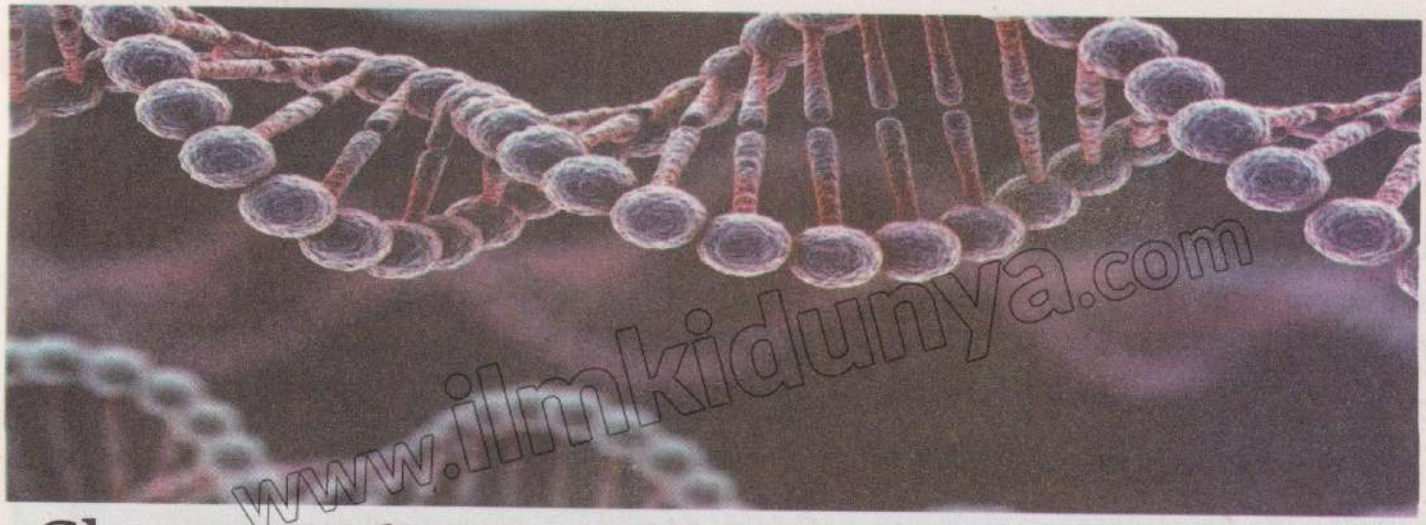


Chapter 6
BIOMOLECULES

After studying this chapter, students will be able to:

- Define biochemistry/ molecular biology.
- Outline the various types of common biomolecules (Carbohydrates, Proteins, Lipids, DNA, RNA) including their locations inside the cell and main roles.
- Define carbohydrates and outline the structure, function and sources of carbohydrates.
- Identify carbohydrates as monosaccharides, disaccharides and polysaccharides.
- Outline the structure and function and sources of proteins with structure of amino acids.
- Outline the structure, function and sources of lipids.
- Describe briefly the structure of DNA.
- Outline the function of DNA as carrier of hereditary information.
- Describe briefly the structure of RNA.
- Outline the function of RNA as aid in converting hereditary information into proteins.
- Outline how information in the DNA is converted to information on RNA and then into proteins.

Biochemistry is the study of the chemical processes that occur within living organisms (e.g., photosynthesis, cellular respiration). Molecular biology is the study of the structure and function of the biomolecules (e.g., carbohydrates, proteins, nucleic acids). This chapter digs into the fascinating world of biomolecules.

6.1- BIOMOLECULES

The molecules produced by organisms are called biomolecules or biological molecules. They include carbohydrates, lipids, proteins, and nucleic acids (DNA and RNA). They are mostly large in size and are called macromolecules. Biomolecules play crucial roles in the structure and functions in organisms. The following table mentions important biomolecules and their functions.

Table: Major Biomolecules and their Functions

Biomolecule	Location in the cell	Main Functions
Carbohydrates	• Cytoplasm • Cell membrane	• Act as source of energy • Act as energy storage molecules
Proteins	• Cell membrane • Cytoplasm • Endoplasmic reticulum • Golgi apparatus • Lysosome, mitochondria	• Many proteins act as enzymes • Some hormones are proteins • Make membranes and many other structures in cells • Control cellular traffic
Lipids	• Cell membrane • Cytoplasm	• Act as energy storage molecules • Act as heat insulators • Make structure of cell membrane
DNA (Deoxyribonucleic Acid)	• Nucleus (eukaryotes) • Nucleoid region (prokaryotes) • Mitochondria • Chloroplasts	• Carries genetic information for the development, functioning, and characteristics of organism
RNA (Ribonucleic Acid)	• Nucleus • Ribosomes • Cytoplasm	• Carries genetic information from DNA to ribosome for protein synthesis

Biomolecules make the 93% of the dry mass of protoplasm. The remaining 7% of dry mass comprises of vitamins and inorganic substances like carbon dioxide, acids, bases and salts.

