Unit 5 CARBOHYDRATES

Gerty Cori

Gerty Cori along with her husband Carl Cori made important discoveries in Carbohydrate biochemistry. They were particularly interested in glucose metabolism and its hormonal regulation. Their proposed cycle of reactions is now known as Cori's cycle. They were awarded the Nobel prize in 1947 for their discoveries. Gerty Cori was the first American woman to receive a Nobel prize.

The US government has also released an US Postal Service stamp in Honour of Gerty Cori. The Cori craters in the moon and venus were also named after them.

Learning Objectives

After reading this Chapter, you will be able to:

- Explain the functions of carbohydrates
- Draw the chemical structure of glucose, galactose, fructose, maltose, lactose and sucrose.
- Write the physical and chemical properties of carbohydrates
- Draw the Haworth projection of glucose, galactose and fructose
- Describe the structural arrangement of the Homo polysaccharides (Starch & Glycogen) and Hetero polysaccharides (Heparin and hyaluronic acid)

Introduction

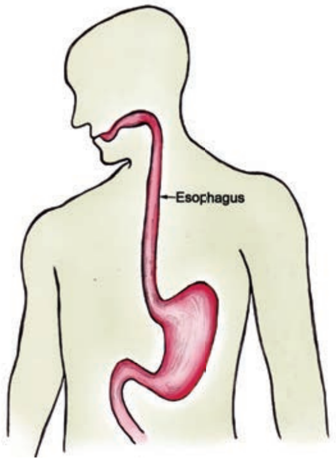
Carbohydrates are widely distributed in plants and animals. Plants produce carbohydrates from carbon dioxide and water by photosynthesis. The important carbohydrate found in plants is starch. Animals mainly depend upon plant sources for their carbohydrates. The carbohydrate stored in animals is glycogen.

Chemically, carbohydrates are defined as polyhydric aldehyde or ketone or compounds which produce them on hydrolysis.

Example: Glucose, fructose, starch, cellulose, glycogen etc.

5.1 A Primary Source of Energy

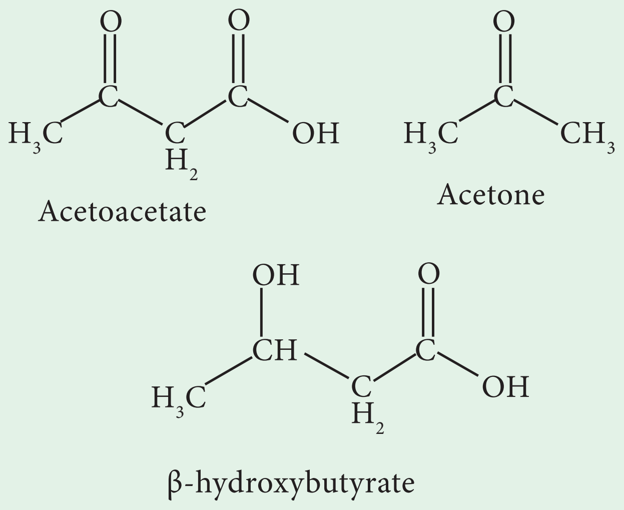
Digestion of carbohydrates starts in the mouth. Enzymes in saliva begin to break down carbohydrates. The Carbohydrates travel through the esophagus, stomach and enter the small intestine.



In the small intestine, carbohydrates get further broken down into single carbohydrate units called monosaccharides. These single molecules get absorbed across the intestine wall and are sent through the blood stream. Carbohydrate in the blood is in the form of a monosaccharide called glucose. The more carbohydrate eaten at one time, the more glucose will be released into the blood after digestion.

It is important to note, that fats and proteins can also be burnt to provide energy but fats are only burned if there is non-availability of carbohydrates. When fat is burnt in absence of carbohydrates, toxic compounds called ketone bodies are produced.

Accumulation of these ketone bodies over a long period causes a condition called ‘Ketosis” In this condition, blood is unable to carry oxygen properly and this can be fatal. Thus, “one of the important functions of carbohydrate is to help burn fat properly”.



Acetoacetate

Acetone

β-hydroxybutyrate

Ketone bodies

i. As a source of energy:

The main function of carbohydrate is to supply energy for the body processes. A greater part of the energy in the diet (more than 50-80%) is supplied by carbohydrates. Some of the carbohydrates are immediately utilized by the tissues and the remaining are stored as glycogen in the liver and muscles and some are stored as adipose tissues for future energy needs.

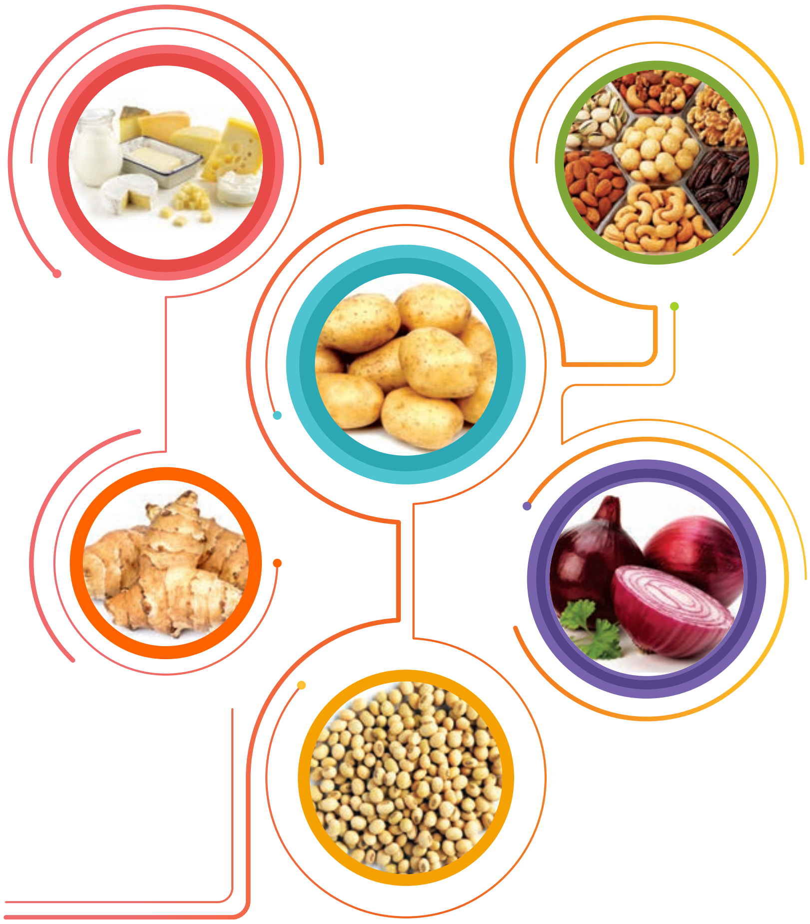


Figure 5.1 Foods rich in carbohydrate

ii. Protein-sparing action:

Carbohydrates are mainly utilized by the body for fulfilling the major part of the energy needs, thus sparing protein for tissue building and repairing. The first physiological demand of the body is the need for energy, which must be satisfied before the nutrients are used for other functions. So, this function of carbohydrates is to spare protein for body building and repair of tissues.

iii. Essential for Fat Oxidation:

Even though fat yields twice as much as energy as carbohydrate per unit weight, carbohydrate is essential for the oxidation of fats. The common expression that ‘fat burns in the fire of carbohydrates’ is used to emphasize, that in absence of carbohydrates, fats cannot be oxidised by the body to yield energy. A breakdown product of carbohydrate is essential for the oxidation of acetate, which is the breakdown product of fats.

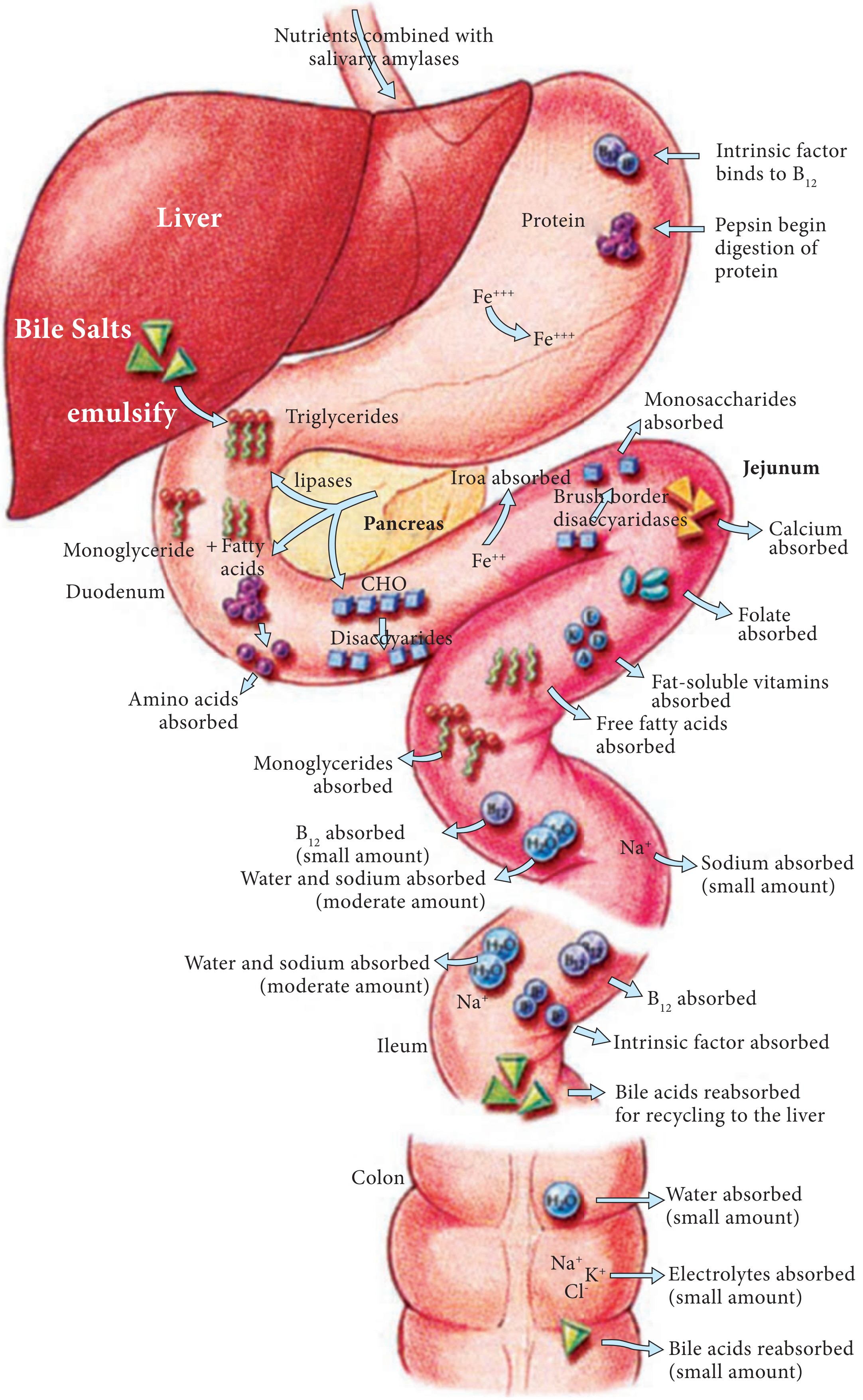


Figure 5.2 Digestion and absorption of nutrients in the gastrointestinal tract

iv. Role in gastro-intestinal function:

Carbohydrates play an important role in the gastro-intestinal functions of mammals. The digestive system changes carbohydrates into glucose, also known as blood sugar. Some glucose is used for energy and the rest is stored in the liver and muscles for later use. When blood sugar rises, pancreas pumps out more and more insulin, a hormone that tells cells to absorb glucose for energy or storage. As cells absorb glucose, blood sugar levels begin to fall, which signals the pancreas to start making glucagon, a hormone that tells the liver to release stored glucose.

