

Carbohydrates

Carbohydrates are the most abundant class of macromolecule on earth. They constitute about 75% by mass of dry plant material. The plants produced carbohydrate via photosynthesis. In this process, glucose is synthesized from carbon dioxide and water by photosynthesis and stored as starch or converted to cellulose in the plant framework. Animals can synthesize some carbohydrate from fat and protein, but the bulk of animal carbohydrate is derived ultimately from plants.

They are organic compounds that contain **carbon, hydrogen, and oxygen**. Generally the hydrogen and oxygen in carbohydrates are present in the ratio of **two hydrogen to one oxygen (2:1)** as in water H₂O hence the term carbohydrates (carbon hydrate) were derived. But all compounds grouped under this heading have a similar structure.

The simple sugar glucose contains **6** carbon atoms, **12** hydrogen atoms, and **6** oxygen atoms giving the molecular formula **C₆H₁₂O₆**. Carbohydrates are derivatives of **polyhydroxy aldehydes or ketone**.

Functions: [Carbohydrate](#) oxidation provides energy. They are stored as [glycogen](#) in animal tissues and serve as short-term energy reserve. They supply carbon atoms for the synthesis of other biochemical compounds- proteins, lipids and nucleic acids. [Carbohydrate](#) form part of the structural component of DNA and RNA molecule.

Classification

The carbohydrates are often referred as saccharides named after the Greek word '**Sakcharon**', meaning sugar.

They are classified as follows.

1. [Monosaccharides](#)
2. [Disaccharides](#)
3. [Oligosaccharides](#)
4. [Polysaccharides](#)

Monosaccharide

5. A **monosaccharide** is a carbohydrate that contains a single polyhydroxy aldehyde or polyhydroxy [ketone](#) unit. Monosaccharides can not be hydrolyzed to simpler carbohydrates. They may be subdivided into **trioses, tetroses, pentoses, hexoses or heptoses** depending upon the number of carbon atoms they possess. Pentoses and hexoses are important simple sugars present in food.
- 6.

Type of pentose	Source	Functions
D-Ribose	Nucleic acids	Structural elements in nucleic acids and coenzymes, e.g. ATP, NAD , NADP , flavoprotein. Ribose-phosphate is an intermediate in pentose phosphate pathway.
D-Ribulose	Formed in metabolism	Ribulose phosphate is an intermediate in pentose phosphate pathway.
D-Arabinose	Gum arabic, plum and cherry gums.	Constituent of glycoproteins
D-Xylose	Wood gums, proteoglycans, glycosaminoglycans	Constituent of glycoproteins

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Type of Hexose	Source	Functions
D-Glucose	Fruit juices. Hydrolysis of starch, cane sugar, maltose, and lactose.	The free sugar of the body. The sugar carried by the blood, and the principal one

		used by the tissues.
D-Fructose	Fruit juices, Honey, Hydrolysis of cane sugar.	It can be changed to glucose in the liver and thus used in the body.
D-Galactose	Hydrolysis of lactose.	It can be changed to glucose in the liver and metabolized. It is synthesized in the mammary gland to make the lactose of milk. It is a constituent of glycolipid and glycoprotein.
D-Mannose	Hydrolysis of plant polysaccharides) and gums.	mannan(plant It is a constituent of many glycoproteins.

Disaccharide

A **disaccharide** is a carbohydrate that contains two molecules of monosaccharide units covalently bonded to each other. **Examples:** Maltose, lactose and sucrose.

On hydrolysis, **maltose** yields two molecules of glucose, **lactose** yields one molecule of galactose and one molecule of glucose, and **sucrose** yields one molecule of glucose and one molecule of fructose. **Maltose** is formed when starchy material is hydrolysed. **Sucrose** is present in fruit juices, sugarcane and sugar beet. **Lactose** is the principal sugar present in milk.

Oligosaccharide

An **oligosaccharide** is a carbohydrate that contains two to ten monosaccharide units covalently bonded to each other. **Raffinose** and **stachyose** are two important [oligosaccharides](#) present in dried beans, peas and lentils, which yield three and four monosaccharide units respectively on hydrolysis.