Table: Percentage of Biomolecules in the Dry Mass of Protoplasm

Biomolecules	% Dry mass
Proteins	50
Nucleic acids	18
Carbohydrates	15
Lipids	10

All the chemical reactions that occur in an organism are collectively called **metabolism**. Metabolism can be divided into two main categories: anabolism and catabolism. **Anabolism** is the type of metabolism in which simpler substances are combined to form complex substances. Energy is used in these reactions. **Catabolism** is the type of metabolism in which complex molecules are broken down into simpler ones. Energy is released in these reactions.

6.2- CARBOHYDRATES

"Carbohydrate" means 'hydrated carbons'. They are the organic compounds in which the ratio of H and O is 2:1 (same as in water). They are also known as "Saccharides" (meaning sugar). They have the general formula $C_n(H_2O)_n$ where n is the number of carbon atoms. There are three classes of carbohydrates: monosaccharides, disaccharides, and polysaccharides.

1. Monosaccharides

Monosaccharides (simple sugars) are made of single sugar molecule. They are easily soluble in water and have sweet taste. They may have 3 to 7 carbon atoms. Pentoses (5 C) and hexoses (6 C) are most common.

Examples:

- Ribose ($C_5H_{10}O_5$) and deoxyribose ($C_5H_{10}O_4$) are pentoses.
- Glucose, fructose, and galactose are hexoses ($C_6H_{12}O_6$).

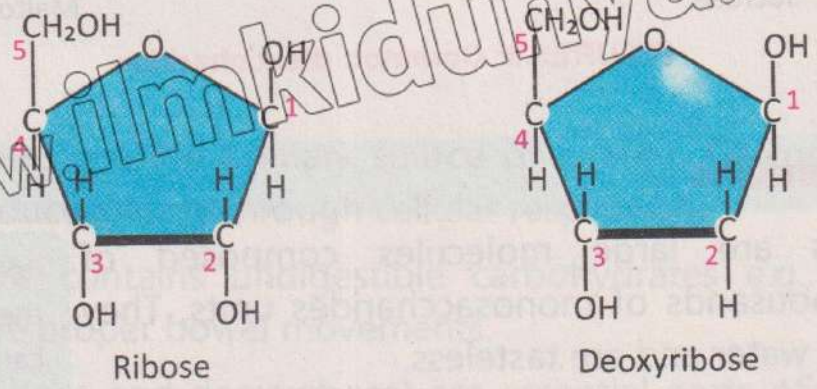


FIGURE 6.1: Common pentoses

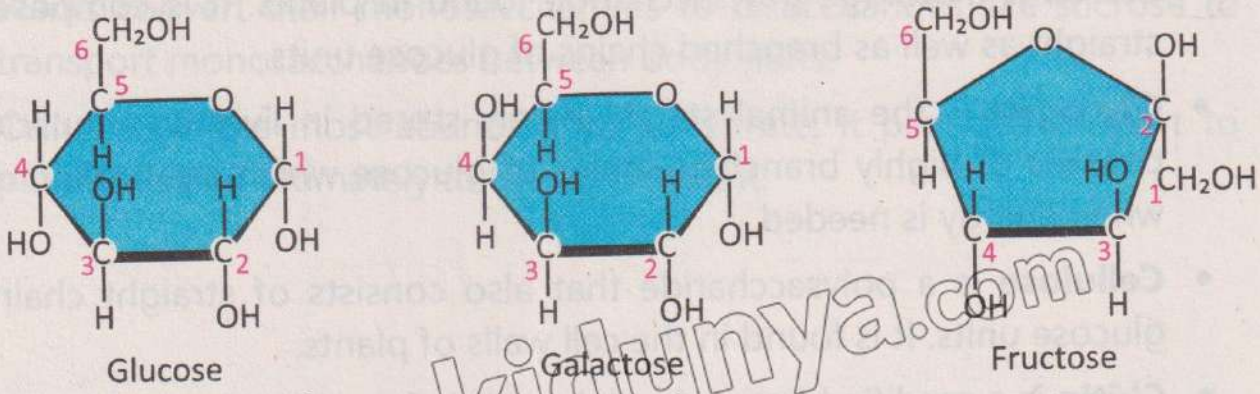


FIGURE 6.2: Common hexoses

2. Disaccharides

They are made of two monosaccharides units. They are less soluble in water and are less sweet in taste.

Examples:

- **Sucrose** (table sugar) is made of two monosaccharides i.e., glucose and fructose.
- **Maltose** is made of two glucose molecules.

