Unit 04

Biomoelcules

STUDENTS LEARNING OUTCOMES (SLO's)

After studying this unit, 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). Illustr te the formation of phosphodiester bond.
- Explain the double helical structure of DNA as proposed by Watson and Cri k. 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.

INTRODUCTION

In your previous classes, you learned about the levels of biological organization and were briefly introduced to biological molecules. In this chapter, we will explore these molecules in greater detail, focusing on carbohydrates, proteins, lipids, and nucleic acids. We will also examine the importance of water and the role of conjugated molecules in living organisms. This study falls under the domain of **biochemistry.**

BIOCHEMISTRY

It deals with the chemical components and processes that occur in living organisms. Every structure and function within a living organism is based on a biochemical foundation. Understanding biochemistry is essential for grasping how anatomical structures work and how physiological processes such as photosynthesis, respiration, digestion, and muscle contraction operate at the molecular level.

> **Recalling**
> Life of an organism depends upon the ceaseless chemical activities in its cells. All the chemical reactions taking place within a cell are collectively called metabolism. The processes in metabolism may be either anabolism or catabolism. In anabolism, simpler substances are combined to form complex substances and in catabolism complex molecules are broken down into simpler ones.

4.1 BIOLOGICAL MOLECULES

Q 1. What are biological molecules? Discuss their types, composition, and structure in detail.

Ans. Life on Earth evolved in water, and all life still depends on water. At least 80% of the mass of living organisms (protoplasm) is water, and almost all chemical reactions of life take place in aqueous solutions.

The other chemicals that make up living things are mostly organic macromolecules and certain inorganic molecules

> Organic molecules have carbon-based core withspecial groups of atoms attached. These groupsare called **functional groups** for example OH, CO, COOH, NH2 etc. Most biochemical reactionsinvolve the transfer of a functional group fromone molecule to another, or the breaking ofcarbon-carbon bond.

Table 4.1 %age of major organic molecules in the dry mass of cell

Group name	% Dry mass
Protein	50
Nucleic acid	18
Carbohydrates	15
Lipids	10

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. Carbohydrates, proteins, lipids and nucleic acids are important organic molecules in living organisms. They make 93% of the dry mass of living organisms (Table 4.1). The remaining 7% comprises of small organic molecules (like vitamins) and inorganic molecules (like carbon dioxide, acids, bases, and salts).

Most of the organic molecules are large in size and biologists call them macromolecules. Many macromolecules are in the form of polymers. A polymer is a molecule consisting of many identical molecular units, called monomers. Important macromolecules like carbohydrates, proteins, and nucleic acids are the polymers of simple monomers i.e. sugars, amino acids and nucleotides respectively.

mCQs

1. **What percentage of a living organism's mass is water?**
   A) 50% B) 80% ✓
   C) 30% D) 10%

2. **Where do most chemical reactions of life take place?**
   A) In the air B) In solid substances
   C) In aqueous solutions ✓ D) In dry environments

3. **What type of molecules are synthesized by cells and contain carbon?**
   A) Inorganic molecules B) Organic molecules ✓
   C) Radioactive molecules D) Artificial molecules

4. **Organic molecules naturally occur in:**
   A) Only laboratories B) The Earth's crust
   C) Bodies of living organisms or their remains ✓
   D) In the atmosphere only

5. **Which of the following is not an organic molecule?**
A) Proteins B) Lipids
C) Nucleic acids D) Carbon dioxide ✓

6. **What percentage of the dry mass of living organisms is made up of carbohydrates, proteins, lipids, and nucleic acids?**
A) 100% B) 93% ✓
C) 50% D) 7%

7. **Which molecules make up the remaining 7% of dry mass in living organisms?**
A) Water and glucose B) Only salts
C) Small organic and inorganic molecules ✓
D) Only amino acids

8. **What are large organic molecules called?**
A) Atoms B) Elements
C) Macromolecules ✓ D) Ions

9. **What is a polymer?**
A) A molecule made up of salts
B) A molecule made up of many identical monomers ✓
C) A molecule with no carbon
D) A single molecule only

10. **Proteins are polymers of which monomer?**
A) Sugars B) Amino acids ✓
C) Nucleotides D) Fatty acids

SQ

1. **What is the significance of water in the evolution and survival of life on Earth?**
Ans. Life on Earth evolved in water, and all life still depends on water. At least 80% of the mass of living organisms (protoplasm) is water, and almost all chemical reactions of life take place in aqueous solutions.

2. **What types of molecules primarily make up living organisms?**
Ans. The other chemicals that make up living things are mostly organic macromolecules and certain inorganic molecules.

3. **What are organic molecules and how are they formed?**
Ans. 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.

4. **Which organic molecules are most important in living organisms and what is their contribution to dry mass?**
Ans. Carbohydrates, proteins, lipids and nucleic acids are important organic molecules in living organisms. They make 93% of the dry mass of living organisms (Table 4.1).

5. **What makes up the remaining 7% of the dry mass of living organisms?**
Ans. The remaining 7% comprises of small organic molecules (like vitamins) and inorganic molecules (like carbon dioxide, acids, bases, and salts).

6. **What are macromolecules and polymers in biological context?**
Ans. Most of the organic molecules are large in size and biologists call them macromolecules. Many macromolecules are in the form of polymers. A polymer is a molecule consisting of many identical molecular units, called monomers.

7. **What are the monomers of carbohydrates, proteins, and nucleic acids?**
Ans. Important macromolecules like carbohydrates, proteins, and nucleic acids are the polymers of simple monomers i.e., sugars, amino acids and nucleotides respectively.

8. **What is the importance of carbon in biological molecules?**
Ans. Carbon is the basic element of organic molecules. It is tetravalent and can react with many other known elements like H, O, N, P and S. Carbon and hydrogen bond (C-H bond) is the potential source of chemical energy for cellular activities. Carbon-oxygen association in glycosidic linkages provides stability to the complex carbohydrate molecules. 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.

4.2 TYPES OF BONDS IN BIOLOGY

Q 2. Describe the different types of bonds and interactions important in biological molecules.

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

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Covalent bonds form when two atoms share electrons (Figure 4.1). These bonds are often found in organic molecules like proteins and nucleic acids, providing stability to the molecules.

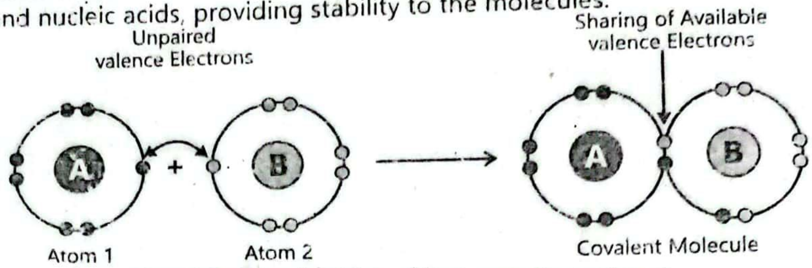


Fig. 4.1: Covalent bond between two atoms

Ionic bonds are 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) (Figure 4.2). 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.

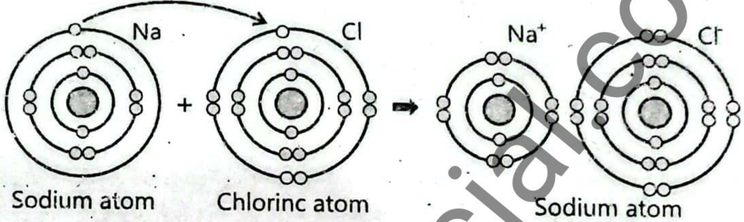


Fig. 4.2: Ionic bond between sodium and chlorine atoms

Hydrogen bonds are weak attractions that occur between a hydrogen atom and an electronegative atom (such as oxygen or nitrogen). 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.

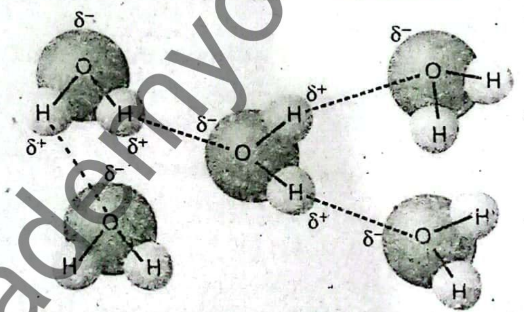


Fig. 4.3: Hydrogen bond between water molecules

Hydrophobic interactions occur between nonpolar molecules which tend to cluster together in aqueous environments to minimize contact with water molecules. This phenomenon is crucial for the folding of proteins and the formation of lipid bilayers in cell membranes.

Hydrophilic interactions occur between polar molecules and water molecules. 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.

mQ's

1. **Which element is considered the basic element of organic molecules?**
   A) Oxygen B) Carbon✓
   C) Nitrogen D) Phosphorus
2. **What is the valency of carbon?**
   A) 2 B) 3
   C) 4✓ D) 6
3. **What type of bond forms between carbon and hydrogen?**
   A) Ionic bond B) Peptide bond
   C) C-H bond (source of chemical energy)✓
   D) Hydrogen bond
4. **What type of linkage stabilizes complex carbohydrate molecules?**
   A) Peptide linkage B) Glycosidic linkage✓
   C) Hydrogen bond D) Disulfide bond
5. **Peptide bonds are formed between which two atoms?**
   A) Carbon and oxygen B) Hydrogen and sulfur
   C) Carbon and nitrogen✓ D) Nitrogen and phosphorus
6. **Covalent bonds are formed when:**

A) One atom loses electrons
B) One atom gains protons
C) Two atoms share electrons ✓
D) Molecules repel each other

7. **Ionic bonds form due to:**
A) Sharing of neutrons
B) Transfer of electrons between atoms ✓
C) Exchange of protons
D) No interaction

8. **What is the strength of ionic bonds in solid state?**
A) Weak B) Unstable
C) Relatively strong ✓ D) Always broken

9. **What type of bond is responsible for holding the two strands of DNA together?**
A) Covalent bond B) Hydrogen bond ✓
C) Ionic bond D) Peptide bond

10. **What kind of interaction occurs between nonpolar molecules in water?**
A) Ionic interaction
B) Hydrophobic interaction ✓
C) Covalent interaction D) Hydrogen bonding

SQ

1. **What is the role of covalent bonds in biological molecules?**
Ans. Covalent bonds form when two atoms share electrons. These bonds are often found in organic molecules like proteins and nucleic acids, providing stability to the molecules.

2. **What is the function of ionic bonds in biological molecules?**
Ans. Ionic bonds are 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). 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.

3. **What role hydrogen bonds play in biological molecules?**
Ans. Hydrogen bonds are weak attractions that occur between a hydrogen atom and an electronegative atom (such as oxygen or nitrogen). 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.

4. **Differentiate between hydrophobic and hydrophilic interactions and their biological roles.**

Aspect	Hydrophobic Interactions	Hydrophilic Interactions
Molecules Involved	Nonpolar molecules	Polar molecules
Behavior in Water	Tend to cluster together to minimize contact with water	Readily interact with and dissolve in water
Biological Role	Crucial for protein folding and formation of iipid bilayers in cell membranes	Essential for the dissolution of polar and ionic compounds in water
Function in Cellular Processes	Help maintain structure and compartmentalization in cells	Facilitate nutrient transport and chemical reactions within cells

4.3 CONDENSATION (SYNTHESIS) AND HYDROLYSIS

Q 3. **Explain condensation (synthesis) and hydrolysis in biological molecules.**

Ans. Condensation (Synthesis) Reaction

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. 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

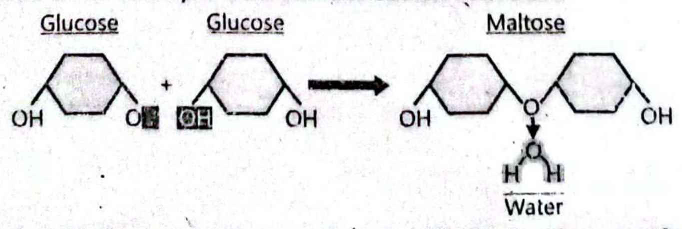


Fig. 4.4: Making of macromolecules (Dehydration synthesis)

Hydrolysis Reaction

Along with making polymers by combining their monomers, cells keep on breaking polymers too. Hydrolysis is a chemical process in which macromolecule (polymer) is broken down into smaller fragments by the addition of water molecules. 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. Breakdown of maltose into two glucose monomers by the addition of a water molecule is an example of hydrolysis.

> This breakdown of macromolecules is essential in various biological processes, such as digestion and cellular respiration, where smaller

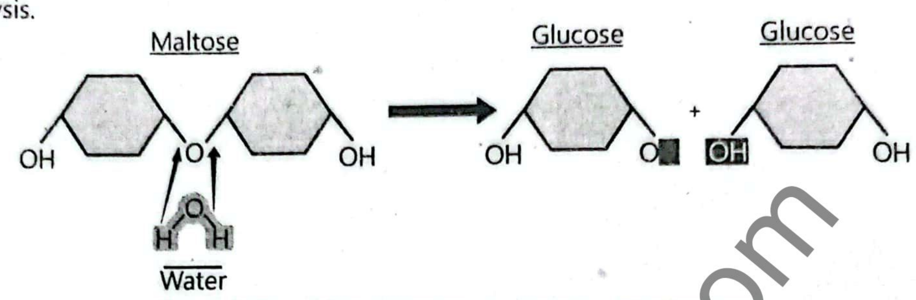


Fig. 4.5: Breaking of macromolecules (Hydrolysis)

MCQs

1. What type of reaction is used to join monomers in biological macromolecules?
A. Hydrolysis
B. Oxidation
C. Condensation (Dehydration synthesis) ✓
D. Respiration

2. What is removed from the monomers during a condensation reaction?
A. Two hydrogen atoms
B. An -OH group from one monomer and an -H atom from another ✓
C. A glucose molecule
D. An oxygen atom and a nitrogen atom

3. What is another name for condensation reaction?
A. Hydrogenation
B. Hydrolysis
C. Photosynthesis
D. Dehydration synthesis ✓

4. Which of the following is an example of a condensation reaction?
A. Formation of maltose from two glucose monomers ✓
B. Digestion of proteins into amino acids
C. Breakdown of fats into fatty acids
D. Addition of water to break polymers

5. What is hydrolysis?
A. Joining monomers by removing water
B. Breaking polymers by adding water ✓
C. A process of respiration
D. Synthesis of glucose

6. What happens to the water molecule during hydrolysis?
A. It evaporates
B. Its -OH joins one monomer and H joins the other ✓
C. It freezes
D. It becomes oxygen and hydrogen gas

SQ

1. What are the biological molecules that are assembled from monomers?

Ans. Proteins, nucleic acids, carbohydrates, and lipids are assembled from different kinds of monomers. All these biomolecules join their monomers by condensation or dehydration process.

2. What happens during condensation or dehydration synthesis?

Ans. 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.

3. Give an example of a condensation reaction.

Ans. The formation of maltose by two glucose monomers is an example of a condensation reaction.

4. What is hydrolysis and how does it work in cells?

Ans. Hydrolysis is a chemical process in which macromolecule (polymer) is broken down into smaller fragments by the addition of water molecules. It is the reverse of dehydration synthesis. Cells break bonds between monomers by adding water to them.

5. **How does a water molecule participate in the hydrolysis reaction?**

Ans. In hydrolysis, OH group from a water molecule joins to one monomer and hydrogen joins to the second monomer. Breakdown of maltose into two glucose monomers by the addition of a water molecule is an example of hydrolysis.

4.4 IMPORTANCE OF WATER

Q 4. Discuss the importance of water in biological systems.

Ans. Introduction

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. For 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 a suitable environment, necessary for the working of life. Water has many important properties which make it essential for life.

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 ability of water molecules to form hydrogen bonds.

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. Partial negative charge at one end of a water molecule is attracted to partial positive of another water molecule. This weak attraction is 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

> 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")

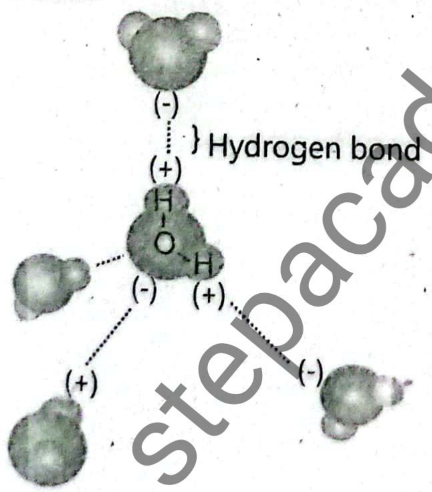


Fig. 4.6: Hydrogen bonds among water molecules

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). For 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.

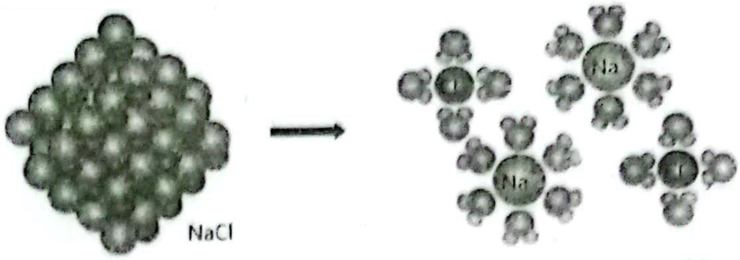


Fig. 4.7: Water as a solvent of inorganic molecules (NaCl)

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. 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.

> Polar molecules such as salts, sugars, and amino acids dissolve readily in water and are called hydrophilic (water-loving). Uncharged or nonpolar molecules such as lipids do not dissolve in water and are called hydrophobic (water-hating).

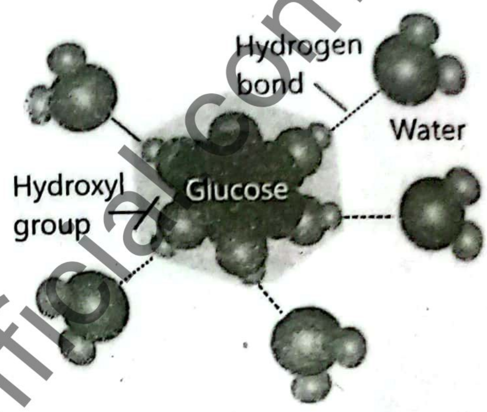


Fig. 4.8: Water as a solvent of organic molecules (glucose)

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. For 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.

Fig. 4.9: Hydrophobic association of oil (lipid) with water molecules

Heat Capacity

Specific heat capacity is defined as the number of calories (amount of heat) required to raise the temperature of 1 gram of a substance from 15°C to 16°C (i.e., 1°C). 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

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

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.

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.

Heat of Vaporization

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

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

Due to this property, Earth's temperature is kept moderate. 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.

Cohesion

Hydrogen bonds among water molecules enable them to "stick together". This type of attraction between same type of molecules is called cohesion. Inside water, molecules have high cohesion. The 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. 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.

Fig. 4.10: A wat\a(,)er strider walking on the surface of water

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.

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.

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

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.

