31

CARBOHYDRATES

31.1 INTRODUCTION

Carbohydrates are the most commonly found biomolecules on earth Every morning when we take breakfast we add sugar in our tea or milk We eat cereals, slices of bread or corn flakes During lunch or dinner time we eat chapatis or rice. All these things contain mainly carbohydrates Photosynthesis by plants and algae converts more than 100 billion metric tons of CO_2 and H_2O into carbohydrates each year Certain carbohydrates e.g sugar and starch are main constituent of human diet, and the oxidation of carbohydrates provides energy for most of the organisms.

Activity: After playing for a long time or after doing physical exercise for a long time, try to drink a glass of water with glucose Do you feel less tired? Why? This is because glucose is a carbohydrate which can provide energy to your body very fast

In this lesson you will learn about various carbohydrates and their chemical nature and functions.

31.2 OBJECTIVES

After studying this lesson, you will be able to

- list the natural sources of carbohydrates
- differentiate between monosaccharide, disaccharide and polysaccharides.
- recognize triose, tetrose, pentose, and hexoses.
- depict carbohydrate structure in open chain and ring structure
- understand structure of carbohydrates
- explain biological significance of carbohydrates

31.3 NATURAL SOURCES OF CARBOHYDRATE

Carbohydrates are mainly derived from plants in nature. They make up more than 70% of the solid plant material We obtain different types of carbohydrates from different natural sources in our diet.

The table 31.1 shows the natural sources of carbohydrates

Table 31.1 Natural sources of carbohydrates

Name of the Carbohydrates	Sources
Glucose	Grapes
Fructose	Honey
Sucrose	Sugarcane
Lactose	Milk
Starch	Cereals e.g. maize
Cellulose	Plant cell well
Glycogen	Liver

INTEXT QUESTIONS 31.1

1. Name three constituents of your diet which provide carbohydrates.

   .....

2. Name the process which makes carboyhdrates from carbon dioxide and water.

   .....

3. Who makes carbohydrates for your diet?

   .....

31.4 CLASSIFICATION OF CARBOHYDRATES :

Carbohydrates are polyhydroxy aldehydes or Ketones, or the substances that yield such compounds on hydrolysis.

Carbohydrates may be classified into following depending on their size.

Monosaccharides or simple sugars, which consist of single polyhydroxy aldehyde or ketone unit. It cannot be broken down to smaller carbohydrate units by hydrolysis The most widely found monosaccharide in the nature is the six carbon atom sugar D-glucose ($C_6H_{12}O_6$)

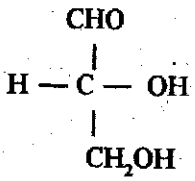
Oligosaccharides, which consist of short chain of monosaccharides units joined together The most abundant are disaccharides, with two monosaccharide units e g. sucrose from

sugarcane which is made up of the six carbon sugar D-glucose and D-fructose units joined covalently. Bigger oligosaccharides are trisaccharides, tetrasaccharide and so on.

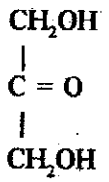
Polysaccharides, which consist of long chains of hundreds or thousands of monosaccharide units. Examples are starch, cellulose and glycogen (animal starch).

31.5 STRUCTURE OF CARBOHYDRATES

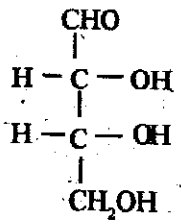
Monosaccharides are the simplest carbohydrates. The empirical formula for the monosaccharide is $(CH_2O)_n$. Simplest of them are trioses where n = 3. Carbohydrates containing -CHO are known as aldoses, and those containing >C = O are known as ketoses. Monosaccharide with 4, 5, 6 or seven carbon atoms are called tetrose, pentose, hexoses and heptose respectively.



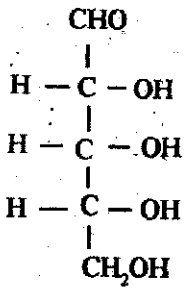
Glyceraldehyde
(An aldose)



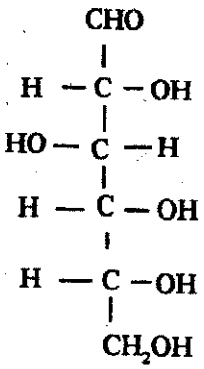
Dihydroxyacetone
(A Ketose)



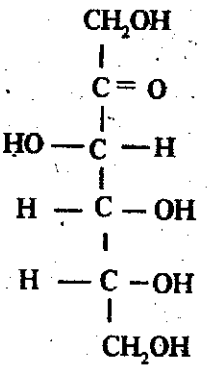
Erythrose
(A tetrose)



Ribose (A Pentose)



D-Glucose
(A Hexose)



D-Fructose (a hexose)

INTEXT QUESTION 31.2

1. What is the most abundant hexose in nature? Is it an aldose or ketose?

.....