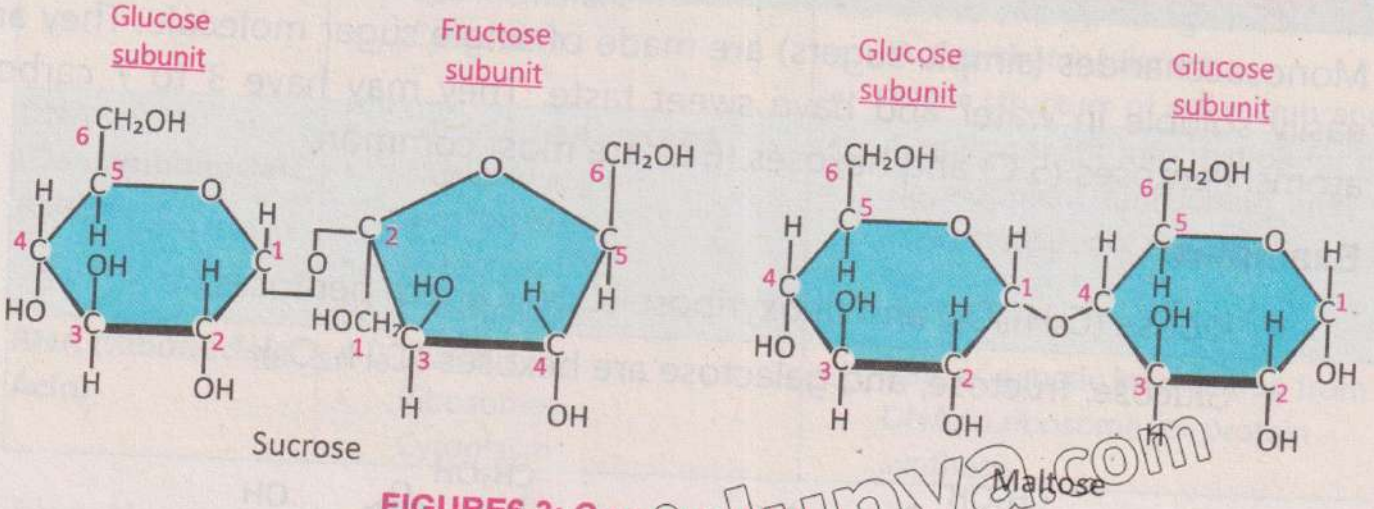


FIGURE6.3: Common disaccharides

3. Polysaccharides

Polysaccharides are large molecules composed of hundreds to thousands of monosaccharides units. They are insoluble in water and are tasteless.

Polysaccharides are the most abundant carbohydrates in nature.

Examples:

- **Starch** is a storage polysaccharide found in plants. It is composed of straight as well as branched chains of glucose units.
- **Glycogen** is the animal starch mainly stored in liver and muscles. It consists of highly branched chains of glucose which are broken down when energy is needed.
- **Cellulose** is a polysaccharide that also consists of straight chains of glucose units. It is found in the cell walls of plants.
- **Chitin** is a modified form of cellulose. It is found in the exoskeletons of crabs, lobsters and insects. It also makes the cell wall of fungi.

FIGURE 6.4: Polysaccharides

Sources and Functions of Carbohydrates

Sources:

- **Monosaccharides:** Glucose, fructose and galactose are found in fruits, vegetables, honey and cereals.
- **Disaccharides:** Sucrose is found in sugar beet, sugar cane and fruits. Lactose is found in milk and dairy products. Maltose is found in cereals.
- **Polysaccharides:** Starch is found in cereal crops; wheat, barley, maize, rice etc.

Functions:

- Carbohydrates are the primary source of energy. Glucose is used by cells to produce energy through cellular respiration.
- Dietary fibre contains undigestible carbohydrates e.g., cellulose. It helps for the proper bowel movements.
- Pentoses (ribose and deoxyribose) are essential parts of nucleic acids (RNA and DNA respectively).
- Plants convert their monosaccharides to disaccharides like sucrose to transport monosaccharides between body parts.
- Cellulose is the most abundant carbohydrate. It provides support to plant cells and ultimately to the whole plant.

6.3- PROTEINS

Proteins are the most abundant biomolecules in cell. They are defined as the polymers of amino acids. Proteins are important for the structures of cells. They also participate in everything organisms do.

Structure of Proteins

Proteins are made up of monomers called **amino acids** Different proteins contain different numbers of amino acids. For example, insulin protein has 51 amino acids and haemoglobin has 574 amino acids.

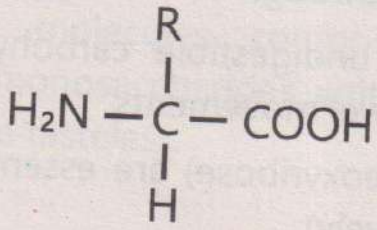
Amino acids

Amino acids are the organic molecules that join in specific number and sequence to make proteins. About 170 types of amino acids occur in organisms. However, 20 types of amino acids participate in making most of the proteins.

Essential amino acids: These are the 09 amino acids which cannot be synthesized by our body and are supplied by foods.

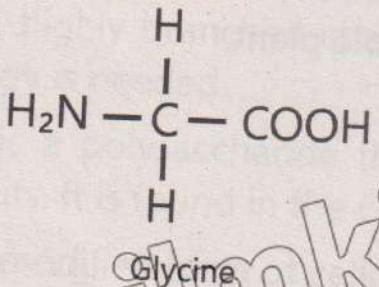
Non-essential amino acids: These are 11 amino acids that can be synthesised in our bodies.