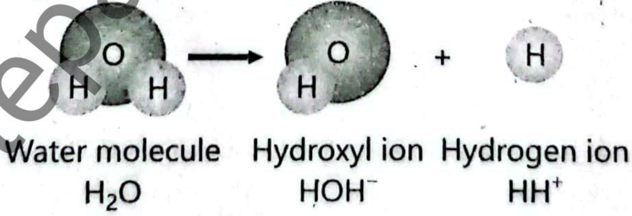


Fig. 4.11: Ionization of water

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. 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. 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 4.2: 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 breaking	Determine the acidity and alkalinity of medium
Cohesion	Polarity, Hydrogen bonding	Water and nutrients are transported from roots to leaves

MCQs ✓

1. **What is the chemical formula of water?**
   A) H_2O_2 B) HO
   C) H_2O ✓ D) OH_2

2. **What percentage of the human body is made up of water?**
   A) About one-third B) About two-thirds ✓
   C) About 90% D) About 50%

3. **What is the water content in bone cells?**
   A) 10% B) 20% ✓
   C) 50% D) 80%

4. **Brain cells contain approximately how much water?**
   A) 65% B) 75%
   C) 95% D) 85% ✓

5. **Which property of water makes it a good solvent?**
   A) Polarity and hydrogen bonding ✓
   B) Non-polarity
   C) Low boiling point D) High density

6. **What are molecules with partial charges called?**
   A) Non-polar molecules B) Polar molecules ✓
   C) Neutral molecules D) Covalent molecules

7. **What is a hydrogen bond?**
   A) A covalent bond between hydrogen atoms
   B) A weak attraction between polar molecules ✓
   C) A bond between two hydrogen atoms
   D) A bond in metals

8. **What happens when salt (NaCl) is placed in water?**
   A) It forms a gas B) It sinks
   C) It dissociates into Na^+ and Cl^- ions ✓
   D) It burns

9. **Which functional groups in glucose form hydrogen bonds with water?**
   A) Carboxyl B) Hydroxyl ✓
   C) Amino D) Carbonyl

10. **What role does water play in metabolism?**
    A) Prevents reactions
    B) Acts as a medium for chemical reactions ✓
    C) Breaks bonds permanently
    D) Blocks enzyme function

11. **What are molecules that do not dissolve in water called?**
    A) Hydrophobic ✓ B) Hydrophilic
    C) Polar D) Aqueous

12. **Which type of molecules are moved out by water molecules due to lack of bonding?**
    A) Ionic B) Non-polar ✓
    C) Polar D) Charged

13. **What structure is maintained by lipid associations in water?**
    A) Ribosomes B) Chloroplasts
    C) Cell membranes ✓ D) Cell wall

14. **What is specific heat capacity?**
    A) Energy required to boil a liquid
    B) Energy to raise temperature of 1g by 1°C ✓
    C) Heat lost during freezing
    D) Heat of reaction

15. **What is the specific heat capacity of water?**
    A) 2.1 Joules B) 3.5 Joules
    C) 4.184 Joules ✓ D) 5.5 Joules

16. **Why does water resist temperature change?**
    A) Because of its density
    B) Due to hydrogen bond breakage absorbing energy ✓
    C) Because of its color
    D) Due to low boiling point

17. **What is heat of vaporization?**
    A) Temperature at which water freezes
    B) Temperature water boils
    C) Heat required to convert liquid to gas ✓
    D) Heat required to melt ice

18. **What is water's heat of vaporization?**
    A) 400 Kcal/kg B) 450 Kcal/kg
    C) 574 Kcal/kg ✓ D) 600 Kcal/kg

19. **How does water help in cooling during perspir**
    A) It contracts the body B) It blocks pores
    C) Each gram removes 574 calories as it evaporate
    D) It adds salt to the skin

20. **What is cohesion in water?**
    A) Attraction between similar molecules ✓

B) Repulsion between molecules
C) Movement against gravity
D) Adhesion with solids

21. **What helps water move upward in plants?**
A) Gravity
B) Cohesion among water molecules ✓
C) Sunlight
D) Oxygen

22. **What is surface tension in water due to?**
A) Temperature
B) Hydrogen bonds ✓
C) Air pressure
D) Ionic strength

23. **How is water ionized?**
A) By sunlight
B) Through boiling
C) By breaking covalent bonds into H^+ and OH^- ✓
D) Through electrolysis

24. **What is the concentration of H^+ ions in pure water at 25°C?**
A) 10^{-5} M
B) 10^{-6} M
C) 10^{-7} M ✓
D) 10^{-8} M

25. **Why is ice less dense than water?**
A) It contains air
B) Hydrogen bonds keep molecules further apart ✓
C) It evaporates easily
D) It is heavier

SQ

1. **What is the chemical formula of water?**

Ans. Water is an oxide of hydrogen and its chemical formula is H_2O. This simple molecule has extraordinary properties that make it essential for life.

2. **What proportion of the human body is made up of water?**

Ans. About two-thirds of the human body is composed of water. It plays a critical role in maintaining bodily functions and structure.

3. **How does water content vary in different tissues of multicellular organisms?**

Ans. Water concentration varies from tissue to tissue in multicellular organisms. For example, bone cells contain about 20% water, while brain cells contain about 85%.

4. **Why is water known as the "medium of life"?**

Ans. Water is called the "medium of life" because it is essential for making and maintaining protoplasm and supports all cellular processes. It is also the most abundant compound in organisms.

5. **What properties of water make it a good solvent?**

Ans. The polarity of water molecules and their ability to form hydrogen bonds make water an excellent solvent. These properties allow it to dissolve a wide range of substances.

6. **What is a hydrogen bond in water molecules?**

Ans. A hydrogen bond is a weak attraction between the partially positive hydrogen of one water molecule and the partially negative oxygen of another. These bonds help form a network among water molecules.

7. **How do water molecules interact with ions like sodium and chloride?**

Ans. Water molecules surround the positive and negative ions due to their polarity. For example, Na^+ ions are attracted to the negative ends of water molecules, while Cl^- ions are attracted to the positive ends.

8. **Why do glucose molecules dissolve in water?**

Ans. Water forms hydrogen bonds with the polar hydroxyl groups of glucose molecules. This allows glucose to dissolve easily in water, making it available for metabolic processes.

9. **What role does water play in metabolism?**

Ans. Water acts as a medium in which ions and molecules can dissolve and react easily. This makes it crucial for chemical reactions, including those involved in metabolism.

10. **Why are non-polar molecules like lipids insoluble in water?**

Ans. Non-polar molecules do not form hydrogen bonds with water. As a result, water molecules push them out, a process called hydrophobic exclusion.

11. **What happens when non-polar molecules are placed in water?**

Ans. Water molecules exclude non-polar molecules and force them to associate with each other. This helps in the formation of structures like cell membranes.

12. **How do lipids contribute to the structure of cells?**

Ans. Lipids are hydrophobic and form strong associations among themselves in water. These associations help maintain the integrity of cell membranes.

13. **What is the specific heat capacity of water and why is it significant?**

Ans. Water has a high specific heat capacity of 4.184 Joules per gram per °C. This means it can absorb a lot of heat without a significant rise in temperature, helping to stabilize temperatures in living organisms.

14. How does water's heat capacity affect temperature regulation in organisms?

Ans. Water heats up slowly and cools down slowly due to its high specific heat. This helps maintain a stable internal and external environment for organisms.

15. What is meant by the heat of vaporization of water?

Ans. The heat of vaporization is the amount of heat needed to convert liquid water into gas. For water, this value is high—574 Kcal/kg—making it effective for cooling through evaporation.

16. How does water help regulate Earth's temperature and cool living organisms?

Ans. Water absorbs a large amount of heat during evaporation, which helps regulate Earth's temperature. It also provides a cooling effect during transpiration in plants and sweating in animals.

17. What is cohesion in water, and why is it important?

Ans. Cohesion is the attraction between similar molecules, and in water, it occurs due to hydrogen bonding. This property is important for processes like the upward transport of water in plants.

18. How does water move upward in plants against gravity?

Ans. Water moves upward due to cohesion among water molecules. Evaporation from leaves creates a pulling force that is relayed down through xylem vessels.

19. What is the role of hydrogen bonds in water's surface tension?

Ans. Hydrogen bonds give water a high surface tension, making it behave as if covered with a film. This allows small organisms like water striders to walk on water.

20. Why is ice less dense than liquid water, and how does it help aquatic life?

Ans. Ice is less dense because hydrogen bonds keep water molecules farther apart in the solid state. It floats on the surface and insulates the water below, protecting aquatic organisms from freezing.

4.5 CARBOHYDRATES

Carbohydrates

Carbohydrates are naturally occurring organic compounds essential to all living organisms. The term "carbohydrate" is derived from the words "hydrated carbon," indicating that these molecules are composed of carbon and water. Chemically, carbohydrates are synthesized as the primary products of photosynthesis. During this process, carbon dioxide (CO_2) is reduced using energy from sunlight, and the resulting carbohydrate molecule contains the elements carbon, hydrogen, and oxygen.

The elements in carbohydrates occur in the molar ratio of 1:2:1 for carbon, hydrogen, and oxygen respectively. Hence, the empirical formula for a carbohydrate is represented as $\mathbf{C(H_2O)_n}$, where 'n' indicates the number of carbon atoms in the molecule.

Classification of Carbohydrates

Carbohydrates are also known as **"Saccharides"**, derived from the Latin word *"Saccharum"*, meaning sugar. Based on their structure and complexity, carbohydrates are classified into three main categories:

1. **Monosaccharides**
2. **Disaccharides**
3. **Polysaccharides**

Q 5. Describe the structure and chemical composition of monosaccharides along with examples.

OR Distinguish the properties and roles of monosaccharides and classify them.

Ans. Monosaccharides (Simple Sugars)

Monosaccharides are the most basic units of carbohydrates, consisting of a single sugar molecule. These are soluble in water and generally contain between 3 to 7 carbon atoms. Depending on the number of carbon atoms monosaccharides are further subdivided. Among these, **pentoses (5-carbon sugars)** and **hexoses (6-carbon sugars)** are the most common and are found in all living organisms.

Hexoses play a central role in biological energy storage. One of the most important hexoses is **glucos** which serves as the primary energy-storage molecule. It contains **seven energy-storing carbon-hydrogen (CH) b** and has the molecular formula $\mathbf{C_6H_{12}O_6}$.

Table 4.3: Classification of monosaccharides

Monosaccharides	Carbon atoms	Formula	Examples
Trioses	3	$C_3H_6O_3$	Glyceraldehyde, Dihydroxyacetone
Tetroses	4	$C_4H_8O_4$	Erythrose, Erythralose (intermediate in photosynthesis in bacteria)
Pentoses	5	$C_5H_{10}O_5$	Ribose, Deoxyribose ($C_5H_{10}O_4$)
Hexoses	6	$C_6H_{12}O_6$	Glucose, Fructose, Galactose
Heptoses	7	$C_7H_{14}O_7$	Rare in nature (intermediate in photosynthesis)

Isomers of Monosaccharides

Compare the structural isomers and stereoisomers of glucose. (from Exercise)

Monosaccharides can exist in different structural forms known as **isomers**. Isomers are molecules that have the same molecular formula but differ in the arrangement of atoms within the molecule.

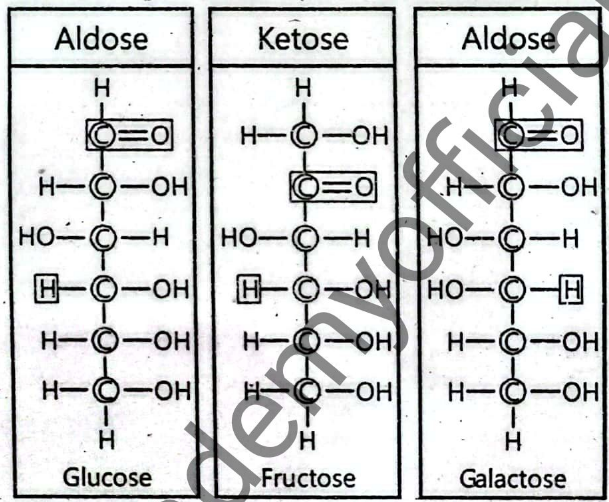


Fig. 4.12: Structural and stereoisomers of glucose

For example, **glucose**, **fructose**, and **galactose** all have the same molecular formula (**$C_6H_{12}O_6$**), but their structural formulas vary.

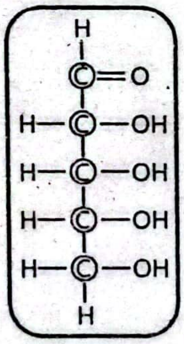


Fig. 4.13: Structure of Ribose

These differences have important biological consequences, especially in the synthesis of polymers.

- **Structural Isomers:** Glucose and fructose are structural isomers. In fructose, the double-bonded oxygen atom is attached to an internal carbon atom (carbon 2), while in glucose it is attached to a terminal carbon atom.
- **Stereoisomers:** Glucose and galactose are stereoisomers. The difference lies in the orientation of a single hydroxyl (OH) group on carbon number 4. This slight variation affects how these sugars interact in the formation of macromolecules.

Important Pentose Sugars

Among five-carbon sugars, the most important ones are:

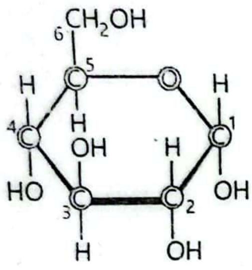
- **Ribose and Deoxyribose** – Found in nucleic acids (RNA and DNA) and ATP.
- **Ribulose** – Functions as a precursor in the process of photosynthesis.

Ring Structures of Monosaccharides

In aqueous solutions, most monosaccharides adopt **ring structures**. This ring formation occurs when an oxygen bridge forms between two carbon atoms within the same sugar molecule.

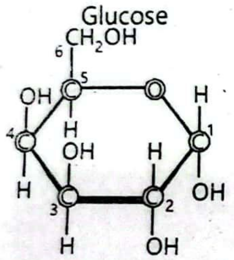
There are two standard ways to represent sugar structures:

- **Fischer Projection**: Developed by German chemist **Emil Fischer** in 1891, this method displays the carbohydrate in an **open-chain form**.
- **Haworth Projection**: Named after British chemist **Sir Norman Haworth**, this format shows the sugar molecule in its **cyclic (ring) form**, which is more representative of its actual structure in biological systems.



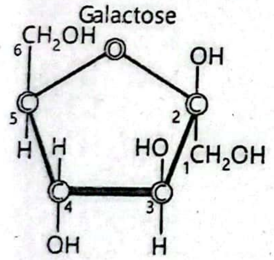
Glucose

In case of glucose, oxygen-bridge develops between carbon number 1 and 5. So, a six cornered ring is formed.



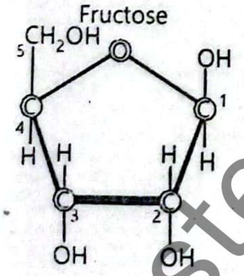
Galactose

In galactose too, oxygen-bridge is formed between carbon number 1 and 5. It again gives a sixcornered ring



Fructose

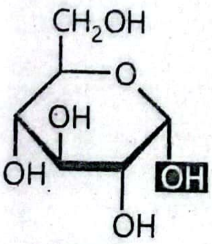
In fructose, oxygen-bridge is formed between carbon number 2 and 5. So, a five cornered ring is formed.



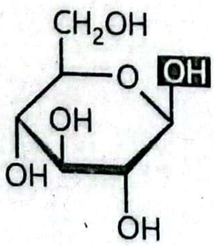
Ribose

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

Fig. 4.14: Ring structures of glucose, galactose, fructose, and ribose

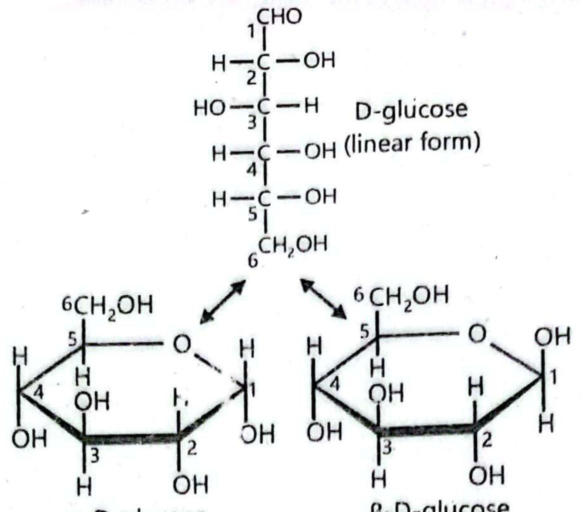


α-D-glucose



β-D-glucose

There are two forms of D-glucose i.e., alpha-D-glucose and 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



Q 6. Describe the structure and chemical composition of disaccharides along with examples.

OR Distinguish the properties and roles of disaccharides.

Ans. Disaccharides

Disaccharides are formed when **two monosaccharide units** are linked together through a process known as **dehydration synthesis**, in which a water molecule is removed. The resulting covalent bond between the two sugar units is called a **glycosidic bond.**

Disaccharides can be broken down into their monosaccharide components by **hydrolysis**, a reaction that involves the addition of water. Compared to monosaccharides, disaccharides are **less soluble in water.**

Some physiologically important disaccharides include:

Maltose (Malt Sugar)

Maltose consists of **two glucose molecules.** These glucose units are connected by a **1,4-glycosidic bond**, meaning the bond forms between carbon 1 of one glucose and carbon 4 of the other. Maltose is commonly found in cereals such as wheat and corn and is also an intermediate product during the digestion of starch.

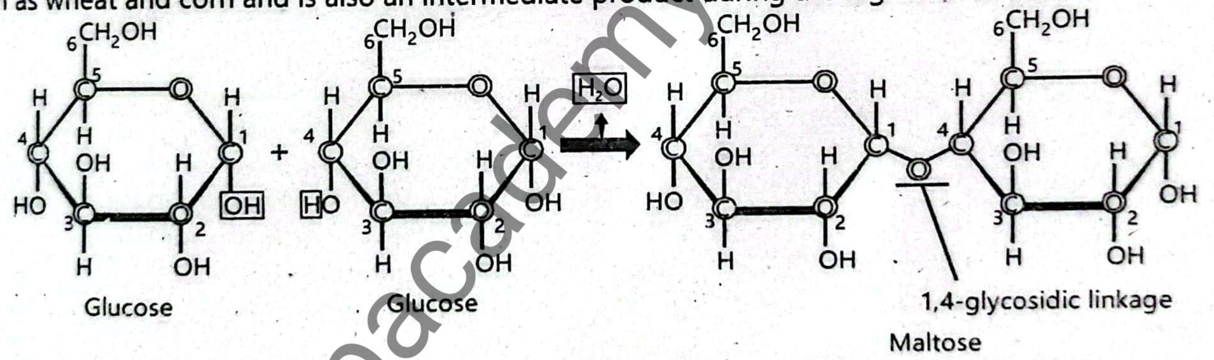


Fig. 4.15: Dehydration synthesis of one maltose by the condensation of two glucose

Lactose (Milk Sugar)

Lactose is made up of one glucose and one galactose unit, joined through a **1-4 glycosidic bond**. It is primarily found in **mammalian milk** and serves as a major **source of energy for infant mammals.**

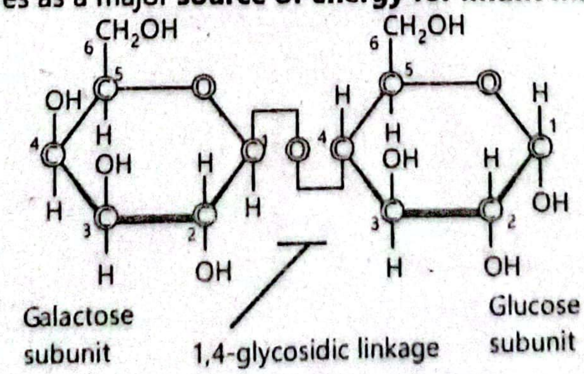


Fig. 4.16: Structure of lactose

Sucrose (Cane Sugar or Table Sugar)

Sucrose is a disaccharide formed by one glucose and one fructose unit, joined through a **1-2 glycosidic bond**. It is the most familiar disaccharide and is widely used as a **sweetener in food**. Its molecular formula is $C_{12}H_{22}O_{11}$.

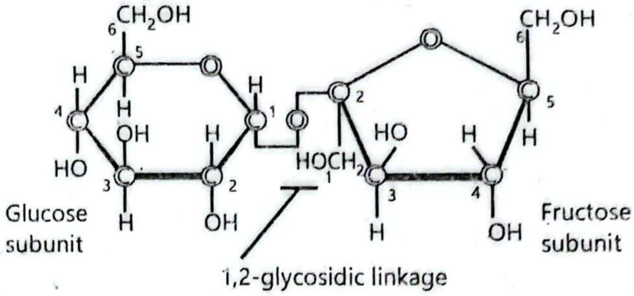


Fig. 4.17: Structure of sucrose

In plants, sucrose is transported through **phloem vessels**, acting as a **transport disaccharide**. It facilitates the conduction of glucose between various parts of the plant.

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

mcqs ✓

1. **What does the term "carbohydrate" literally mean?**
   A) Complex sugar　B) Hydrated carbon ✓
   C) Organic compound　D) Energy source
2. **Which process primarily synthesizes carbohydrates in nature?**
   A) Respiration　B) Digestion
   C) Photosynthesis ✓　D) Fermentation
3. **What is the general empirical formula of carbohydrates?**
   A) CHO　B) CnH2nOn
   C) C(H2O)n ✓　D) CnHnOn
4. **Carbohydrates are also known as:**
   A) Polymers　B) Lipids
   C) Saccharides ✓　D) Proteins
5. **Which of the following is a monosaccharide?**
   A) Maltose　B) Lactose
   C) Glucose ✓　D) Sucrose
6. **How many carbon atoms are typically found in monosaccharides?**
   A) 1–2　B) 3–7 ✓
   C) 8–10　D) 10–12
7. **Which type of sugar is most common in energy storage?**
   A) Ribose　B) Fructose
   C) Galactose　D) Glucose ✓
8. **Which of the following are isomers?**
   A) Glucose and maltose　B) Glucose and fructose ✓
   C) Fructose and sucrose　D) Ribose and deoxyribose
9. **Fructose is different from glucose because:**
   A) It contains no carbon
   B) It has a terminal oxygen
   C) Its oxygen is bonded to an internal carbon ✓
   D) It has no hydroxyl groups
10. **Glucose and galactose differ in:**
    A) Number of carbon atoms
    B) Presence of hydrogen
    C) Orientation of hydroxyl group ✓
    D) Number of oxygen atoms
11. **Ribose and deoxyribose are examples of:**
    A) Disaccharides　B) Pentoses ✓
    C) Hexoses　D) Polysaccharides
12. **What structure do monosaccharides usually form in solution?**
    A) Chain　B) Ring ✓
    C) Spiral　D) Double helix
13. **Which projection shows sugar in a ring form?**
    A) Fischer projection　B) Haworth projection ✓
    C) Lewis structure　D) Kekulé structure
14. **Disaccharides are formed through what type of reaction?**
    A) Hydrolysis　B) Oxidation
    C) Dehydration synthesis ✓
    D) Neutralization
15. **The bond formed between two monosaccharides is called:**
    A) Hydrogen bond　B) Ionic bond
    C) Peptide bond　D) Glycosidic bond ✓

16. **What is the composition of maltose?**
A) Glucose + Galactose
B) Glucose + Glucose✓
C) Glucose + Fructose
D) Fructose + Galactose

17. **Lactose is commonly found in:**
A) Sugarcane
B) Fruits
C) Milk✓
D) Cereals

18. **Sucrose is a combination of which two sugars?**
A) Glucose and maltose
B) Glucose and galactose
C) Glucose and fructose✓
D) Galactose and ribose

19. **The molecular formula of sucrose is:**
A) C12H24O12
B) C10H20O10
C) C11H22O11✓
D) C6H12O6

20. **In plants, sucrose acts as:**
A) Storage sugar
B) Structural sugar
C) Transport disaccharide✓
D) Reducing sugar

21. **Which monosaccharides contain three carbon atoms?**
A) Tetroses
B) Hexoses
C) Trioses✓
D) Heptoses

22. **What is the molecular formula of pentoses?**
A) $C_6H_{12}O_6$
B) $C_3H_6O_3$
C) $C_5H_{10}O_5$✓
D) $C_7H_{14}O_7$

23. **Which monosaccharides are components of nucleic acids?**
A) Trioses
B) Pentoses✓
C) Hexoses
D) Heptoses

24. **Which class of monosaccharides is rare in nature but acts as an intermediate in photosynthesis?**
A) Tetroses
B) Heptoses✓
C) Hexoses
D) Trioses

25. **Which of the following is a hexose sugar?**
A) Ribose
B) Erythrose
C) Fructose✓
D) Glyceraldehyde

SQ

1. **What are carbohydrates and what does the term mean?**

Ans. Carbohydrates are naturally occurring organic compounds essential to living organisms. The term "carbohydrate" literally means "hydrated carbon," as they contain carbon and water elements in a specific ratio.

