- The change occurs due to the difference in polarity and charge of the substituted amino acids.
- Thus, protein function is highly sensitive to its exact amino acid sequence.

Q.2 How does the three-dimensional structure of a protein relate to its function?

Ans. **Relationship Between 3D Structure of a Protein and Its Function:**

- The three-dimensional (tertiary and quaternary) structure of a protein determines its specific shape.
- This shape is critical for the protein's ability to bind to other molecules, like substrates or receptors.
- For example, an enzyme's active site fits only specific substrates, like a lock and key.
- Folding creates binding pockets, surface charge, and flexibility needed for activity.
- If the protein loses its shape (denatures), it loses its function.
- Proper 3D structure ensures the protein performs roles such as catalysis, transport, or signaling.
- Therefore, structure and function are directly linked in all proteins.

Q.3 How do nucleic acids encode genetic information, and how is this information translated into proteins?

Ans.
- The process by which genetic information flows from DNA to RNA to proteins is known as the Central Dogma of Molecular Biology.
- Nucleic acids (DNA and RNA) store and carry genetic instructions essential for life.
- DNA contains the genetic code in the sequence of its nitrogenous bases (A, T, C, G), which serves as a blueprint for all cellular activities.
- This information is transcribed into messenger RNA (mRNA) inside the nucleus.
- The mRNA then moves to the cytoplasm, where it is translated by ribosomes into a specific sequence of amino acids, forming proteins.
- Proteins are the functional molecules that carry out various biological tasks in the cell.
- Therefore, through the Central Dogma, nucleic acids provide genetic instructions that are expressed as proteins, linking genotype to phenotype.

ADDITIONAL MCQs

Q.1 Which type of bond is primarily responsible for the reversible association between complementary DNA strands under physiological conditions?

A) Covalent bond B) Hydrogen bond C) Phosphodiester bond D) Peptide bond

Q.2 The inability of nonpolar substances to dissolve in water is most accurately explained by:

A) High surface tension of water B) Lack of hydrogen bonding potential
C) Presence of ionic dipoles D) High boiling point of water

Q.3 If a disaccharide is treated with an enzyme that breaks only α-1,4-glycosidic bonds, which of the following will likely not be hydrolyzed?

A) Maltose B) Isomaltose C) Glycogen D) Starch

Q.4 Which change would most likely disrupt the secondary structure of a polypeptide without affecting its primary structure?

A) Hydrolysis of peptide bonds B) Denaturation by heat
C) Mutation in DNA D) Replacement of one amino acid

Q.5 Why does cellulose not serve as a significant energy source in humans, despite being a polysaccharide like starch?

A) It is insoluble in water
B) It contains β-glycosidic bonds that human enzymes cannot break
C) It contains toxic functional groups
D) It lacks hydrogen bonds

Q.6 A point mutation results in an amino acid substitution from glutamic acid to valine. What level of protein structure is most directly impacted?

A) Primary B) Secondary C) Quaternary D) Tertiary

Q.7 Which of the following would most likely decrease membrane fluidity at low temperatures?

A) Increased cholesterol content B) More unsaturated fatty acids
C) More saturated fatty acids D) Phospholipids with shorter tails

Q.8 Which interaction is crucial in stabilizing the quaternary structure of hemoglobin?

A) Ester bonds B) Disulfide bridges
C) Hydrogen bonding D) Hydrophobic interactions between subunits

Q.9 Which RNA molecule has enzymatic properties and is involved in ribosomal peptide bond formation?

A) tRNA B) mRNA C) snRNA D) rRNA

Q.10 Which structural feature allows tRNA molecules to bring specific amino acids to ribosomes?

A) Complementary base pairing with rRNA B) Attachment of amino acid to 3' CCA end
C) Presence of codon loop D) Linear conformation

Q.11 Why does high heat capacity of water matter biologically?
A) It prevents water from boiling in cells B) It slows down enzymatic activity
C) It buffers temperature fluctuations in organisms D) It increases reaction rates

Q.12 If a protein denatures but no peptide bonds are broken, what level of structure remains intact?
A) Secondary B) Tertiary C) Primary D) Quaternary

Q.13 Which aspect of phospholipids makes them suitable for bilayer formation?
A) Polar tails and polar heads B) Amphipathic nature
C) Saturated fatty acid chains D) High melting point

Q.14 Which of the following best explains the hydrophobic effect in protein folding?
A) Attraction between water molecules and polar side chains
B) Exclusion of nonpolar side chains from aqueous environment
C) Formation of peptide bonds in aqueous solution
D) Van der Waals forces between charged residues