2. Give an example of a triose. Is it the smallest monosaccharide or not?

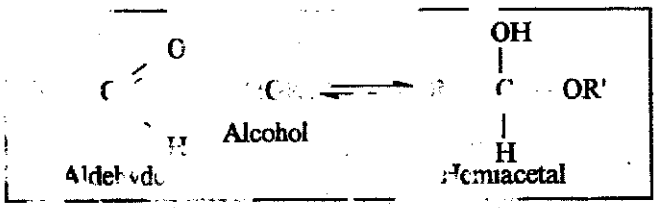
.....

3. Mark the most correct statement
   i) Starch is a monosaccharide obtained from plants
   ii) Starch is another name for glucose
   iii) Starch is polysaccharide
   iv) Starch is oligosaccharide made up of glucose and fructose

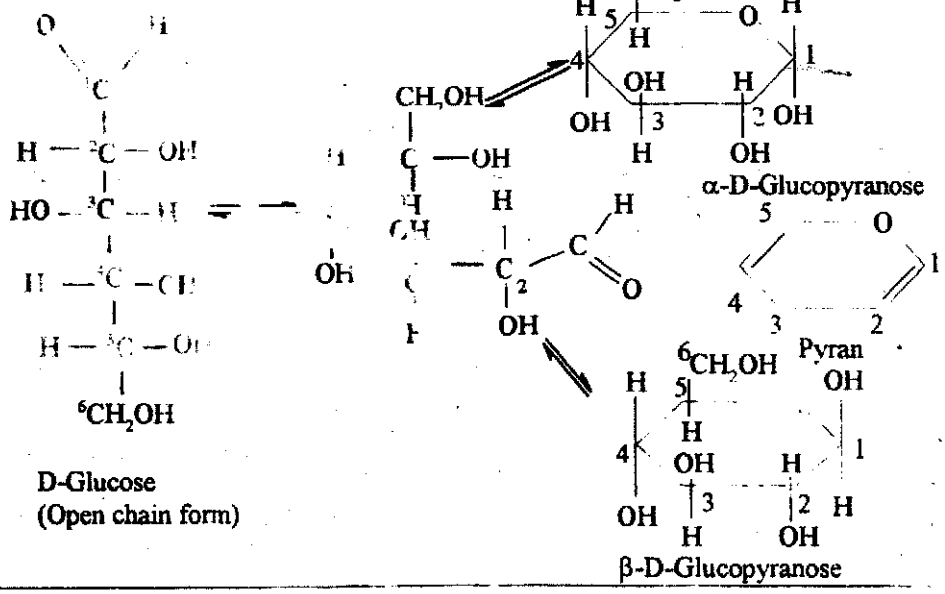
.....

31.3 Pentose and Hexose cyclize to form Ring Structure

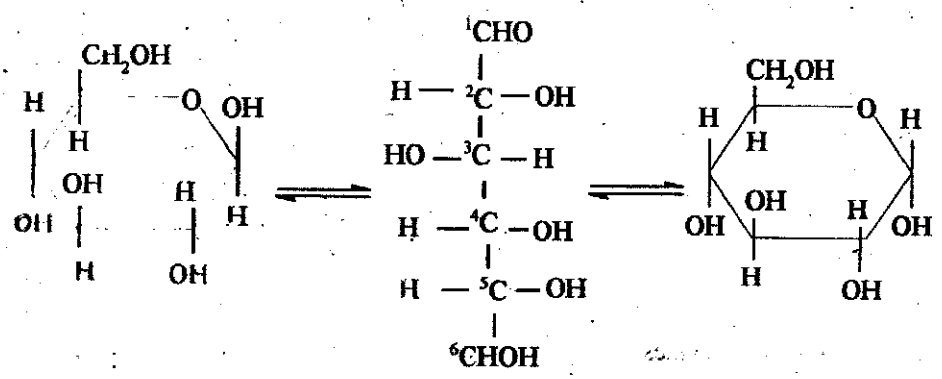
In general an aldehyde can react with an alcohol to form a hemiacetal (a product formed by addition of one molecule of alcohol).



The C-1 of aldehyde in the open chain form of glucose reacts with C_5 hydroxy group to form an intramolecular hemiacetal. The resulting six membered ring is called pyranose because of its similarity to pyran.

