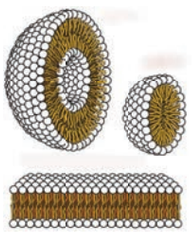
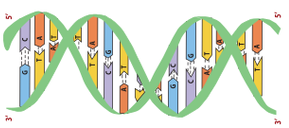
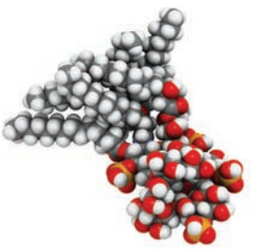
Unit 2 BIOMOLECULES



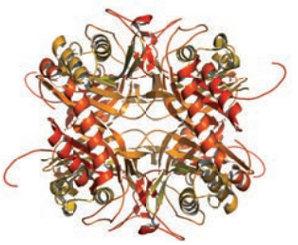
Lipids



Nucleic Acids



Carbohydrates



Proteins

Friedrich Wöhler

Friedrich Wöhler was a German chemist best known for his synthesis of urea from ammonium cyanate in 1828 (Wohler synthesis), which was the first synthesis of an organic chemical compound from an inorganic one; it contributed to the foundation of modern organic chemistry.

Learning Objectives

After studying this unit, students will be able to

- Classify the different biomolecules.
- Describe the importance of carbohydrates.
- Distinguish monosaccharides, oligo saccharides and polysaccharides.
- Classify various types of proteins.
- Explain the functions of proteins.
- Classify various types of lipids.
- Explain the biological functions of lipids.
- Describe the biological functions of nucleic acids.
- Differentiate between DNA and RNA.

Introduction:

All the major components of the cells are made up of four types of macromolecules namely carbohydrates, proteins, lipids and nucleic acids. These molecules are called biomolecules. In this unit, we will see the overview of these biomolecules. Detailed information about these molecules are discussed in the subsequent chapters

2.1 Carbohydrates

Carbohydrates, otherwise known as saccharides (derived from the Greek Sakcharon– sugar; many simple sugars taste sweet) are one of the abundant molecules in earth. They are essential to maintain life in both plants and animals. They are synthesised in plants by photosynthesis.

$$x\,CO_2 + y\,H_2O \xrightarrow{sunlight} C_x(H_2O)_y + xO_2$$

The compounds that we come across in our daily life such as table sugar, wood, cotton, starch, and honey etc... are all carbohydrates.

2.1.1 Importance

Carbohydrates are widely distributed in both plant and animal tissues. They occur as food reserves in the storage organs of plants and animals. They are the important source of energy which is required for the various metabolic activities of living organisms.

They provide raw material for many important industries including textiles, artificial silks, paper, films, plastics, lacquers, confectionary, drugs, fermentation and explosives.