Q.15 What would most likely happen if phosphodiester bonds in DNA were susceptible to hydrolysis under normal cellular conditions?
A) Translation would accelerate B) DNA would denature at low temperatures
C) Genetic information would degrade rapidly D) Transcription would stop entirely

Q.16 Which of the following contributes most to the specificity of enzyme-substrate interaction?
A) Van der Waals forces B) Shape complementarity and charge distribution
C) Covalent bonding D) Size of substrate

Q.17 How is the energy from ATP typically transferred to cellular processes?
A) Complete hydrolysis to adenosine and phosphate B) Release of adenine
C) Transfer of phosphate group to another molecule D) Loss of ribose

Q.18 Which process directly involves the hydrolysis of phosphodiester bonds?
A) DNA replication B) RNA transcription C) Nuclease activity D) Protein translation

Q.19 Which of the following is true regarding essential amino acids?
A) They are synthesized by all eukaryotes B) They must be obtained from diet in humans
C) They contain more nitrogen D) They are only found in nucleoproteins

Q.20 The amphipathic nature of phospholipids is crucial for:
A) Enzyme specificity B) Membrane permeability and self-assembly
C) Ribosome structure D) DNA replication

Q.21 The directionality of nucleic acid synthesis is due to:
A) Antiparallel structure B) DNA polymerase adding nucleotides to 3' OH
C) Hydrogen bonding between bases D) Peptide bond formation

Q.22 Which property allows RNA to sometimes act as a catalyst (ribozyme)?
A) Double-stranded structure B) 3D folding from intramolecular base pairing
C) Its linearity D) Stability of ribose

Q.23 Which of the following explains why starch is digestible in humans but cellulose is not?
A) Cellulose is insoluble
B) Starch contains α-linkages, which human enzymes can hydrolyze
C) Starch is composed of glucose and fructose
D) Cellulose lacks hydrogen bonding

Q.24 In sickle cell anemia, a single amino acid substitution affects:
A) Only the primary structure
B) Oxygen-carrying ability due to altered tertiary/quaternary structure
C) The mRNA only
D) ATP synthesis

Q.25 Which factor plays a direct role in protein denaturation?
A) Breakage of covalent peptide bonds B) Disruption of hydrogen and ionic bonds
C) Loss of genetic code D) DNA fragmentation

Q.26 Which biomolecule contains both ester and phosphate bonds?
A) Glycogen B) Phospholipid C) RNA D) Protein

Q.27 What allows DNA strands to maintain a uniform diameter in the double helix?
A) Purines pair with purines B) Consistent phosphate spacing
C) Purines pair with pyrimidines D) DNA backbone symmetry

Q.28 Which process converts information stored in nucleotides into a sequence of amino acids?
A) Transcription B) Replication C) Translation D) Reverse transcription

Q.29 Which feature of RNA makes it less stable than DNA?
A) Single-stranded structure B) Lack of thymine
C) Presence of uracil D) Presence of hydroxyl group on 2' carbon

Q.30 Which conjugated molecule is primarily involved in immune recognition and cell signaling?
A) Lipoprotein B) Glycoprotein C) Nucleoprotein D) Glycolipid

ANSWER KEY

1. B)	2. B)	3. C)	4. B)	5. B)	6. A)	7. C)	8. D)	9. D)	10. C)	11. C)	12. C)
13. B)	14. B)	15. C)	16. B)	17. C)	18. C)	19. B)	20. B)	21. B)	22. B)	23. B)	24. B)
25. B)	26. B)	27. C)	28. C)	29. D)	30. B)						

ADDITIONAL SHORT ANSWER QUESTIONS

Q.1 What role do hydrophobic interactions play in the folding and function of proteins?

Ans.
- Hydrophobic interactions occur between nonpolar molecules avoiding water.
- Drive protein folding by clustering nonpolar side chains inward.
- Help maintain the protein's three-dimensional structure.
- Essential for proper protein function and molecular binding.

Q.2 Why is water considered a universal solvent in biological systems?

Ans.
- Water dissolves a wide variety of polar and charged substances due to its polarity.
- This allows essential ions and molecules to move freely in cells and blood.
- It supports biochemical reactions by enabling reactants to interact.
- Without this property, life-sustaining chemistry wouldn't occur efficiently.

Q.3 Why do hydrophobic molecules clump together in water?

Ans.
- Water molecules form hydrogen bonds with each other, excluding nonpolar molecules.
- This exclusion reduces disruption to water's hydrogen-bonding network.
- It forces hydrophobic molecules to aggregate.
- This property is critical in protein folding and membrane structure.

Q.4 Why is water's high heat of vaporization important for climate stability?