Polysaccharides

A **polysaccharide** is a polymeric carbohydrate chain that contains **more than ten molecules** of monosaccharide units covalently bonded to each other.

E.g. **Glycogen** present in liver and muscle cells of animals

Starches, cellulose and dextrans in plant tissues.

These are sometimes designated as **hexosans or pentosans**, depending upon the identity of the **monosaccharides** they yield on hydrolysis.

These may be classified as homopolysaccharides and heteropolysaccharides depending on the presence of either the same monosaccharides or more than one monosaccharide.

E.g. Homopolysaccharide- Starch, [Glycogen](#), cellulose, Dextrin

Heteropolysaccharide- Mucopolysaccharide

Structure and Properties of Monosaccharides

Structure of Carbohydrates

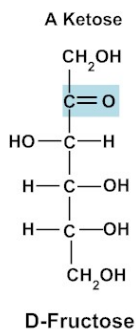
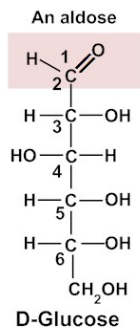
The name carbohydrate owes its origin to the fact that most substances of this class have empirical formulas suggesting they are **carbon "hydrates"** in which the ratio of carbon to hydrogen to oxygen atoms is 1:2:1.

For example, the empirical formula is of D-glucose is $C_6H_{12}O_6$.

This also can be written as $(CH_2O)_6$ or $C_6(H_2O)_6$. Many carbohydrates conform to the empirical formula $(CH_2O)_n$ while others do not show this ratio.

Structure of Monosaccharides

Monosaccharides are polyhydric alcohols containing aldehyde or keto groups. They may be classified into aldoses or ketoses depending upon whether the aldehyde or [ketone](#) groups are present. Depending upon the number of carbon atoms they divided into trioses, tetroses, pentoses, hexoses or heptoses.



Stereochemistry

Stereochemistry is the study of the arrangement of atoms in three-dimensional space. Stereoisomer is compounds in which the atoms are linked in the same order but differ in their spatial arrangement. Many carbohydrates exhibit stereoisomerism as they contain the same number of atoms and the same kinds of group but have different chemical and biological properties. This is due to the presence of asymmetric carbon atom in the structure.

A carbon atom attached to four different atoms or groups is called an asymmetric carbon atom. When there are many asymmetric carbon atom in a chain molecule the number of stereoisomer possible is equal to 2^n , where n is the number of asymmetric carbon atoms. The simple sugars corresponding to the formula $C_6H_{12}O_6$ have 4 asymmetric carbon atoms and hence have $2^4 = 16$ stereoisomer each have identical functional groups but with different spatial configurations. This is due to the presence of asymmetric carbon atom in the structure.

Glucose has 4 asymmetric carbon atoms (2, 3, 4 & 5). The structure of glucose can be represented in three ways (1) the straight - chain structural formula (aldohexose, as simple ring or a chair form.

Isomerism

Monosaccharide exhibits various forms of isomerism due to the presence of **asymmetric carbon atom**. There are six types of isomerism found with monosaccharides.

1. [Aldose](#)-ketose isomerism
2. D&L isomerism
3. Optical isomerism
4. [Pyranose](#) and furanose isomerism
5. Alpha and Beta isomerism
6. Epimerism

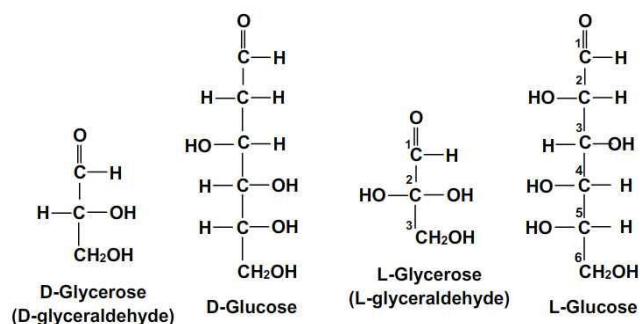
Aldose -Ketose Isomerism

[Monosaccharides](#) exhibit aldose-ketose isomerism. Sugar with a **keto groups** is called a **ketose** and that with an **aldehyde** group is called an **aldose**. Glucose is an aldose since there is a potential aldehyde group in position 1 of glucose. Fructose is a ketose since it has a potential keto group in position 2. Fructose has the same molecular formula as glucose but differs in its structural formula.