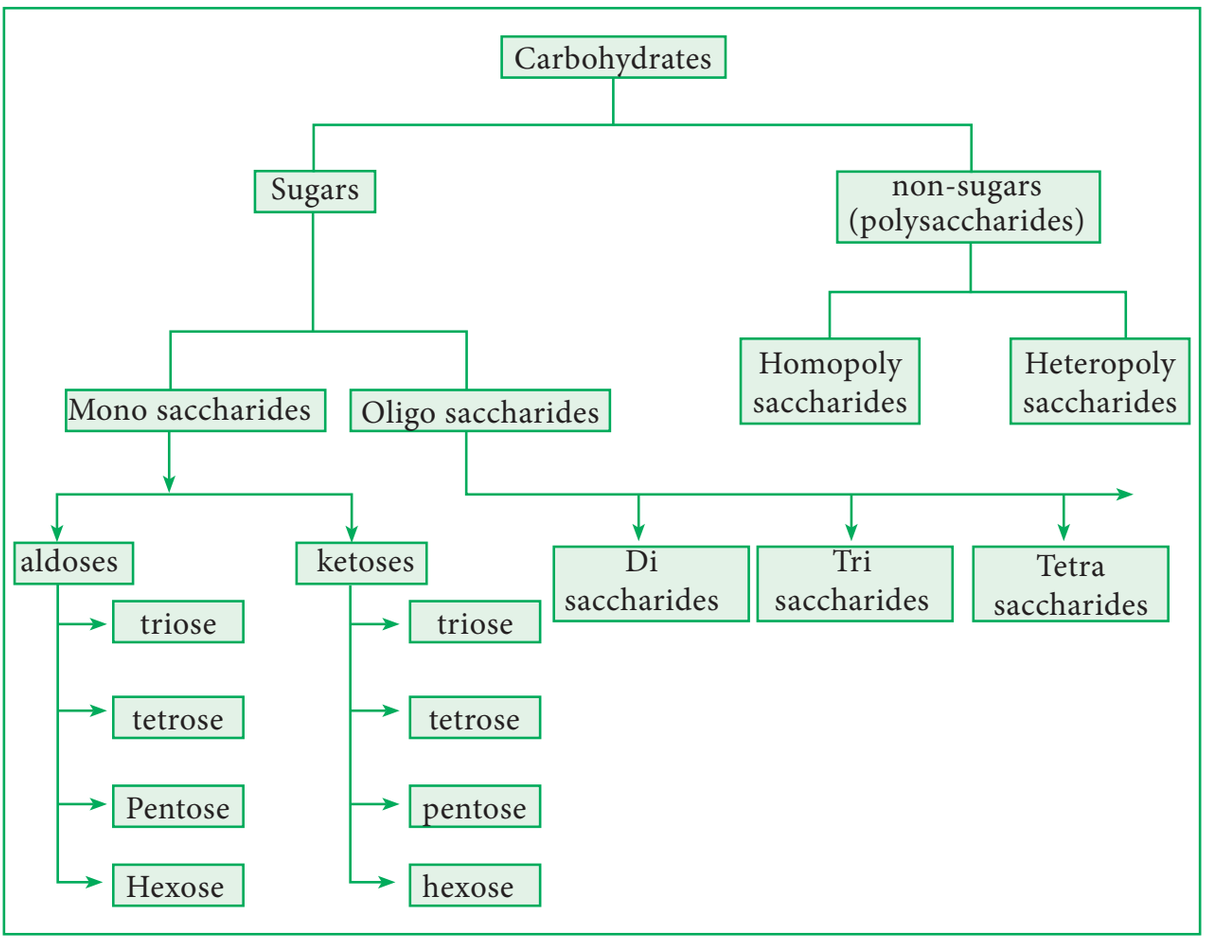
2.1.2 Definition

Carbohydrates are defined as poly-hydroxy aldehydes or ketones. They contain hydrogen and oxygen in the same ratio as in water (2:1)

The names of most of carbohydrates are characterised by the ending '-ose'. For example glucose, fructose, sucrose, cellulose, etc.

2.1.3 Classification

Carbohydrates are generally classified as Sugars and Non-sugars.



Sugars

Sugars are sweet, crystalline and soluble in water. They are classified further as below.

2.1.4 Monosaccharides

Mono saccharides have a general formula $C_n(H_2O)_n$. Based on the number of carbon atoms they are further classified into trioses, tetroses, pentoses, hexoses etc. They can also be classified as aldoses and ketoses based on the functional group present in them. They cannot be hydrolysed into simpler units. This can be further classified as aldoses and ketoses based on the functional group present in C1 position.

Aldoses:

Aldoses contain aldehyde group (-CHO) as a functional group along with two or more hydroxyl groups. Examples: glyceraldehyde, ribose, glucose galactose

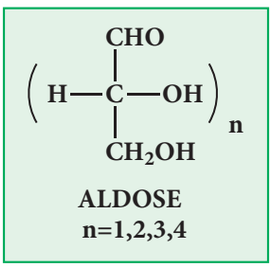


Figure 2.1 General structure of aldoses

Ketoses:

Ketoses contain keto group (>C=O) as a functional group along with two or more hydroxyl groups.

Examples: dihydroxy acetone, ribulose, fructose.

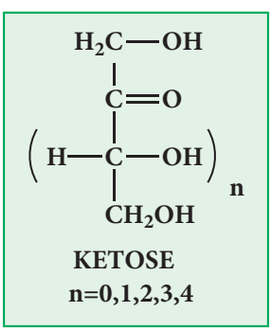


Figure 2.2 General structure of ketoses

2.1.5 Oligosaccharides

Oligosaccharides are sugars that yield 2 to 10 monosaccharide molecules on hydrolysis. This can be further classified as di, tri, tetra saccharides etc. based on the number of monosaccharide units present. In these molecules monosaccharide units are interlinked by glyosidic bridges

Disaccharides

Disaccharides have a general formula C_n $(H_2O)_{n-1}$Example: sucrose, lactose and maltose. In these molecules monosaccharide units are inter linked by a glyosidic bridges.

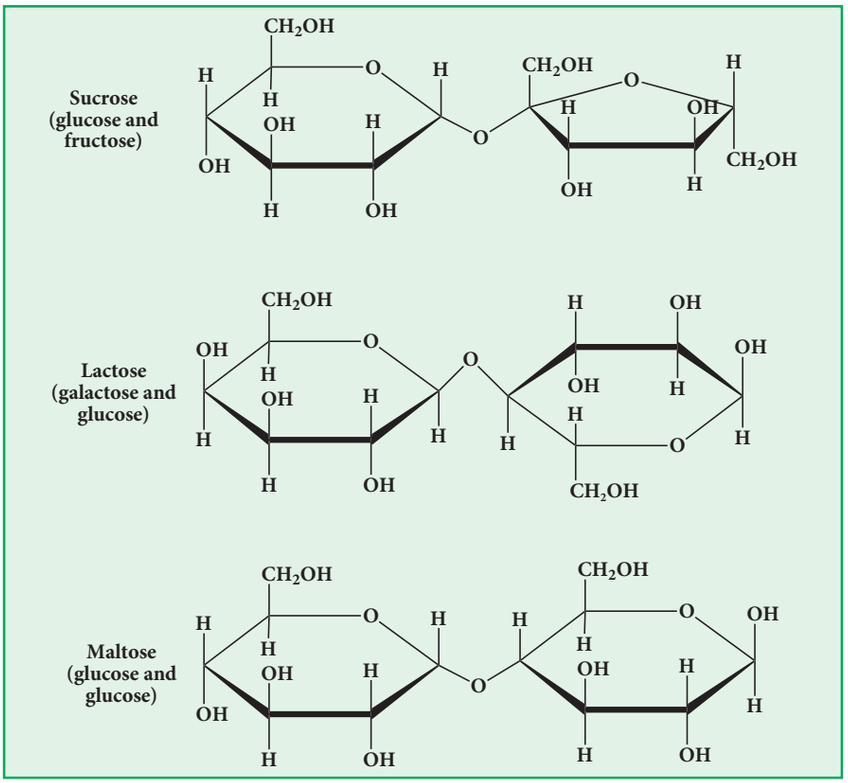


Figure 2.3 Structure of common disaccharides

Hydrolysis of disaccharides in presence of mineral acid yields corresponding monosaccharides. For example hydrolysis of sucrose gives glucose and fructose. Similarly maltose gives two molecules of glucose.