DO YOU KNOW?

Anticoagulants, commonly referred to as blood thinners, are chemical substances that prevent or reduce coagulation of blood, prolonging the clotting time.

v. Carbohydrate functions as Antigen:

Many antigens are glycoproteins (which contain oligosaccharides) in nature and give immunological properties to the blood.

vi. Carbohydrate functions as Hormone:

Many Hormones like FSH (Follicular Stimulating Hormone which takes part in ovulation in females) and LH (Leutinizing Hormone) are glycoproteins and help in reproductive processes.

vii. Carbohydrates provide raw material for industry:

Carbohydrates are an important component of many industries like textile, paper, lacquers and breweries.

viii. Other Functions

Agar is a polysaccharide used in culture media, laxative and food.

Cellulose acts as roughage of food. It stimulates peristaltic movement and in the secretion of digestive enzymes.

Hyaluronic acid is found between joints acts as synovial fluid and provides frictionless movement.

5.2 Classification

Carbohydrates are often referred to as saccharides. They are classified into three main groups

i) Monosaccharides ii) Oligosaccharides iii) Polysaccharides.

5.2.1 Monosaccharides:

Monosaccharides are the simplest group of carbohydrates which cannot be hydrolysed further. They are often referred to as "simple sugars". They have the general formula $C_n(H_2O)_n$. They can be further subdivided on the basis of the number of carbon atoms (triose, tetrose, pentose etc.) and on the basis of the functional group (aldose, ketose) as given in Table – 5.1.

Table – 5.1 Classification of monosaccharides

Number of 'C' atoms	Name of the monosaccharide	Aldose	Ketose
3	Triose	Glyceraldehyde (Glycerose)	Dihydroxyacetone
4	Tetrose	Erythrose	Erythrulose
5	Pentose	Ribose	Ribulose
6	Hexose	Glucose	Fructose
7	Heptose	Glucoheptose	Sedoheptulose

5.2.2 Oligosaccharides :

Oligosaccharides are the carbohydrates which yield two to ten monosaccharide units on hydrolysis. They are further classified into di, tri, tetra (or) penta saccharides, respectively, containing 2, 3, 4 (or) 5 monosaccharide units.

Example:

a) Maltose (disaccharide) (Glucose + Glucose)

b) Sucrose (disaccharide) (Glucose + Fructose)

c) Lactose (disaccharide) (Glucose + Galactose)

d) Isomaltose (disaccharide) (Glucose + Glucose)

e) Raffinose (Trisaccharide) (Fructose + Glucose + Galactose)

f) Stachyose (tetrasaccharide) (Galactose + Galactose + Glucose + Fructose)

g) Verbascose (pentasaccharide) (Galactose + Galactose + Galactose + Glucose + Fructose)

5.2.3 Polysaccharides

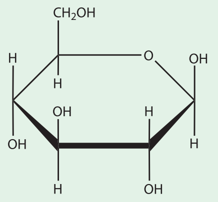
Polysaccharides are the carbohydrates which yield more than ten molecules of monosaccharides on hydrolysis. They are usually tasteless (non-sugars). They have the general formula $(C_6H_{10}O_5)_n$.

a) The polysaccharides composed of a single type of monosaccharide are called homoglycans (or) homopolysaccharides. They have the general formula $(C_6H_{10}O_5)_n$.

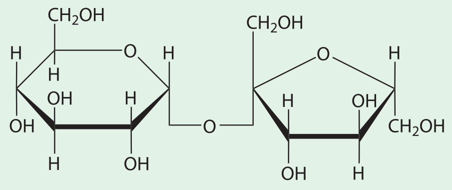
Example : Starch, cellulose, glycogen, insulin.

b) Polysaccharides composed of two (or) more different types of monosaccharides are called heteroglycans (or) heteropolysaccharides.

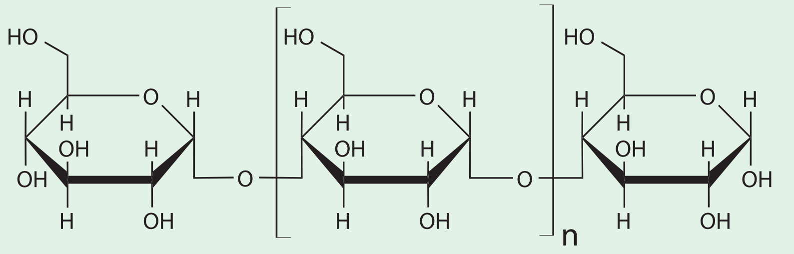
Example : Agar, heparin, pectins, gum arabic, hyaluronic acid etc.



glucose
(a monosaccharide)



Sucrose (a disaccharide)



amylose (a polysaccharide / starch)

5.3 Structure of Glucose, Fructose and Galactose

5.3.1 Glucose:

Glucose has the molecular formula ($C_6H_{12}O_6$) and has a six member ring. Glucose may be represented by the following open chain structure. But in solution it exists only as a six membered ring structure called pyranose. Glucose is known as grape sugar.

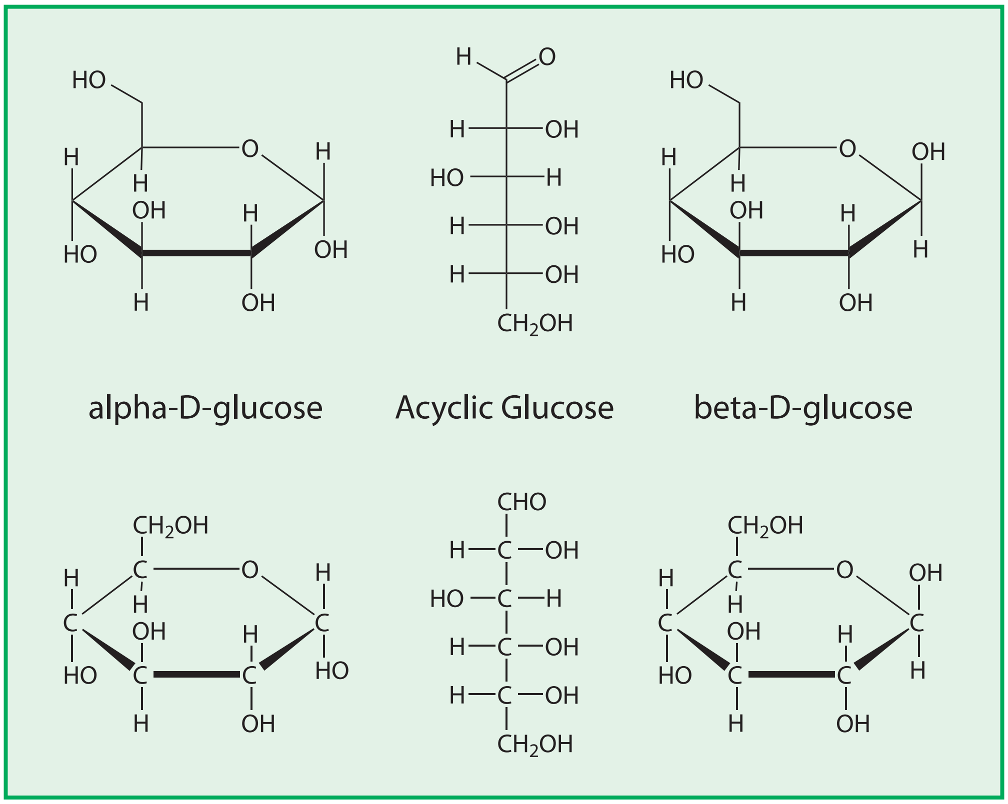


Figure 5.3 Structures of Glucose

DO YOU KNOW?

Glucose is eaten, absorbed into the blood stream, and makes its way to the liver where it is broken down to supply energy to the entire body. This breaking down process requires insulin.

5.3.2 Fructose

Fructose has the molecular formula ($C_6H_{12}O_6$). Fructose exists mostly as a five membered ring structure called "furanose form". Fructose is known as fruit sugar as its source in the diet is fruits and vegetables. Honey is also a good source.

Fructose is more soluble than other sugars and hard to crystallize because it is more hygroscopic and holds onto water stronger than the others. This means that fructose can be used to extend the shelf life of baked products more than other sugars.

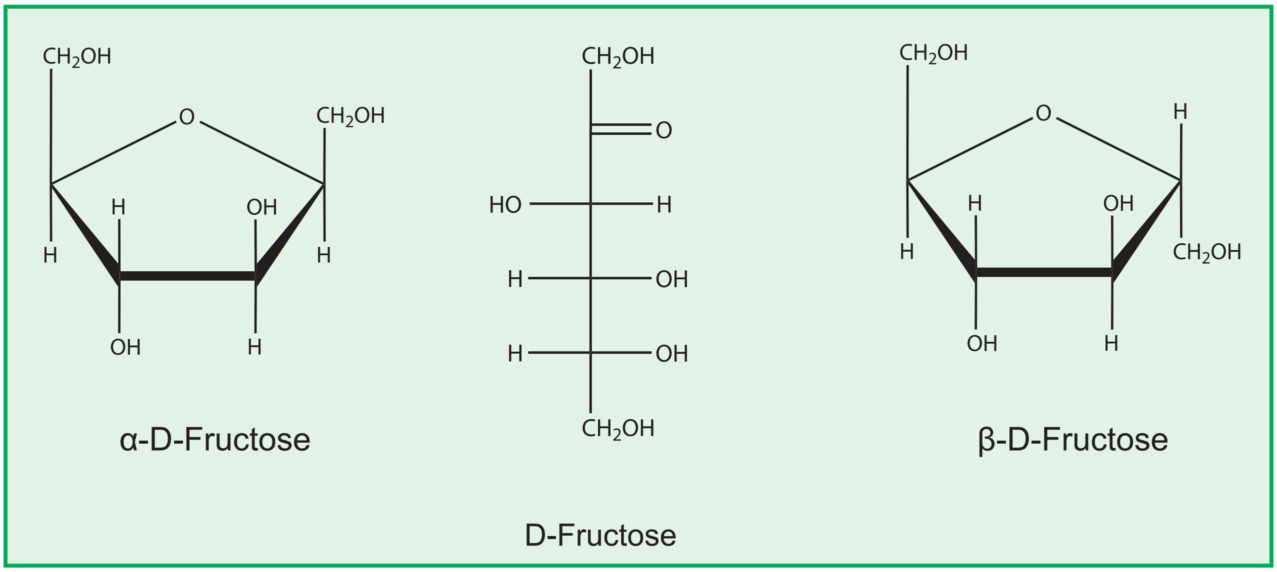


Figure 5.4 Structures of Fructose

5.3.3 Galactose

Galactose is a monosaccharide and has the same chemical formula as glucose, i.e., $C_6H_{12}O_6$. It is similar to glucose in its structure, differing only in the position of one hydroxyl group. This difference, however, gives galactose different chemical and biochemical properties to glucose. In solution, it forms 5- and 6-membered rings but also exists in linear form. Small amounts of lactose and galactose can appear in nondairy foods.