r of its mirror image as the **L form** is determined by its spatial relationship to the parent compound of the carbohydrate family, the three carbon sugar **glyceraldehydes**.

The orientation of the **-H** and **-OH** groups around the carbon atom adjacent to the terminal primary alcohol carbon determines whether the sugar belongs to the D or L series. **When the -OH group on this carbon is on the right**, the sugar is a member of the **D series**; **when it is on the left**, it is a member of the **L series**. Most of the monosaccharide occurring in nature is of the D [configuration](#).

The structure of D and L Glyceraldehyde and D and L glucose are given below:



Optical Isomerism

One of the physical properties of molecules that have asymmetric carbon atoms is that the molecules will rotate the direction in which the light is vibrating as it passes through them. The presence of asymmetric carbon atoms confers **optical activity** on the compound and exhibit optical isomerism.

Optical activity

'When a beam of plane -polarized light is passed through a solution of an optical isomer, it will be rotated either to the right-or left in accordance to the type of compound and it is called optical activity'

A compound which causes rotation of plane polarized light to the right is said to be **dextrorotatory (+) isomer**, and '**d**' is used to designate the fact. Rotation of the plane polarised light to the left is called **levorotatory isomer** and designated by a '**-**' sign and '**l**' is used to designate to the fact. The naturally occurring form of fructose is the D (-) isomer. When equal amounts of D and L isomers are present, the resulting mixture has no optical activity, since the activities of each isomer cancel one another. Such a mixture is said to be a **racemic** or DL mixture. Two important monosaccharides whose isoforms are biologically active –L fucose and L iduronic acid.

Stereoisomerism and optical activity are independent properties. Thus D (+), D (-), L (-), or L (+), indicate structural relationship to D or L glyceraldehyde and the optical activity exhibited.. Synthetically produced compounds are racemic. The optical rotation of glucose in solution is dextrorotation hence, the alternative name of dextrose.

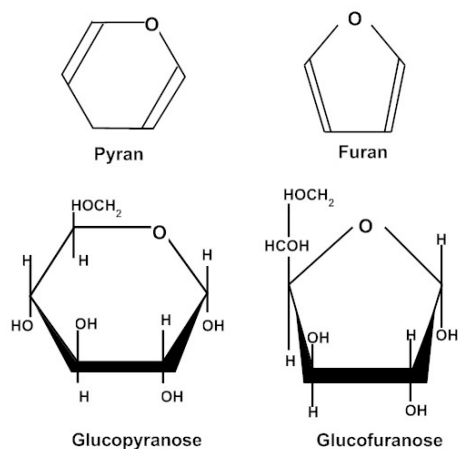
Pyranose and Furanose Ring Structures

Alcohols react with the carbonyl groups of aldehydes and ketones to form **hemiacetals** and **hemiketals** respectively. The hydroxyl and either the aldehyde or the **ketone** groups of monosaccharides can likewise react intramolecularly to form cyclic hemiacetals and hemiketals.

The configurations of the substitutes of each carbon atom in these sugar rings are conveniently represented by their **Haworth's Projection**, in which the heavier ring bond project in front of the plane of the paper and the lighter ring bonds project behind it.