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{H^+} C_6H_{12}O_6 + C_6H_{12}O_6$$

Sucrose — Glucose + Fructose

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{H^+} C_6H_{12}O_6 + C_6H_{12}O_6$$

Maltose — Glucose + Glucose

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{H^+} C_6H_{12}O_6 + C_6H_{12}O_6$$

Lactose — Glucose + Galactose

Figure 2.4 Hydrolysis of disaccharides

Trisaccharides

This will give three monosaccharide units on hydrolysis. These have a general formula as $C_n(H_2O)_{n-2}$ Example: raffinose.

2.1.6 Polysaccharides (Non Sugars)

Polysaccharides are the carbohydrates that yield more than ten monosaccharide units upon hydrolysis.They are further classified into homopoly saccharides and heteropoly saccharides based on the monomeric units. Example: starch, cellulose, inulin

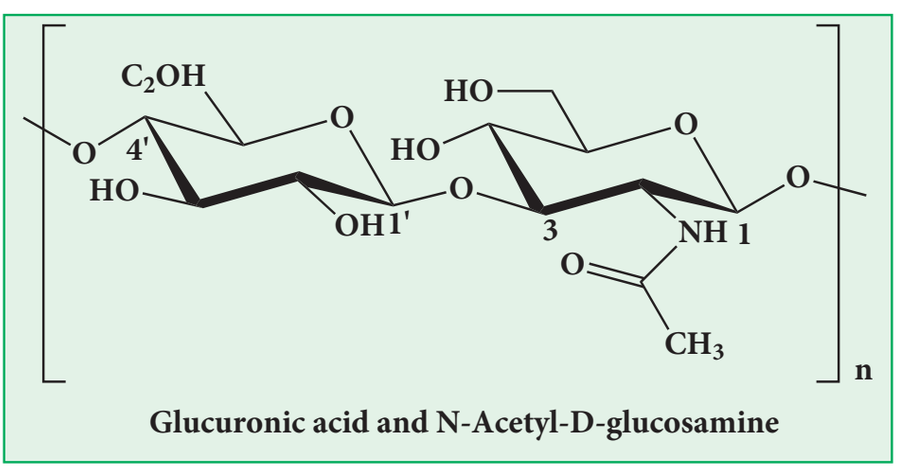
Homopolysaccharides

A homopolysaccharide yields the same type of monosaccharide units on hydrolysis. For example starch a homopolysaccharide yields only glucose upon hydrolysis. Similarly glycogen and cellulose also yield glucose on hydrolysis.

Heteropolysaccharides

A heteropolysaccharide yields more than one type of monosaccharide upon hydrolysis. Eg. Hyaluronic acid, heparin, keratan sulphate and chondroitin sulphate

These are present in extra cellular matrix and therefore they are called as mucopolysaccharides.



Glucuronic acid and N-Acetyl-D-glucosamine

Figure 2.5 Structure of hyaluronic acid

Hyaluronic acid is made up of glucuronic acid and N-acetyl glucosamine.

Starch:

Starch is the major form of stored carbohydrate in plants. Starch is composed of a mixture of two substances namely amylose, a linear polysaccharide and amylopectin, a branched polysaccharide. The detailed study of starch will be discussed in the unit 5.

Cellulose:

Cellulose is an unbranched polymer of β-D-glucose. Because of the absence of side chains, molecules stay together to form rigid structures in plants. Wood is largely made up of cellulose and cotton is almost pure cellulose.

Cellulose may be modified in the laboratory by treating it with nitric acid to produce nitrocellulose or gun cotton which is an explosive component of smokeless powder. Partially nitrated cellulose, known as pyroxylin, is used in the manufacture of collodion, plastics, lacquers, and nail polish.

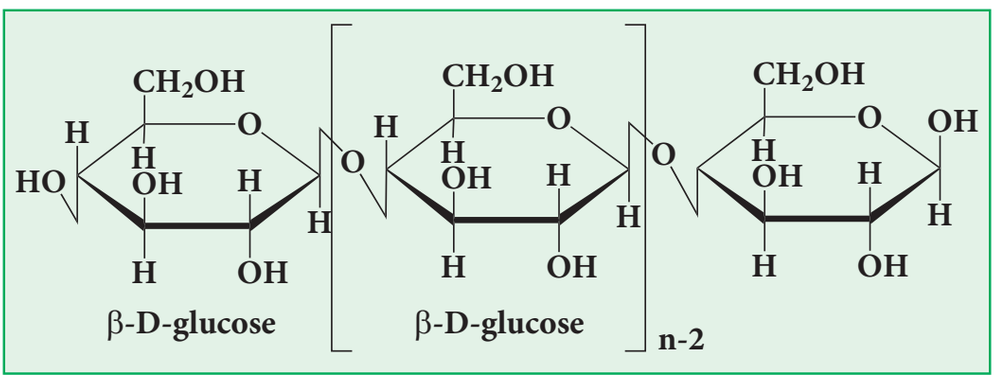


Figure 2.6 Structure of cellulose

Glycogen:

Glycogen is a storage form of glucose which is mainly present in liver and muscle. Glycogen is also known as animal starch. It is a multi branched polysaccharide of glucose. The polysaccharide structure represents the main storage form of glucose in the body.