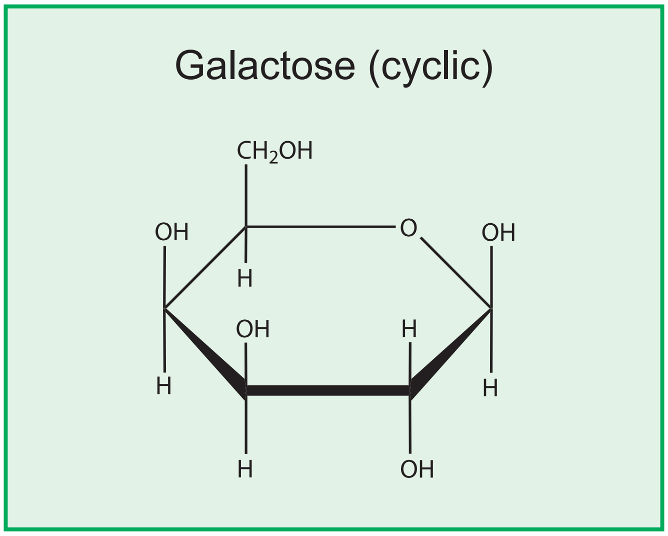
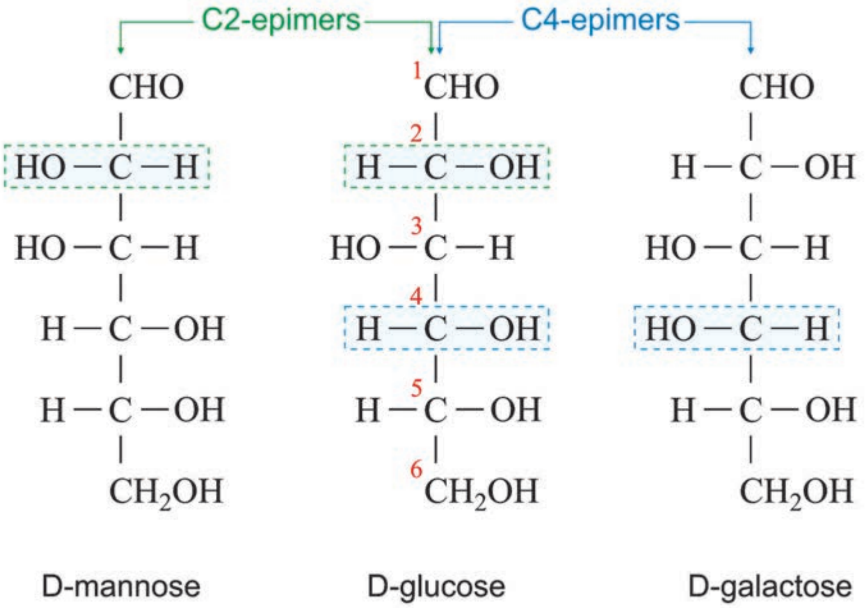


Figure 5.5 Pyranose structure of galactose

Epimers

D-sugars differing in configuration at a single asymmetric center are known as epimers. Thus D-glucose and D-galactose are epimers at C4 ; D- glucose and D-mannose are epimers at C2.



Anomers:

Sugars differing in configuration at the C1 asymmetric center are known as anomers. The C1–carbon is called as anomeric carbon. Thus α-D and β-D forms of glucose are anomers.

Mutarotation:

Mutarotation was discovered by the chemist Dubrunfaut in 1814. Mutorotation is the change in optical rotation due to change in equilibrium between two anomers.

When D-glucose is crystallized at room temperature and a fresh solution is prepared, its specific rotation of polarized light is +112°; but after 12-18 hours it changes to +52.5°. If initial crystallization is taking place at 98° C and then solubilized, the specific rotation is found to be +19°, which also changes to +52.5° within few hours. This change in rotation with time is called mutarotation.

5.4 Properties of Glucose, Fructose and Galactose:

5.4.1 Glucose:

- Glucose can be a solid or liquid.
- Melting Point of glucose is 146°C
- Molar mass of glucose is 180.16 g/mol
- Density of glucose is 1.54 g/cm^3
- Glucose is soluble in water and acetic acid

5.4.2 Fructose:

Fructose has a higher solubility than other sugars; therefore, it is harder for fructose to crystallize from an aqueous solution.

- Fructose is white powder
- Melting point of fructose is 103°C
- Molar mass of fructose is 180.16 g/mol
- Density of fructose is 1.69 g/cm^3.
- Fructose is soluble in water

5.4.3 Galactose:

- Galactose is White powder.
- Melting point of galactose is 167 °C
- Molar mass of galactose is 180.16 g/mol
- Soluble in water.

Note

Galactosemia is a rare genetic metabolic disorder that affects an individual's ability to metabolize the sugar galactose properly.

Chemical Properties:

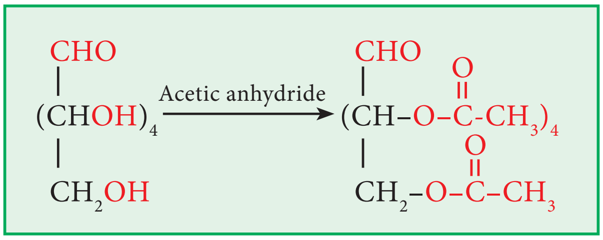
Reactions of Glucose, Fructose and Galactose:

i. Acidic character:

Both glucose and fructose behave as weak acids and form salts with $Ca(OH)_2$ (lime water).

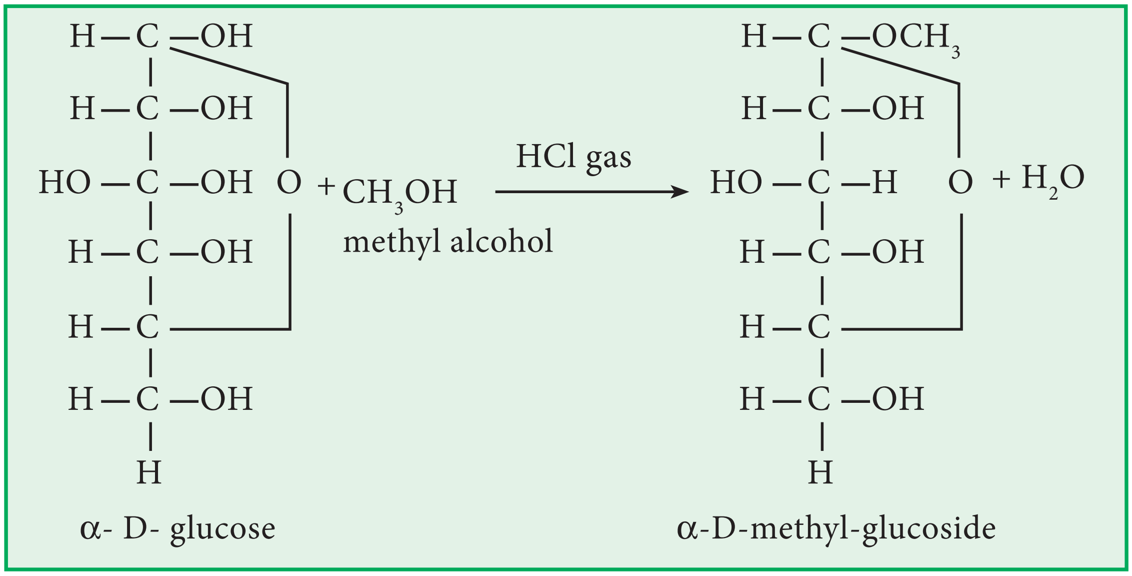
ii. Ester formation:

Glucose and Fructose form penta acetyl derivative when treated with acetic anhydride.



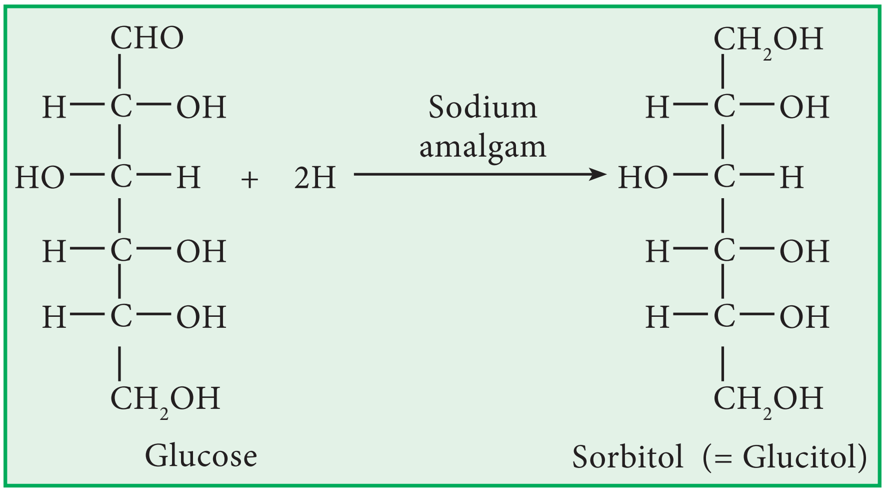
iii. Ether formation:

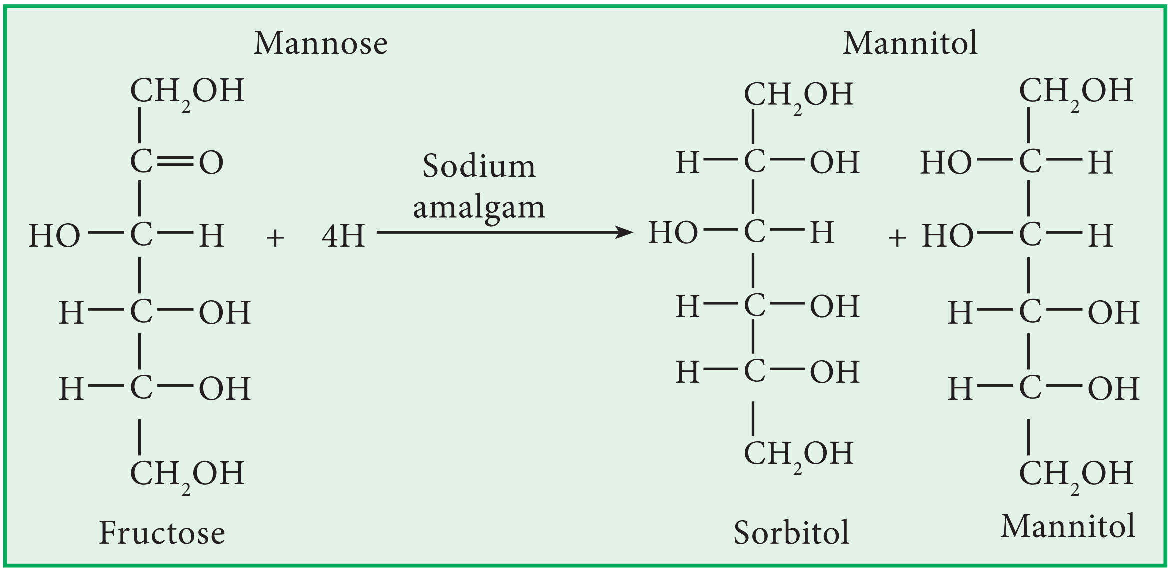
Glucose and fructose react with methanol in the presence of dry HCl gas to give ethers known as methyl glucoside and methyl fructoside, respectively.