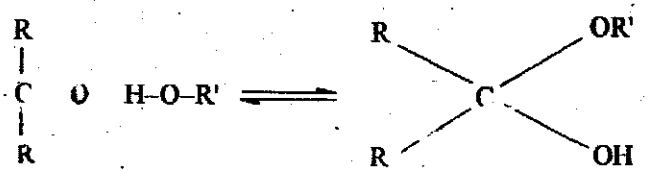


α and β forms of glucose can be obtained using different conditions during crystallization. They differ only in the orientation of the hydroxyl group at C-1. However when they are dissolved in water an equilibrium is established.

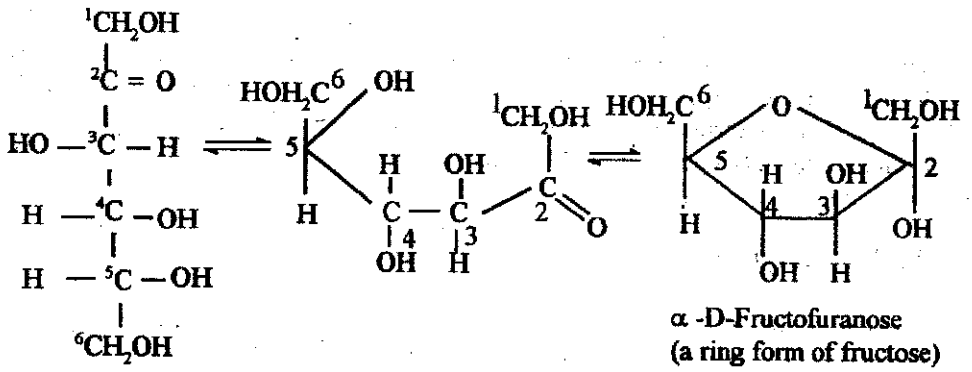


β-D Glucose open chain form of Glucose α-D glucose

Similarly, a ketone can react with an alcohol to form a hemiketal

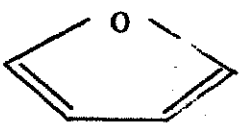


The C-2 keto group in the open chain form of fructose can react with C5 hydroxy group to form intra molecular (within the molecule) hemiketal This five membered ring is called furanose because of its similarity to furan.



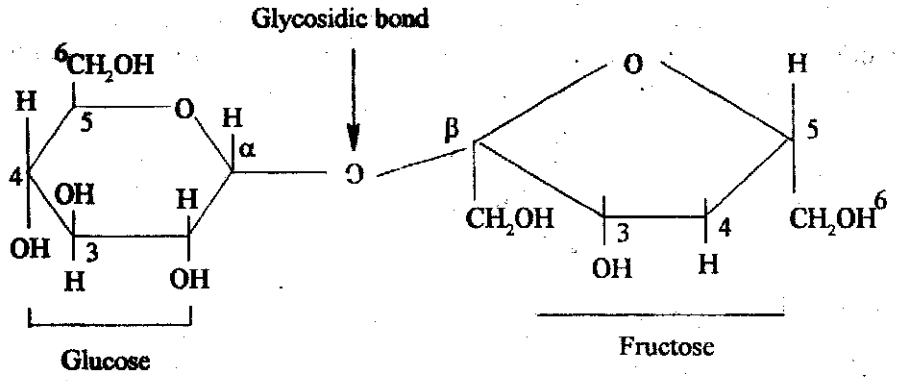
D-Fructose

α -D-Fructofuranose
(a ring form of fructose)



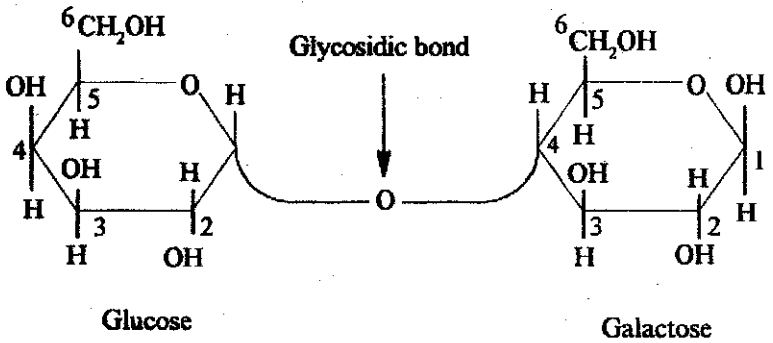
Furan

Structure of sucrose and lactose is given below as an example Note that sucrose is formed by combining α-D- glycose and β-D-fructose



SUCROSE

You will learn about enzymes like β galactocidase in Lesson 34.