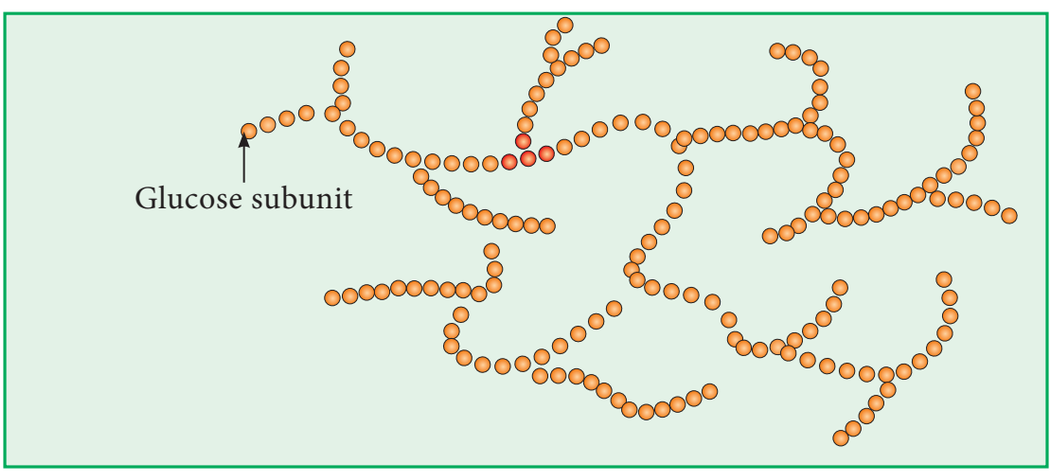


Figure 2.7 Glycogen

2.2 Proteins

Proteins are the fundamental biological components of skin, hair, muscles, connective tissues, enzymes etc...

2.2.1 Definition

Proteins are defined as the biopolymers composed of α-amino acids linked by peptide bonds. They are also known as polypeptides. Proteins are the major constituents of all living organisms. They contain carbon, hydrogen, nitrogen, oxygen and sulphur.

2.2.2 Classification

Proteins are classified into three main groups.

a. Simple protein:

The protein that yields only α-amino acids on hydrolysis is called a simple protein. Examples: albumin and globulin

b. Conjugated protein:

The protein that yields α-amino acids and a non-protein part upon hydrolysis is called a conjugated protein. The non-protein part is called as the prosthetic group.

Based on the nature of prosthetic group, conjugated proteins are further classified as follows.

i Nucleoprotein:

Protein associated with nucleic acids is called as nucleo protein.

Example: Histone(in DNA).

ii. Phosphoprotein:

Protein containing phosphoric acid is called as phosphoprotein.

Example: casein (in milk).

iii. Glycoprotein:

Protein containing carbohydrate moiety is called as glycoprotein.

Example: mucin (in saliva)

iv. Chromoprotein:

Protein containing heterocyclic compounds like porphyrins is called as chromo protein.

Example: myoglobin (in muscle).

v. Lipoprotein:

Protein conjugated with lipids is called lipoprotein.

Examples: chylomicron (in small intestine)

vi. Metalloprotein:

Protein containing metal ion is called as metalloprotein.

Examples: ceruloplasmin (in blood).

c. Derived protein:

Protein that is derived from simple or conjugated proteins by the action of acids, alkalies or enzyme is called as derived protein. These are partially hydrolysed proteins.

Example: peptones

2.2.3 Functional diversity of Proteins.

Repair and Maintenance:

Protein is termed as the building block of the body. Protein is vital in the maintenance of body tissue, including development and repair.

Hormones:

Some proteins acts as a hormones. Example: Insulin, a small protein, which regulates blood sugar level.

Enzymes:

Most of the enzymes are proteins, they act as biocatalysts in chemical reactions taking place in the body.

Transportation:

Protein is a major component in transportation of certain molecules. For example, haemoglobin is a protein that transports oxygen throughout the body.

Storage:

Proteins are used to store certain molecules. Ferritin is a protein which stores iron in the liver.

Antibodies:

All antibodies are proteins. Antibodies neutralize infection, illness and diseases.

2.3 Lipids

2.3.1 Definition

Chemically, Lipids can be defined as esters of fatty acids with alcohol. They are insoluble in water and soluble in organic solvents such as alcohol, ether, benzene and chloroform.

2.3.2 Classification

Based on the chemical nature, lipids are classified as

Simple lipids

These are esters of fatty acids with glycerol or long chain alcohols. They are further classified as follows.

(a) Fats: Fats are glyceric esters of fatty acids. Lipids in animals are called as fats while the lipids in plants are called as oils. Example: Triacylglycerol.

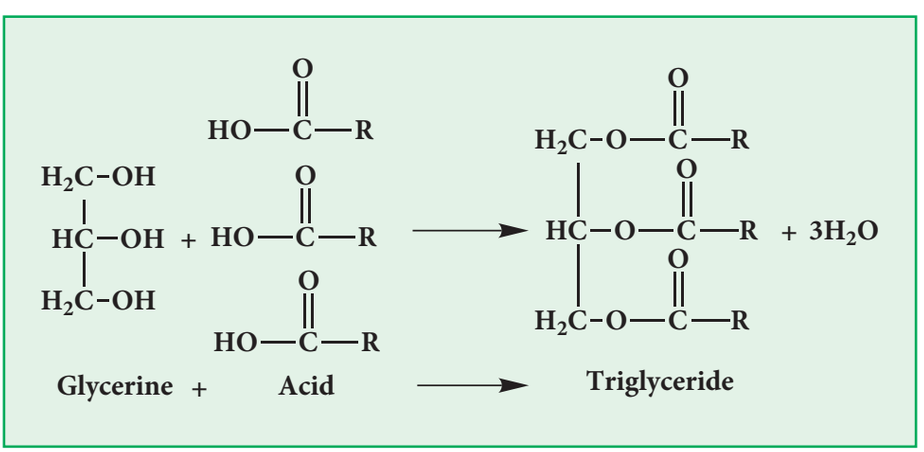


Figure 2.8 Formation of triacylglyceride

(b) Waxes: Waxes are esters of fatty acids with long chain monohydric alcohols.

Examples: Cerylmyristate (bees wax).