An amino acid is an organic molecule made of an amino group (NH_2), a carboxyl group (COOH), a hydrogen group (H) and a side group (R) which are attached to a central carbon atom:

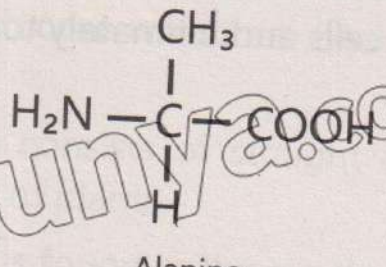


Amino acid - general structure

Different amino acids contain different side groups. For example, in amino acid glycine the side group is H and in amino acid alanine, the side group is CH_3.



Glycine



Alanine

Sources and Functions of Proteins

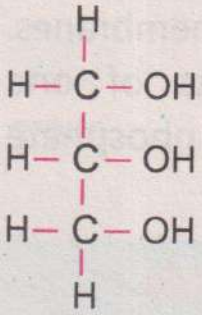
Good sources of protein include meat (mutton, beef, chicken), fish, eggs, milk, pulses, beans etc. Proteins perform various functions in our bodies, including:

- Proteins are an important part of all cell membranes.
- Some proteins e.g. collagen and keratin make almost whole structures of cartilage, hair, and nails.
- Enzymes are proteins that catalyse all biochemical reactions occurring in organisms.
- Some proteins are hormones. They regulate body processes.
- Haemoglobin protein transports oxygen in the blood.
- Actin and myosin proteins are the main components of muscle cells. They are responsible for muscular contractions.
- Fibrin is a blood clotting protein that makes blood clot to prevent the loss of blood after an injury.
- Some proteins called antibodies (part of our immune system) defend the body against harmful pathogens.

6.4- LIPIDS

Lipids are organic compounds that are insoluble in water but are soluble in organic solvents (e.g., alcohol, ether, benzene). They are composed of glycerol and fatty acids.

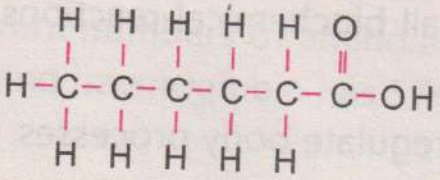
Glycerol is an alcohol having 3 carbon atoms. Each carbon has a hydroxyl group.



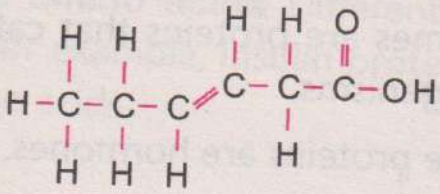
Glycerol

Fatty acids are long hydrocarbon chains with carboxyl group (COOH) at the end. There are two types of fatty acids:

- **Saturated fatty acids** have internal carbon atoms bonded with maximum number of hydrogen atoms. They do not have double bonds between carbon atoms. Saturated fatty acids are solid at room temperature.
- **Unsaturated fatty acids** have one or more double bonds between carbon atoms. They are liquid at room temperature.



Saturated fatty acid

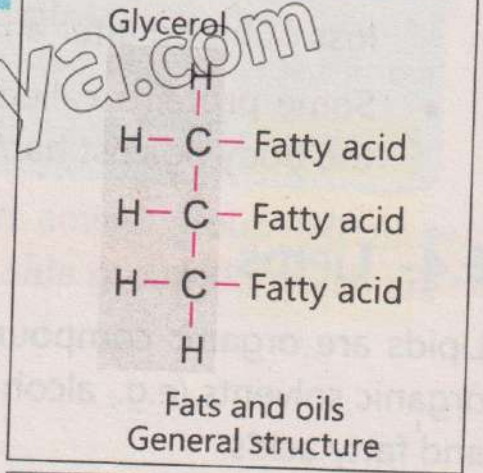


Unsaturated fatty acid

Main Groups of Lipids

1- Fats and Oils

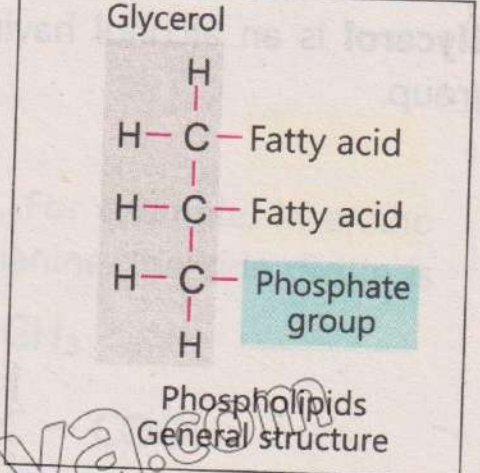
Fats and oils are the most familiar lipids. They contain one glycerol and three fatty acids. Fats contain saturated fatty acids and so are solid at room temperature e.g., animal fats. On the other hands, oils contain unsaturated fatty acids and so are liquid at room temperature e.g., plant oils such as olive oil, corn oil, and coconut oil.