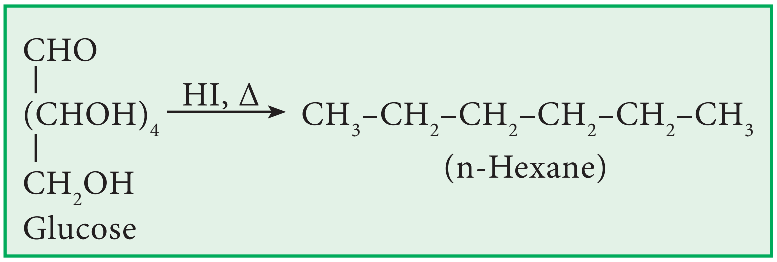
iv. Reduction:

i. Sodium amalgum reduces glucose into sorbitol and fructose into a mixture of sorbitol and mannitol. Similarly, it reduces fructose into a mixture of sorbitol and mannitol.

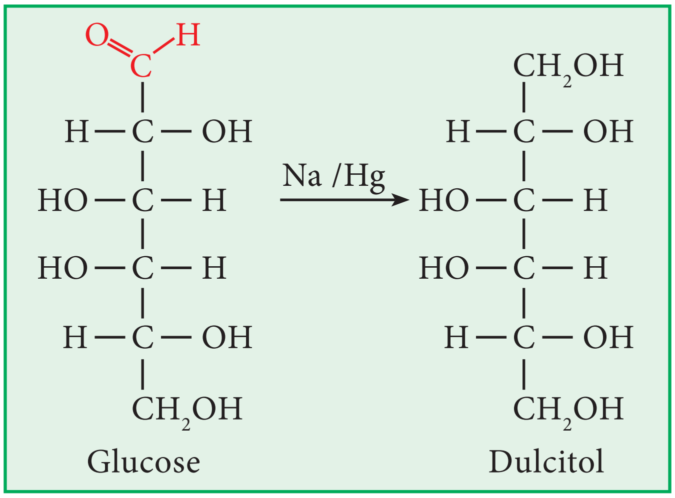




a. Both are reduced to n-hexane by HI / red 'P'.

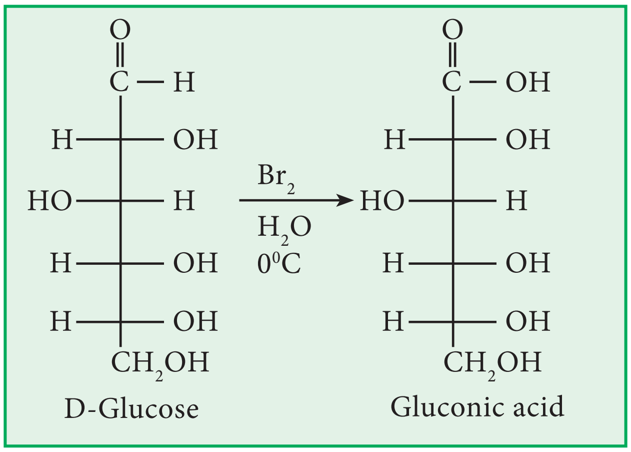


b. Galactose on reduction with Na/Hg, gives dulcitol (and with HI/red P, n-hexane will be obtained).



v. Oxidation:

a. Glucose is oxidized by mild oxidizing agents like bromine water into gluconic acid. Strong oxidizing agents like conc. HNO_3 oxidize glucose into gluconic acid.

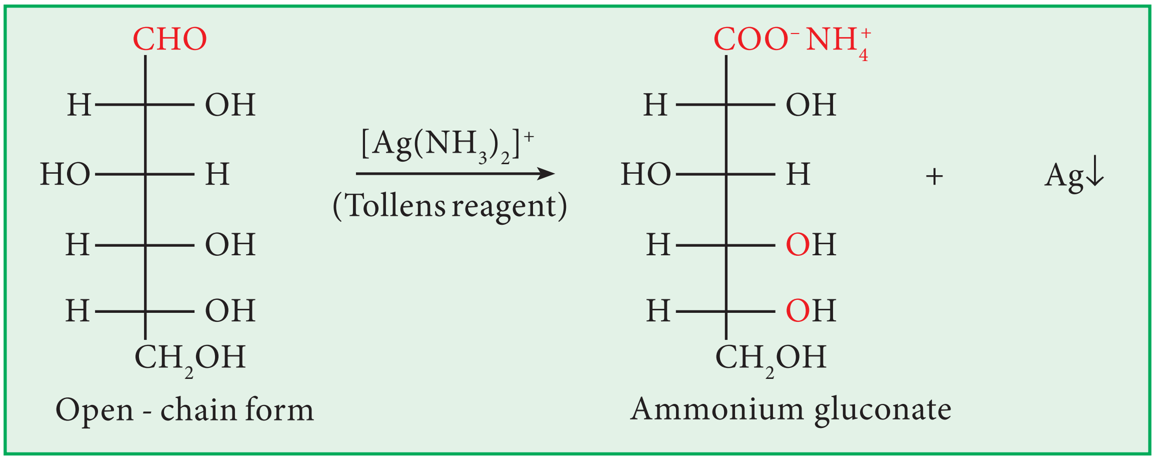


b. Fructose is not oxidised by mild oxidising agents. But strong oxidising agents like conc. HNO_3 split fructose into a mixture of trihydroxy glutaric, tartaric and glycollic acids.

c. Galactose on oxidation with mild oxidizing agent such as bromine water, gives galactonic acid. On oxidation with strong oxidizing agents like HNO_3, it gives galactaric (or) mucic acid. This acid is insoluble in water and hence this reaction is used as a test for galactose. On oxidation with O_2/Pt-C (as in glucose, after protecting the –CHO group into ispropylidene group) it gives galacturonic acid.

vi. Action with Tollen's reagent:

Both glucose and fructose reduce Tollen's reagent into silver mirror.

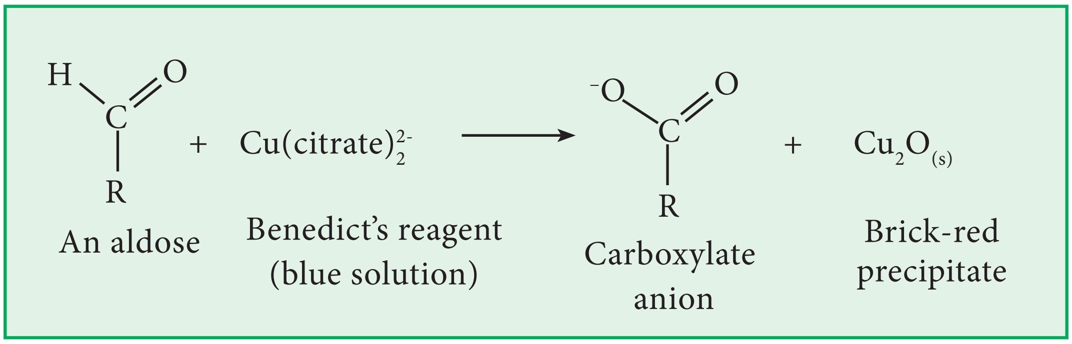


vii. Action with Fehling's solution:

Both glucose and fructose reduce Fehling's solution into red cuprous oxide.

viii. Action with Barfoed's and Benedict's reagents:

Both glucose and fructose reduce Barfoed's and Benedict's reagents into red cuprous oxide as in the case of Fehling's solution.



Glucose+CuO→Gluconic acid + Cu_2O ↓

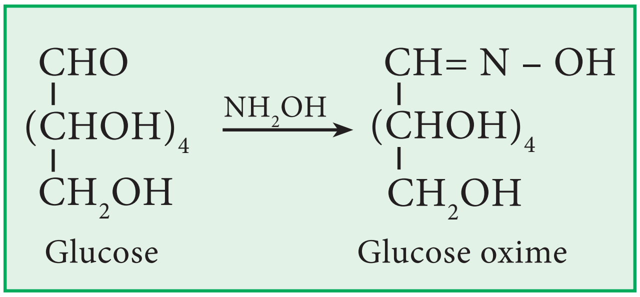
Fructose+CuO→Tartaric acid+glycollic acid+Cu_2O↓

Since both glucose and fructose reduce all these four reagents (Tollen's, Fehling's, Benedict's and Barfoed's reagent), these sugars are known as reducing sugars.

ix. Action with hydroxylamine:

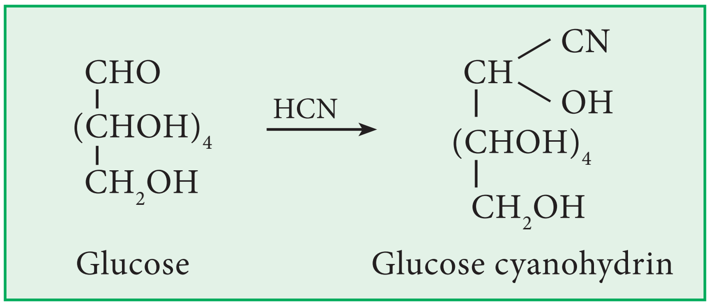
a. Both glucose and fructose form oximes with hydroxylamine.

b. With NH_2OH, galactose forms galactose oxime.



x. Action with HCN (Kiliani synthesis):

Both glucose and fructose form cyanohydrins with HCN.



Note

Tollen's Reagent:

Ammonical Silver Nitrate : $[Ag(NH_3)_2]NO_3$

Fehling's Reagent:

A- Copper(II) Sulfate

B- aqueous potassium sodium tartrate

Benedict's Reagent:

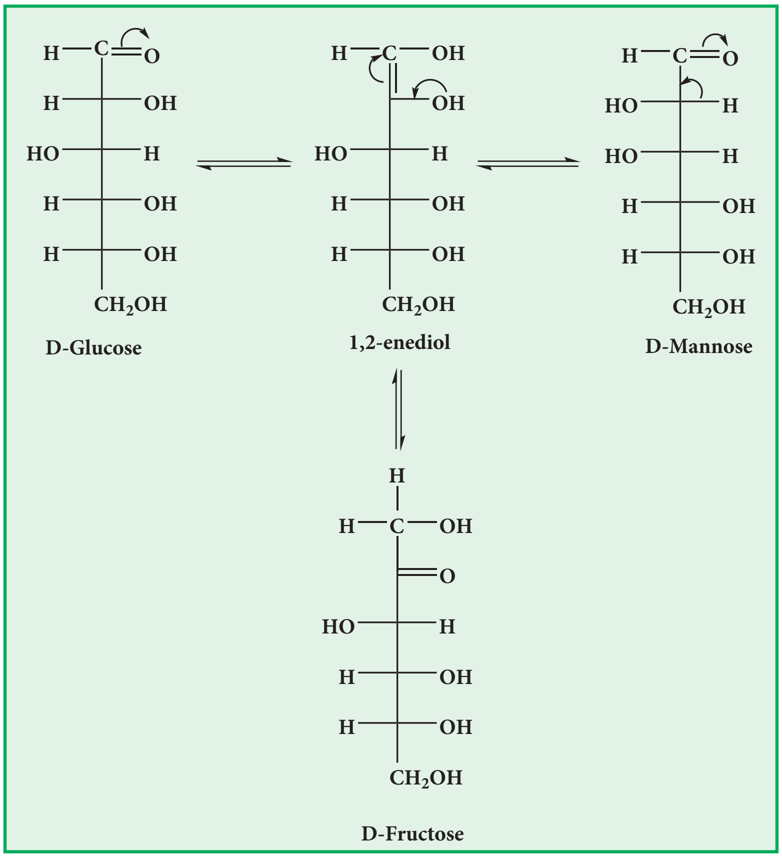
Mixture of sodium carbonate, sodium citrate and copper (II) sulfate

xi. Action with Conc. HCl:

Both glucose and fructose when heated with conc. HCl give laevulic acid.