Figure 2.9 Bee's wax

Compound lipids

Compound lipids are esters of fatty acids with alcohol, and they contain extra groups. Depending upon the extra group present they are subdivided as follows:

a. Phospholipids (Phosphatides)

A glyceric ester containing phosphate and nitrogen base or an alcohol are called phospholipids. These lipids are present in large amounts in nerve tissue, brain, liver, kidney, pancreas and heart. Phospholipids are further classified into three types based on the type of group connected to phosphatidyl group.

i. Glycerophosphatides:

In these phospholipids, a nitrogen base is connected with phosphatidyl group.

Examples: Lecithin, Cephalin

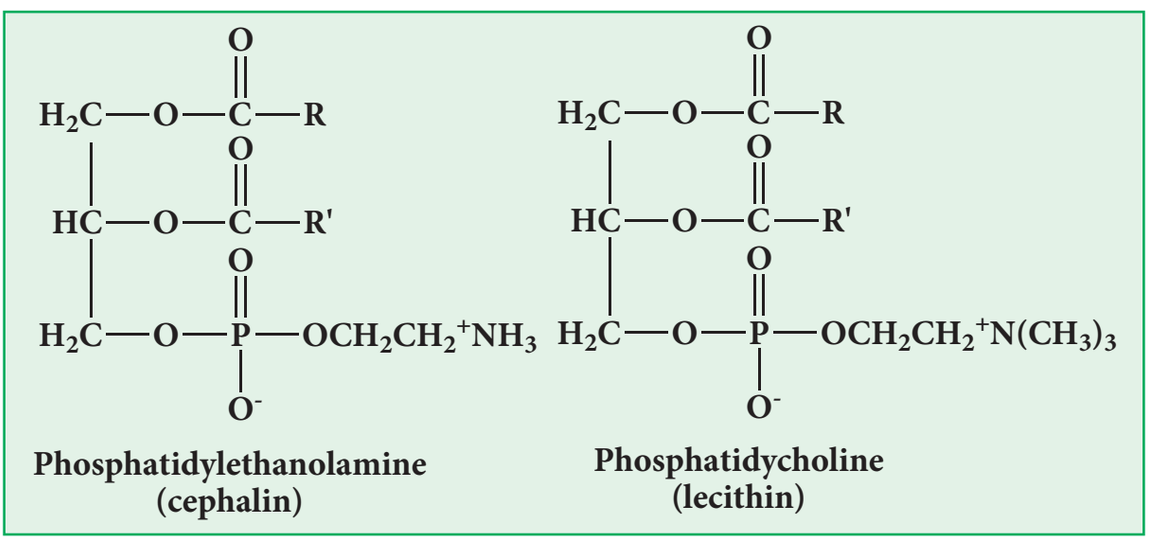


Figure 2.10 Structure of lecithin, cephalin

ii) Phosphoinositides:

In these phospholipids, inositol is connected with phosphatidyl group. Example: Phosphatidylinositol (lipositol)

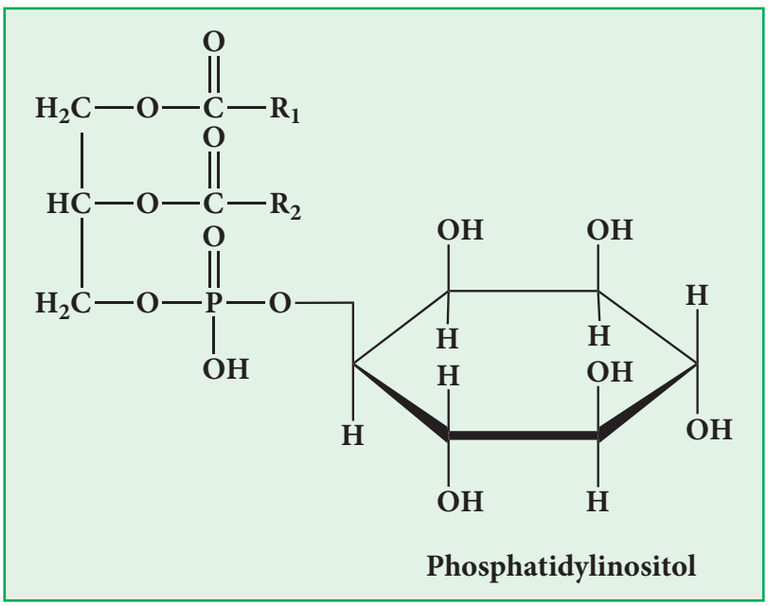


Figure 2.11 Structure of phosphatidylinositol

iii) Phosphosphingoside:

A group of phospholipids containing 1-phosphocholine combined with a ceramide (sphingosine + fatty acid). Example: Sphingomyelin

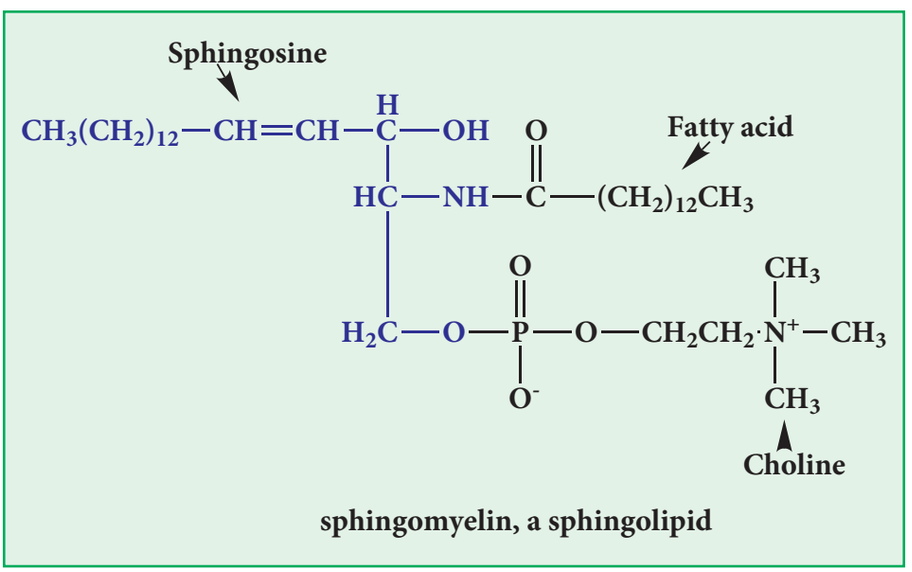


Figure 2.12 Structure of phosphosphingosides

b. Glycolipids

The lipids which contain a carbohydrate moiety linked with ceramide is called a glycolipid.