Fats and oils
General structure

2- Phospholipids

These lipids make the core of all membranes. A phospholipid molecule consists of one glycerol, two fatty acids and a phosphate group.



Phospholipids
General structure

Sources and Functions of Lipids

Sources

Sources of lipids from animals are meat and dairy products, while the sources of lipids from plants are nuts, seeds, olive oil etc. Plants synthesize oils and

store them in seeds, such as sunflower oil, coconut oil, groundnut oil and corn oil.

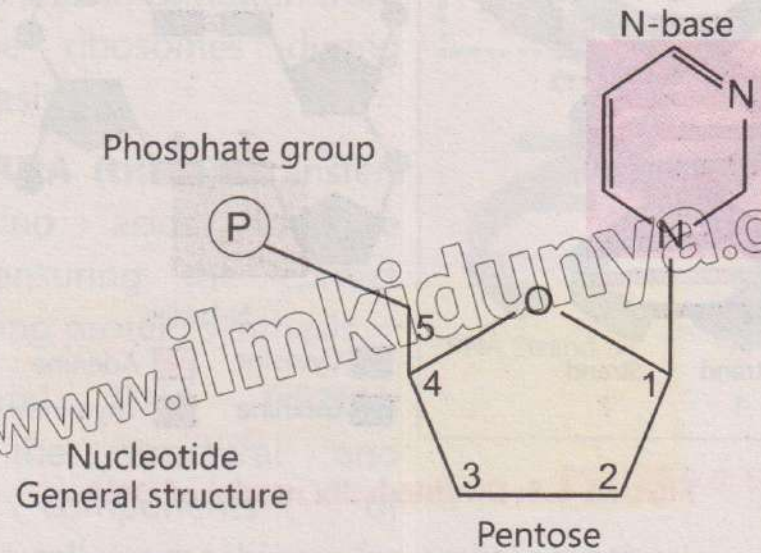
Functions

- Lipids are the most energy-rich biomolecules. They serve as a long-term energy reserve in the form of fats in adipose tissues. When the body requires energy, these stored lipids are broken down to release fatty acids and glycerol, which can be used as fuel for energy.
- Lipids are essential components of cell membranes.
- Lipids act as insulators and protect vital organs. For example, adipose tissue surrounding organs provides cushioning and heat insulation.
- Some lipids help in the synthesis of hormones. Steroid hormones are derived from a lipid i.e., cholesterol.
- Lipids help in the absorption of fat-soluble vitamins (A, D, E, and K) in the digestive system.

6.5- Nucleic Acids

Nucleic acids are the biomolecules that are composed of units called nucleotides. A nucleotide is made up of three components:

1. Pentose sugar (ribose or deoxyribose)
2. Nitrogenous base
3. Phosphate group (PO_4)



Nucleotide
General structure

Pentose

There are two types of nucleic acids:

1- Deoxyribonucleic Acid (DNA)

DNA is made of deoxyribonucleotides (de-oxy-ribo-nucleotides). In this nucleotide, the pentose sugar is deoxyribose while the nitrogenous base may be adenine (A), thymine (T), cytosine (C), or guanine (G).

In 1953, US biologist James Watson and British biologist Francis Crick proposed the double helix model of DNA. According to this model:

In 1962, James Watson and Francise Crick received Nobel prize for the discovery of the double helix structure of DNA.

- DNA is a double helix molecule. It is made of two strands of nucleotides.
- Both strands are coiled around each other.
- The nitrogenous bases of one strand make hydrogen bonds with the nitrogenous bases of the opposite strand.