2. **How are carbohydrates synthesized in nature?**

Ans. Carbohydrates are synthesized through the process of photosynthesis. During this process, carbon dioxide (CO_2) is reduced, resulting in a compound composed of carbon, hydrogen, and oxygen.

3. **What is the general formula of carbohydrates?**

Ans. The empirical formula of carbohydrates is $\mathbf{C(H_2O)_n}$, where 'n' represents the number of carbon atoms. This indicates that for every carbon atom, there are two hydrogen and one oxygen atoms

4. **Why are carbohydrates called saccharides?**

Ans. The term "saccharide" is derived from the Latin word *saccharum*, which means sugar. Carbohydrates are called saccharides because many of them taste sweet and are structurally related to sugars.

5. **What are the three main types of carbohydrates?**

Ans. Carbohydrates are classified into monosaccharides, disaccharides, and polysaccharides. This classification is based on the number of sugar units they contain.

6. **What are monosaccharides?**

Ans. Monosaccharides are simple sugars made up of a single sugar molecule. They are soluble in water and may contain 3 to 7 carbon atoms.

7. **Which monosaccharides are most commonly found in living organisms?**

Ans. Pentoses (5-carbon sugars) and hexoses (6-carbon sugars) are the most common monosaccharides in living organisms. They play crucial roles in biological functions like energy storage and nucleic acid structure.

8. **What is the primary energy-storage monosaccharide?**

Glucose is the primary energy-storage monosaccharide. It contains seven energy-storing CH bonds and has the molecular formula $C_6H_{12}O_6$.

9. **What are isomers in the context of monosaccharides?**

Isomers are molecules that have the same molecular formula but different structural arrangements. For example, glucose, fructose, and galactose all have the formula $C_6H_{12}O_6$ but differ in structure.

10. **How is fructose different from glucose structurally?**

Ans. In fructose, the double-bonded oxygen is attached to the second carbon atom, which is an internal carbon. In contrast, glucose has this oxygen bonded to a terminal carbon atom.

11. **What kind of isomers are glucose and fructose?**

Ans. Glucose and fructose are **structural isomers** because they have the same molecular formula but different connectivity of atoms.

12. **How do glucose and galactose differ?**

Ans. Glucose and galactose differ in the orientation of a hydroxyl (OH) group on carbon number 4. This makes them **stereoisomers**.

13. **Name some important pentose sugars and their functions.**

Ans. Important pentose sugars include ribose and deoxyribose, which are found in nucleic acids and ATP. Another is ribulose, which acts as a precursor in photosynthesis.

14. **What happens to monosaccharides in aqueous solution?**

Ans. In aqueous solutions, most monosaccharides form ring structures. This occurs due to the formation of an oxygen bridge between two carbon atoms in the same molecule.

15. **What are Fischer and Haworth projections?**

Ans. Fischer projection is a way to represent sugar molecules in their open-chain form, developed by Emil Fischer. Haworth projection, introduced by Norman Haworth, shows sugars in their cyclic ring form.

16. **What are disaccharides and how are they formed?**

Ans. Disaccharides are carbohydrates made from two monosaccharide units. They are formed by a dehydration synthesis reaction, creating a covalent glycosidic bond.

17. **What happens to disaccharides during hydrolysis?**

Ans. During hydrolysis, disaccharides break down into their monosaccharide components. This reaction requires the addition of water.

18. **What is maltose and where is it found?**

Ans. Maltose is a disaccharide made up of two glucose units connected by a 1,4-glycosidic bond. It is found in cereals like wheat and corn and also forms during starch digestion.

19. **What is lactose and what is its biological importance?**

Ans. Lactose is made up of glucose and galactose linked by a 1-4 glycosidic bond. It is found in mammalian milk and is an important energy source for infant mammals.

20. **What is sucrose and what role does it play in plants?**

Ans. Sucrose is made of one glucose and one fructose unit and is known as table sugar. In plants, it is transported through phloem and acts as a transport disaccharide for distributing energy.

21. **What are trioses? Give examples.**

Ans. Trioses are monosaccharides that contain three carbon atoms and have the chemical formula $C_3H_6O_3$. Examples include glyceraldehyde and dihydroxyacetone.

22. **What is the significance of pentoses in biological systems?**

Ans. Pentoses are five-carbon sugars with the formula $C_5H_{10}O_5$. Important examples include ribose and deoxyribose, which are key components of nucleic acids (RNA and DNA).

23. **Name any two hexoses and mention their molecular formula.**

Ans. Two common hexoses are glucose and fructose. They both have the molecular formula $C_6H_{12}O_6$ and are vital for energy production in living organisms.

24. **What are tetroses? Give examples.**

Ans. Tetroses are monosaccharides that contain four carbon atoms with the molecular formula $C_4H_8O_4$. Examples include erythrose and erythralose, which serve as intermediates in photosynthesis in certain bacteria.

25. **Why are heptoses considered rare, and where are they found?**

Ans. Heptoses are seven-carbon sugars with the molecular formula $C_7H_{14}O_7$. They are rare in nature but are known to function as intermediates during the process of photosynthesis.

POLYSACCHARIDES

Q 7. What are polysaccharides? Explain their types with examples and structural features.

Ans. Introduction

Polysaccharides are the most complex and most abundant carbohydrates found in nature. These macromolecules are composed of long chains of many monosaccharides joined together by glycosidic bonds. Polysaccharides serve various structural and storage functions in both plants and animals. Based on their roles and chemical structures, several important types of polysaccharides are identified.

Starch – Plant Storage Polysaccharide

Starch is the primary storage polysaccharide found in plants. It is insoluble in water and forms starch granules within many plant cells. Due to its insolubility, starch does not alter the water potential of plant cells, thus preventing them from taking in water through osmosis.

Starch is not a pure compound but a mixture of two different types of glucose polymers: **amylose** and **amylopectin**.

- **Amylose** consists of unbranched chains of glucose monomers linked by 1,4-glycosidic bonds. Though the chains are straight, they tend to coil into a helical shape.
- **Amylopectin** also contains glucose monomers linked by 1,4-glycosidic bonds, but it has additional branches connected by 1,6-glycosidic linkages. Due to these branches, amylopectin has more terminal ends, which can be broken down faster by amylase enzymes.

Both amylose and amylopectin are hydrolyzed by the enzyme **amylase** into **maltose**, although they break down at different rates due to their structural differences.

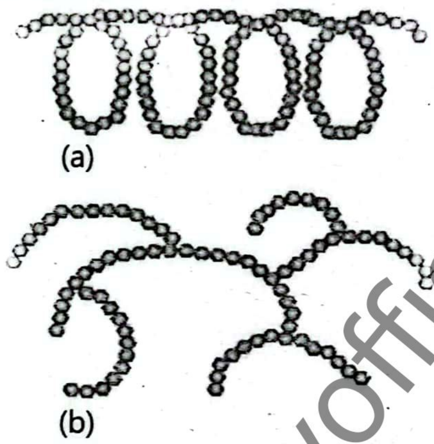


Fig. 4.18: (a) amylose, (b) amylopectin

Glycogen – Animal Storage Polysaccharide

Glycogen is the storage polysaccharide in animals and is structurally similar to amylopectin. It consists of glucose monomers linked by 1,4-glycosidic bonds and also features branches connected by 1,6-glycosidic bonds.

Glycogen is highly branched and is stored mainly in **muscles and liver** tissues. The extensive branching allows glycogen to be rapidly broken down into glucose molecules when energy is needed, making it a readily accessible energy source for animal cells.

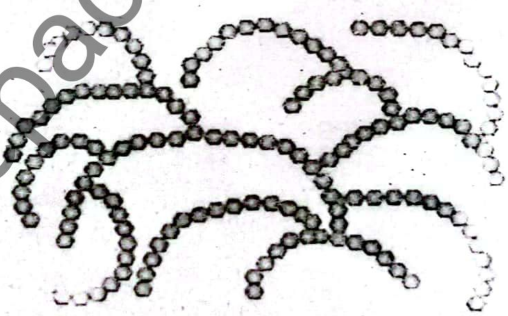


Fig. 4.19: Glycogen

Cellulose – Structural Polysaccharide in Plants

Cellulose is found exclusively in plants, where it forms the primary structural component of plant cell walls. It consists of glucose monomers connected by 1,4-glycosidic bonds, but unlike starch and glycogen, it is made up of **beta-glucose** units.

In beta-glucose, the hydroxyl (OH) group on carbon 1 points upward, unlike in alpha-glucose (used in starch and glycogen), where it points downward. This difference in isomer structure leads to an alternating inversion of glucose units in cellulose chains.

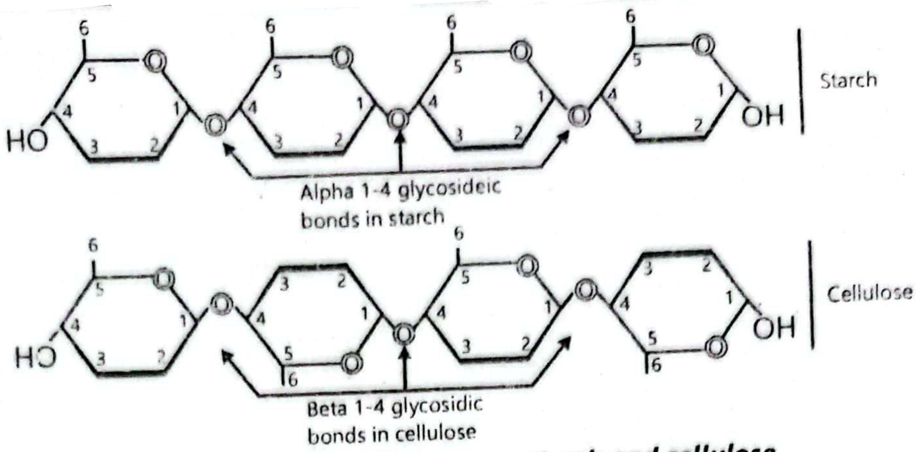


Fig. 4.20: Difference between starch and cellulose

The alternating orientation results in the formation of **straight chains** rather than coils. These chains are held together by hydrogen bonds, forming **cellulose microfibrils**, which further group to form **cellulose fibrils**. These structures are very strong and rigid, providing mechanical strength to plant cells and materials like **paper, cotton**, and plant stems.

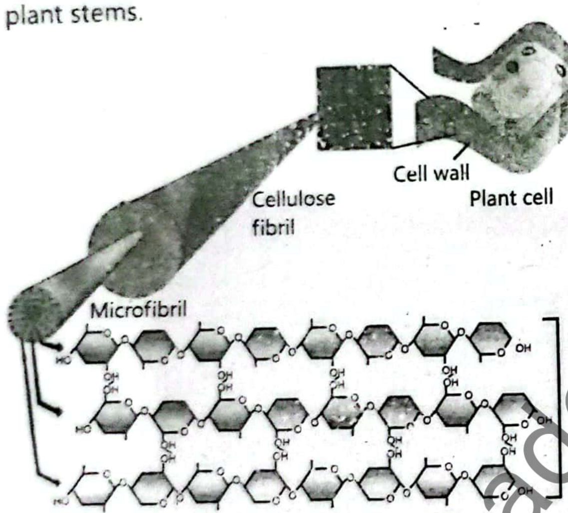


Fig. 4.21: Cellulose fibrils in plant cell wall

The beta-glycosidic bond cannot be broken by amylase. It requires a specific **cellulose** 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

Chitin – Modified Form of Cellulose

Chitin is a modified polysaccharide similar in structure to cellulose. It is found in the **exoskeletons of crabs, lobsters, and insects**, and also in the **cell walls of fungi**.

Like cellulose, chitin is a polymer of glucose with beta 1,4-glycosidic linkages. However, each glucose monomer in chitin has been chemically modified by the **addition of a nitrogen-containing group**. This modification gives chitin added strength and rigidity. Only a few organisms possess the enzymes required to digest chitin.

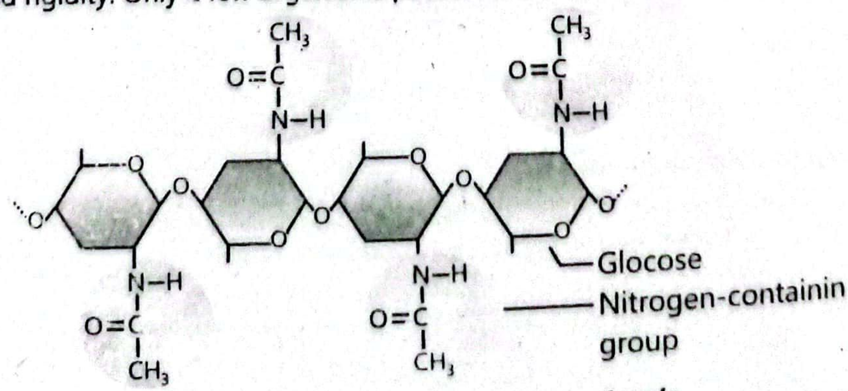


Fig. 4.22: A part of the chitin molecule

Other Polysaccharides

- **Pectin and Lignin**: These are additional structural polysaccharides found in **plant cell walls**, where they contribute to cell rigidity and support.
- **Agar**: Found in the **cell walls of red algae**, agar is used as a **thickening agent in foods**. It is also an essential medium for **growing bacteria and fungi** in laboratories due to its gel-forming properties.
- **Murein**: Also known as **peptidoglycan**, murein is a **sugar-peptide polymer** found in the **cell walls of prokaryotes**. It provides strength and shape to bacterial cells.

MCQs ✓

1. **Which of the following is the most abundant type of carbohydrate in nature?**
   A) Monosaccharides B) Disaccharides
   C) Polysaccharides ✓ D) Nucleotides
2. **What type of bond links the monosaccharides in polysaccharides?**
   A) Peptide bond B) Glycosidic bond ✓
   C) Hydrogen bond D) Ionic bond
3. **Which of the following is a plant storage polysaccharide?**
   A) Glycogen B) Cellulose
   C) Starch ✓ D) Chitin
4. **Why is starch ideal for storage in plant cells?**
   A) It is sweet
   B) It is insoluble and does not affect water potential ✓
   C) It digests proteins D) It dissolves easily
5. **Starch is a mixture of:**
   A) Amylose and Amylopectin ✓
   B) Glucose and Maltose
   C) Glucose and Fructose
   D) Amylose and Cellulose
6. **Amylose consists of glucose monomers joined by:**
   A) 1,4-glycosidic linkages ✓
   B) 1,6-glycosidic linkages
   C) Peptide linkages D) Ester bonds
7. **Amylopectin differs from amylose because it:**
   A) Is shorter
   B) Has 1,6-glycosidic branches ✓
   C) Is soluble in water
   D) Forms straight chains
8. **Which enzyme breaks down starch components?**
   A) Amylase ✓ B) Lactase
   C) Cellulase D) Protease
9. **Glycogen is primarily stored in which animal tissues?**
   A) Skin and lungs B) Muscles and liver ✓
   C) Heart and kidneys D) Brain and bones
10. **Which polysaccharide is most structurally similar to amylopectin?**
    A) Cellulose B) Glycogen ✓
    C) Chitin D) Agar
11. **Cellulose is composed of which type of glucose?**
    A) Alpha-glucose only B) Beta-glucose ✓
    C) Fructose D) Mixed sugars
12. **What is the key structural difference between alpha-glucose and beta-glucose in polysaccharides?**
    A) Position of OH group on carbon 1 ✓
    B) Number of hydrogen atoms
    C) Carbon count
    D) Type of linkage
13. **What kind of chains does cellulose form?**
    A) Straight chains ✓ B) Coiled chains
    C) Branched chains D) Cross-linked rings
14. **What are cellulose microfibrils made of?**
    A) Amylopectin chains
    B) Hydrogen-bonded cellulose chains ✓
    C) Protein bundles D) Fatty acids
15. **Which polysaccharide is found in exoskeletons and fungal cell walls?**
    A) Glycogen B) Agar
    C) Chitin ✓ D) Cellulose
16. **What distinguishes chitin from cellulose?**
    A) It's made of lipids
    B) It contains nitrogen-containing groups ✓
    C) It dissolves in water D) It is not a polymer
17. **Which polysaccharide is used in laboratories as a culture medium?**
    A) Glycogen B) Cellulose
    C) Agar ✓ D) Pectin
18. **Where is agar found naturally?**
    A) In fungi B) In red algae ✓
    C) In animals D) In bacteria
19. **Which polysaccharide is a sugar-peptide polymer in prokaryotes?**
    A) Pectin B) Cellulose
    C) Agar D) Murein ✓
20. **What role do pectin and lignin play in plants?**
    A) Transport of sugars
    B) Structural support in cell walls ✓
    C) Digestion D) Water transport

SQ

1. **What are polysaccharides?**

Ans. Polysaccharides are complex carbohydrates made of long chains of monosaccharides linked by glycosidic bonds. They are the most abundant carbohydrates found in nature.

2. Why is starch suitable for storage in plant cells?

Ans. Starch is insoluble, so it does not affect the water potential of plant cells. This prevents water from entering cells by osmosis, making it an ideal storage material.

3. What are the two main components of starch?

Ans. Starch is composed of amylose and amylopectin. Amylose is unbranched and helical, while amylopectin is branched.

4. How is amylose structured?

Ans. Amylose is a straight, unbranched chain of glucose monomers linked by 1,4-glycosidic bonds. It tends to coil into a helical shape.

5. What makes amylopectin different from amylose?

Ans. Amylopectin has a similar structure to amylose but contains branches formed by 1,6-glycosidic linkages. This branching allows enzymes to break it down more quickly.

6. What enzyme breaks down both amylose and amylopectin?

Ans. The enzyme amylase breaks down both amylose and amylopectin into maltose. However, they are broken down at different rates due to structural differences.

7. Where is glycogen found, and what is its function?

Ans. Glycogen is found mainly in the liver and muscles of animals. It serves as a quick source of energy because it can be rapidly broken down into glucose.

8. What structural feature allows glycogen to be broken down quickly?

Ans. Glycogen is highly branched with many ends for enzymatic action. This makes it a readily available source of glucose when needed.

9. What is cellulose and where is it found?

Ans. Cellulose is a structural polysaccharide found only in plants. It forms the main component of the plant cell wall.

10. What is the difference between the glucose monomers in cellulose and starch?

Ans. Cellulose contains beta-glucose, whereas starch contains alpha-glucose. This small difference results in different structural properties.

11. Why are cellulose chains straight instead of coiled?

Ans. The alternate arrangement of beta-glucose units causes cellulose chains to remain straight. These chains are linked by hydrogen bonds to form strong microfibrils.

12. What is chitin and where is it found?

Ans. Chitin is a modified form of cellulose found in the exoskeletons of crabs, lobsters, insects, and in fungal cell walls. It contains glucose units modified with nitrogen-containing groups.

13. How is chitin different from cellulose?

Ans. While both have beta 1,4-glucose linkages, chitin's glucose units have added nitrogen-containing groups. This makes chitin stronger and more rigid.

14. What are pectin and lignin?

Ans. Pectin and lignin are structural polysaccharides found in plant cell walls. They help strengthen the cells and support the plant structure.

15. What is the role of agar and murein?

Ans. Agar, from red algae, is used in food and labs as a thickening or growth medium. Murein is a sugar-peptide polymer found in bacterial cell walls, providing strength and shape.

4.6 PROTEINS

Q 8. Define proteins and amino acids and outline the synthesis and breakage of peptide linkages.