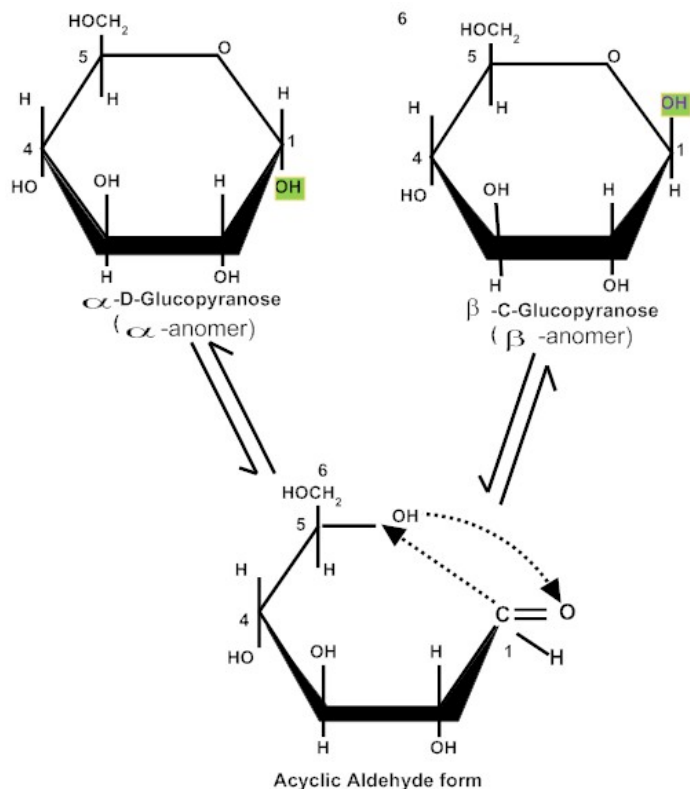
A sugar with a six-member ring is known as a **pyranose** in analogy with **pyran**, the simplest compound containing such a ring. Similarly, sugars with five-member rings are **furanoses** in analogy with **furan**.

Glucose and **fructose** form **pyranose** and **furanose** ring structures. Other pentoses and ketoses may also show ring structures. Ring structures of sugars presented are the most stable structures present in natural compounds.



Alpha and Beta Anomers

When a monosaccharide cyclizes, the **carbonyl carbon**, called the **anomeric carbon**, becomes a chiral center with two possible configurations. The pair of stereoisomers that differ in [configuration](#) at the anomeric carbon are called anomers. In the **α anomer**, the **-OH** substituent of the anomeric carbon is on the opposite side of the sugar ring from the **-CH₂OH** group at the chiral center that designates the D or L [configuration](#) (**C5** in hexoses). The other form is known as the **β anomer**.

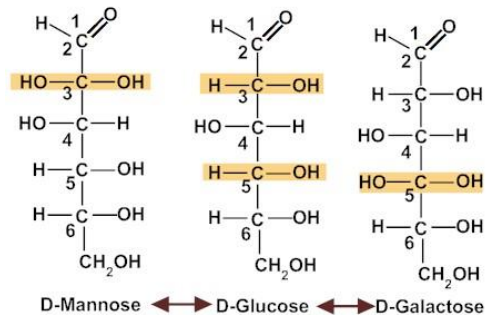


Alpha-Beta anomers of Glucose

The two anomers of D-glucose have slightly different physical and chemical properties, including different optical rotations. The anomers freely interconvert in aqueous solution, so at equilibrium, D-glucose is a mixture of the **β anomer (63.6%)** and the **α anomer (36.4%)**. The linear form is normally present in only minute amounts.

Epimerism

Epimers are diastereoisomers whose molecules differ only in the [configuration](#) at one chiral center. Isomers differing as a result of variations in [configuration](#) of the **-OH** and **-H** on carbon atoms **2, 3** and **4** glucose are known as **epimers** of glucose. The most important epimers of **glucose** are **mannose** and **galactose**, formed by epimerization at carbons **2** and **4**, respectively.