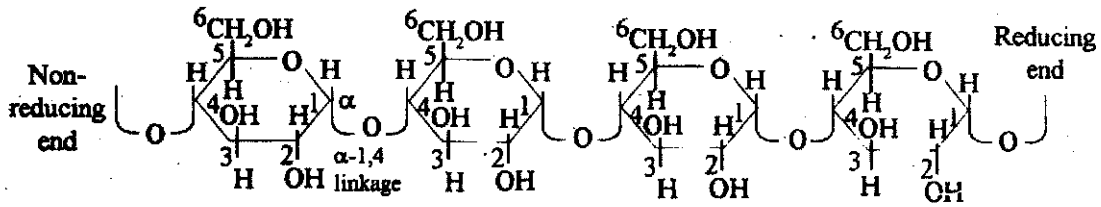


LACTOSE

Polysaccharides are formed by polymerization (joining of many small molecules to form a long chain molecule) of many molecules of monosaccharide. They are joined by the glycosidic linkage (linkage formed by joining two monosaccharides), which may he either α or β. For example, starch is a polymer of α-D-glucose, whereas cellulose is a polymer of β-D glucose Some polysaccharides are linear and some are branched.

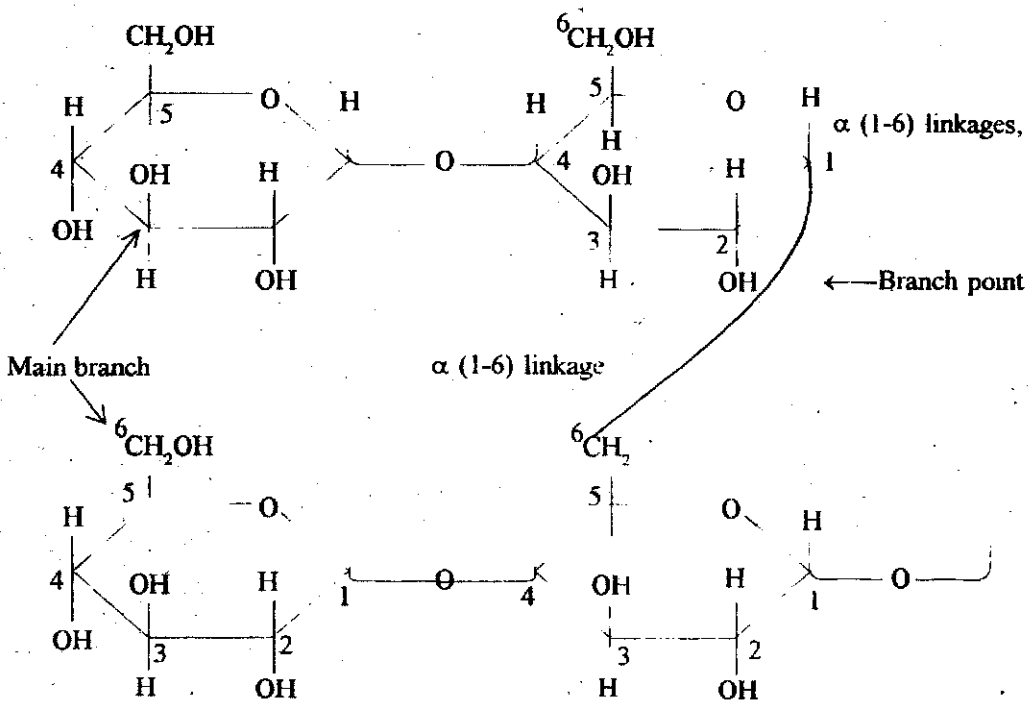
31.7 Amylose

Amylose a component of starch is a linear polymer of α-D-glucose joined together with α–1–4 linkage. In other words, first carbon of a glucose molecule is linked to fourth carbon atom of neighbouring glucose molecule.



31.8 AMYLOPECTIN

Amylopectin contains few branches which connect first carbon atom of a glucose molecule to 6 carbon atom of another glucose molecule. This kind of connection of two glucose molecule is called branch point. Remember this branch connection is in addition to regular α–D (1-4) linkages.