OR Describe in detail the structure and chemical composition of proteins.

Ans. Introduction

Definition: They are defined as **polymers of amino acids**, and they play a crucial role in nearly every biological process. Proteins are the most abundant organic compounds found in cells. The importance of proteins is so significant that J. J. Berzelius coined the term **"protein"** in 1838 from the Greek word *Proteios*,

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

meaning "molecules of the first rank." This term reflects their primary role in the structure and functioning of living organisms. Proteins serve as the **building blocks of life**, forming the structural framework of cells and performing various biological functions.

Structure of Proteins

Proteins are large macromolecules made by the **interlinking of amino acid monomers**. The number of amino acids in a protein can vary from a few to several thousand. For example, **insulin** consists of 51 amino acids, whereas **haemoglobin** has 574 amino acids.

Amino Acids: The Basic Units of Proteins

An **amino acid** is an organic molecule that consists of:

- An amino group (**$-NH_2$**)
- A carboxyl group (**$-COOH$**)
- A hydrogen atom (**$-H$**)
- A distinctive **side chain (R group)**

All these groups are attached to the **same carbon atom**, known as the **alpha carbon**.

Although about **170 amino acids** are known to occur in nature, only about **25 types** are found in living organisms. Most proteins are composed of **20 standard amino acids**, and the chemical properties of each amino acid are determined by the structure of its side chain (**R group**). For instance:

- **Glycine** has a hydrogen as its side group.
- **Alanine** has a methyl group (**$-CH_3$**) as its side group.

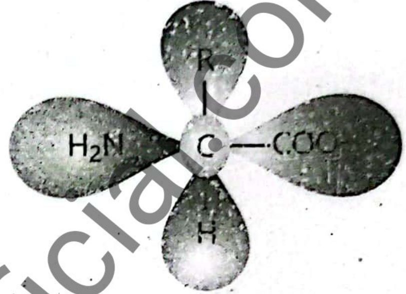


Fig. 4.23: Structure of an amino acid

Fig. 4.24: General structures of glycine and alanine

Essential and Non-Essential Amino Acids

Of the 20 standard amino acids:

- The **human body can synthesize 11** amino acids. These are called **non-essential amino acids** and include:
- *alanine, arginine, asparagine, aspartic acid, cysteine, glutamic acid, glutamine, glycine, proline, serine,* and *tyrosine.*
- The remaining **9 amino acids** must be obtained through diet and are called **essential amino acids**. These include:
- *methionine, valine, tryptophan, isoleucine, leucine, lysine, threonine, phenylalanine,* and *histidine* (essential for babies).

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

Peptide Bonds and Polypeptides

A **peptide bond** is a covalent bond that links two amino acids. When the **amino group of one amino acid** reacts with the **carboxyl group of another**, a **dehydration synthesis reaction** occurs. This results in the release of a water molecule and the formation of a peptide bond between the nitrogen and carbon atoms of the two amino acids.

- A **dipeptide** is formed from two linked amino acids (e.g., **glycylalanine** from glycine and alanine).
- Dipeptides have a free amino group at one end and a free carboxyl group at the other, allowing further amino acids to attach.
- A **polypeptide** is a long chain of amino acids linked by peptide bonds.

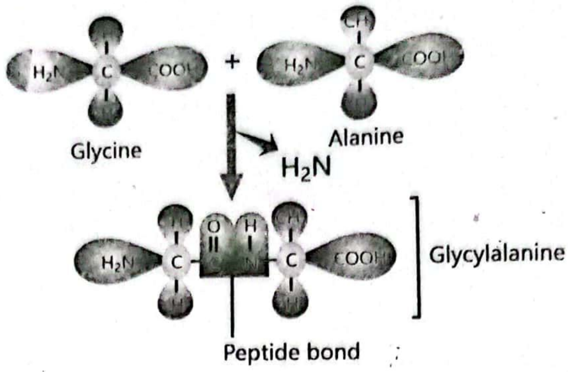


Figure 4.25: Formation of peptide bond between glycine and alanine

A **protein** may consist of one or more polypeptide chains. **For example:**

- **Insulin** has two polypeptide chains.
- **Haemoglobin** has four polypeptide chains.

The **shape and function** of a protein depend on the number, types, and sequence of amino acids in its polypeptide chains.

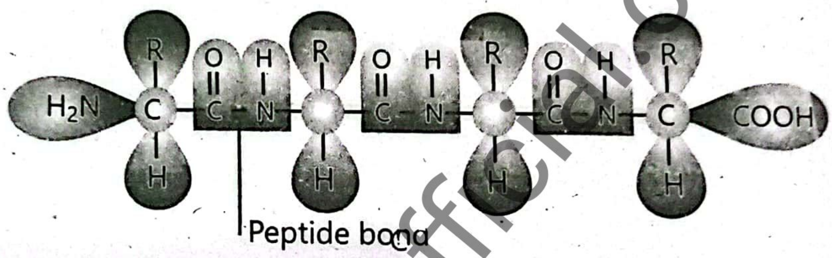


Fig. 4.26: Section from a polypeptide chain

9. Discuss the structural levels of organization of proteins in detail.

Ans. Structural Levels of Proteins

Proteins exist in four levels of structural organization:

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

1. Primary Structure

This is the **simplest level** of protein structure. It is the **linear sequence** of amino acids in a polypeptide chain. The exact order and number of amino acids are specific to each protein and are crucial for its proper function.

- **Insulin** has two chains:
  - Alpha chain: 21 amino acids
  - Beta chain: 30 amino acids
- **Haemoglobin** has four chains:
  - Two alpha chains (141 amino acids each)
  - Two beta chains (146 amino acids each)

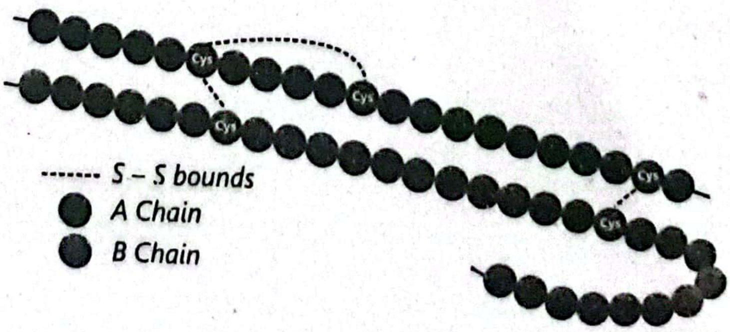


Fig. 4.27: Chains of Insulin

The primary structure is **genetically determined** by the sequence of nucleotides in DNA. Any error in this sequence can result in a **malfunctioning protein**.

For example, in **sickle cell anaemia**, one amino acid (glutamic acid) is replaced by valine at position six in the beta chain of haemoglobin. This causes the red blood cells to become sickle-shaped and impairs oxygen transport.

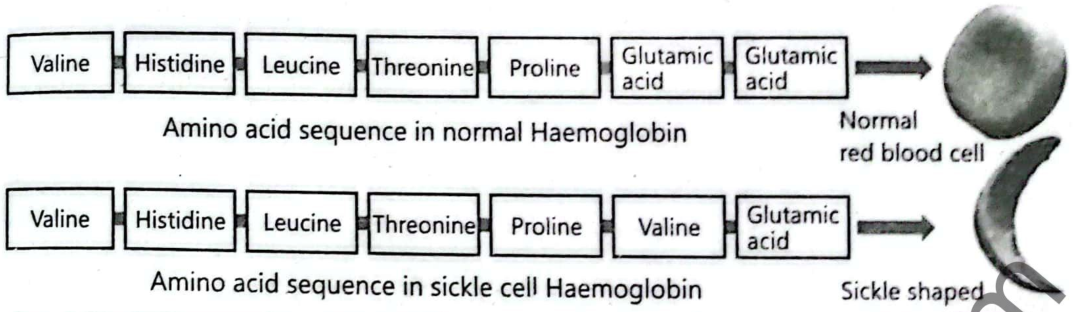


Fig. 4.28: Difference in amino acid sequence in normal and sickle cell haemoglobin

2. Secondary Structure

This structure arises when the **polypeptide chain folds or coils** in specific patterns due to **hydrogen bonding** between amino acids. The two common secondary structures are:

- **Alpha helix** (a coiled shape)
- **Beta-pleated sheet** (a folded, sheet-like structure)

Hydrogen bonds stabilize these structures and contribute to the overall shape of the protein.

3. Tertiary Structure

This is the **three-dimensional globular structure** that forms when the secondary structure folds further. The folding is stabilized by several interactions:

- **Hydrogen bonds**
- **Ionic bonds**
- **Disulphide bridges**
- **Hydrophobic interactions**

Hydrophilic (water-attracting) amino acids are usually exposed on the surface, while **hydrophobic (water-repelling)** amino acids are buried inside. This structure determines the **functionality** of many enzymes and other complex proteins.

4. Quaternary Structure

This structure is formed when **two or more polypeptide chains**, each with its own tertiary structure, combine to form a **functional protein**. The chains are held together by:

- **Hydrophobic interactions**
- **Hydrogen bonds**
- **Ionic bonds**

An example is **haemoglobin**, which consists of **four polypeptide chains** that function together to transport oxygen.

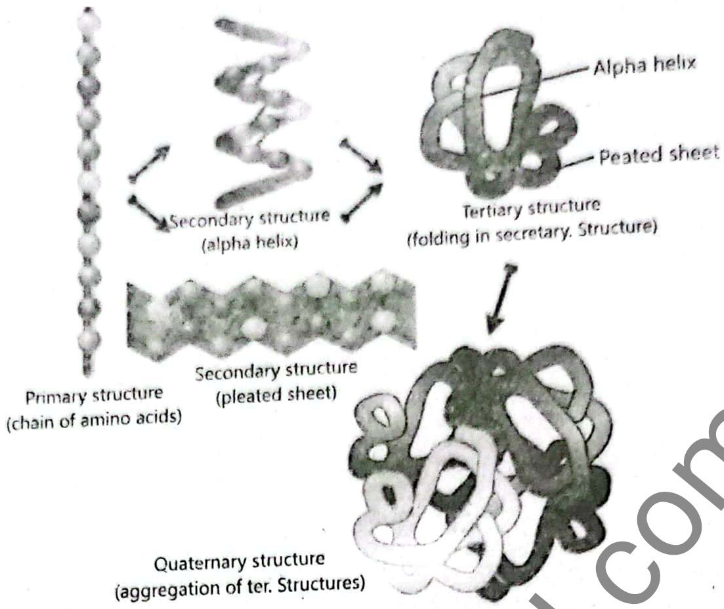


Fig. 4.29: Levels of protein structure

Q 10. Outline the different basis of classification of proteins.

Ans. Proteins are highly diverse organic compounds essential for life. Their functions and structures vary widely, allowing them to participate in almost every biological process. Due to this diversity, proteins can be classified based on different criteria. One of the most important and scientifically recommended classifications is based on their **structure**.

Basis of Protein Classification

Proteins can be classified according to their **role** in living organisms or according to their **structural configuration**:

- **Based on Role:**
  - **Structural Proteins:** These proteins form the structure of cells and tissues.
  - **Functional Proteins:** These proteins perform specific functions such as catalyzing reactions, transporting molecules, and defending against pathogens.
- **Based on Structure:**
  - **Fibrous Proteins**
  - **Globular Proteins**

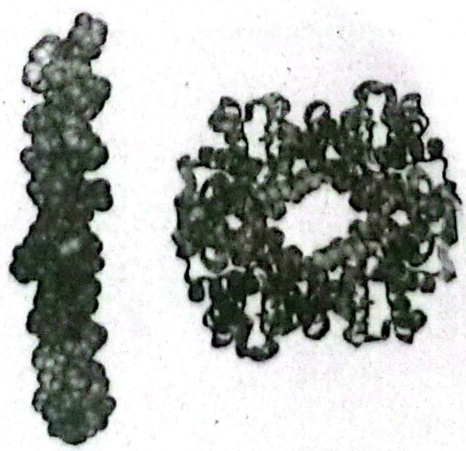


Fig. 4.30: (a) Collagen – a fibrous protein, (b) haemoglobin – a globular protein

The structural classification is widely accepted and helps in understanding the physical and chemical properties of proteins more precisely.

11. Compare the characteristics and examples of fibrous and globular proteins.

Ans. Structural Classification of Proteins

Structural classification divides proteins into two major types:

a. Fibrous Proteins

These proteins are generally long and thread-like. They are primarily structural and are found in connective tissues, skin, hair, and other supportive frameworks of the body.

b. Globular Proteins

These proteins are more compact, spherical in shape, and perform a wide range of biological functions such as enzymatic activity, immunity, and transport.

Comparison of Fibrous and Globular Proteins

The table below provides a clear comparison between the two types of proteins:

Table 4.4: 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:** Forms the webs of silkworm and spider	- **Enzymes:** Act as biological catalysts (biocatalysts)
	- **Actin:** Present in muscle cells	- **Antibodies:** Active against invading antigens
	- **Fibrin:** Forms blood clots	- **Some Hormones:** Regulate body activities
	- **Keratin:** Found in nails, hairs, beak, skin, etc.	- **Haemoglobin:** Oxygen-carrying protein in red blood cells
	- **Collagen:** Found in the matrix of connective tissues	

12. Describe the structural and functional roles of proteins in the life of living organisms.

Ans. Introduction

Proteins are essential biomolecules that perform virtually all structural and functional activities in living organisms. From forming cellular structures to catalyzing biochemical reactions and regulating physiological processes, proteins play an irreplaceable role in life. Their diversity in function is a key to maintaining life processes in both simple and complex organisms.

Proteins as Components of Plasma Membranes

Proteins are an important part of the composition of all plasma membranes. They contribute to the selective permeability and functionality of membranes.

- **Channel Proteins:** These proteins control the movement of materials into and out of the cells. They form channels and pores that allow specific molecules to pass through the lipid bilayer.
- **Sodium–Potassium Pump:** A specific example is the sodium-potassium pump found in the membrane of neurons. This protein structure actively transports Na^+ (sodium ions) and K^+ (potassium ions) in and out of nerve cells, which is crucial for nerve impulse transmission.

Fibrous Proteins as Structural Materials

Certain fibrous proteins form the structure of tissues and external body parts.

- **Collagen:** This protein makes up a significant part of cartilage, providing strength and flexibility.
- **Keratin:** Found in hair and nails, keratin gives these structures durability and protection.

Proteins as Enzymes

Enzymes are a diverse class of proteins that act as biological catalysts.

- **Function:** They accelerate metabolic processes within cells without being consumed in the reactions.
- **Examples:**
  - **Proteases** catalyze the breakdown of proteins.
  - **Polymerases** catalyze the synthesis of polymers such as DNA and RNA.

Proteins as Hormones

Some hormones are protein or peptide in nature, performing critical regulatory roles in the body.

- **Insulin:** Regulates blood glucose levels by promoting glucose uptake into cells.
- **Antidiuretic Hormone (ADH):** Increases water retention by the kidneys, aiding in water balance.
- **Oxytocin:** Helps in the regulation of milk production and plays a role in social bonding and childbirth.

Transport Proteins

Many globular proteins transport vital substances throughout the body.

- **Haemoglobin and Myoglobin:** Transport oxygen and some carbon dioxide.
- **Cytochromes:** Act as electron carriers in the electron transport chain during cellular respiration.

Osmotic Regulation

Proteins help maintain the osmotic balance in blood and other body fluids.

- **Albumin:** A blood protein that maintains the osmotic concentration of the blood, thereby supporting proper blood flow and distribution of fluids between tissues and vessels.

Blood ferritin levels are measured in patients as a diagnostic tool of anaemia. If ferritin is high there is iron in excess. If ferritin is low there is a risk for lack of iron which sooner or later could lead to anaemia

Blood Clotting Proteins

Proteins play a crucial role in preventing blood loss through clot formation.

- **Fibrinogen and Fibrin:** Fibrinogen is an inactive protein present in the blood. Upon injury, it is converted into fibrin, which forms a fibrous network that helps in clotting and stops bleeding.

Proteins in Movement and Contraction

Proteins are responsible for all types of contraction and movement in living organisms.

- **Actin and Myosin:** The primary proteins found in muscle cells; they are responsible for muscle contraction.
- **Tubulin:** This protein forms spindle fibers that are essential for chromosome movement during cell division.

Defense Proteins (Antibodies)

Antibodies are specialized proteins involved in the immune response.

- **Function:** They recognize and bind with foreign substances (antigens), such as bacteria and viruses, and neutralize or eliminate them, protecting the organism from infection and disease.

Ion-Binding and Storage Proteins

Some proteins store essential ions in specific body regions.

- **Ferritin:** The main protein that stores iron inside cells, especially in the liver, spleen, and bone marrow.
- **Casein:** A protein found in milk that stores calcium and potassium ions, especially important for infant nutrition.

Regulatory Proteins

Some proteins regulate gene expression and cellular activity.

- **Repressor Proteins:** These proteins control gene expression by binding to specific DNA sequences and preventing the synthesis of RNA. As a result, they allow genes to work only when and where needed.

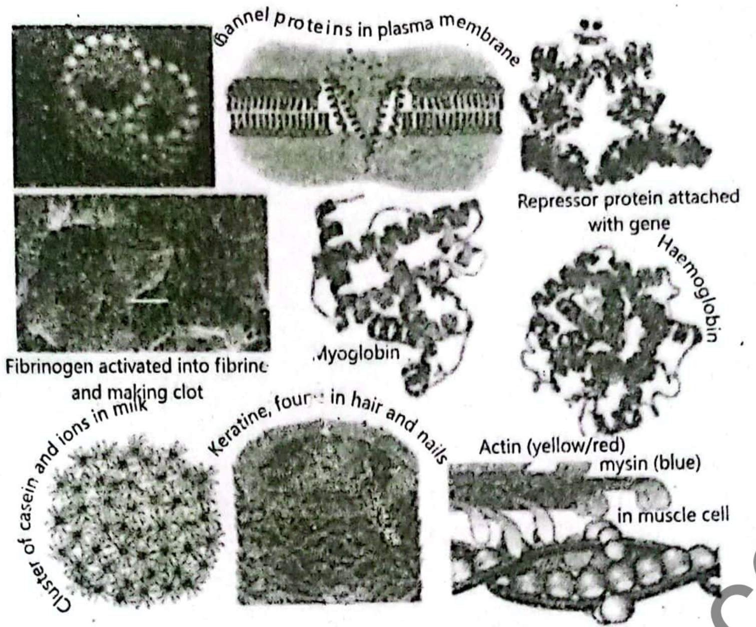


Fig. 4.31: Different proteins of human body

1. Who coined the term "protein"?
A) Robert Hooke B) J.J. Berzelius✓
C) Watson D) Linus Pauling

2. What are proteins made of?
A) Nucleotides B) Monosaccharides
C) Amino acids✓ D) Fatty acids

3. What is the function of proteins in cells?
A) Genetic information storage
B) Energy storage
C) Building structure and function✓
D) Hormone secretion only

4. How many amino acids are commonly used in proteins?
A) 10 B) 20✓
C) 30 D) 50

5. What determines the identity of an amino acid?
A) Number of amino groups
B) Presence of sugar
C) Type of R group✓
D) Length of carbon chain

6. What is the basic structure of an amino acid?
A) One carboxyl group only
B) A sugar ring
C) Amino group, carboxyl group, hydrogen, and R group✓
D) Phosphate and sugar

7. Which of the following is an essential amino acid?
A) Glycine B) Alanine
C) Valine✓ D) Serine

8. Which amino acid is essential only for babies?
A) Histidine✓ B) Glutamic acid
C) Glycine D) Alanine

9. How are two amino acids linked together?
A) Hydrogen bond B) Ionic bond
C) Peptide bond✓ D) Disulphide bond

10. What is formed when two amino acids link together?
A) Polypeptide B) Dipeptide✓
C) Monopeptide D) Lipid

11. What is a long chain of amino acids called?
A) Fatty acid B) Monomer
C) Polypeptide✓ D) Disaccharide

12. How many polypeptide chains does haemoglobin have?
A) 2 B) 3
C) 4✓ D) 5

13. What is the smallest chain of insulin composed of?
A) 30 amino acids B) 21 amino acids✓
C) 50 amino acids D) 146 amino acids

14. What is the primary structure of a protein?
A) Folding of a chain B) Number of peptide bonds
C) Linear sequence of amino acids✓
D) Interaction with DNA

15. What determines the sequence of amino acids in a protein?
A) Type of lipids present B) Temperature
C) DNA nucleotide sequence✓
D) Presence of sugars

16. What disorder is caused by a mutation in the primary structure of haemoglobin?
A) Diabetes B) Haemophilia
C) Sickle cell anaemia✓ D) Asthma

17. What is the secondary structure of a protein?
A) Disulphide linkage
B) Coiling and folding like alpha helix and beta sheet✓

C) Genetic code D) Protein breakdown

18. **Which bond stabilizes secondary structures in proteins?**
A) Disulphide bond B) Ionic bond
C) Hydrogen bond✓ D) Covalent bond

19. **What is the tertiary structure of a protein?**
A) Linear sequence
B) Arrangement of nucleotides
C) 3D folding of a polypeptide✓
D) Double helix