Ans.
- Water absorbs a lot of solar energy during evaporation from oceans and lakes.
- This delays rapid warming of Earth's surface.
- Evaporation and condensation cycle influences weather patterns.
- It contributes to climate moderation on a global scale.

Q.5 Why is the ionization of water important in maintaining pH balance in cells?

Ans.
- Water ionizes into H^+ and OH^-, allowing the cell to respond to pH changes.
- These ions are crucial in buffering systems like the bicarbonate buffer.
- Maintains optimal pH for enzyme activity and biochemical reactions.
- Imbalance can lead to disrupted metabolism and disease.

Q.6 What defines a monosaccharide and how is it classified?

Ans.
- Monosaccharides are the simplest carbohydrates that cannot be hydrolyzed into smaller sugars.
- They are classified based on the number of carbon atoms (triose, pentose, hexose) and functional group (aldose or ketose).
- They serve as building blocks for complex carbohydrates and play a key role in energy metabolism.

Q.7 What is the significance of Fischer projection in monosaccharide chemistry?

Ans.
- The Fischer projection is a 2D representation that shows the spatial arrangement of atoms in monosaccharides.
- It highlights the D- or L- configuration based on the orientation of the hydroxyl group on the asymmetric carbon farthest from the carbonyl.
- It is commonly used to identify and compare isomers of sugars.

Q.8 What makes sucrose a non-reducing sugar, unlike maltose and lactose?

Ans.
- Sucrose consists of glucose and fructose linked via an α-1→β-2 glycosidic bond between their anomeric carbons.
- This linkage prevents the free aldehyde or ketone group from reacting, making sucrose non-reducing.
- In contrast, maltose and lactose have a free anomeric carbon, making them reducing sugars.

Q.9 What makes glycogen an efficient energy storage molecule in animals?

Ans.
- Glycogen has a highly branched structure, allowing enzymes to release glucose rapidly during energy demand.
- It is stored in the liver and muscles, where it acts as a short-term energy reserve.
- Its solubility and compactness make it ideal for animal metabolism.

Q.10 What structural similarities and differences exist between chitin and cellulose?

Ans.
- Chitin and cellulose are both made of β-1→4 linked polymers, but chitin contains N-acetylglucosamine instead of glucose.
- This modification gives chitin added rigidity and resistance to microbial degradation.
- It serves as a structural polysaccharide in fungal cell walls and arthropod exoskeletons.

Q.11 How does the structure of amino acids enable them to form proteins?

Ans.
- Each amino acid has a central carbon, an amino group ($-NH_2$), a carboxyl group ($-COOH$), and a side chain (R group).
- The amino and carboxyl groups participate in peptide bond formation, linking amino acids into chains.
- The unique R groups determine the structure and function of the resulting protein.

Q.12 How does the sequence of amino acids affect a protein's function?

Ans.
- The amino acid sequence determines how a protein folds into its functional 3D shape.
- Interactions among R-groups and the environment affect folding.
- A correct sequence ensures proper binding, enzymatic activity, and structural role.
- Errors in sequence often lead to misfolding and diseases like Alzheimer's or cystic fibrosis.

Q.13 How do structural proteins contribute to the body's integrity?

Ans.
- Structural proteins like collagen and keratin form the framework of tissues.
- Collagen provides tensile strength in bones, skin, and cartilage.
- Keratin strengthens hair, nails, and the outer skin layer.
- Their fibrous nature gives shape, support, and resilience to the body.

Q.14 Explain the difference between saturated and unsaturated fatty acids and how this affects fats and oils.

Ans.
- Saturated fatty acids have no double bonds; their chains are straight.
- Unsaturated fatty acids have one or more double bonds, causing kinks.
- Saturated fats are solid at room temperature; unsaturated fats are liquid.
- This difference influences whether a lipid is fat (solid) or oil (liquid).

Q.15 How do steroids differ structurally and functionally from other lipids?

Ans.
- Steroids have four fused carbon rings.
- Function as hormones (e.g., testosterone) and membrane components (cholesterol).
- Regulate metabolism, inflammation, and development.
- Influence membrane fluidity and cell signalling.

Q.16 Describe the amphipathic nature of phospholipids and its importance for cell membrane formation.

Ans.
- Phospholipids have hydrophilic (water-loving) heads and hydrophobic (water-fearing) tails.
- This causes them to form bilayers in aqueous environments.
- Bilayers create semi-permeable membranes.
- Enable compartmentalization and regulate cellular environment.

Q.17 What roles do transfer RNA (tRNA) play in protein synthesis?

Ans.
- tRNA transports specific amino acids to the ribosome during translation.
- It recognizes codons on mRNA via its anticodon region.
- This ensures correct amino acids are added to the growing polypeptide chain.