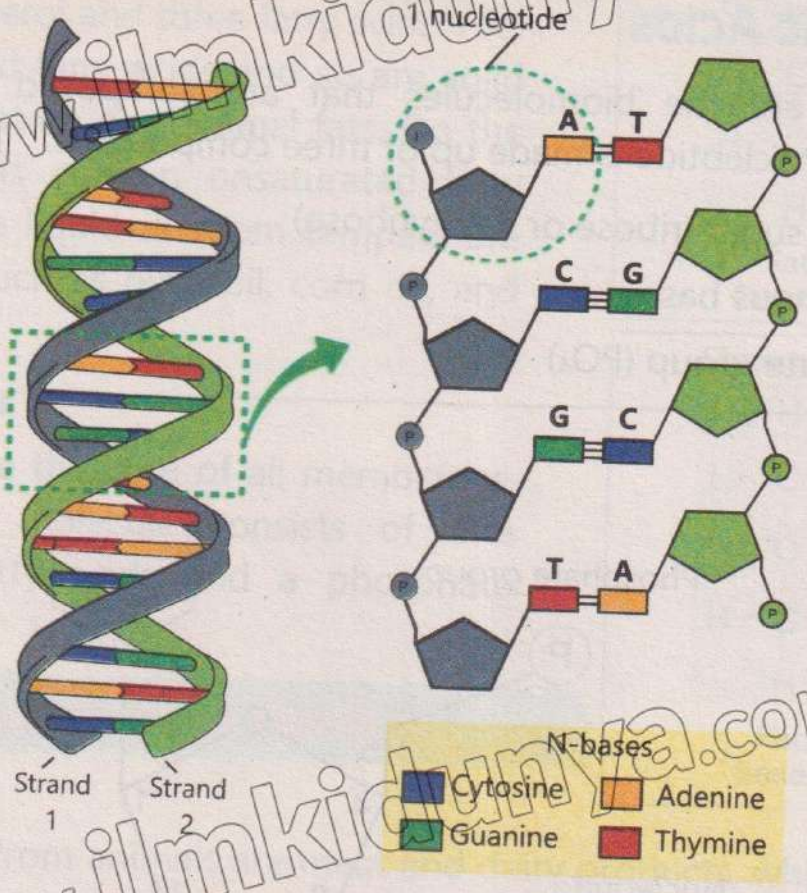


FIGURE 6.5: Double helix model of DNA

- The paring of nitrogenous bases is specific i.e., adenine of one strand forms a pair with thymine of opposing strand. Similarly, cytosine forms a pair with guanine.
- There are two hydrogen bonds between adenine and thymine and three hydrogen bonds between cytosine and guanine.

Function of DNA

DNA contains the hereditary information. This information is in the form of a sequence of nucleotides. This sequence determines the order of amino acids during protein synthesis.. The segment of DNA in which the sequence of nucleotides determines the synthesis of a protein (polypeptide chain) is called a gene. During reproduction, DNA is passed from one generation to the next. In this way, DNA carries the heredity information to the next generation.

2- Ribonucleic Acid (RNA)

RNA is single-stranded. Its strand consists of ribonucleotides. A ribonucleotide contains ribose sugar instead of deoxyribose. In a ribonucleotide, the nitrogenous base may be adenine (A), uracil (U), cytosine (C), or guanine (G). There are three types of RNA:

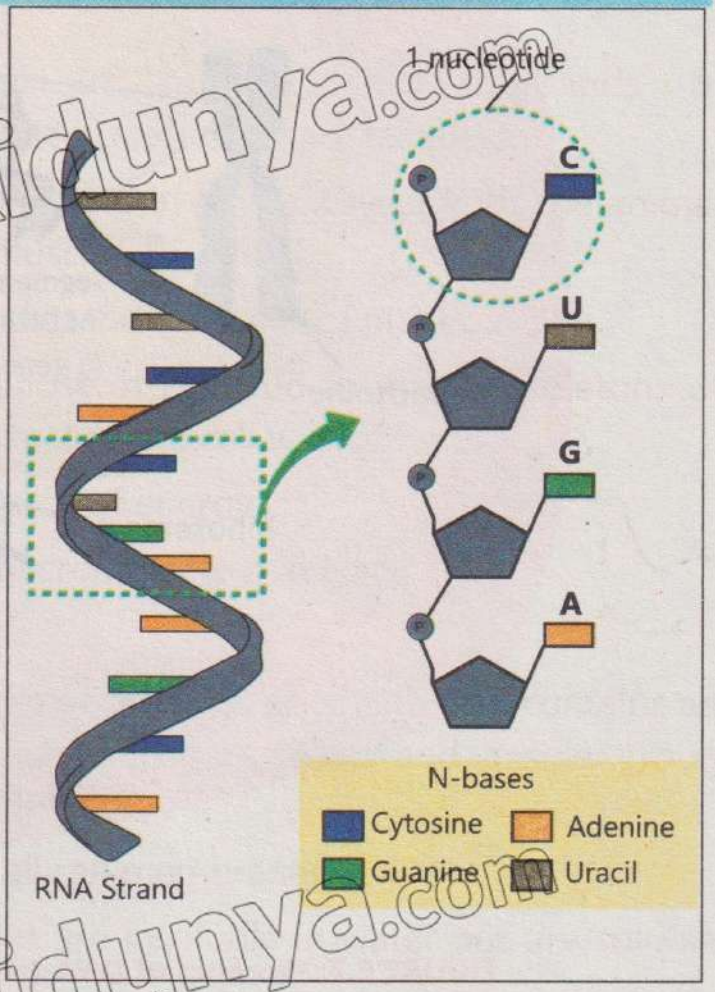


FIGURE 6.6: Structure of RNA

a. Messenger RNA (mRNA): Carries the genetic information from DNA to the ribosomes during protein synthesis.

b. Transfer RNA (tRNA): Transfers specific amino acids to the ribosomes, ensuring the correct sequence during protein synthesis.

c. Ribosomal RNA (rRNA): Constitutes the structural and functional components of ribosomes, the cellular machinery for protein synthesis.