20. **What bonds maintain the tertiary structure of a protein?**
A) Peptide and covalent bonds only
B) Hydrogen, ionic, and disulphide bonds✓
C) Glycosidic bonds D) Ester bonds

21. **What happens to hydrophobic amino acids in tertiary structure?**
A) They stay on the surface
B) They dissolve in water
C) They aggregate inside the protein✓
D) They convert to hydrophilic

22. **What is the quaternary structure of a protein?**
A) Sequence of amino acids
B) One folded chain
C) Association of multiple polypeptide chains✓
D) Chain of sugars

23. **Which interaction is not involved in quaternary structure?**
A) Hydrogen bond B) Ionic bond
C) Peptide bond✓ D) Hydrophobic interaction

24. **What is an example of a protein with quaternary structure?**
A) Glycine B) Insulin
C) Glucose D) Haemoglobin✓

25. **Why is the structure of proteins important?**
A) It affects color B) It determines DNA type
C) It defines the protein's function✓
D) It is unrelated to function

26. **On what basis are proteins commonly classified in biology?**
A. Shape of cells B. Their chemical formula
C. Their structure✓ D. Their color

27. **What are the two main structural classes of proteins?**
A. Active and Passive
B. Essential and Non-essential
C. Fibrous and Globular✓
D. Primary and Secondary

28. **What is the shape of fibrous proteins?**
A. Circular B. Thread-like✓
C. Spherical D. Oval

29. **What kind of structure do globular proteins typically have?**
A. Primary B. Secondary
C. Tertiary or Quaternary✓ D. No defined structure

30. **Which type of protein is non-crystalline and elastic?**
A. Enzymes B. Fibrous✓
C. Globular D. Hormonal

31. **Which proteins can be crystallized?**
A. Structural B. Fibrous
C. Globular✓ D. Collagen

32. **Which proteins are soluble in salt, acid, or base solutions?**
A. Fibrous B. Structural
C. Collagen D. Globular✓

33. **Which type of protein disorganizes easily with environmental changes?**
A. Keratin B. Fibrous
C. Globular✓ D. Silk

34. **Which type of protein forms the structure of nails and hair?**
A. Collagen B. Fibrin
C. Keratin✓ D. Actin

35. **What type of protein is haemoglobin?**
A. Fibrous B. Structural
C. Hormonal D. Globular✓

36. **What type of role do fibrous proteins mainly perform?**
A. Digestive B. Structural✓
C. Catalytic D. Transport

37. **Which of the following is a fibrous protein involved in blood clotting?**
A. Fibrin✓ B. Insulin
C. Myosin D. Albumin

38. **What characteristic of fibrous proteins helps them resist environmental changes?**
A. Tertiary structure B. Elasticity
C. Insolubility✓ D. Tough peptide bonds

39. **Which protein forms silk fibers in spiders and silk worms?**
A. Actin B. Collagen
C. Silk protein✓ D. Myosin

40. **Which of the following is a hormone and a globular protein?**
A. Fibrin B. Keratin
C. Collagen D. Insulin✓

41. **What is the main role of enzymes in the body?**
A. Storage B. Biocatalyst✓
C. Defense D. Structure

42. **Which of the following is not a fibrous protein?**
A. Collagen B. Keratin
C. Enzyme✓ D. Actin

43. **What is a key structural difference between fibrous and globular proteins?**
A. Number of amino acids B. Solubility
C. Shape D. All of the above✓

44. **What makes globular proteins more functional than fibrous ones?**
A. Linear structure B. Compact, folded shape✓
C. Elasticity D. Insolubility

45. **Which protein provides strength in connective tissues?**

A. Actin B Insulin

C. Collagen✓ D. Haemoglobin

46. **Which protein in the plasma membrane controls the movement of sodium and potassium ions in neurons?**

a) Haemoglobin

b) Sodium-potassium pump✓

c) Albumin d) Fibrinogen

47. **Which fibrous protein is primarily responsible for the structure of hair and nails?**

a) Collagen b) Keratin✓

c) Actin d) Myosin

48. **What is the main function of enzymes in cells?**

a) Transport oxygen

b) Catalyze metabolic reactions✓

c) Store ions

d) Form structural components

49. **Which protein hormone regulates blood glucose levels?**

a) Oxytocin b) Insulin✓

c) Antidiuretic hormone d) Fibrinogen

50. **Haemoglobin primarily transports which molecule in the blood?**

a) Carbon dioxide b) Oxygen✓

c) Water d) Sodium ions

51. **Which protein maintains the osmotic concentration of blood?**

a) Fibrinogen b) Albumin✓

c) Myosin d) Tubulin

52. **What protein is converted into fibrin to form blood clots after injury?**

a) Albumin b) Actin

c) Fibrinogen✓ d) Myoglobin

53. **Which proteins are mainly responsible for muscle contraction?**

a) Keratin and collagen b) Actin and myosin✓

c) Tubulin and fibrinogen d) Albumin and haemoglobin

54. **What role do antibodies play in the immune system?**

a) Transport oxygen

b) Catalyze chemical reactions

c) Recognize and neutralize foreign antigens✓

d) Store ions

55. **Which protein stores iron inside cells?**

a) Casein b) Ferritin✓

c) Myoglobin d) Albumin

SQ

1. **What are proteins and why are they important?**

Ans. Proteins are polymers of amino acids and are the most abundant organic compounds in cells. They are vital for the structure and functioning of cells and organisms.

2. **Who coined the term "protein" and what does it mean?**

Ans. The term "protein" was coined by J. J. Berzelius in 1838. It comes from the Greek word "Proteios," meaning "molecules of the first rank," to highlight their importance.

3. **What are amino acids?**

Ans. Amino acids are organic molecules that serve as the building blocks of proteins. Each amino acid has an amino group, a carboxyl group, a hydrogen atom, and a unique side group attached to a central carbon atom.

4. **How many types of amino acids are commonly found in proteins?**

Ans. About 20 types of amino acids are commonly found in proteins. These amino acids vary by their side groups, which give them unique chemical properties.

5. **What determines the identity of an amino acid?**

Ans. The identity of an amino acid is determined by its side group (R group). This group varies between amino acids and affects how they behave chemically.

6. **What are essential amino acids?**

Ans. Essential amino acids are those that the human body cannot synthesize. They must be obtained from food and include valine, leucine, methionine, and others.

7. **What are non-essential amino acids?**

Ans. Non-essential amino acids are produced by the human body. They include alanine, glycine, serine, and others.

8. **What is a peptide bond?**

Ans. A peptide bond is a covalent bond that joins two amino acids. It forms through a dehydration reaction between the amino group of one amino acid and the carboxyl group of another.

9. **What is a dipeptide?**

Ans. A dipeptide is a molecule made by linking two amino acids through a peptide bond. An example is glycylalanine, formed from glycine and alanine.

10. What is a polypeptide?

Ans. A polypeptide is a long chain of amino acids joined by peptide bonds. Proteins consist of one or more polypeptide chains.

11. How many polypeptide chains are found in insulin and haemoglobin?

Ans. Insulin has two polypeptide chains, while haemoglobin contains four. This structural variation contributes to their different biological functions.

12. What is the primary structure of a protein?

Ans. The primary structure is the specific sequence of amino acids in a polypeptide chain. It determines the protein's unique function and shape.

13. How is the primary structure of a protein determined?

Ans. It is determined by the nucleotide sequence of the corresponding gene in DNA. Any change in this sequence can affect the protein's function.

14. What causes sickle cell anaemia?

Ans. Sickle cell anaemia is caused by a change in the primary structure of haemoglobin. Valine replaces glutamic acid at position six in the beta chain, altering the red blood cell shape.

15. What is the secondary structure of a protein?

Ans. It refers to localized folding patterns in the polypeptide chain, such as alpha helices and beta-pleated sheets. These are stabilized by hydrogen bonds.

16. What is the tertiary structure of a protein?

Ans. Tertiary structure is the overall three-dimensional shape of a polypeptide chain. It is maintained by hydrogen bonds, ionic bonds, disulphide bridges, and hydrophobic interactions.

17. How do hydrophilic and hydrophobic amino acids affect tertiary structure?

Ans. Hydrophobic amino acids are buried inside the protein, avoiding water, while hydrophilic amino acids are exposed on the surface. This distribution stabilizes the globular shape.

18. What is the quaternary structure of a protein?

Ans. Quaternary structure arises when two or more polypeptide chains with tertiary structures combine. These are held together by various bonds like hydrogen and ionic bonds.

19. How is a protein's structure related to its function?

Ans. The structure, especially the sequence and shape of amino acids, determines a protein's specific function. Even small changes can render a protein ineffective or harmful.

20. Why is the study of protein structure important?

Ans. Understanding protein structure helps explain how proteins work and how mutations can cause diseases. It is essential in fields like genetics, medicine, and biotechnology.

21. On what basis are proteins commonly classified?

Ans. Proteins are commonly classified based on their structure. This classification divides them into fibrous and globular proteins.

22. What are structural and functional proteins?

Ans. Structural proteins help build and support the structure of cells and tissues. Functional proteins perform biological functions such as catalysis, defense, and regulation.

23. What are fibrous proteins?

Ans. Fibrous proteins are elongated, thread-like proteins that mainly serve structural roles in organisms. They have primary or secondary structures and are usually insoluble in water.

24. What are globular proteins?

Ans. Globular proteins are compact, spherical proteins that play various functional roles in the body. They have tertiary or quaternary structures and are generally soluble in water and other solutions.

25. How do fibrous and globular proteins differ in solubility?

Ans. Fibrous proteins are insoluble in water and other common solvents. In contrast, globular proteins are soluble in salt, acid or base solutions, and in aqueous alcohol.

26. Describe the crystallization properties of fibrous and globular proteins.

Ans. Fibrous proteins are non-crystalline and elastic in nature. Globular proteins, however, can be crystallized under certain conditions.

27. **What happens to fibrous and globular proteins when environmental conditions change?**

Ans. Fibrous proteins do not disorganize easily and maintain their shape under various conditions. Globular proteins, on the other hand, can be disorganized when exposed to changes in their environment.

28. **Give two examples of fibrous proteins and their roles.**

Ans. Keratin is a fibrous protein found in nails, hair, and skin. Collagen is another fibrous protein that provides structural support in the matrix of connective tissues.

29. **Give two examples of globular proteins and their functions.**

Ans. Enzymes are globular proteins that act as biocatalysts to speed up chemical reactions. Antibodies are also globular proteins that help defend the body against invading antigens.

30. **What is the significance of the table comparing fibrous and globular proteins?**

Ans. The table clearly outlines the differences in shape, structure, function, solubility, and examples of fibrous and globular proteins. It helps in understanding the unique roles each type of protein plays in biological systems.

31. **What role do proteins play in plasma membranes?**

Ans. Proteins are essential components of plasma membranes, where they control the movement of materials in and out of cells. For example, the sodium-potassium pump in neuron membranes regulates the flow of Na^+ and K^+ ions, which is vital for nerve function.

32. **How do enzymes function as proteins in living organisms?**

Ans. Enzymes are proteins that act as biological catalysts, speeding up metabolic reactions without being consumed. Different enzymes specialize in different tasks, such as proteases breaking down proteins and polymerases synthesizing polymers like DNA.

33. **What is the importance of haemoglobin and myoglobin?**

Ans. Haemoglobin and myoglobin are globular proteins responsible for transporting oxygen and some carbon dioxide in the body. Haemoglobin carries oxygen in the blood, while myoglobin stores oxygen in muscle tissues.

34. **How do fibrinogen and fibrin contribute to blood clotting?**

Ans. Fibrinogen is a protein in the blood that, when activated by injury, converts into fibrin. Fibrin forms fibrous networks that trap blood cells and form a clot, preventing excessive blood loss.

35. **What is the function of antibodies as proteins?**

Ans. Antibodies are proteins that identify and bind to foreign substances called antigens. This binding neutralizes or helps remove harmful pathogens, playing a crucial role in the immune defense system.

4.7 LIPIDS

Q 13. Describe the properties and roles of acylglycerols, phospholipids, terpenes and waxes. OR Explain the structure, classification, chemical composition and functions of lipids.

Ans. Introduction

Lipids are a loosely defined group of non-polar molecules that share a common characteristic: they are insoluble in water but soluble in organic solvents such as ether and alcohol. Due to their non-polar nature, lipids do not dissolve in aqueous environments but are easily dissolved in non-polar solvents.

> An ester is the compound produced as the result of a chemical reaction of an alcohol with an acid and a water molecule is release

Classification of lipids

Lipids are a highly diverse group of molecules and are classified into several major categories, including acylglycerols (fats and oils), waxes, phospholipids, terpenes, steroids, and prostaglandins.

1. Acylglycerols (Fats and Oils)

Composition and Types

Acylglycerols are made up of two subunits: glycerol and fatty acids. The state of acylglycerols at room temperature determines their classification: those that are liquid at room temperature are called oils, whereas those that are solid are called fats. In animals, most acylglycerols are fats, while in plants, most are oils, such as peanut oil, corn oil, and castor oil.

Chemical Nature

Chemically, acylglycerols are esters formed from fatty acids and alcohol (glycerol). They are synthesized by dehydration synthesis, a reaction where a hydroxyl group (OH) is removed from the alcohol and a hydrogen atom (H) is removed from the fatty acid, resulting in the formation of water and an ester bond.

Structure of Acylglycerols

The most common form of acylglycerols is triacylglycerols (also called triglycerides or neutral lipids), where three fatty acid molecules (which may be the same or different) are esterified to a single glycerol backbone.

$$\underset{\text{alcohol}}{C_2H_5OH} + \underset{\text{acetic acid}}{HOOCCH_3} \longrightarrow \underset{\text{an ester}}{C_2H_2OCOCH_3} + H_2O$$

- **Glycerol:** A 3-carbon alcohol molecule with each carbon attached to a hydroxyl group (OH). This forms the backbone of the acylglycerol molecule.
- **Fatty Acids:** Long hydrocarbon chains ending in a carboxyl (-COOH) group. These chains usually have an even number of carbons, ranging from 4 to 30. Fatty acids vary in their chain length and structure, being straight in animals or branched/ringed in plants.

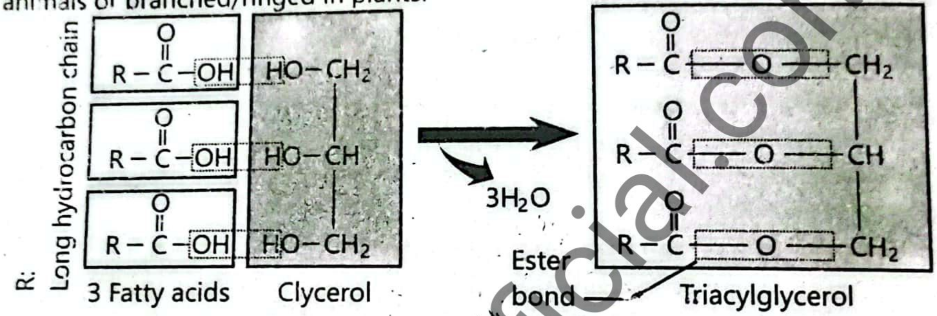


Fig. 4.33: Dehydration synthesis of a triacylglycerol

Types of Fatty Acids:

- **Saturated Fatty Acids:** These contain no double bonds between carbon atoms. All internal carbons are fully saturated with hydrogen atoms, resulting in straight chains and higher melting points.
- **Unsaturated Fatty Acids:** These contain one or more double bonds (up to six) which reduce the number of hydrogen atoms attached. The double bonds cause bends in the chain and result in lower melting points.

> 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

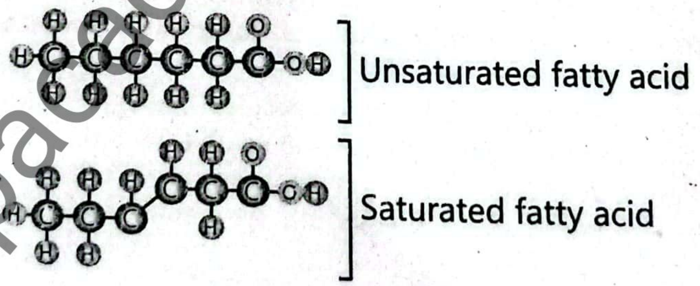


Fig. 4.32 Fatty acids

The solubility of fatty acids in organic solvents and their melting points increase as the length of the carbon chain increases.

Energy Storage Role

Acylglycerols are efficient energy storage molecules due to the high number of carbon-hydrogen (C-H) bonds. Their non-polar nature makes them insoluble in water, allowing them to be stored in specific locations in organisms without disrupting cellular water balance. Animal fats tend to have more energy than plant oils because they contain saturated fatty acids with more C-H bonds, whereas plant oils contain more unsaturated fatty acids and fewer C-H bonds.

Organisms convert excess glucose into fats or oils for long-term energy storage.

2. Waxes

Chemical Composition and Properties

Waxes are lipids derived from acylglycerols but differ chemically. They have high melting points and are solid at room temperature due to their long carbon chains. Waxes consist of mixtures of long-chain alkanes (usually with an odd number of carbon atoms, 25–35), alcohols other than glycerol, ketones, and long-chain fatty acids.

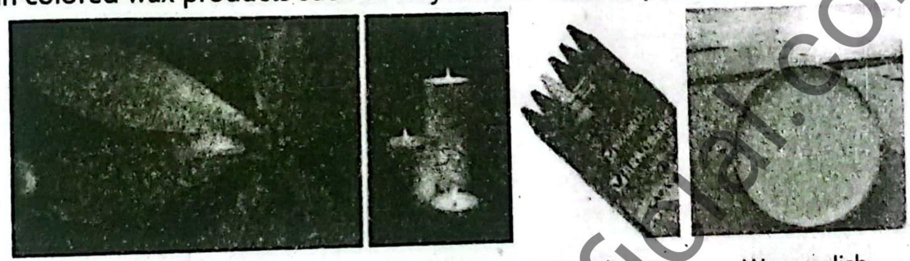
> Honeybees produce waxes and use it to make six sided (hexagonal) chambers of their combs, where honey is stored. In humans, wax is secreted by glands of the outer ear canal

Physical and Biological Roles

Waxes are chemically inert and strongly hydrophobic. They act as protective coverings and water barriers for living organisms. Waxes commonly coat fruits and leaves to prevent water loss. Animals such as insects, birds, and sheep also secrete waxes on their skin for protection.

Uses of Waxes

Waxes are used industrially for waterproofing paper and cards, polishing furniture, footwear, and vehicles, making candles, and in colored wax products such as crayons and colored pencils.



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

Fig. 4.34: Some uses of waxes

Phospholipids

Structural Role in Membranes

Phospholipids play a critical structural role in forming plasma membranes of cells. Chemically, phospholipids are derivatives of phosphatidic acid, which consists of a glycerol molecule attached to two fatty acids and one phosphoric acid (phosphate) group.

A nitrogenous base such as choline, ethanolamine, or serine attaches to the phosphate group, creating different phospholipids such as phosphatidyl choline (lecithin), phosphatidyl ethanolamine, and phosphatidyl serine. For example, phosphatidyl choline is a major component of the lipid bilayer in plasma membranes.

Molecular Structure

Phospholipids have a dual nature:

- The **head** is polar and hydrophilic, containing the nitrogenous base and phosphate group.
- The **tail** is non-polar and hydrophobic, consisting of two fatty acid chains.

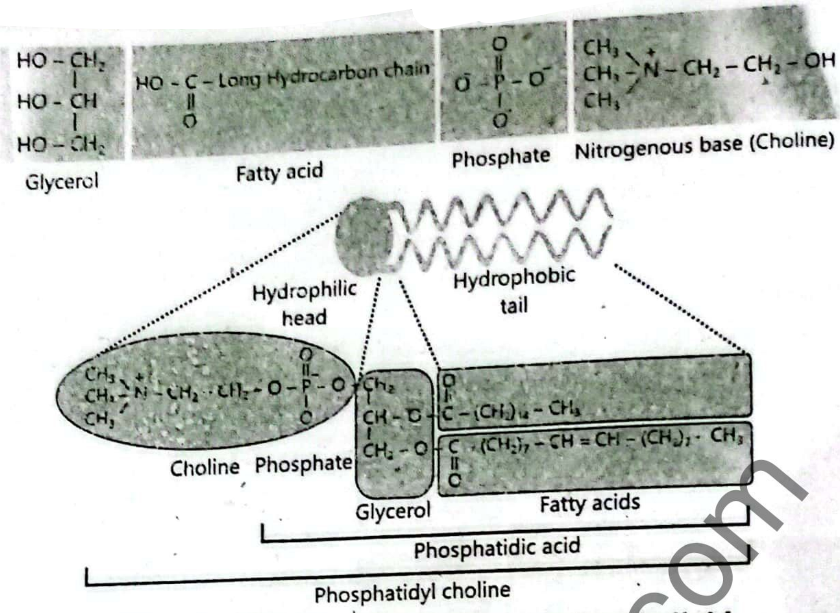
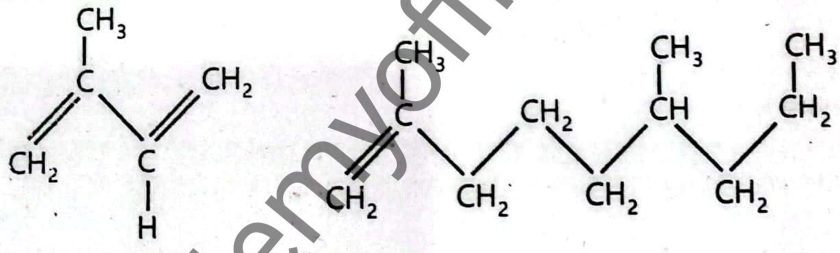


Fig. 4.35: Phosphatidyl choline – a phospholipid

3. Terpenes

Terpenes are a very large and diverse group of lipids composed of isoprene units. An isoprene unit is a branched unsaturated hydrocarbon chain with the formula $CH_2=C(CH_3)-CH=CH_2$.