Examples : Cerebroside and gangliosides.

c. Lipoproteins

A complex of proteins, lipid and cholesterol is called as a lipoprotein. The protein moiety in the lipoprotein is known as apoprotein.

Examples:

- Chylomicron
- Very low density lipoprotein (VLDL)
- Low density lipoprotein (LDL)
- High density lipoprotein (HDL)

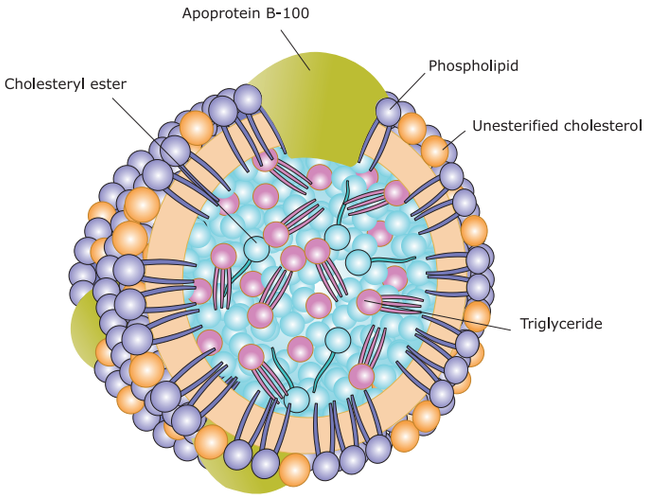


Figure 2.13 Structure of lipoprotein (LDL)

Derived lipids:

Lipids that are derived from the hydrolysis of simple and compound lipids are called derived lipids.

Examples: diacylglycerol, fatty acids, glycerol and cholesterol.

2.3.3 Functions of lipids:

Lipids perform several biological functions such as,

- Triglycerides serve as energy reserve of the body.
- Lipids are important components of cell membranes which regulates membrane permeability.
- Phospholipids, provide fluidity and flexibility to the cell membranes.
- Lipids act as signalling molecules.
- Fat layer provides insulation from cold.
- Lipoproteins transports lipids throughout the body.

2.4 Nucleic acids

Nucleic acids are biopolymers, essential to all known forms of life.

2.4.1 Definition

Nucleic acids are the polymers of nucleotides. Nucleotides are made of three components:

1. 5-carbon sugar
2. Nitrogenous base
3. Phosphate groups

2.4.2 Structure of nucleic acids:

Sugar unit:

If the sugar unit present in the nucleic acid is a ribose, then the polymer is called ribonucleic acid (RNA) and if the sugar is deoxyribose, then the polymer is deoxyribonucleic acid (DNA).

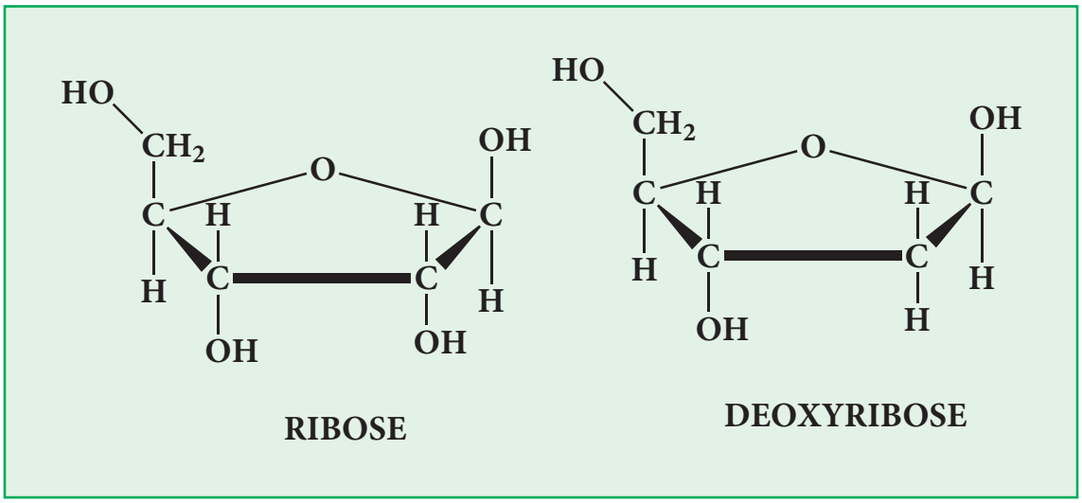


Figure 2.14 Structure of ribose and deoxy ribose

Nitrogen base:

Nucleic acids contain purine and pyrimidine bases. They are Adenine (A), Guanine (G), Cytosine(C), Thymine (T) and uracil(U).