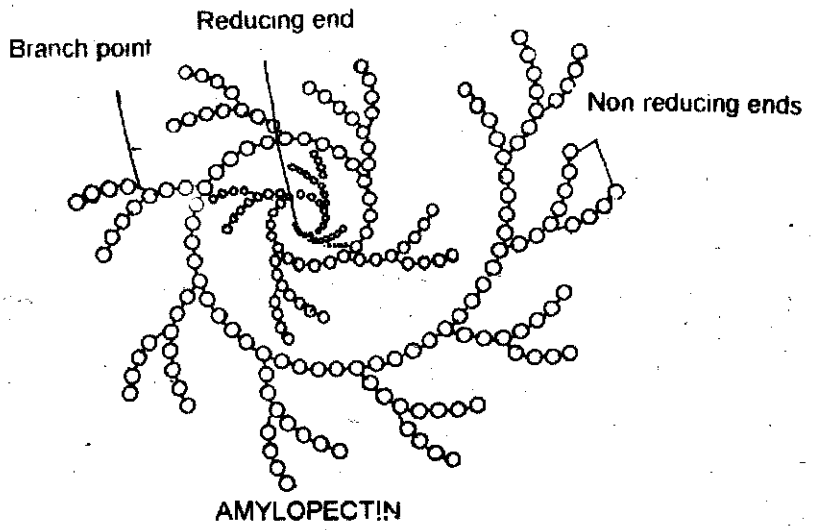


Fig. 31.1. **Amylopectin line diagram to show amylopectin.**

Spiral oval structure in Fig. 31.1 indicates α-D-glucose (1-4) linked polymer. Branch points are shown as α (1-6) linked glucose. The example shown above is components of starch amylopectin. Amylose is water soluble whereas amylopectin is water insoluble and contains branched structure. Starch is composed of amylose and amylopection.

31.9 BIOLOGICAL IMPORTANCE OF CARBOHYDRATES

Carbohydrates are most commonly found organic matter on earth because of their many roles in all forms of life. Following are the important roles they play in the biological organisms.

Carbohydrates are used as storage molecules, fuel and metabolic intermediates. For example starch in plants and glycogen in animals are polysaccharides that can be used to quickly make glucose a source for producing the energy molecule, adenosine triphosphate (ATP) the universal molecule of energy.

Ribose and deoxyribose sugars are essential parts of Ribonucleic Acid (RNA) and Deoxyribonucleic Acid DNA respectively. You will learn about these molecules in Lesson 34. Structural stability of these sugar is necessary for storage and expression of genetic information.

Cellulose of bacteria, plants, and outer parts of wood is made up of cellulose, the most widely found organic molecule on the earth.

4 Carbohydrates are also linked to many proteins and lipids. These molecules are known as glycoproteins and glycolipids respectively. These molecules perform very important and specific function in biological organisms. e.g. human growth horomone is a glycoprotein.

5 Carbohydrates play a very important role in cell to cell communication. For example fertilization begins with the binding of sperm to a specific oligosaccharide on the surface of egg.

INTEXT QUESTIONS 31.3

1 Write a reaction to show the formation of hemiacetal.

.....

2 Write the structure of sucrose & lactose.

.....

3 List the biological importance of carbohydrates.

.....

31.10 WHAT YOU HAVE LEARNT

- Carbohydrates are found everywhere on earth
- Carbohydrates have a wide range of structure and functions.
- Natural sources of carbohydrates are grapes, honey, sugarcane, cereals and milk

- Carbohydrates can be classified on the basis of their size into monosaccharides, oligosaccharides and polysaccharides.
- Structure of mono, di and polysaccharide
- Open and ring strucutre of hexoses
- Biological importance of carbohydrates.

31.11 TERMINAL EXERCISE

1. Describe three important functions of carbohydrates.

   .....

2. Define monosaccharide, disaccharide and polysaccharide. Give one example of each.

   .....

3. Draw the open and ring structures of glucose and fructose.

   .....

4. What monosaccharides constitute sucrose and lactose.

   .....

5. What is the difference between amylose and amylopectin.

   .....

6. What is starch? What is it made up of? What is the difference between starch and cellulose?

   .....

CHECK YOUR ANWER

Intext Questions 31.1

1. Sugar, milk and bread
2. Photosynthesis
3. Plants

Intext Questions 31.2

1. Glucose; aldose
2. Glyceraldehyde. Yes, it is the smallest
3. C

Intext Questions 31.3

1. Refer Section 31.6
2. Refer Section 31.6
3. Refer Section 31.9

Terminal Exercise

1. Refer to introduction and biological importance of carbohydrates (31 9).
2. Refer to classification of carbohydrates (31.4).
3. Refer to structure of carbohydrates (31.5 and 31.6).
4. Refer to structure of sucrose and lactose (31.6)
5. Refer Section 31.7 and 31.8.
6. Refer Section 31.6.and 31.8.