Monosaccharide derivatives

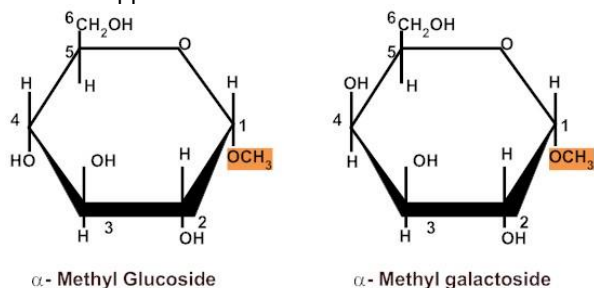
Monosaccharide units in which an OH group is replaced by other groups are called as monosaccharide derivatives.

1. Glycoside
2. Amino sugar
3. Deoxy sugars

Glycosides

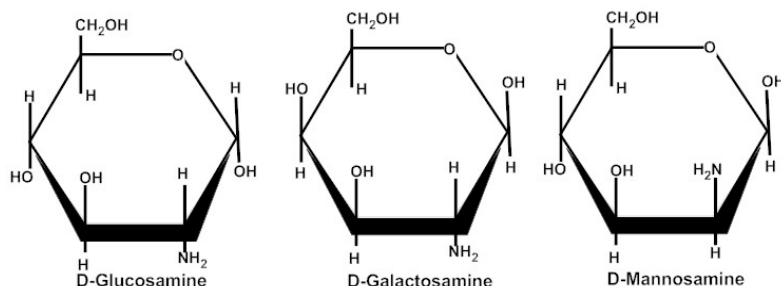
Glycosides are compounds formed by the condensation reaction between the hydroxyl group of a sugar and the hydroxyl group of a second compound (aglycon) which may or may not be another sugar.

A glycoside produced from **glucose** is called a **glucoside**, that from **galactose** is called a **galactoside**, and so on. Glycosides like the hemiacetals from which they are formed, can exist in both α and β forms. Glycosides are named by listing the alkyl or aryl group attached to the oxygen, followed by the name of monosaccharide involved, with the suffix -ide appended to it.



Amino sugars (Hexosamines)

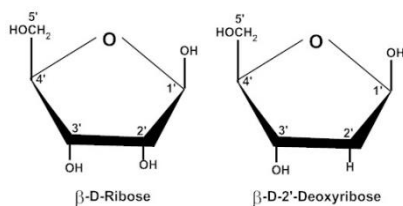
An amino sugar is formed if one of the **hydroxyl groups** of a monosaccharide is replaced with an **amino group**. In naturally occurring amino sugars, of which there are three common ones, the amino group replaces the carbon **2 hydroxyl group**. The three common natural amino sugars are D-Glucosamine, D-Galactosamine and D-Mannosamine.



Amino sugars and their N-acetyl derivatives are important building blocks of polysaccharides found in cartilage and exoskeleton of crustaceans and insects. Glucosamine is a constituent of hyaluronic acid. Chitin is a polymer of N acetyl Glucosamine. Galactosmine is a constituent of glycoprotein and Mannosamine is part of mucoprotein.

Deoxy sugars

Monosaccharide units in which an **OH** group is replaced by **H** are known as **deoxy sugars**. The biologically most important of these is β -D-2'-deoxyribose, the sugar component of DNA's sugar-phosphate backbone.



Oxidation products

When aldoses are oxidised under proper conditions with different types of oxidising products, three types of acids are produced.

1. Aldonic acid
2. Uronic acid
3. Saccharic acid

1. Aldonic acid: Oxidation of an aldose with bromine water at neutral pH converts the aldehyde group to a carboxyl group.

D Glucose → Gluconic acid

2. Uronic acid: When aldoses are oxidised with H₂O₂ uronic acids are formed. Uronic acids are constituents of pectic polysaccharides.

3. Saccharic acid or Aldaric acid: When aldoses are oxidised with nitric acid saccharic acids are formed. Glucose forms glucosaccharic acid and galactose produces mucic acid.

Properties of Monosaccharides

Monosaccharides exhibit different properties due to the presence of aldehyde or ketone groups. Some of these reactions are important for analytical purpose.