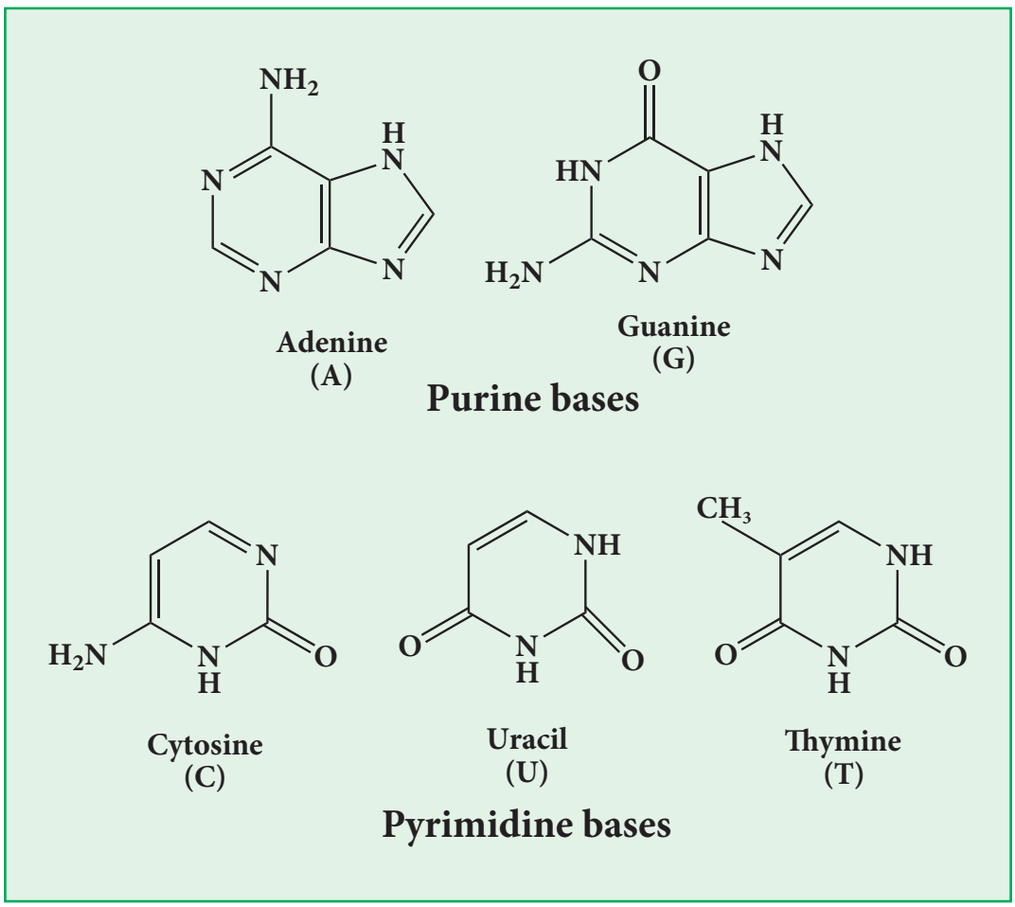
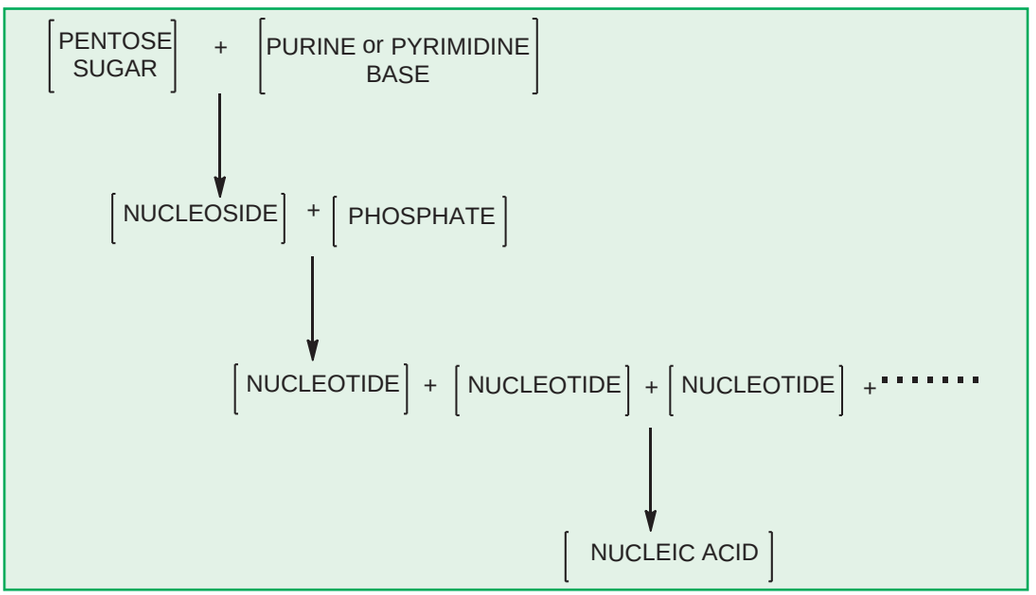


Figure 2.15 Structure of purine and pyrimidine bases

Phosphate group:

In nucleic acids, sugar unit and nitrogenous base can combine to form a nucleoside, these nucleosides combine with a phosphate to form a nucleotide, which in turn polymerises to form nucleic acids.



2.4.3 Classification

Nucleic acids are classified into two types based on the ribose sugar.

a. Deoxyribonucleic acids (DNA)

The most important constituent of chromosome. DNA is a polymer of nucleotides containing 2-deoxyribose sugar and nitrogenous bases like Adenine (A), Guanine (G), Thymine (T) and Cytosine (C).

b.Ribonucleic acids (RNA)

RNA is a polymer of nucleotides containing ribose sugar and nitrogenous bases like Adenine (A), Guanine (G), Uracil (U), and Cytosine (C).