6.6- THE WORKING OF DNA AND RNA

The DNA molecule in a chromosome consists of thousands of nucleotides. Along the length of DNA molecule, there are specific segments called genes. Each gene consists of specific sequence of nucleotides that carries information for the synthesis of a specific protein.

During the working of a gene, the specific sequence of DNA nucleotides is copied. This copy is in the form of a molecule of messenger RNA (mRNA). The process of making mRNA copy of DNA is called **transcription**. The mRNA carries the sequence of its nucleotides to the ribosome. The ribosome reads this sequence and joins specific amino acids to form a protein. This step is known as **translation**.

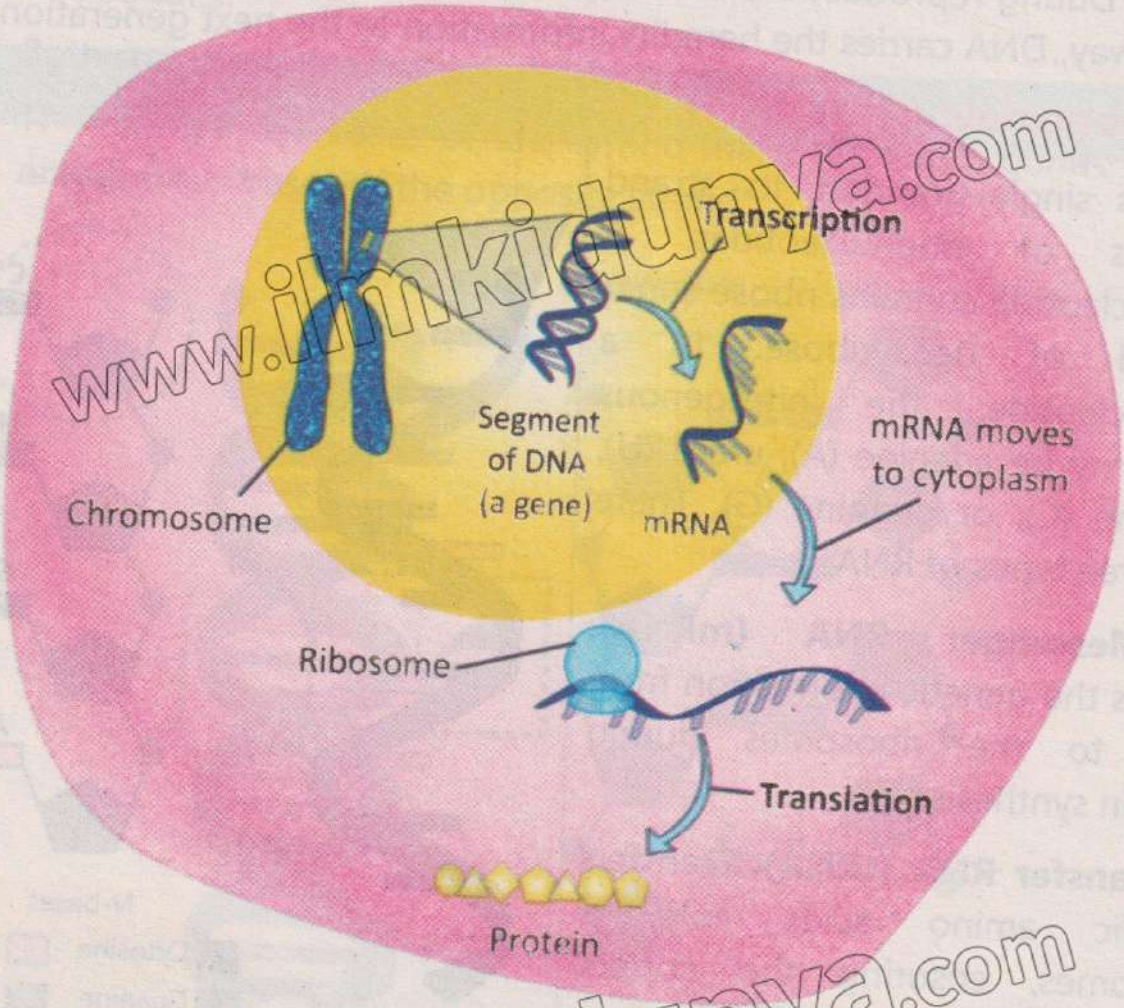


FIGURE 6.7: Working of DNA (also called the Central Dogma)