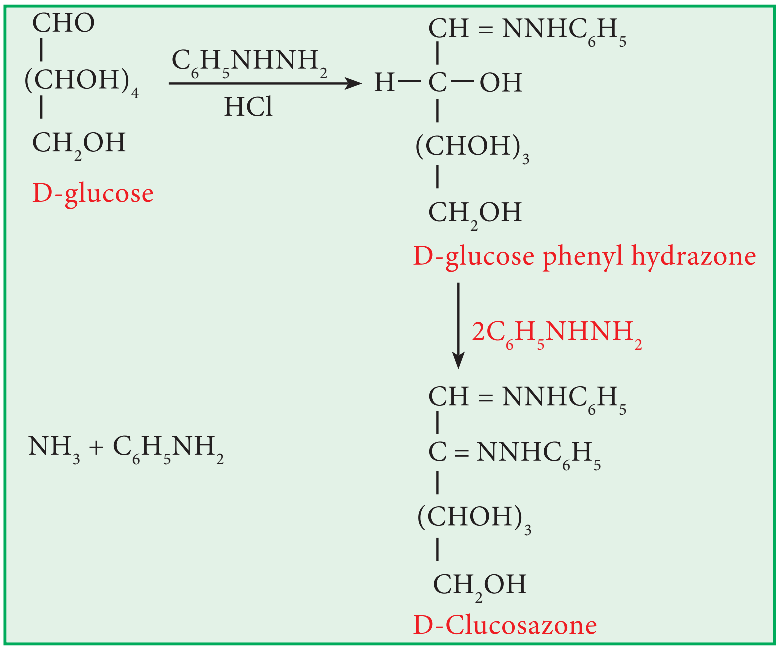
xii. Action with alkalies:

When warmed with conc. alkali, sugars first turn yellow, then brown and finally resinify. But in the presence of dilute. alkali glucose and fructose give a mixture of D-glucose, D-mannose and D-fructose. This is known as Lobry de Bruyn - van Ekenstein rearrangement. This occurs through enediol formation.



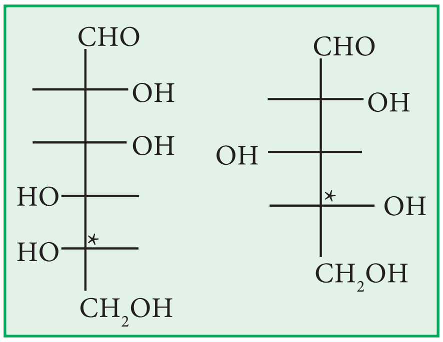
xiii. Osazone formation:

Both glucose and fructose react with excess of phenyl hydrazine to give the same type of osazone. Glucose and fructose have structural difference with respect to only first two carbon atoms, which are involved in osazone formation. The configurations in the rest of the carbon atoms are similar in both glucose and fructose. Hence they form similar osazone crystals.



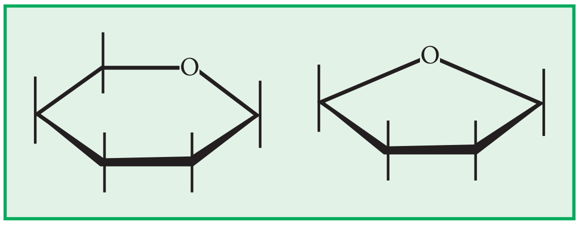
5.5 Haworth's Projection

A Haworth Projection is a common way of writing a structural formula to represent the cyclic structure of monosaccharides. It was named in the remembrance of the chemist Sir Norman Haworth. Let's consider two sugars, one an aldohexose, the other an aldopentose. Fischer projections are shown below. Recall the carbon with the star (*) next to it is the one that determines if the sugar is a D -sugar or an L-sugar.

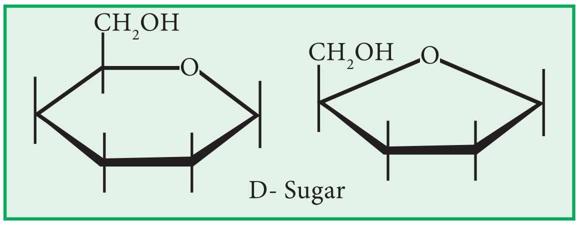


The Following are the rules.

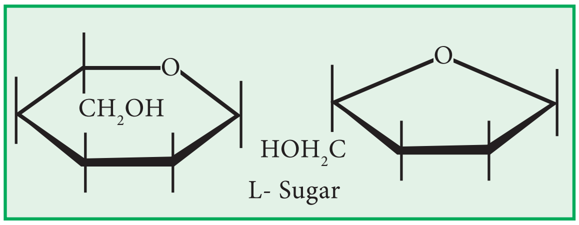
1. Draw the basic structure for the sugar.



2. If the sugar is a D-sugar, place a $-CH_2OH$ above the ring on the carbon to the left of the oxygen, for an L-sugar place it below the ring.

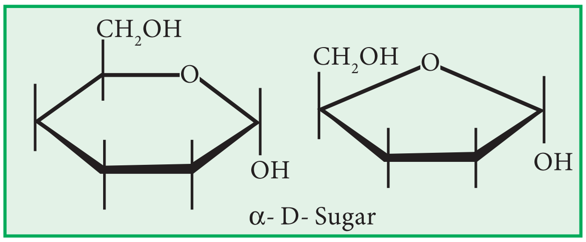


D- Sugar

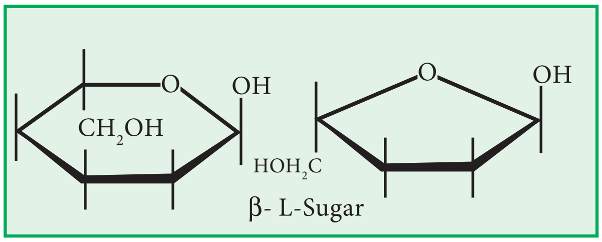


L- Sugar

3. For an α-sugar place an –OH below the ring on the carbon to the right of the ring oxygen, for a β-sugar place the - OH above the ring.

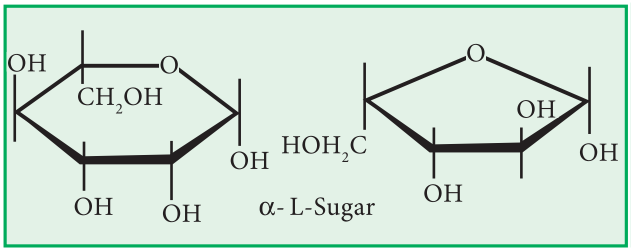


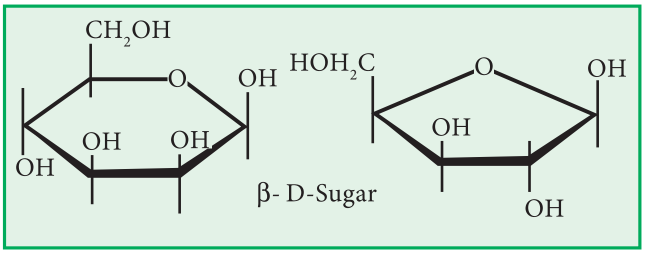
α- D- Sugar



β- L-Sugar

4. Finally, –OH groups on the right go below the ring and those on the left above, using the–CH_2OH group as the reference point for both projections.





5.6 Disaccharides

The carbohydrates which on hydrolysis give two monosaccharide units are known as disaccharides.

Example: Sucrose, maltose, lactose etc.,

5.6.1 Maltose:

Properties of Maltose:

a. Maltose or malt sugar is formed as an intermediate product in the acid hydrolysis of starch.

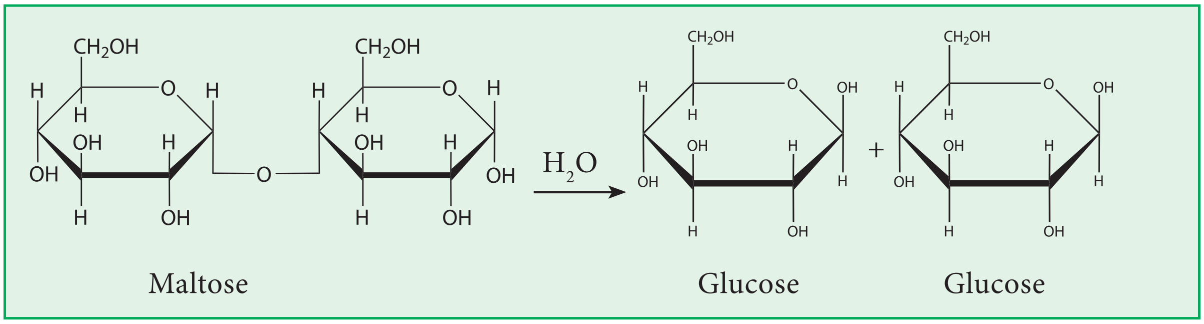
b. It is also produced during the course of digestion of starch by pancreatic amylase.

c. It is a reducing disaccharide.

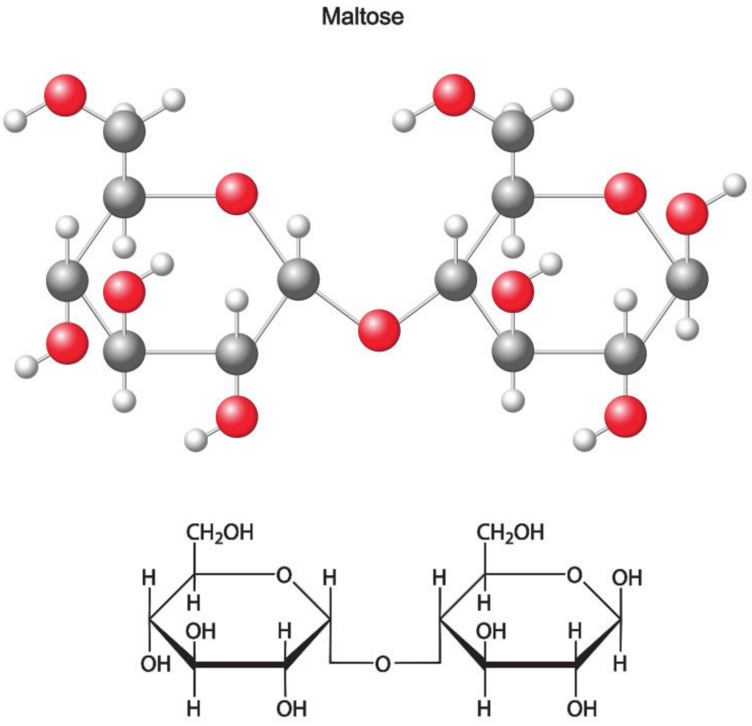
d. Maltose is composed of two α-D-glucose units held together by α(1-4) glycosidic linkage.

e. It is hydrolyzed by dilute acids (or) the enzyme maltase into two α - D - glucose units.

f. Maltose is readily fermented by yeast.