There are three main classes of RNA molecules, they are

i. Messenger RNA (mRNA). ii. Transfer RNA (tRNA) iii. Ribosomal RNA (rRNA)

2.4.4 Functions of DNA and RNA:

- The main function of nucleic acids is to store and transfer genetic information.
- DNA controls the synthesis of RNA in the cell.
- DNA transmits the genetic information to mRNA for the synthesis a specific protein.
- RNA directs synthesis of proteins.
- mRNA takes genetic message from DNA.
- tRNA transfers activated amino acid, to the site of protein synthesis.
- rRNA are mostly present in the ribosomes, and responsible for stability of mRNA.

EVALUATION

I. Choose the correct answer:

1. Glucose is a

   a. Monosaccharide b.Disaccharide c. Oligosaccharide

   d. Polysaccharide

2. An example of a heteropolysaccharide is

   a. Hyaluronic acid b. Cellulose c. Mannose

   d. Starch

3. Chylomicron belongs to the group of

   a. Metalloprotein b. Chromoprotein c. Lipoprotein

   d. Nucleoprotein

4. Long chain alcohols are present in

   a. Waxes b. Fats c. Oils

   d. Phospholipids

5. A Phosphoprotein present in milk is

a. histone b. casein c. mucin d. insulin

6. The metal present in Ceruloplasmin is

a. Fe b. Ca c. Cu d. Mg

7. The differential base present in DNA and RNA is

a. Adenine b. Guanine c. Cytosine d. Uracil

8. Which of the following is ketohexose

a. Glucose b. Fructose c. Ribose d. Galactose

9. Sucrose is a

a. Disaccharide b. Monosaccharide c. Trisaccharide d. Tetra saccharide

10. Lactose is made up

a. Glucose & mannose b. Fructose & glucose

c. Ribose & ribulose d. Glucose & galactose

11. Which of the following is known as animal starch

a. Glycogen b. Amylose

c. Cellulose d. Amylopectin

12. rRNA is present in

a. Nucleus b. Plasma membrane

c. Ribosome d. Nuclear membrane

13. Phosphatidyl choline is

a. Cephalin b. Lecithin

c. Ceramide d. Myristate

14. Which of the following nitrogenous base is not found in DNA

a. Adenine b. Thymine

c. Guanine d. Uracil

15. Sugar present in RNA is

a. Ribulose b. 2-Deoxy ribose

c. Ribose d. Glucose

16. Peptide bond is present in

a. Carbohydrates b. Proteins

c. Lipids d. Nucleic acids

17. Partially hydrolyzed proteins are

a. Peptides b. Poly peptides

c. Peptones d. Simple proteins

II. Give answer for the followings:

1. Write down the hydrolysis reaction of sucrose?
2. Give note on glycogen.
3. What are the basic differences between starch and cellulose?
4. Write note on chromoprotein.
5. What are glycolipids?
6. Give a short note on derived lipids.
7. What are nucleosides?
8. What are three types of RNA?
9. What are hetero polysaccharides? Give an example.
10. What are homo polysaccharides?
11. Give the structure of glucose.
12. Write note on phosphoprotein.
13. Write the equation for triacyl glyceride formation?

14. Explain the lipoproteins.

15. Give structure for lecithin and cephalin?

16. Give the classification of carbohydrates with examples.

17. Explain the functional diversity of proteins

18. Explain the biological functions of lipids.

19. Give an account on classification of lipids.

20. Explain the functions of DNA and RNA.

SUMMARY

Biomolecules are molecules that are present in all living organisms. It includes the macromolecules carbohydrates, proteins, lipids and nucleic acids. These are the four major classes of biomolecules

Carbohydrates

Carbohydrates are essential to maintain the life in both plants and animals. They are synthesized in plants by photosynthesis. Carbohydrates are good source of energy. Monosaccharides are simple sugars. They have a free aldehyde or keto group. Disaccharides are made up of two monosaccharides connected by a glycosidic bond. Polysaccharides are the carbohydrates that yield more than ten monosaccharides units upon hydrolysis. They are further classified into homo polysaccharides and hetero polysaccharides based on the monomeric units. They are non-sugars and complex carbohydrates.

Proteins

Proteins are polymers of α-amino acids. These α-amino acids are joined together by the peptide bond which is formed in between the carboxyl group and amino group of successive amino acids. Proteins are formed from 20 different amino acids.

Proteins are classified into three types namely simple proteins, conjugated proteins and derived proteins. Simple protein yields only α-amino acids on hydrolysis. Conjugated protein yields α-amino acids and a non-protein part upon hydrolysis. The non-protein part is called the prosthetic group. Derived protein is formed by the action of acids, alkalis or enzymes on simple or conjugated proteins. These are partially hydrolyzed proteins.

Lipids

Lipids are generally esters of fatty acids and are building blocks of biological membranes. Lipid molecules hold a large amount of energy and are energy storage

molecules. Based on the chemical nature, lipids are classified as simple lipids, compound lipids and derived lipids. Simple lipids are esters of fatty acids with glycerol or long chain alcohols. Compound lipids are esters of fatty acids with alcohol and they contain extra group. Derived lipids are formed by the hydrolysis of simple and compound lipids.

Nucleic Acids

Nucleic acids are made of polymer of nucleotides. Nucleotides consists of nitrogenous base, a pentose sugar and a phosphate group. Polymerized nucleotides form DNA and RNA which are genetic material.

DNA: DNA is a polymer of nucleotides containing 2-deoxyribose sugar and nitrogen bases like Adenine (A), Guanine (G), Thymine (T) and Cytosine(C).

RNA: RNA is a polymer of nucleotides containing ribose sugar and nitrogen bases like Adenine (A), Guanine (G), Uracil (U), and Cytosine(C).

CONCEPT MAP