Terpenes form many biologically important compounds, including pigments like chlorophyll in plants and retinal pigments in the eyes. Vitamin A and natural rubber are also examples of terpenes.



Isoprene units

Fig. 4.36: Structure of terpenes

4. Steroids

Steroids are lipids characterized by a carbon skeleton bent into four fused rings: three six-membered rings and one five-membered ring. All steroids share this ring structure.

Cholesterol is a common steroid found in animal cell membranes and serves as a precursor for other steroids including male and female sex hormones.

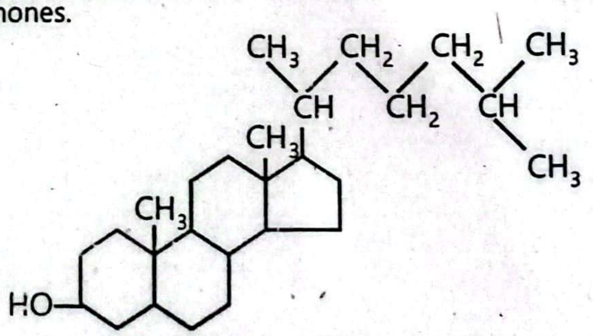


Fig. 4.37: Cholesterol: a steroid

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.

5. ***Prostaglandins***

Prostaglandins are a group of lipids derived from modified fatty acids, containing non-polar tails attached to a five-carbon ring. They are found in many vertebrate tissues where they act as local chemical messengers.

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

Prostaglandins regulate various physiological functions such as stimulating smooth muscle contraction and relaxation, constricting or dilating blood vessels, and mediating inflammatory responses to infection.

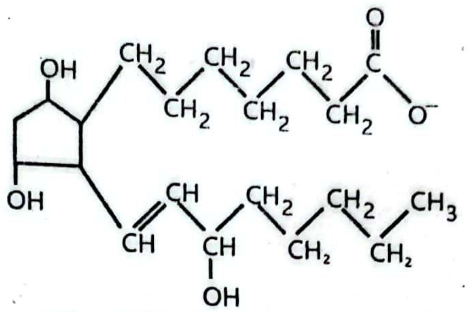


Fig. 4.38: A prostaglandin

14. Describe the role of lipids in life.

Ans. Role of Lipids in Life

- **Energy Source:** Lipids are the most energy-dense nutrients. One gram of lipid provides approximately 9.5 kilocalories of energy, which is more than twice the energy provided by carbohydrates (4.1 kcal/g) and proteins (5.6 kcal/g).
- **Membrane Components:** Lipids are essential structural components of all cellular and subcellular membranes, maintaining membrane integrity and fluidity.
- **Vitamin Carriers:** They serve as biological carriers for fat-soluble vitamins A, D, E, and K, facilitating their absorption and transport.
- **Source of Fatty Acids:** Lipids provide essential fatty acids necessary for various metabolic functions.
- **Mechanical Cushion:** Lipids act as cushioning material to protect vital organs from mechanical injury.
- **Thermal Insulation:** Fat deposits beneath the skin insulate the body against extreme temperature variations.
- **Steroid Functions:** Steroids, such as cholesterol, maintain membrane structure and are precursors to important biomolecules like vitamin D, bile acids, steroid hormones (androgens, estrogens), adrenal hormones, and corticosteroids.

MCQs

1. **Which of the following best describes lipids?**
   A. Polar molecules soluble in water
   B. Non-polar molecules soluble in water
   C. Non-polar molecules insoluble in water ✓
   D. Polar molecules soluble in ether
2. **Which components make up acylglycerols?**
   A. Glycerol and glucose
   B. Fatty acids and alcohol
   C. Glycerol and fatty acids ✓
   D. Phosphate and glycerol
3. **What are fats and oils collectively called?**
   A. Waxes　　B. Triacylglycerols
   C. Acylglycerols ✓　　D. Steroids
4. **Which type of acylglycerol is solid at room temperature?**
   A. Oil　　B. Wax
   C. Fat ✓　　D. Phospholipid
5. **What is the backbone of a triacylglycerol molecule?**
   A. Fatty acid　　B. Phosphate group
   C. Glycerol ✓　　D. Glucose
6. **Saturated fatty acids contain:**
   A. One double bond　　B. Multiple double bonds
   C. No double bonds ✓　　D. Triple bonds
7. **Which fatty acids have a lower melting point?**
   A. Branched fatty acids　　B. Saturated fatty acids
   C. Unsaturated fatty acids ✓
   D. Long-chain fatty acids
8. **Why are acylglycerols good energy-storage molecules?**
   A. They are polar　　B. They contain oxygen
   C. They have many C-H bonds ✓
   D. They are acidic
9. **What causes the hydrophobic nature of lipids?**
   A. Polar bonds　　B. Ionic groups

C. Non-polar structure ✓ D. Hydroxyl groups

10. **Which type of lipid stores more energy?**
A. Plant oil B. Unsaturated lipid
C. Animal fat ✓ D. Wax

11. **Waxes are mainly used in living organisms for:**
A. Insulation B. Structural support
C. Energy production D. Protective coatings ✓

12. **What is a common use of waxes in daily life?**
A. Making proteins B. Strengthening bones
C. Polishing furniture ✓ D. Building cell membranes

13. **Which lipid forms the bilayer of plasma membranes?**
A. Waxes B. Phospholipids ✓
C. Steroids D. Triacylglycerols

14. **Which part of a phospholipid is polar?**
A. Both head and tail B. Tail
C. Head ✓ D. Glycerol only

15. **What is the basic building unit of terpenes?**
A. Glucose B. Glycerol
C. Isoprene ✓ D. Carboxyl group

16. **Which of the following is a terpene?**
A. Cholesterol B. Vitamin A ✓
C. Lecithin D. Testosterone

17. **What is the structure of a steroid based on?**
A. A branched fatty acid
B. Four fused carbon rings ✓
C. A phosphate group
D. A triacylglycerol

18. **Cholesterol is a type of:**
A. Wax B. Protein
C. Steroid ✓ D. Phospholipid

19. **Prostaglandins are involved in:**
A. Bone formation
B. Muscle contraction and inflammation ✓
C. Membrane synthesis
D. Vitamin D production

20. **How much energy (in kilocalories) is provided by 1 gram of lipid?**
A. 4.1 kcal B. 5.6 kcal
C. 9.5 kcal ✓ D. 3.8 kcal

SQ

1. **What are lipids and what is their solubility characteristic?**
Ans. Lipids are non-polar organic molecules that are insoluble in water but soluble in organic solvents such as ether and alcohol. This insolubility is due to their hydrophobic (non-polar) nature.

2. **What are acylglycerols and how are they classified?**
Ans. Acylglycerols are lipids composed of glycerol and fatty acids. They are classified as fats if solid at room temperature and oils if liquid at room temperature.

3. **What is the difference between fats and oils in terms of origin?**
Ans. In animals, most acylglycerols exist as fats which are solid at room temperature. In plants, they usually occur as oils, which are liquid at room temperature.

4. **What is a triacylglycerol (triglyceride)?**
Ans. A triacylglycerol is a lipid in which three fatty acid molecules are attached to a single glycerol molecule. These are also called neutral lipids and serve as energy storage molecules.

5. **What is the structure and function of glycerol in lipids?**
Ans. Glycerol is a three-carbon alcohol with each carbon bearing a hydroxyl group. It forms the backbone of acylglycerols where fatty acids attach to form fats and oils.

6. **What are saturated fatty acids?**
Ans. Saturated fatty acids contain no double bonds in their hydrocarbon chains, and all internal carbon atoms are saturated with hydrogen atoms. These fatty acids form straight chains and have a high melting point.

7. **What are unsaturated fatty acids and how do they differ structurally?**
Ans. Unsaturated fatty acids contain one or more double bonds in the hydrocarbon chain, replacing some hydrogen atoms. This causes bends in the chain and results in a lower melting point.

8. **Why are acylglycerols efficient energy-storage molecules?**
Ans. Acylglycerols have a high number of carbon-hydrogen bonds, which store large amounts of energy. Their non-polar nature allows them to be stored in specific tissues without dissolving in water.

9. **Why do animal fats store more energy than plant oils?**
Ans. Animal fats have saturated fatty acids, which contain more C-H bonds. In contrast, plant oils contain unsaturated fatty acids with fewer C-H bonds, hence slightly less energy.

10. **What are waxes and what is their function in nature?**
Ans. Waxes are mixtures of long-chain hydrocarbons, fatty acids, alcohols, and ketones, and are solid at room temperature. They act as protective, hydrophobic barriers in plants and animals.

11. **What are some uses of waxes in daily life?**

Ans. Waxes are used for waterproofing paper, furniture polish, and making candles. Colored waxes are used in crayons and colored pencils.

12. **What is the structure of phospholipids and their role in cells?**

Ans. Phospholipids are made from glycerol, two fatty acids, and a phosphate group attached to a nitrogenous base. They are the main components of cell membranes and form lipid bilayers.

13. **What is a terpene and what are some examples?**

Ans. Terpenes are lipids made from isoprene units and are highly diverse in function. Examples include chlorophyll, retinal, vitamin A, and natural rubber.

14. **What are steroids and how are they structured?**

Ans. Steroids are lipids composed of four fused rings: three six-membered and one five-membered. Cholesterol is a common steroid and precursor to many hormones.

15. **What are prostaglandins and what is their biological role?**

Ans. Prostaglandins are modified fatty acids with a five-carbon ring and non-polar tails. They act as local chemical messengers involved in muscle contraction, blood flow, and inflammation.

4.8 NUCLEIC ACIDS

Q 15. What are nucleic acids and what are their main types? Describe the structure and components of nucleotides..

Ans.

Nucleic Acids and Their Types

Nucleic acids are polymers made up of repeating units called nucleotides. They are essential biomolecules responsible for storing and transferring genetic information in all living organisms. There are two major types of nucleic acids:

1. **Deoxyribonucleic Acid (DNA)** – Mostly found in the chromosomes, and also in mitochondria and chloroplasts.
2. **Ribonucleic Acid (RNA)** – Located in the nucleolus, ribosomes, and cytosol.

> In 1950, Linus Pauling concluded that DNA is a fibrous substance and the fibre is coiled into a helix. 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.

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

Structure of Nucleotide

(Describe the molecular level structure of nucleotide.) From Chapter Exercise

A nucleotide is the basic building block of nucleic acids. It consists of three main components:

1. A **nitrogenous base**
2. A **pentose sugar**
3. A **phosphoric acid**

The nitrogenous base and pentose sugar together form a **nucleoside**, which then combines with phosphoric acid to form a **nucleotide**.

> 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 hundredbases.

Types of Nitrogenous Bases

Nitrogenous bases in nucleic acids are divided into two categories:

- **Pyrimidines** (single-ring structure):
  - Cytosine (C): found in both DNA and RNA
  - Thymine (T): found only in DNA
  - Uracil (U): found only in RNA
- **Purines** (double-ring structure):
  - Adenine (A): found in both DNA and RNA
  - Guanine (G): found in both DNA and RNA

Each nitrogenous base attaches to carbon 1 of the pentose sugar to form a nucleoside.

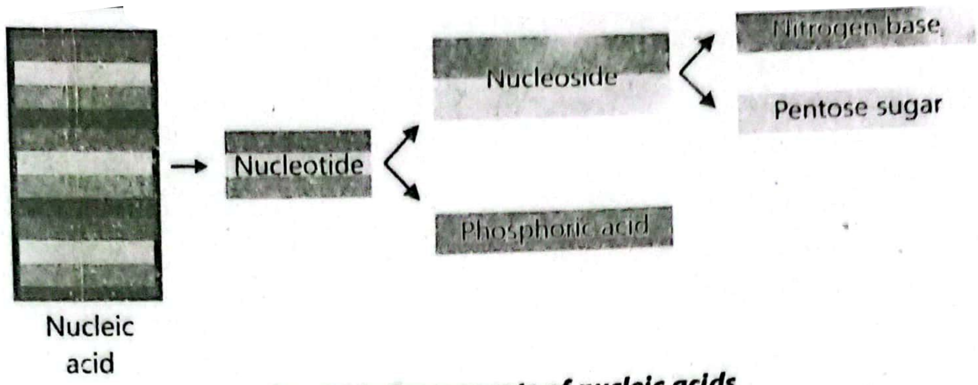


Fig. 4.39: Components of nucleic acids

Q 16. How are nucleotides connected to form nucleic acids? Explain the phosphodiester linkage and polynucleotide chain formation.

Ans. Phosphoric Acid and Ester Linkages

A nucleoside becomes a nucleotide when it forms an ester linkage with phosphoric acid. The phosphoric acid is attached to the carbon 5 (C-5) of the pentose sugar. The backbone of nucleic acids is made of repeating sugar and phosphate units.

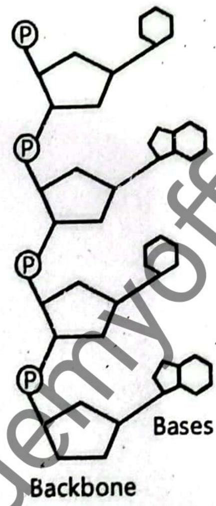


Fig. 4.40: Sugar-phosphate backbone of nucleic acids

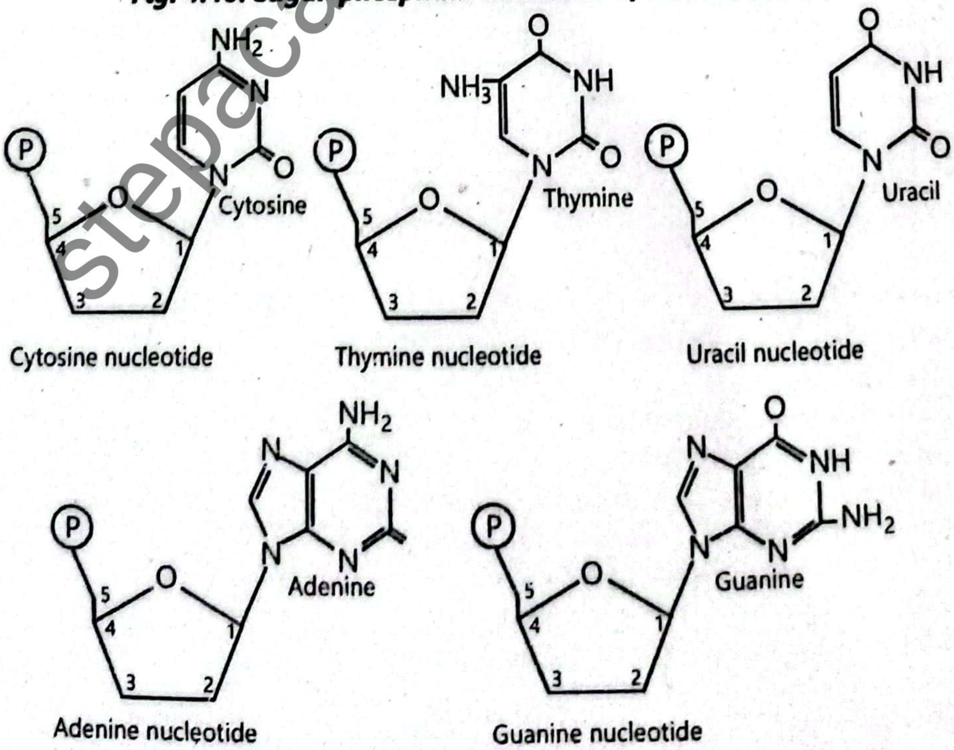


Fig. 4.41: Nucleotides of RNA and DNA

Formation of Phosphodiester Bond

The phosphoric acid in one nucleotide not only forms an ester bond with C-5 of its own sugar but also forms another ester bond with C-3 of the sugar of another nucleotide. This dual linkage is known as a **phosphodiester bond**, which connects successive nucleotides and builds the polynucleotide chain.

Polynucleotide Chains

Nucleotides in DNA are called **deoxyribonucleotides**, while those in RNA are called **ribonucleotides**. They are named based on the nitrogenous base they carry. In a polynucleotide chain, the **5' phosphate end** and **3' hydroxyl end** are always free.

- RNA is composed of a **single polynucleotide chain.**
- DNA is composed of **two polynucleotide chains** that form a **double helix.**

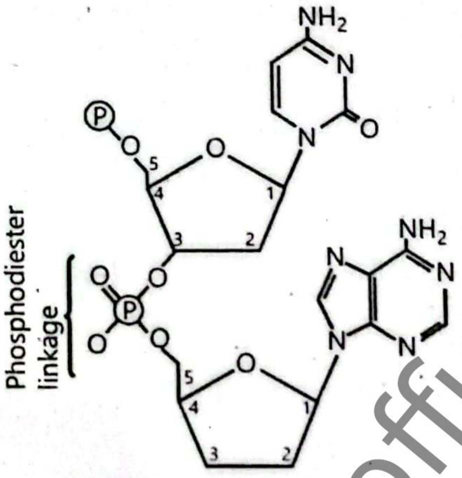


Fig. 4.42: A dinucleotide

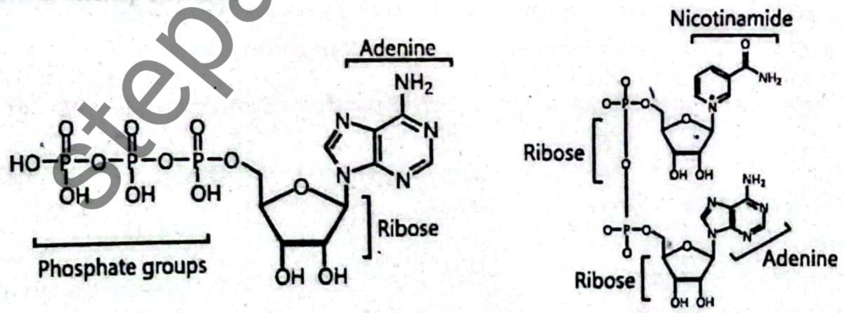
17. What are the roles of special nucleotides such as ATP and NAD in the cell?

Ans. ATP – The Energy Currency

Adenosine Triphosphate (ATP) is a nucleotide consisting of adenine, ribose sugar, and three phosphate groups. ATP serves as the **energy currency** of the cell. Energy is released when ATP successively loses its phosphate groups and converts to **ADP (adenosine diphosphate)** and **AMP (adenosine monophosphate).**

NAD – A Coenzyme

Nicotinamide Adenine Dinucleotide (NAD) is a **co-enzyme** that functions as a **hydrogen acceptor** during oxidation-reduction reactions within the cell.



Adenosine Triphosphate

Nicotinamide Adenine Dinucleotide

Fig. 4.43: ATP and NAD

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

OR Describe the structure of DNA according to Watson and Crick's model. How is DNA organized in different organisms?

Ans. Discovery and Structure

The double helix structure of DNA was first proposed by **James Watson and Francis Crick in 1953**, based on the data from **Rosalind Franklin and Maurice Wilkins**, as well as the base pairing rules discovered by **Chargaff.**

Key Features of DNA Structure

- DNA is composed of **two polynucleotide chains.**
- The two strands twist around each other to form a **double helix**, resembling a twisted ladder.
- The **sugar-phosphate backbone** forms the sides of the ladder.
- The **rungs** of the ladder are formed by **pairs of nitrogenous bases.**

Base Pairing

- A purine always pairs with a pyrimidine.
    - o **Adenine (A)** pairs with **Thymine (T)** via **two hydrogen bonds.**
    - o **Guanine (G)** pairs with **Cytosine (C)** via **three hydrogen bonds.**
- The two strands are **anti-parallel**, meaning they run in opposite directions in terms of their 5' to 3' orientation.