Structure of Maltose



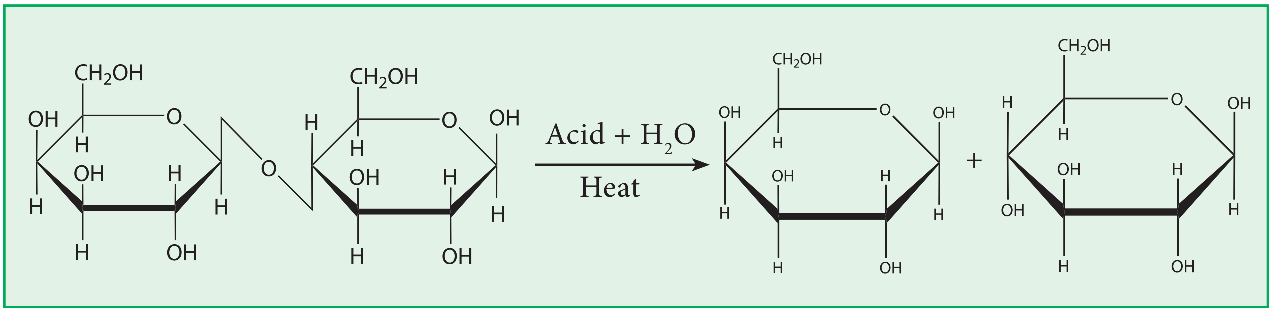
Maltose (α-D-glucopyranosyl-(1→4) α-D-glucopyranose)

5.6.2. Lactose :

a. Lactose is formed by the mammary glands. It is milk sugar.

b. It is a reducing sugar, forms osazone.

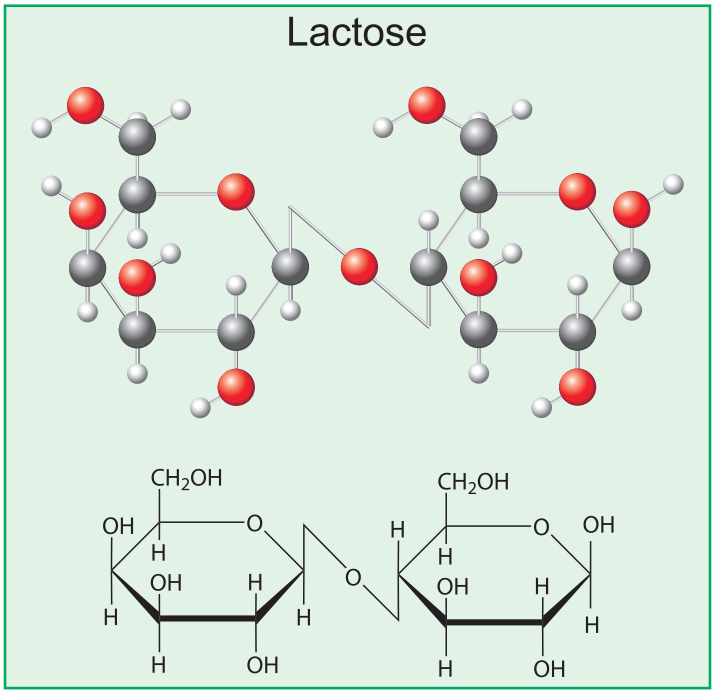
c. It is hydrolysed by acids and the enzyme lactase (β-D galactosidase) into one molecule of α- D- galactose and one molecule of α - D - glucose.



d. It is fermented by yeast.

e. In lactose, the galactose and glucose units are held together by α(1-4) linkage.

Structure of Lactose:



β-D-galactopyranosyl-(1→4) β-D-glucopyranose

(β- Lactose)

5.6.3 Sucrose:

Properties of sucrose:

a) When heated to 200°C it loses water to form a brown mass called caramel. On strong heating, it gives pure carbon with a burnt smell.

b) Concentrated sulphuric acid dehydrates sucrose into carbon. This on further oxidation by H_2SO_4 gives CO_2

$$C_{12}H_{22}O_{11}+H_2SO_4 \rightarrow C + H_2O + SO_2$$

c) When boiled with HCl, sucrose gives laevulic acid.

d) Concentrated nitric acid oxidises cane sugar (sucrose) to oxalic acid.

$$C_{12}H_{22}O_{11}+9O_2 \rightarrow 6(COOH)_2 + 5H_2O$$

e) Sucrose is fermented by invertase into glucose and fructose which are converted to ethanol by zymase. Both these enzymes are available in yeast.

f) Sucrose on acetylation gives octa-acetyl derivative.

g) Sucrose on methylation gives octa-o-methyl derivative.

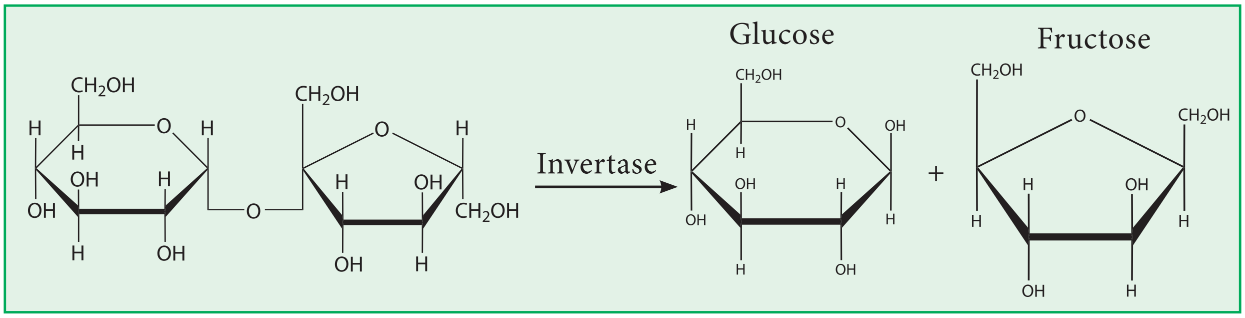
h) Sucrose does not react with HCN, NH_2OH, phenyl hydrazine, Tollen's reagent and Fehling's solution.

i) Controlled reduction of sucrose gives a mixture of sorbitol and mannitol.

j) It reacts with lime water $Ca(OH)_2$ to give calcium sucrate.

Hydrolysis of sucrose:

Sucrose is hydrolysed by dilute acids or enzymes like sucrase or invertase into an equimolar mixture of glucose and fructose.

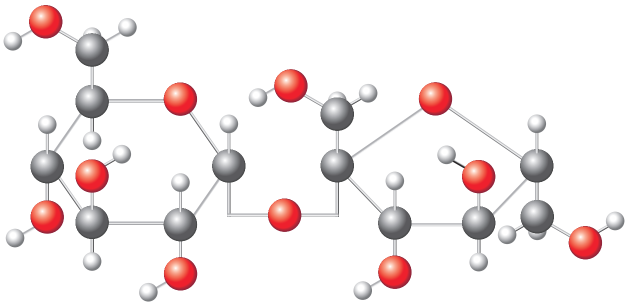


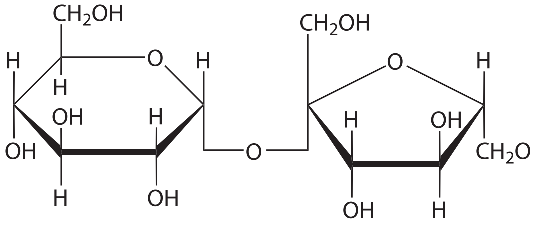
Sucrose is dextrorotatory. But the hydrolysed product is laevorotatory. Since the direction of rotation is reversed, this phenomenon is known as inversion of cane sugar. The mixture of sugars formed on hydrolysis is known as invert sugar.

According to Hudson, sucrose is first split into α-D(+) glucopyranose and β-D(+) fructofuranose, both are dextro rotatory. However, the less stable β-D(+) fructofuranose then sets up an equilibirum with its more stable isomer, α-D(–) fructopyranose which is strongly laevorotatory. Thus, the invert sugar gives a specific rotation of –28.2°.

Structure of Sucrose:

Sucrose (saccharose)





α-D-glucopyranosyl-β-D-fructofuranoside

Table 5.2 Differences between glucose, fructose and galactose

S. No	Character	Glucose	Fructose	Galactose
1.	Optical rotation	Dextro	Laevo	Dextro
2.	Solubility in water	Soluble in water	Soluble in water	Slightly soluble
3.	Reducing nature	Reducing sugar	Reducing sugar	Reducing sugar
4.	Action with Bromine water	Oxidised to gluconicacid	Not oxidised	Oxidised to galactonic acid
5.	Action with HNO_3	Oxidised to glucaric acid	Oxidised to a mixture of glycolic, tartaric and trihydroxy glutaric acid	Oxidised to mucic acid
6.	Action with Na/Hg	Reduced to sorbitol	Reduced to a mixture of sorbitol and mannitol	Reduced to dulcitol
7.	Osazone formation	Yellow coloured needle shaped crystals are formed within 10 minutes	Yellow coloured needle shaped crystals are formed within 5 minutes	Yellow coloured broad stick shaped crystals are formed after 20 minutes
8.	Mutarotation	Exhibits	Exhibits	Exhibits
9.	Nature	aldohexose	ketohexose	Aldohexose

5.3 Differences between sucrose, lactose and maltose

S. No	Character	Sucrose	Lactose	Maltose
1.	Commercial Name	Cane sugar	Milk sugar	Maltsugar
2.	Composition	(Glucose + Fructose)	(Galactose + Glucose)	(Glucose + Glucose)
3.	Glycosidic linkage	α(1-2)	α(1-4)	α(1-4)
4.	Reducing Nature	Non reducing Sugar	Reducing Sugar	Reducing Sugar
5.	Hydrolysing Enzyme	Invertase	Lactase	Maltase
6.	Osazone formation	Does not formed	Yellow colour osazone shaped crystals are formed	Yellow colour sun-flower shaped crystals are formed after 40 minutes

5.7 POLYSACCHARIDES

Carbohydrates which contain more than 10 monosaccharide units are known as polysaccharides. Example : Starch, cellulose, glycogen, inulin etc.

5.7.1 HOMOPOLYSACCHARIDES

Starch:

a) Source:

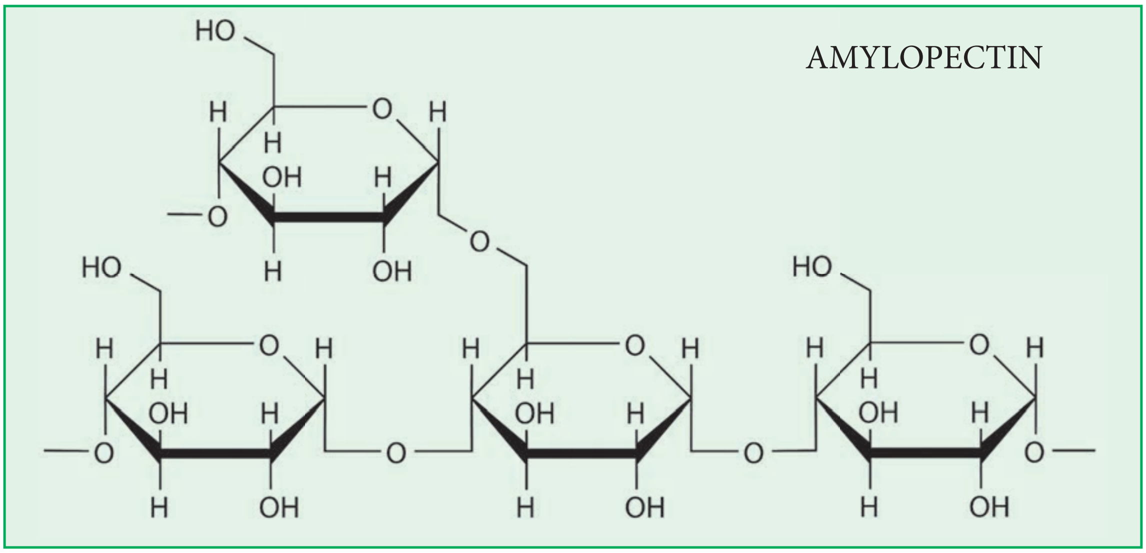
Plant materials such as roots, tubers, stem, vegetables, fruits and cereals are the main sources of starch.