Reducing action of sugars in alkaline solution

All the sugars that contain the free sugar group undergo enolization and various other changes when placed in alkaline solution. The enediol forms of the sugars are highly reactive and are easily oxidized by oxygen and other oxidizing agents. These sugars in alkaline solution are very powerful reducing agents and the sugars are oxidized to complex mixtures of acids.

This reducing action of sugars in alkaline solution is utilized for both the qualitative and quantitative estimation of sugars. When a reducing sugar is heated with the alkaline copper reagents, the following reaction occurs:

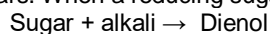
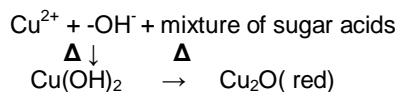


Fig. Reaction of glucose with alkali

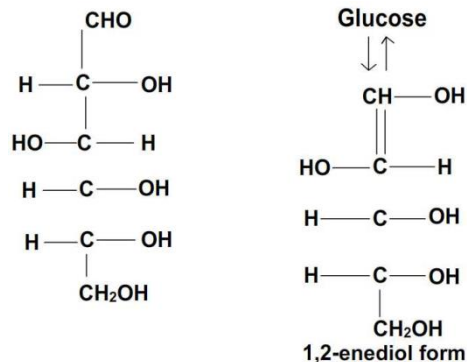
Copper complex of tartarate or citrate (Cu⁺⁺)



The Cu²⁺ ions take electrons from the enediols and oxidize them to sugar acids and are in turn reduced to cuprous ions, Cu⁺. The cuprous ions combine with hydroxyl ions to the yellow cuprous hydroxide, which upon heating is converted to red cuprous oxide, Cu₂O.

The appearance of a yellow-to-red precipitate indicates reduction, and the quantity of sugar present can be roughly estimated from the amount of colour.

In quantitative determination, the amount of copper reduced is obtained by iodometric titration or colorimetric methods by treatment with reagents, and the amount of sugar is calculated.



Action of acids on carbohydrates

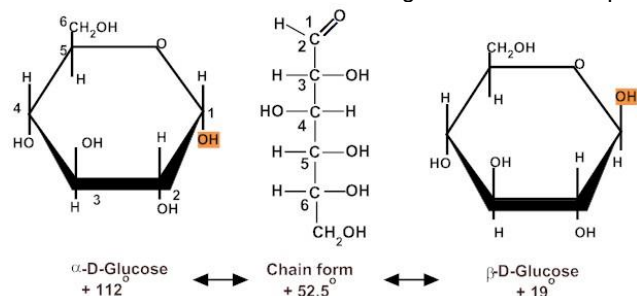
Polysaccharides in general are hydrolyzed into their constituent monosaccharide by boiling with dilute (0.5-1.0N) mineral acids, such as hydrochloric or sulfuric. The monosaccharide when treated with strong acids, to **furfural** and **hydroxy methyl furfural**. The furfural and hydroxyl methyl furfural content may be quantitatively determined by use of its color reaction with organic compounds.

Anthrone is one such compound used for the estimation of sugars which forms a green coloured compound which is measured colorimetrically or spectrometrically.

Mutarotation

The optical rotation of a freshly prepared solution of glucose gradually decreases and finally becomes constant. This change in the rotation of sugar solutions upon standing is called "**mutarotation**". It is a general property of reducing sugars.

When D-glucose is crystallized from water or dilute alcohol at room temperature, a form separates having an initial specific optical rotation of **+112°** which changes to **+52.5°**. If, it is crystallized from water at temperatures above 98°C, a different form of glucose, having an initial specific rotation of **+19°** which changes to **+52.5°**, is obtained. The first of these isomers of glucose was called "**α-D-glucose**" and the second "**β-D-glucose**". Glucose exists in different isomeric forms in solution which change into the same equilibrium mixture regardless of which form is dissolved.