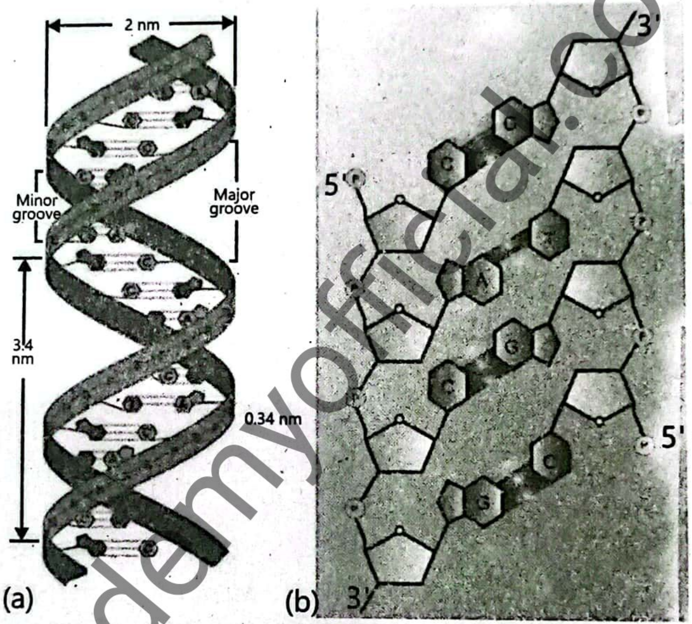


Fig. 4.44: (a) Watson and Crick model of DNA, (b) The detailed structure of DNA

Location of DNA

- In **eukaryotes**, DNA is located in the **nucleus** (mainly in chromosomes).
- In **prokaryotes**, which lack a defined nucleus, DNA is found in the **cytoplasm**.
- In **viruses**, DNA is present as a **core molecule** encased in a **protein coat.**

Q 19. What is the biological significance of DNA? How does DNA control cellular activities?

Ans. DNA is the **hereditary material** in almost all living organisms (except some viruses). It carries the genetic blueprint or "program" that directs all **cellular activities.**

Genes and Protein Synthesis

- A **gene** is a specific sequence of nucleotides in DNA that codes for a **polypeptide (protein).**
- When a gene is turned **"ON"**, its nucleotide sequence is first **transcribed** into RNA.
- This RNA is then **translated** into a specific protein.
- Through this process, DNA indirectly **regulates the structure, function, and behavior of a cell.**

Q 20. Explain the general structure of RNA and differentiate between the three types o

OR What is RNA? Describe its types and their functions.

Ans. RNA (Ribonucleic Acid) is a nucleic acid composed of **ribonucleotides**. It is synthesized during the pro... of **transcription**, where it is formed as a complementary copy of one strand of DNA. There are **three main types of RNA**, each with a specific role in protein synthesis.

1. Messenger RNA (mRNA)

- Consists of a **single strand** of ribonucleotides.
- Its sequence is complementary to one DNA strand.
- It constitutes **3–4%** of total cellular RNA.
- **Function**: Carries the genetic information from DNA to **ribosomes** for protein synthesis.

2. Transfer RNA (tRNA)

- Has a **cloverleaf**-like helical structure.
- Makes up **10–15%** of the cell's RNA.
- **Function**: Transports **amino acids** to the ribosome and aligns them in the correct order during **protein synthesis.**

3. Ribosomal RNA (rRNA)

- Synthesized in the **nucleolus** from DNA.
- Joins with proteins to form **ribosomes.**
- Constitutes about **80%** of the total RNA in the cell.
- **Function**: Acts as a **structural and functional component** of ribosomes, facilitating the synthesis of proteins.

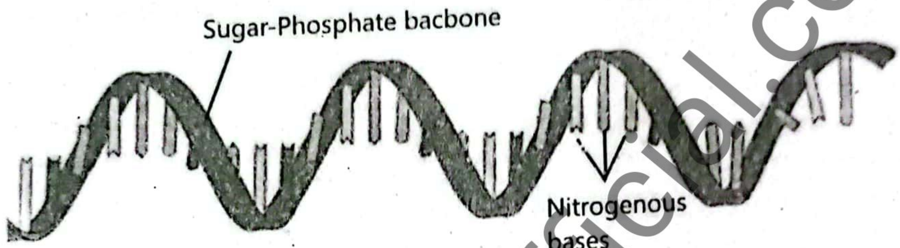


Fig. 4 .45: A model of RNA structure

Q 21. What is the central dogma of molecular biology? Explain transcription and translation.

Ans. The **central dogma** describes the flow of genetic information within a biological system. It explains how DNA directs the synthesis of proteins, which determine the structure and function of a cell.

Steps of Central Dogma

1. **Transcription:**
   - The process by which a segment of DNA is used to produce an **RNA copy.**
   - Occurs in the **nucleus** in eukaryotes.
   - RNA acts as a **messenger** carrying the instructions encoded in DNA.
2. **Translation:**
   - The RNA message is decoded to assemble a specific sequence of **amino acids**, forming a **protein.**
   - Takes place in the **cytoplasm**, usually on **ribosomes.**

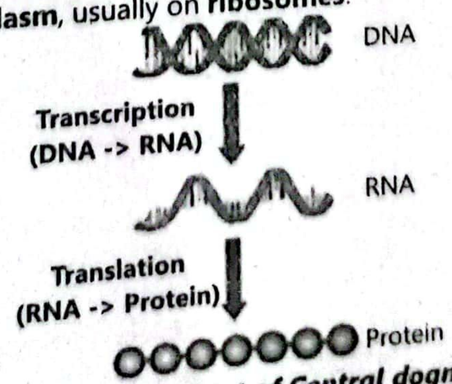


Fig. 4.46: Flow sheet of Central dogma

Through the processes of transcription and translation, **DNA controls the properties and activities of the cell,** ultimately defining the phenotype and functionality of organisms.

MCQs ✓

1. **What are nucleic acids made up of?**
   A. Amino acids B. Fatty acids
   C. Nucleotides✓ D. Monosaccharides

2. **Which sugar is found in DNA?**
   A. Glucose B. Ribose
   C. Fructose D. Deoxyribose✓

3. **Which nitrogenous base is present only in RNA?**
   A. Thymine B. Cytosine
   C. Uracil✓ D. Adenine

4. **Which of the following is a purine base?**
   A. Cytosine B. Thymine
   C. Uracil D. Guanine✓

5. **In which organelles is DNA found apart from the nucleus?**
   A. Lysosomes and ribosomes
   B. Mitochondria and chloroplasts✓
   C. Endoplasmic reticulum and Golgi bodies
   D. Ribosomes and nucleolus

6. **What is the function of mRNA?**
   A. Transport amino acids
   B. Synthesize ribosomes
   C. Carry genetic information from DNA✓
   D. Store lipids

7. **What type of bond connects nucleotides together?**
   A. Peptide bond B. Glycosidic bond
   C. Phosphodiester bond✓
   D. Hydrogen bond

8. **What is the structure of tRNA most similar to?**
   A. Spiral B. Rod
   C. Clover leaf✓ D. Ladder

9. **What is ATP primarily used for in cells?**
   A. DNA synthesis B. Structural support
   C. Energy supply✓ D. Protein digestion

10. **What is the central dogma of molecular biology?**
    A. DNA → Protein → RNA
    B. RNA → DNA → Protein
    C. DNA → RNA → Protein✓
    D. Protein → RNA → DNA

11. **Who proposed the double helix model of DNA?**
    A. Rosalind Franklin B. Chargaff
    C. Watson and Crick✓ D. Avery and McCarty

12 **How many hydrogen bonds form between adenine and thymine?**
    A. One B. Two✓
    C. Three D. Four

13. **Which RNA type is most abundant in the cell?**
    A. mRNA B. tRNA
    C. rRNA✓ D. snRNA

14. **What holds the two DNA strands together?**
    A. Ionic bonds B. Peptide bonds
    C. Hydrogen bonds✓ D. Covalent bonds

15. **What percentage of RNA in the cell is tRNA?**
    A. 3-4% B. 10-15%✓
    C. 50% D. 80%

16. **What kind of sugar is present in RNA?**
    A. Glucose B. Deoxyribose
    C. Ribose✓ D. Maltose

17. **What is a gene?**
    A. A ribosomal structure
    B. A sequence of amino acids
    C. A DNA segment that codes for a polypeptide✓
    D. An RNA fragment

18. **What enzyme is involved in the synthesis of RNA from DNA?**
    A. DNA polymerase
    B. RNA polymerase✓
    C. Ligase
    D. Helicase

19. **Where is rRNA synthesized?**
    A. Cytoplasm B. Ribosomes
    C. Golgi bodies D. Nucleoli✓

20. **Which of the following is NOT a component of a nucleotide?**
    A. Phosphate group B. Nitrogen base
    C. Fatty acid✓ D. Pentose sugar

SQ

1. **What are nucleic acids?**
Ans. Nucleic acids are large biomolecules that are made up of repeating units called nucleotides. They play a crucial role in storing and transmitting genetic information in all living organisms.

2. **What are the two main types of nucleic acids?**
Ans: The two main types of nucleic acids are DNA (Deoxyribonucleic Acid) and RNA (Ribonucleic Acid). Both perform essential functions related to heredity and protein synthesis.

3. **Where is DNA mainly found in a cell?**
Ans. DNA is primarily found in the chromosomes within the nucleus of a cell. However, small amounts of D[illegible] are also present in organelles like mitochondria and chloroplasts.

4. **Where is RNA located in a cell?**
Ans. RNA is found in several parts of the cell including the nucleolus, ribosomes, and cytosol. These locati[illegible] are related to its various functions, especially in protein synthesis.

5. **What are the components of a nucleotide?**

Ans. A nucleotide consists of three components: a nitrogenous base, a pentose sugar (either ribose or deoxyribose), and a phosphate group. These components join together to form the basic unit of nucleic acids.

6. **What is the difference between a nucleotide and a nucleoside?**

Ans. A nucleoside is made up of a nitrogen base and a pentose sugar. When a phosphate group is added to a nucleoside, it becomes a nucleotide.

7. **What are pyrimidine bases?**

Ans. Pyrimidine bases are nitrogenous bases that contain a single ring structure. The main pyrimidine bases are cytosine, thymine (in DNA), and uracil (in RNA).

8. **Which pyrimidine bases are found in DNA and RNA?**

Ans. Cytosine is found in both DNA and RNA. Thymine is found only in DNA, while uracil is found only in RNA.

9. **What are purine bases?**

Ans. Purine bases are double-ring nitrogenous bases found in nucleic acids. The two purines, adenine and guanine, are present in both DNA and RNA.

10. **What type of bond connects phosphoric acid to the pentose sugar?**

Ans. An ester linkage connects the phosphate group to the C-5 carbon of the pentose sugar. This bond is crucial for the formation of the nucleotide structure.

11. **What is a phosphodiester bond?**

Ans. A phosphodiester bond is formed when a phosphate group links the C-5 carbon of one sugar to the C-3 carbon of another sugar. This bond helps join nucleotides into long chains in nucleic acids.

12. **What are ribonucleotides and deoxyribonucleotides?**

Ans. Ribonucleotides are the nucleotide units of RNA, which contain ribose sugar. Deoxyribonucleotides are the nucleotide units of DNA, which contain deoxyribose sugar.

13. **What is ATP and its function?**

Ans. ATP (Adenosine Triphosphate) is a nucleotide that acts as the main energy currency of the cell. It provides energy by losing phosphate groups and converting to ADP or AMP.

14. **What is NAD and its role?**

Ans. NAD (Nicotinamide Adenine Dinucleotide) is a coenzyme involved in redox reactions in the cell. It functions as a hydrogen acceptor, helping in energy metabolism.

15. **What is the structural model of DNA proposed by Watson and Crick?**

Ans. Watson and Crick proposed that DNA consists of two polynucleotide strands arranged in a double helix. The strands are held together by base pairs, forming a ladder-like structure.

16. **What holds the two strands of DNA together?**

Ans. The two strands of DNA are held together by hydrogen bonds between complementary nitrogenous bases. These bonds provide the stability needed for the double helix structure.

17. **Which base pairs are found in DNA and how many hydrogen bonds do they form?**

Ans. Adenine pairs with thymine through two hydrogen bonds, while guanine pairs with cytosine through three hydrogen bonds. This specific pairing ensures accurate DNA replication.

18. **What is a gene?**

Ans. A gene is a specific sequence of DNA nucleotides that contains the instructions for making a particular protein. It plays a key role in determining the traits and functions of an organism.

19. **Name the three types of RNA.**

Ans. The three types of RNA are messenger RNA (mRNA), transfer RNA (tRNA), and ribosomal RNA (rRNA). Each type plays a distinct role in the process of protein synthesis.

20. **What is the central dogma of molecular biology?**

Ans. The central dogma describes the flow of genetic information from DNA to RNA to protein. It involves two main steps: transcription and translation, which together control cellular functions.

4.9 CONJUGATED MOLECULES

22. Define conjugated molecules and describe the roles of common conjugated molecules

OR What are conjugated molecules? Describe the different types of conjugated molecules with examples.

Ans. Introduction to Conjugated Molecules

Conjugated molecules are complex biomolecules that are formed by the combination of two or more different types of molecules, each belonging to different chemical categories. These conjugations result in compounds with unique structures and functions that are essential for the structure and function of biological systems. These molecules often serve important roles in cell membranes, gene regulation, transport, and structural stability.

Some of the most significant types of conjugated molecules include glycoproteins, glycolipids, lipoproteins, and nucleoproteins.

1. Glycoproteins

Structure:

Glycoproteins are formed by a covalent linkage between a protein and a carbohydrate polymer. The carbohydrate chains are often attached to the amino acid side chains of the protein through glycosidic bonds.

Occurrence and Functions:

Glycoproteins are widely distributed in nature and play diverse roles in biological systems. They are found:

- As integral structural components of cell membranes
- In blood serum
- As cellular secretions
- In various body tissues such as cartilage, eyes, and skin

These molecules contribute to cellular recognition, signaling, immune responses, and structural integrity.

2. Glycolipids

Structure:

Glycolipids are formed by the covalent linkage between a lipid and a carbohydrate. The carbohydrate portion is usually a short chain of sugars, and the lipid component helps anchor the molecule in the cell membrane.

Occurrence and Functions:

Glycolipids are essential structural components of cell membranes. They play crucial roles in:

- Maintaining the stability of the cell membrane
- Facilitating cell-cell interactions
- Acting as receptors for certain toxins, viruses, and hormones

3. Lipoproteins

Structure:

Lipoproteins are biomolecular complexes formed by **hydrophobic interactions** (rather than covalent or ionic bonds) between lipids and proteins. These interactions allow the formation of spherical structures that can transport lipids through the aqueous environment of the bloodstream.

Occurrence and Functions:

Lipoproteins serve as the **basic structural framework of all types of plasma membranes**. They are particularly important in the **transport of lipids in the blood**. One common form of lipoprotein involved in lipid transport is **very low-density lipoproteins (VLDLs)**. These molecules are essential for distributing triglycerides and cholesterol throughout the body.

4. Nucleoproteins

Structure:

Nucleoproteins are conjugated molecules formed by **ionic bonds** between chromosomal DNA and proteins. One of the most important examples of nucleoproteins is the association of DNA with **histone proteins**, forming a structure called the **nucleosome**.

Functions:

Nucleoproteins have two major roles in eukaryotic cells:

- **Stabilizing the chromosomal structure:** The interaction between DNA and histones compacts the long DNA molecules so they can fit inside the cell nucleus.

- **Regulating gene expression:** The positioning and modification of histone lay a critical role in turning genes on or off, making nucleoproteins essential in gene regulation mechanisms.

MCQs ✓

1. **What are conjugated molecules composed of?**
   A) Similar molecules only
   B) Molecules from the same category
   C) Two or more molecules from different categories ✓
   D) Only proteins and carbohydrates
2. **Glycoproteins are formed by the linkage of which two components?**
   A) Protein and lipid
   B) Carbohydrate and lipid
   C) Protein and carbohydrate ✓
   D) Lipid and nucleic acid
3. **Where are glycoproteins commonly found?**
   A) Only in the skin
   B) In bones and teeth
   C) In membranes, blood serum, and secretions ✓
   D) Only in the digestive system
4. **Glycolipids are a combination of:**
   A) Lipids and nucleic acids
   B) Proteins and carbohydrates
   C) Lipids and carbohydrates ✓
   D) Proteins and lipid
5. **What type of bond forms glycolipids?**
   A) Ionic bond B) Hydrogen bond
   C) Covalent bond ✓ D) Peptide bond
6. **Lipoproteins are formed through:**
   A) Covalent bonds B) Ionic bonds
   C) Peptide bonds
   D) Hydrophobic interactions ✓
7. **Which of the following is NOT a conjugated molecule?**
   A) Glycoprotein B) Lipid ✓
   C) Glycolipid D) Lipoprotein
8. **Lipoproteins play an important role in:**
   A) Blood clotting
   B) Transporting lipids in blood ✓
   C) Making enzymes D) Digesting carbohydrates
9. **Very low-density lipoproteins (VLDLs) are involved in transporting:**
   A) Glucose B) Water
   C) Triglycerides ✓ D) DNA
10. **Nucleoproteins are made by the combination of:**
    A) Lipids and DNA B) Proteins and RNA
    C) Chromosomal DNA and proteins ✓
    D) Carbohydrates and RNA
11. **What type of bond forms nucleoproteins?**
    A) Covalent bond B) Peptide bond
    C) Ionic bond ✓ D) Hydrogen bond
12. **Histone proteins bind with DNA to form:**
    A) Liposomes B) Enzymes
    C) Nucleosomes ✓ D) Glycoproteins
13. **What is the role of histone proteins in nucleoproteins?**
    A) Energy production B) Digestion
    C) DNA stabilization and gene regulation ✓
    D) Transport of oxygen
14. **Where are glycolipids commonly located?**
    A) Inside the nucleus B) In the cell membrane ✓
    C) In the mitochondria D) In the Golgi apparatus
15. **Glycoproteins serve which of the following functions?**
    A) Only structural B) Only enzymatic
    C) Structural and signaling ✓
    D) Only storage
16. **What kind of interaction holds lipoproteins together?**
    A) Peptide bonds B) Hydrogen bonds
    C) Hydrophobic interactions ✓
    D) Glycosidic bonds
17. **Lipoproteins are the structural framework of:**
    A) Enzymes B) Plasma membranes ✓
    C) Ribosomes D) Chromosomes
18. **Which conjugated molecule is involved in gene expression regulation?**
    A) Glycolipid B) Lipoprotein
    C) Nucleoprotein ✓ D) Glycoprotein
19. **What are nucleosomes?**
    A) Protein-carbohydrate complexes
    B) Lipid transport vesicles
    C) DNA-histone structures ✓
    D) Carbohydrate storage molecules
20. **Which conjugated molecule is most directly related to immune recognition and cellular communication?**
    A) Glycoprotein ✓ B) Lipid
    C) RNA D) DNA

SQ

1. What are conjugated molecules?

Ans. Conjugated molecules are formed by the combination of two or more different types of molecules from separate chemical categories. These combinations allow the resulting molecules to perform specialized structural and functional roles in living organisms.

2. What are glycoproteins composed of?

Ans. Glycoproteins are composed of a covalent linkage between a protein and a carbohydrate polymer. The carbohydrate is usually attached to specific amino acid residues of the protein through glycosidic bonds.

3. **Where are glycoproteins commonly found in the body?**

Ans. Glycoproteins are commonly found in cell membranes, blood serum, and secretions. They are also present in cartilage, eyes, and skin, playing structural and communicative roles.

4. **What are some functions of glycoproteins?**

Ans. Glycoproteins assist in cellular recognition and signaling. They also contribute to structural stability and immune system functioning.

5. **What is a glycolipid?**

Ans. A glycolipid is a conjugated molecule formed by the covalent bonding of a lipid and a carbohydrate. These molecules are typically found in the outer layer of cell membranes.

6. **What is the role of glycolipids in the cell membrane?**

Ans. Glycolipids help maintain membrane stability and facilitate cell recognition. They also act as receptors for specific molecules, including toxins and hormones.

7. **How are lipoproteins formed?**

Ans. Lipoproteins are formed through hydrophobic interactions between lipids and proteins, not through covalent or ionic bonds. This allows them to transport hydrophobic lipid molecules in aqueous environments like blood.

8. **What is the function of lipoproteins in the human body?**

Ans. Lipoproteins play a major role in transporting lipids such as cholesterol and triglycerides in the blood. They are also a fundamental part of plasma membrane structure.

9 **What are very low-density lipoproteins (VLDLs)?**

Ans. VLDLs are a type of lipoprotein that transport lipids in the blood. They are especially involved in moving triglycerides from the liver to other tissues.

10. **What are nucleoproteins made of?**

Ans. Nucleoproteins are formed by ionic bonds between chromosomal DNA and proteins, especially histones. This structure helps in organizing and stabilizing DNA within the cell nucleus.

11. **What is the function of nucleoproteins in eukaryotic cells?**

Ans. In eukaryotic cells, nucleoproteins help stabilize the chromosomal structure. They also play a critical role in regulating gene expression.

12. **How do histone proteins contribute to nucleoproteins?**

Ans. Histone proteins bind to DNA and form nucleosomes, which compact the DNA. This compaction is necessary for fitting the DNA into the nucleus and for regulating access to genetic information.

13. **Why are conjugated molecules important in biology?**

Ans. Conjugated molecules are important because they perform complex and essential functions in biological systems. They contribute to structure, transport, signaling, and gene regulation.

14 **How do conjugated molecules differ from simple molecules?**

Ans. Conjugated molecules consist of different types of biomolecules linked together, providing specialized functions. In contrast, simple molecules consist of only one type of biomolecule and usually have more basic roles.