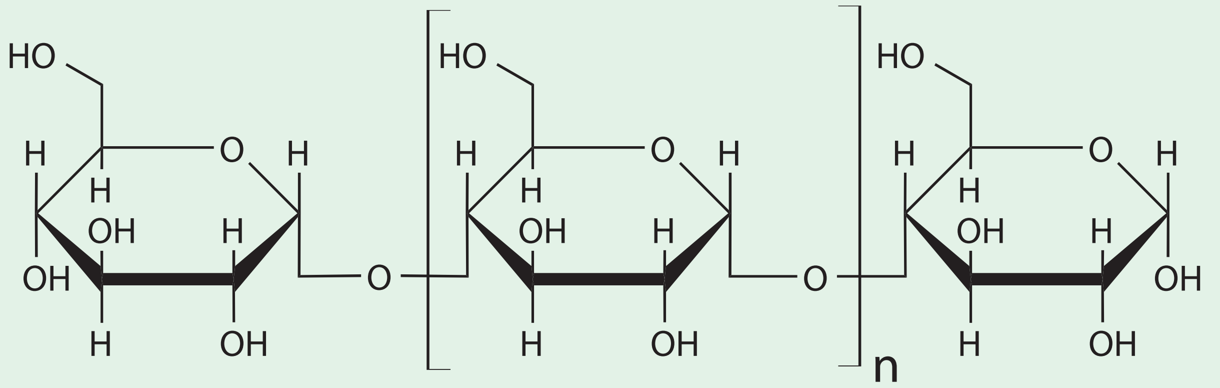
b) Structure:

Starch is the nutritional reservoir in plants. Starch is a homopolysaccharide and consists of only α-D-glucose. The two chief constituents of starch are (i) Amylose (15-20%) and (ii) Amylopectin (80 - 85%).

Amylose forms the inner portion of the starch grain and is soluble in water. It is a linear, non-branched polymer of glucose. The glucose residues are united by α(1-4) linkage. The molecular weight of amylose is 60,000.

Amylopectin forms the outer covering of the starch grain and is insoluble in water. It is a highly branched polymer of glucose. The glucose residues are united by α(1- 4) linkages in the chains and by α (1 - 6) at the branch points. Its molecular weight is 2,00,000. It is like glycogen except for its lower degree of branching.





AMYLASE

c) Hydrolysis of starch :

Starch is hydrolysed both by acids and enzymes. Both amylose and amylopectin are rapidly hydrolysed by α-amylase which is secreted by salivary glands and pancreas. α-Amylase acts upon starch and finally hydrolyses it into maltose molecules.

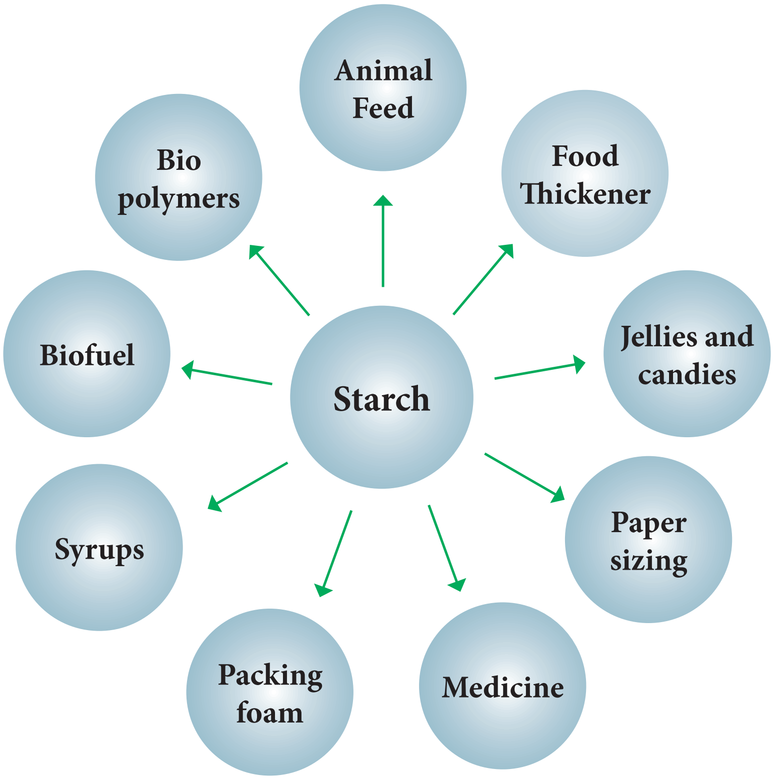
d) Uses : Starch is used

(i) as a food material. (ii) for the manufacture of glucose and alcohol.

(iii) in paper industry. (iv) in textile industry. (v) in printing.

(vi) to prepare starch acetate, nitrostarch etc. (vii) for making adhesives.

(viii) as an indicator.



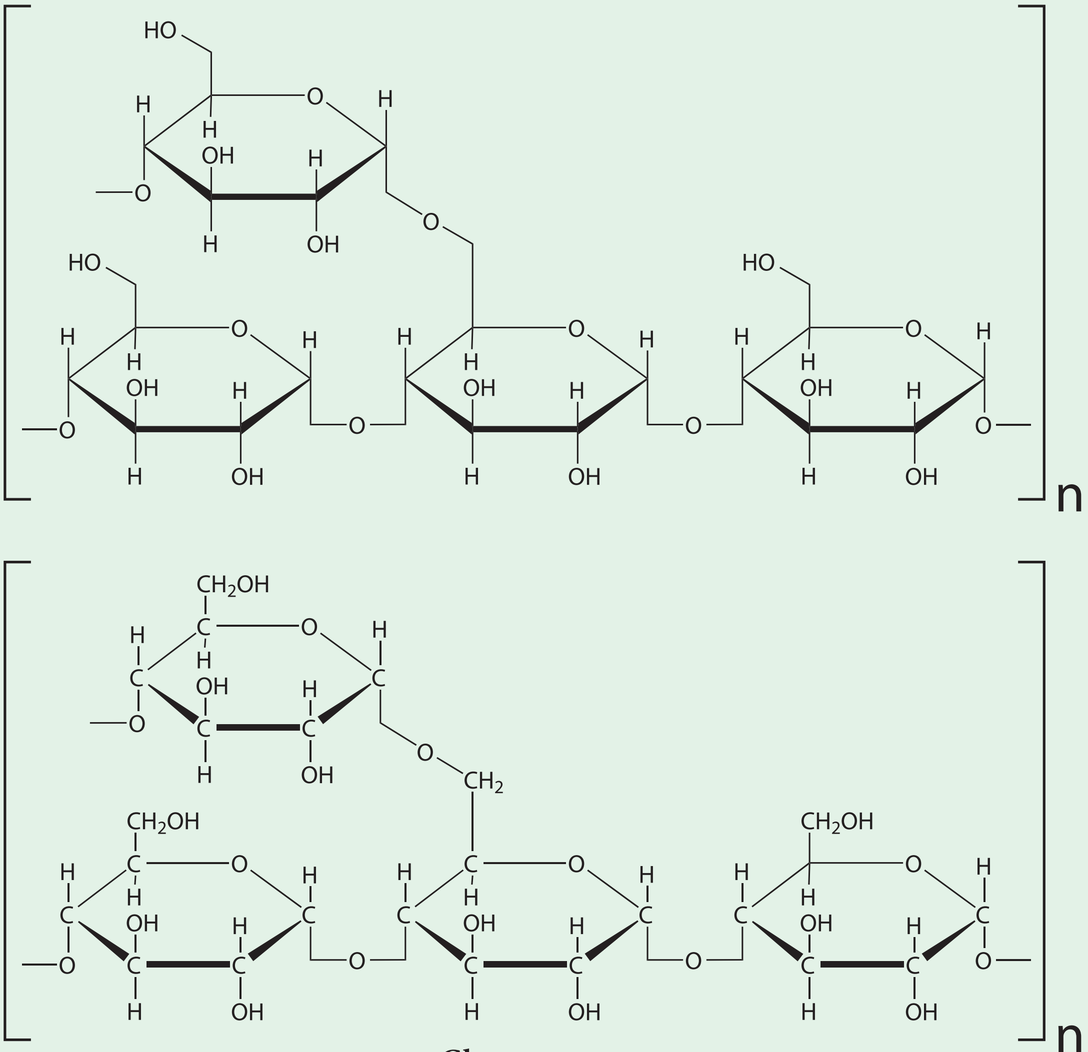
Glycogen :

a) Source :

Glycogen is the carbohydrate reserve in animals; hence often referred as animal starch. It is present in high concentrations in liver, muscle and brain.

b) Structure :

Glycogen is a very large, branched polymer of glucose residues. The structure of glycogen is similar to that of amylopectin with more number of branches. The glucose units in glycogen are linked by α(1-4) glycosidic bonds and α-(1-6) glycosidic bonds at branching points. Branching occurs about once in 10 units. The molecular weight (upto 1×10^8) and the number of glucose units (upto 25,000) vary in glycogen depending upon the source.

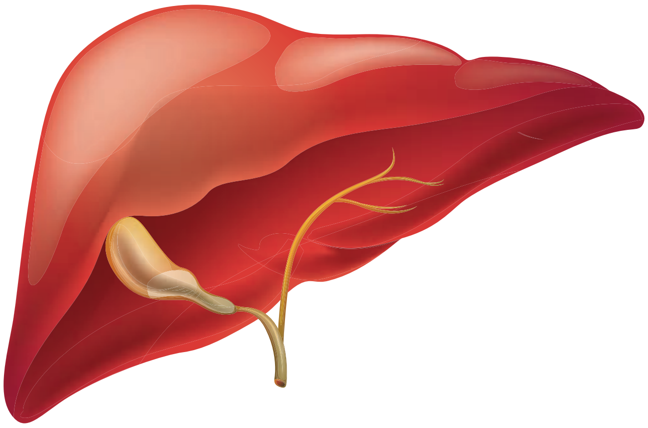


Glycogen

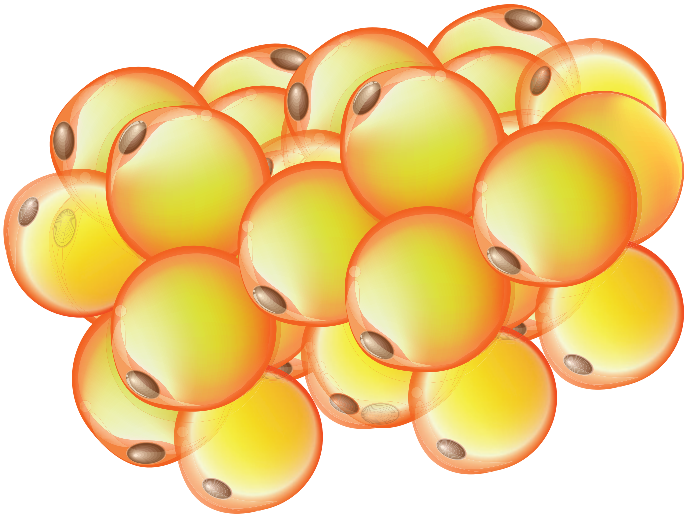
c) Uses :

(i) Excess carbohydrate in the body are deposited as glycogen.

(ii) Animal glycogen is used as food.