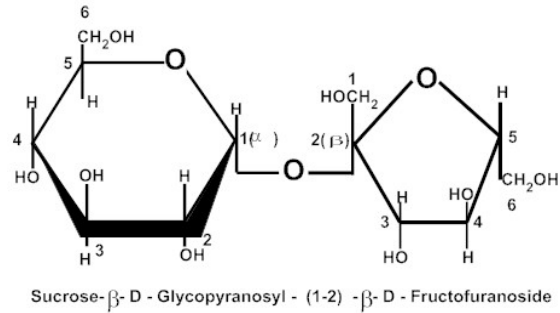
Chapter 3: Structure and function of Polysaccharides

Structure of Disaccharides

The **disaccharides** are sugars composed of **two monosaccharide** residues united by a **glycosidic linkage**. Their chemical name reflects their component monosaccharide. The important disaccharides of food are maltose, sucrose, and lactose.

a. Structure of Sucrose

Sucrose, common table sugar, is the most abundant of all disaccharides and occurs throughout the plant kingdom. It is made up of one **glucose** unit and a **fructose** unit linked by **α 1-2 β glycosidic** bond between the aldehyde or keto groups. Hence it is a nonreducing sugar. Sucrose occurs in the juices of sugar beets, sugar cane, sorghum, sugar maple and juices of pineapple and other fruits. Ripe fruits are rich in sucrose. It is the most abundantly distributed sugar.

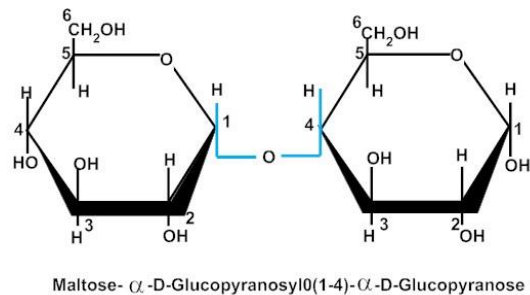


Invert Sugar

Hydrolysis of sucrose yields a crude mixture called “**invert sugar**” because the optical activity of dextro rotatory sucrose (+66.5°) changes (inverts) to -19.5° due to the production of the strongly levorotatory fructose. Because of the inversion of the sign of rotation in the reaction, the process is referred to as “**inversion**”, and the mixture of glucose and fructose obtained is called “**invert sugar**”. Honey contains a large proportion of invert sugar.

b. Structure of Maltose

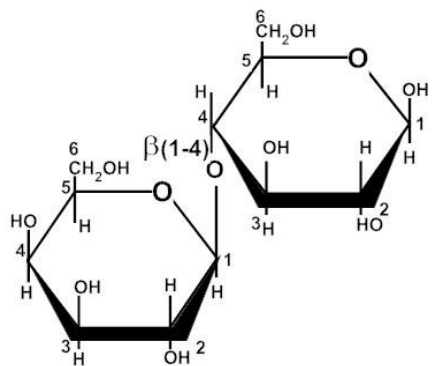
Maltose is composed of **two glucose** units linked by α **1-4 glycosidic bond**.



It is formed when starch is hydrolysed by the action of salivary amylase (ptyalin) and pancreatic amylase during the processes of digestion. Maltose is also formed as an intermediate product in the acid hydrolysis of starch and consequently is an important constituent of corn syrups, which are prepared by partial hydrolysis of starch with dilute acid. These syrups are complex mixtures of dextrans, maltose, and glucose. Commercial malt sugar is a mixture of maltose and dextrans formed from starch by hydrolysis with amylase.

c. Structure of Lactose

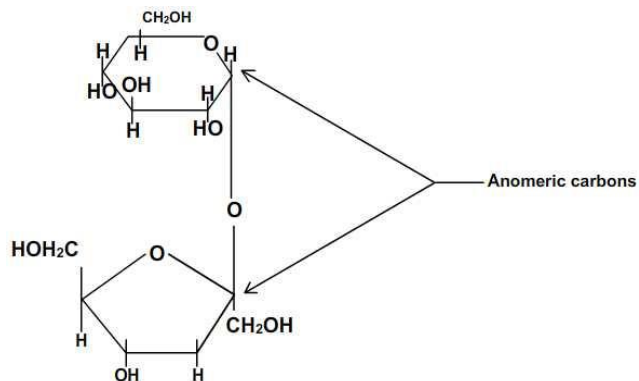
Lactose is the milk sugar and it is made up of **galactose** and **glucose** linked by β **(1-4)glycosidic bond**.