KEY POINTS

- Biochemistry is the study of the substances and chemical processes that occur within living organisms.
- Molecular biology is the study of the structure and function of the biomolecules.
- Biomolecules are the molecules produced by organisms. They include carbohydrates, lipids, proteins, and nucleic acids.
- Carbohydrates are organic compounds composed of carbon, hydrogen, and oxygen in which the ratio of H and O is 2:1 (same as in water).
- Monosaccharides are made of single sugar molecule. They are easily soluble in water and have sweet taste.
- Disaccharides are made of two monosaccharides. They are less soluble in water and are less sweet in taste.
- Polysaccharides are composed of hundreds to thousands of monosaccharides. They are insoluble in water and are tasteless.
- Starch is a storage polysaccharide found in plants. Glycogen is the animal starch mainly stored in liver and muscles.
- Cellulose is a polysaccharide found in the cell walls of plants.
- Chitin is a modified form of cellulose. It is found in the exoskeletons of crabs, lobsters and insects. It also makes the cell wall of fungi.
- Carbohydrates are the primary source of energy.
- Proteins are the most abundant macromolecules in a cell.
- Proteins are made of amino acids.
- Amino acids are the building blocks of proteins; an amino acid contains an amino group, a carboxyl group, a hydrogen group and a side group attached to a central carbon atom.
- Proteins are an important part of all cell membranes.
- Lipids are organic compounds that are insoluble in water but are soluble in organic solvents.
- Saturated fatty acids have single bond in carbon-to-carbon atoms

- Unsaturated fatty acids have one or more double bonds between carbon atoms.
- Lipids serve as a long-term energy reserve in the form of fats in adipose tissues.
- Lipids are essential components of cell membranes.
- DNA is a double-stranded molecule while RNA is a single-stranded molecule. Both DNA and RNA are composed of nucleotides.
- Each nucleotide of DNA consists of a deoxyribose sugar, a phosphate group, and one of four nitrogenous bases: adenine (A), thymine (T), cytosine (C), and guanine (G).
- Each nucleotide of RNA consists of a ribose sugar, a phosphate group, and one of four nitrogenous bases: adenine (A), Uracil (U), cytosine (C), and guanine (G).
- The copying of a specific sequence of DNA nucleotides in the form of messenger RNA (mRNA) is called transcription.
- Ribosome reads the nucleotide sequence of mRNA and joins specific amino acids according to it to form a protein. It is known as translation.

EXERCISE

A. Select the correct answers for the following questions.

1. What is the primary function of carbohydrates?
   a) Provide energy
   b) Act as enzymes
   c) Regulate processes
   d) Make membranes
2. How will you differentiate between monosaccharides and polysaccharides?
   a) Monosaccharides are single sugars.
   b) Polysaccharides are sweet in taste.

c) Monosaccharides are present in plant cell wall.
d) Polysaccharides dissolve easily.

3. What is true about cellulose?
   a) It is sweet in taste.
   b) It is digestible by human digestive system.
   c) It provides structural support in plants.
   d) It is soluble in water.
4. Which of the following proteins is involved in oxygen transport?
   a) Insulin
   b) Haemoglobin
   c) Collagen
   d) Keratin
5. Which component of an amino acid determines its unique properties?
   a) Amino group
   b) Carboxyl group
   c) R group (side group)
   d) Hydrogen group
6. Which proteins are involved in defence against pathogens?
   a) Antibodies
   b) Myosin
   c) Fibrinogen
   d) Haemoglobin
7. Which of the following are the units of most lipids?
   a) Amino acids
   b) Fatty acids and glycerol
   c) Nucleotides
   d) Simple sugars
8. How do unsaturated fatty acids differ from saturated fatty acids?
   a) They have more hydrogen atoms.
   b) They contain double bonds in their hydrocarbon chains.
   c) They are solid at room temperature.
   d) They are found only in animal fats.
9. Which of the following is NOT a function of proteins?
   a) Transport oxygen in the blood.
   b) Carry genetic information.
   c) Help in digesting food.
   d) Fight against pathogens.
10. Which components make up a nucleotide?
    a) Sugar, phosphate, nitrogenous base
    b) Amino acid, sugar, nitrogenous base
    c) Fatty acid, phosphate, nitrogenous base
    d) Protein, sugar, nitrogenous base

11. Which nitrogenous base is found in RNA but not in DNA?

a) Adenine
b) Thymine
c) Uracil
d) Guanine

B. Write short answers.

1. What are the main functions of carbohydrates in the body?
2. How do the three group of carbohydrates differ in taste?
3. Name two common monosaccharides and two disaccharides.
4. Which monosaccharides make a sucrose molecule?
5. Give an example of a storage polysaccharide in plants.
6. Define amino acid and draw its structure.
7. What are the basic components of lipids? Draw their structures.
8. What are the types of RNA? Write their functions.
9. Briefly describe the function of DNA.

C. Write answers in detail.

1. Write a comprehensive note on the structures and roles of the three classes of carbohydrates.
2. Discuss the functions of proteins.
3. What are fatty acids? Explain their types.
4. Describe the basic structure of fats and oils. Explain how lipids play role in energy storage.
5. Explain the double helix structure of DNA, and discuss the base pairing in this structure.
6. Explain how the information in DNA is converted to RNA and then to proteins.

D. Inquisitive questions.

1. Evaluate the importance of water in the functioning of biomolecules.
2. Find the amount/ percentage of carbohydrates, Proteins, Fats and water in the following food product and compare them with each other.
   Roti(40gm), Burger, Cucumber, Egg, Rice(100gm), Potato fries(100gm),Carrot