Liver glycogen ~300 kcal



Adipose tissue (fat)*10000kcal

5.7.2 HETEROPOLYSACCHARIDES (HETEROGLYCANS)

Glycosaminoglycans :

a. Glycosaminoglycans are otherwise known as mucopolysaccharides.

b. These are heteroglycans made up of repeating unit of aminosugars and uronic acids.

c. Because of the presence of charged groups (carboxyl group, sulphate group, acetylated amino group), they attract water molecules and so they produce viscous solutions.

d. Some of the mucopolysaccharides are found in combination with protein to form mucoproteins (or) mucoids (or) proteoglycans. They contain 95% carbohydrate and 5% protein.

e. Examples : i) hyaluronic acid ii) heparin iii) chondroitin sulpahte iv) keratan sulphate v) dermatan sulphate.

(i) Heparin:

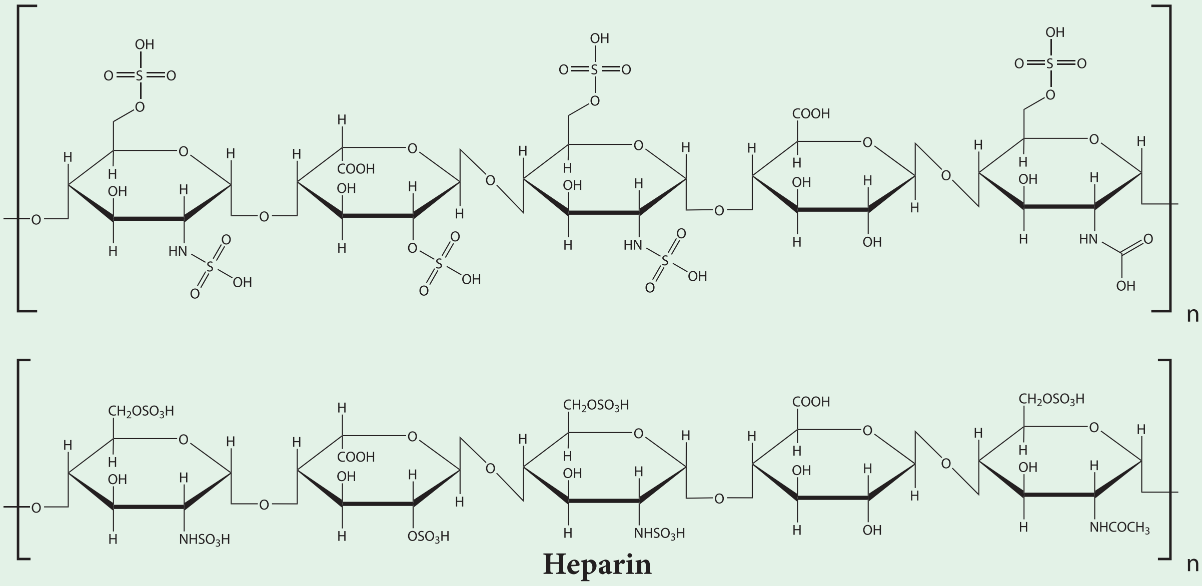
a. It is a mucopolysaccharide present in liver, lung, spleen, kidney, and blood.

b. It is a blood anticoagulant.

c. Heparin is composed of alternating units of N-sulpho-glucosamine-6 sulphate and L-iduronate-2-sulphate.

d. These two molecules are held together by α(1-4) glycosidic bond.

e. Its molecular weight is 20,000.



Heparin

ii) Hyaluronic acid :

a. It is a mucopolysaccharide present in syanovial fluid, vitreous humor of eyes, cartilage tissues, loose connective tissues and in bacteria.

b. It consists of repeated units of α-glucuronic acid and N-acetylglucosamine.

c. These two molecules are held together by α(1-3) glycosidic bond.

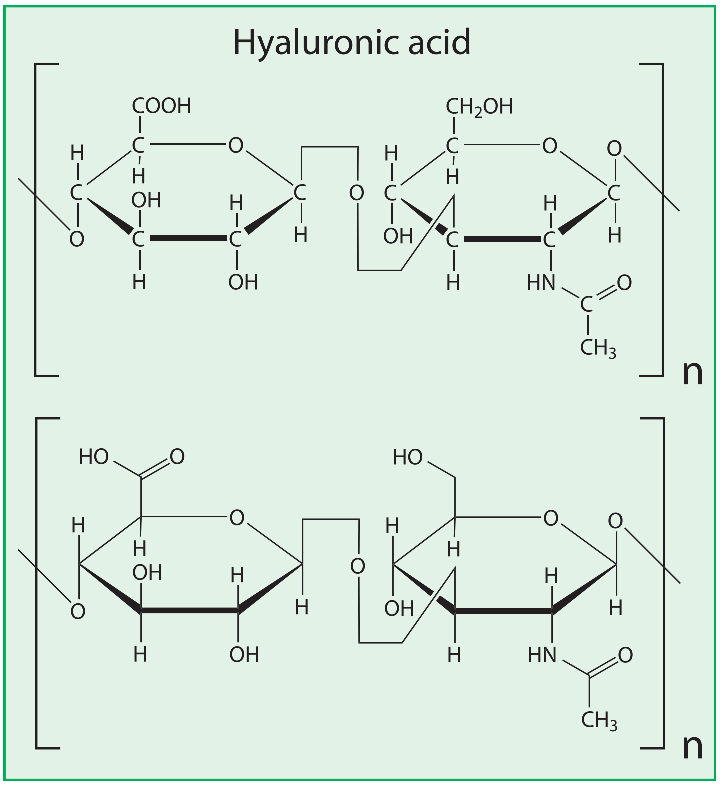
d. It is an unbranched chain polymer.

e. Its solutions are viscous and hence acts as lubricant and shock absorbent in joints.

f. In tissues, it acts as a barrier and permits the metabolites to pass through but not the bacteria and other infectious agents.

g. Hyaluronic acid contains about 250-25,000 disaccharide units, held by α-(1-4) glycosidic bonds with a molecular weight upto 4 million.

h. The α(1-4) linkage in hyaluronic acid is cleaved by the enzyme hyaluronidase. This enzyme is present in high concentration in testes, seminal fluid and certain snake venom.


Hyaluronic acid

EVALUATION

I. Choose the correct answer from the given four alternatives

1. The functional groups present in carbohydrates are

a) Alcohol and Carboxyl groups

b) Aldehyde and Ketone groups

c) Hydroxyl groups and Hydrogen groups

d) Carboxyl groups and others

2. which of the following has reducing property?

a) Glucose	b) Fructose
c) Starch	d) Sucrose

3. The end product of hydrolysis of "Starch" by amylase is …………

a) Soluble starch	b) Glucose
c) Dextrins	d) Maltose

4. Fructose and Glucose can be distinguished by …………

a) Seliwanoff's reagent	b) Benedict's reagent
c) Fehling's reagent	d) Barfoed's reagent

II. Fill up the blanks

1. Carbohydrate consists of ...., ... and .... molecule

2. Hydrogen Oxygen atom ratio in Carbohydrate is ....

3. Molecules having only one actual sugar group is called as ....

4. Sugars having aldehyde group are called as ....

5. Sugars with keto group are called as ....

6. Compounds having same structural formula but differing in spatial configuration are known as ....

7. The change in rotation of plane of plane polarised light with time is called ....

8. Equimolecular mixture of glucose and fructose thus formed is called …………

9. Types of Polysaccharides are .... and ....

10. Starch is composed of amylose and …………

III. Give short answers for the following

1. What is the structural difference between glycogen and starch?

2. What is glycogenolysis?

3. Give the structure of sucrose.

4. What is epimerisation?

5. Mention the reaction between fructose and sodium amalgam.

6. What is a racemic mixture?

IV. Answer the following:

1. What are the organic chemical groups that compose carbohydrates? How are carbohydrates classified according to the presence of those groups?

2. What are the functions of carbohydrates?

3. What is the difference between monosaccharides and disaccharides? What are some examples of them?

4. Explain the property of stereoisomerism in monosaccharides with two examples.

5. What are the reaction sequences of glucosazone formation?

6. Mention the difference between amylose and amylopectin.

7. What is the molecular formula for glucose? How can its structural formula be described?

8. What are the main biological functions of polysaccharides?

9. Explain the muta rotation of glucose.

SUMMARY

- Carbohydrates are the most abundant biomolecules, also considered as a primary source of energy.

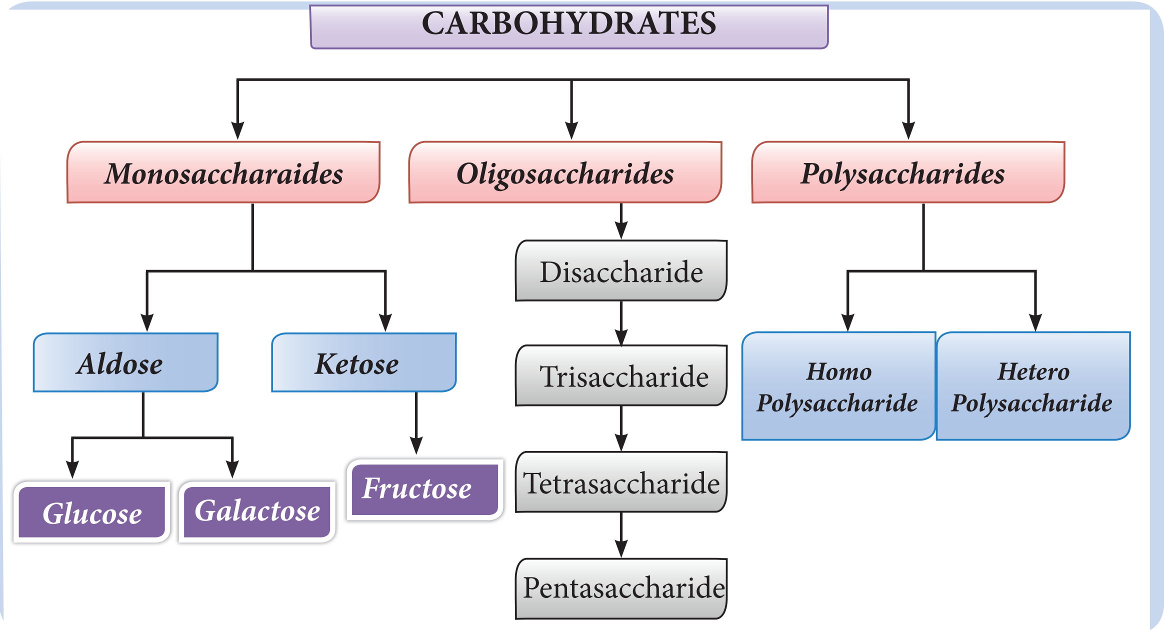
- Structurally they can be classified as aldose (polyhydroxy aldehyde) and ketose (polyhydroxy ketones).

- Depending upon the number of sugar moieties carbohydrates are classified as monosaccharides, oligosaccharides and polysaccharides.

- Aldoses and ketoses are isomers of monosaccharides .

- Carbohydrates have the tendency to undergo oxidation and reduction in the presence of suitable reagents.
- The aldehyde and keto group of a monosaccharide can react with any one hydroxy group present in the same molecule to form cyclic hemiacetals or hemiketals.
- Sugars differing in configuration at the C1 asymmetric center are known as "anomers" and at C4 are called as "epimers".
- Polysaccharides are classified as homo polysaccharides and heteropolysaccharides which have same sugar moiety and different sugar moiety, respectively.

CONCEPT MAP



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