15. **What is the significance of combining different molecular categories in conjugated molecules?**

Ans. The combination of different molecular categories allows conjugated molecules to carry out multifunctional roles. This structural diversity enables cells to perform complex processes efficiently.

SOLVED EXERCISE

MULTIPLE CHOICE QUESTIONS

Tick (✓) the correct answer.

1. **Which domain of life is characterized by organisms that often inhabit extreme environments and have cell membranes with ether-linked lipids?**
   (a) Bacteria (b) Archaea ✓
   (c) Eukarya (d) Protista
2. **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 ✓
3. **To which group of lipids do the human sex hormones belong?**
   (a) Steroid ✓ (b) Waxes
   (c) Prostaglandins (d) Phospholipids
4. **Which of the following is NOT a protein?**
   (a) Haemoglobin (b) Cholesterol ✓
   (c) Pepsin (d) Antibody
5. **Which one is the largest carbohydrate?**
   (a) Cellulose ✓ (b) Ribose
   (c) Glyceraldehyde (d) Glucose
6. **What compound would be manufactured with difficulty when soil has a shortage of phosphorous?**
   (a) DNA ✓ (b) Fatty acids
   (c) Proteins (d) Cellulose
7. **A compound whose chemical composition is most closely related to maltose is:**
   (a) Starch ✓ (b) Protein
   (c) ATP (d) RNA
8. **Which group is found in all fatty acids?**
   (a) PO_4 (b) SO_4
   (c) C-N (d) COOH ✓
9. **Haemoglobin has:**
   (a) Primary structure (b) Secondary structure
   (c) Tertiary structure (d) Quaternary structure ✓
10. **Which process produces peptide bonds?**
    (a) Digestion (b) Dehydration synthesis ✓
    (c) Hydrolysis (d) Enzyme deactivation

SHORT ANSWER QUESTIONS

1. **Draw a sketch of hydrolysis reactions.**

Ans. Hydrolysis is a chemical reaction where a molecule is broken down into smaller units by the addition of water. It typically breaks bonds such as peptide bonds in proteins or glycosidic bonds in carbohydrates

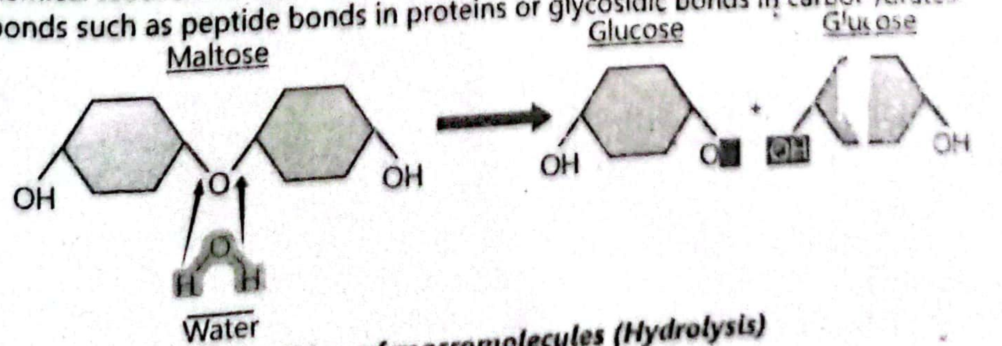
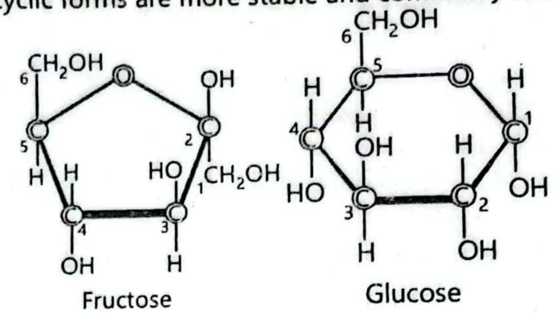


Fig.: Breaking of macromolecules (Hydrolysis)

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

Ans. Glucose usually forms a six-membered ring called a pyranose ring, while fructose forms a five-membered ring called a furanose ring. These cyclic forms are more stable and commonly found in biological systems.



3. **Define isomers and stereoisomers.**

Ans. Isomers are molecules with the same molecular formula but different structural arrangements. Stereoisomers are a type of isomer where atoms are connected in the same order but differ in spatial orientation.

4. **Draw the sketch of amino acid.**

Ans. An amino acid consists of a central carbon atom bonded to an amino group ($-NH_2$), a carboxyl group ($-COOH$), a hydrogen atom, and a variable side chain (R group) that defines each amino acid's unique properties.

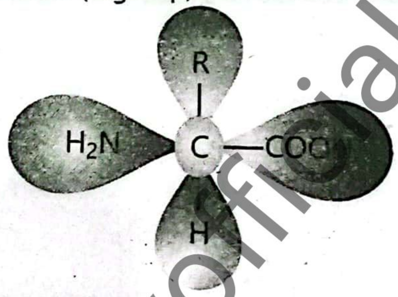


Fig. 4.23: Structure of an amino acid

5. **Outline the synthesis of peptide linkages.**

Ans. Peptide linkages form when the amino group of one amino acid reacts with the carboxyl group of another, releasing a water molecule in a dehydration synthesis reaction. This bond, called a peptide bond, links amino acids into polypeptide chains.

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

Ans. Acylglycerols consist of glycerol bonded to one or more fatty acids. Phospholipids have a glycerol backbone, two fatty acids, and a phosphate group. Terpenes are built from isoprene units and form a large class of hydrocarbons.

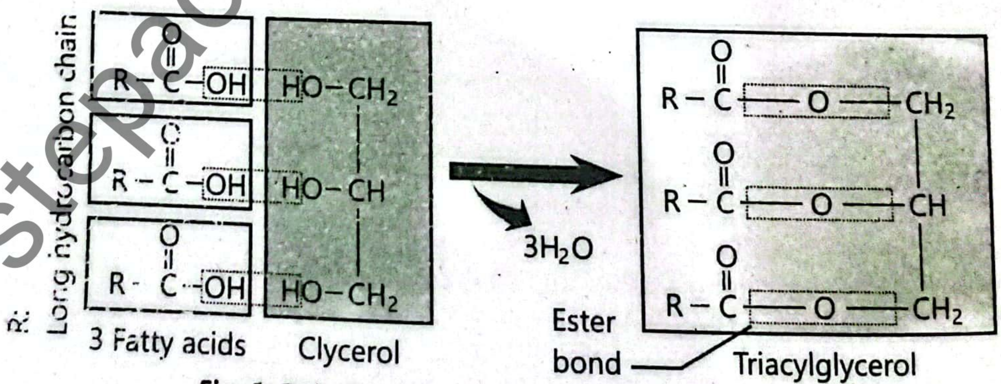


Fig. 1: Dehydration synthesis of a triacylglycerol

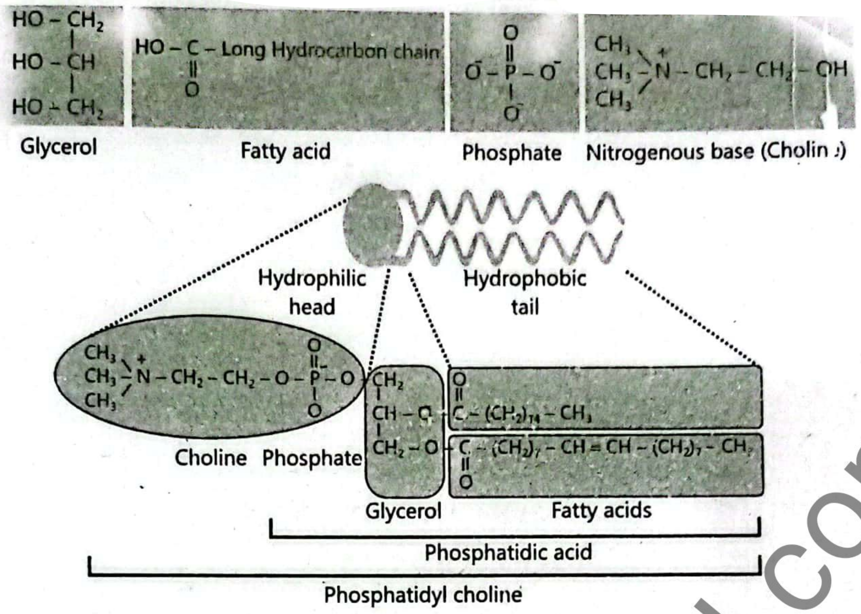
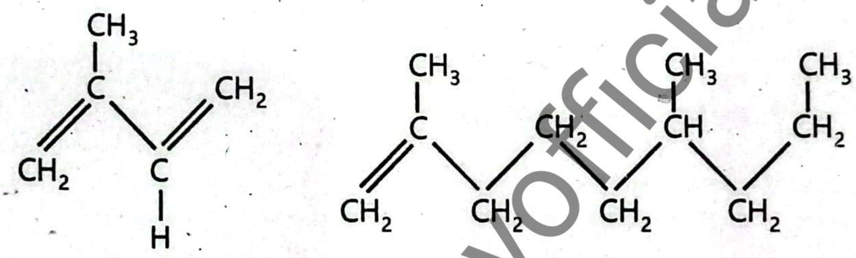


Fig. 2: Phosphatidyl choline – a phospholipid



Isoprene units

Fig. 3: Structure of terpenes

7. **Differentiate between nucleoside and nucleotide.**

Ans. A nucleoside is composed of a nitrogenous base attached to a pentose sugar. A nucleotide is a nucleoside with one or more phosphate groups attached to the sugar.

8. **Illustrate the formation of phosphodiester bond.**

Ans. A phosphodiester bond forms when the phosphate group of one nucleotide links the 3' carbon of one sugar to the 5' carbon of another sugar in the next nucleotide. This bond creates the sugar-phosphate backbone of nucleic acid chains.

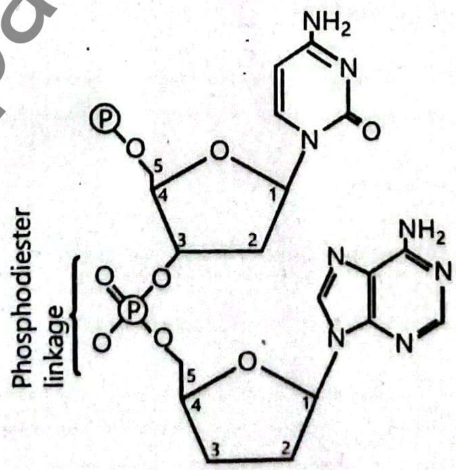


Fig. A dinucleotide

9. State the central dogma of gene expression.

Ans. The central dogma explains the flow of genetic information in a cell from DNA to RNA to protein. It involves transcription, where DNA is copied into RNA, and translation, where RNA directs protein synthesis.

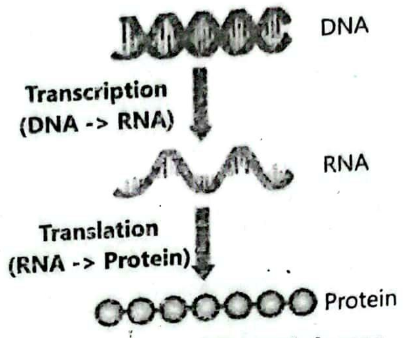


Fig. Flow sheet of Central dogma

LONG QUESTIONS

Q1. Distinguish carbohydrates, proteins, lipids and nucleic acids as the four fundamental biological molecules.

Ans.

1. Carbohydrates

- **Elements**: Carbon (C), Hydroge [illegible] xygen (O)
- **Monomers**: Monosaccharides (e.g., glucose, fructose)
- **Function**:
  - Primary source of **energy** (glucose)
  - Structural components in plants (cellulose) and insects (chitin)
- **Examples**:
  - Glucose, starch, glycogen, cellulose

2. Proteins

- **Elements**: Carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N), sometimes Sulfur (S)
- **Monomers**: Amino acids (20 different kinds)
- **Function**:
  - Structural support (keratin, collagen)
  - Enzymes (catalyze biochemical reactions)
  - Transport (hemoglobin), defense (antibodies), and communication (hormones)
- **Examples**:
  - Enzymes, insulin, hemoglobin, antibodies

3. Lipids

- **Elements**: Carbon (C), Hydrogen (H), Oxygen (O) (less oxygen than carbohydrates)
- **Monomers**: Not true polymers, but composed of **glycerol** and **fatty acids**
- **Function**:
  - Long-term **energy storage**
  - Insulation and protection
  - Structural components of cell membranes (phospholipids)
- **Examples**:
  - Fats, oils, waxes, phospholipids, steroids (e.g., cholesterol)

4. Nucleic Acids

- **Elements**: Carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N), Phosphorus (P)
- **Monomers**: Nucleotides (composed of a sugar, phosphate group, and nitrogenous base)
- **Function**:
  - **Store and transmit genetic information**
  - Direct protein synthesis

- **Examples:**
  - DNA (deoxyribonucleic acid), RNA (ribonucleic acid)

Comparison of carbohydrates, proteins, lipids and nucleic acids

Molecule	Monomer	Elements	Key Functions	Examples
Carbohydrates	Monosaccharides	C, H, O	Quick energy, structure	Glucose, starch
Proteins	Amino acids	C, H, O, N, (S)	Enzymes, structure, transport, defense	Enzymes, antibodies
Lipids	Glycerol & fatty acids	C, H, O	Energy storage, membranes, insulation	Fats, oils, phospholipids
Nucleic Acids	Nucleotides	C, H, O, N, P	Genetic info storage, protein synthesis	DNA, RNA

Q2. Describe and draw sketches of dehydration synthesis reactions.
Ans. See long Question 3 section 4.3.

Q3. Explain how the properties of water make it the medium of life.
Ans. See long question 4 and table 4.2.

Q4. Distinguish the properties and roles of monosaccharides and classify them.
Ans. See long Question 5 section 4.5.

Q5. Compare the structural isomers and stereoisomers of glucose.
Ans. See long Question 5 section 4.5.

Q6. Distinguish the properties and roles of disaccharides.
Ans. See long Question 6 section 4.5.

Q7. Define proteins and amino acids and outline the synthesis and breakage of peptide linkages.
Ans. See long Question 8 section 4.6.

Q8. Justify the significance of the sequence of amino acids through the example of sickle cell haemoglobin.
Ans. Hemoglobin:

The **sequence of amino acids** in a protein is critical because it determines the **protein's three-dimensional structure**, and thus its **function**. Even a **single change** in this sequence can drastically alter the protein's shape and impair its function.

Example: Sickle Cell Hemoglobin

In sickle cell anemia, there is a mutation in the **gene that codes for the β-globin chain** of hemoglobin. Specifically:

- In **normal hemoglobin (HbA)**, the 6th amino acid in the β-chain is **glutamic acid** (a polar, hydrophilic amino acid).
- In **sickle cell hemoglobin (HbS)**, due to a single point mutation in the DNA, **valine** (a non-polar, hydrophobic amino acid) replaces glutamic acid at this position.

Consequences of the Substitution:

- This small change in amino acid sequence causes hemoglobin molecules to **stick together** under low oxygen conditions.
- As a result, red blood cells take on a **rigid, sickle-like shape.**
- These sickled cells are **less flexible**, get stuck in blood vessels, and have a **shorter lifespan**, leading to symptoms like pain, anemia, and organ damage.

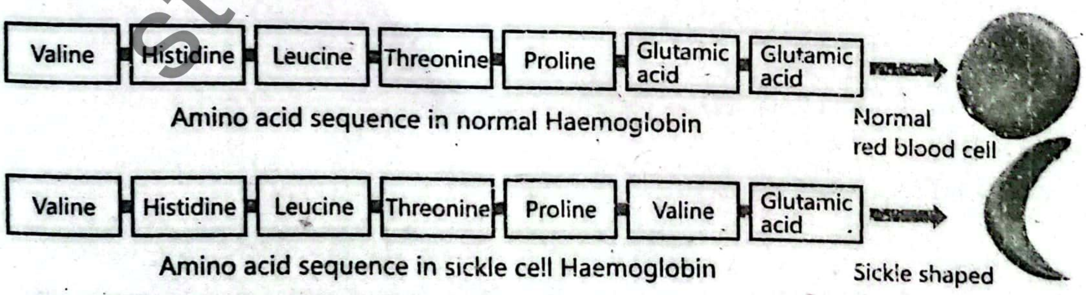


Fig.: Difference in amino acid sequence in normal and sickle cell haemoglobin

Q9. Describe the properties and roles of acylglycerols, phospholipids, terpenes and waxes.
Ans. See section 4.7 Long Q13.

Q10. Describe the molecular level structure of nucleotide.
Ans. See long Q.15 Section 4.8.
Q11. Explain the double helical structure of DNA as proposed by Watson and Crick.
Ans. See long Q.18 Section 4.8.
Q12. Explain the general structure of RNA and differentiate between the three types of RNA.
Ans. See long Q.20 Section 4.8.
Q13. Define conjugated molecules and describe the roles of common conjugated molecules.
Ans. See long Q22 section 4.9

INQUISITIVE QUESTIONS

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

Ans. Even a single amino acid substitution in a polypeptide chain can significantly affect the structure and function of a protein. This is because the sequence of amino acids determines how the protein folds into its functional three-dimensional shape. A change in one amino acid may disrupt this folding, leading to a malfunctioning or non-functional protein.

Example:
A classic example is **sickle cell anemia**, a genetic disorder caused by a single amino acid substitution in the β-globin chain of hemoglobin. In this condition, the amino acid **glutamic acid** is replaced by **valine** at the sixth position of the β-globin chain. This substitution causes hemoglobin molecules to stick together, forming rigid fibers that distort red blood cells into a sickle shape. These misshapen cells can block blood flow and lead to serious health problems.

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

Ans. The three-dimensional (3D) structure of a protein, also known as its **tertiary structure**, is critical to its function. This structure determines how the protein interacts with other molecules. The shape of a protein creates **active sites**, **binding pockets**, or **structural frameworks** necessary for its specific role in the cell.

For example, **enzymes** rely on their 3D structure to form an active site where specific substrates bind and undergo a chemical reaction. If the protein loses its proper shape (a process called **denaturation**, which can occur due to heat, pH changes, or chemicals), it can no longer function properly because the substrate can no longer bind effectively.

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

Ans. Nucleic acids, particularly **DNA**, encode genetic information in the form of a specific sequence of four nitrogenous bases: **adenine (A), thymine (T), cytosine (C), and guanine (G)**. Each group of three bases (called a **codon**) specifies a particular amino acid.

The process of converting genetic information into proteins involves two main steps:

1. **Transcription:** The DNA sequence of a gene is copied into **messenger RNA (mRNA)** in the nucleus.
2. **Translation:** The mRNA travels to the **ribosome**, where it is read in codons. Each codon directs the incorporation of a specific amino acid into a growing polypeptide chain, using **transfer RNA (tRNA)** molecules that bring the correct amino acids.

This entire process, known as the **central dogma of molecular biology**, ensures that the genetic code in DNA is accurately translated into functional proteins.

Self-Assessment Unit 4

Max. Marks: 28 **Time allowed 60 Mins**

Q1. Each of the following question has four options. Select the correct answer. **(10x1=10)**

1. **Which domain of life includes organisms that thrive in extreme environments and possess ether-linked lipids in their membranes?**
(a) Bacteria (b) Archaea (c) Eukarya (d) Protista
2. **Which property of water molecules accounts for most of water's unusual characteristics?**
(a) Their small molecular size (b) Their covalent bonding
(c) Their ability to separate easily (d) Their tendency to cling together
3. **Human sex hormones are classified under which type of lipid?**
(a) Steroids (b) Waxes (c) Prostaglandins (d) Phospholipids
4. **Which of the following is not considered a protein?**
(a) Haemoglobin (b) Cholesterol (c) Pepsin (d) Antibody
5. **Which of these carbohydrates is the most complex and largest in size?**
(a) Cellulose (b) Ribose (c) Glyceraldehyde (d) Glucose
6. **A deficiency of phosphorus in the soil would hinder the production of which biological molecule?**
(a) DNA (b) Fatty acids (c) Proteins (d) Cellulose
7. **Maltose is most chemically similar in composition to which of the following?**
(a) Starch (b) Protein (c) ATP (d) RNA
8. **Which functional group is present in all fatty acid molecules?**
(a) Phosphate (PO_4) (b) Sulfate (SO_4) (c) Carbon-nitrogen (C–N) (d) Carboxyl (COOH)
9. **Haemoglobin exhibits which level of protein structure?**
(a) Primary (b) Secondary (c) Tertiary (d) Quaternary
10. **Which biological process is responsible for the formation of peptide bonds?**
(a) Digestion (b) Dehydration synthesis (c) Hydrolysis (d) Enzyme inactivation

Q2. Write short answers to the following questions. **(5x2=10)**

1. Outline the synthesis of peptide linkages.
2. Differentiate between nucleoside and nucleotide.
3. State the central dogma of gene expression.
4. Define isomers and stereoisomers.
5. What is the function of glycoproteins in cell?

Q3. Write detailed answer to the following question. **(4+4=8)**

1. Distinguish the properties and roles of monosaccharides and classify them.
2. Explain the double helical structure of DNA as proposed by Watson and Crick.