Lactose- β -D-- Galactopyranosyl -(1-4)- β -D-Glucopyranose

Lactose is formed by the mammary glands and occurs to the extent of about 5 per cent in milk . It has a free aldehyde group and hence shows mutarotation and the final specific rotation is $+55.2^\circ$.

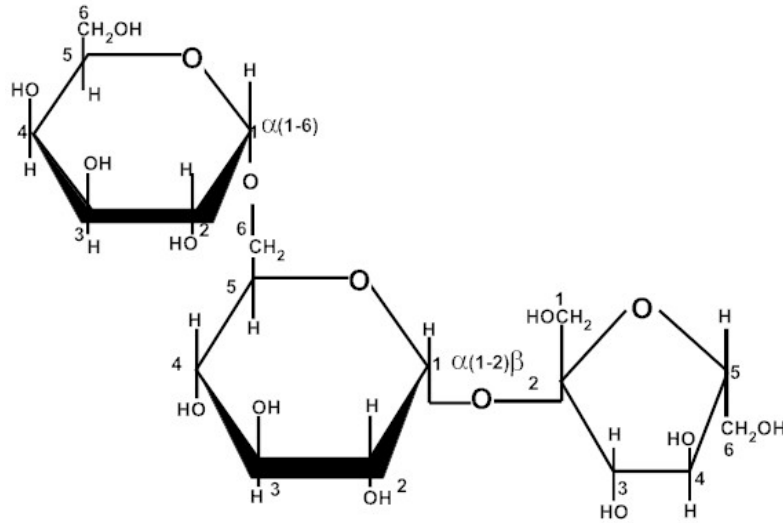
d.Trehalose: It is a nonreducing disaccharide, occurs as a major constituent of the circulating fluids (hemolymph) of insects and serve as energy storage compound. It is made of two glucose molecules in which the anomeric carbon of these units is linked by glycosidic bond.



Structure of Oligosaccharide

Raffinose, also called melitose, is a **trisaccharide** that is widely found in legumes and cruciferous vegetables, including beans, peas, cabbage, brussels, sprouts, and broccoli. It consists of galactose connected to sucrose via a **α 1 \rightarrow 6 glycosidic linkage**. Humans cannot digest polysaccharides with this linkage and the trisaccharides are fermented in the large intestine by gas-producing bacteria.

Stachyose is a **tetrasaccharide** containing **glucose, fructose and two galactose units**. It occurs in legumes and dry beans and peas.



Structure of Raffinose

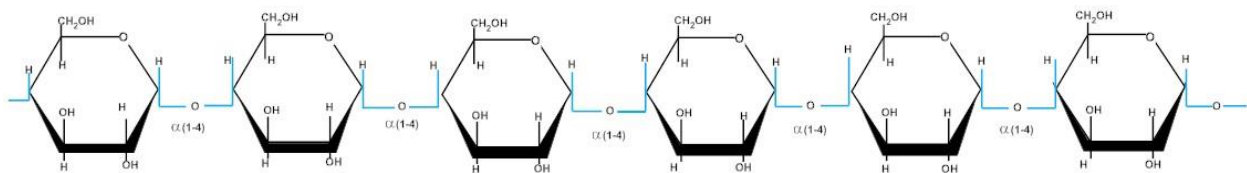
Structure of polysaccharides

Polysaccharides consist of long chains having hundred or thousands of monosaccharides units bonded to each other by glycosidic linkages. **Polysaccharides** are often also called glycans. They are classified as **homopolysaccharides** or **heteropolysaccharides** if they consist of one or more types of monosaccharide.

Some polysaccharides such as cellulose linear chain whereas others, such as **glycogen**, have branched chains.

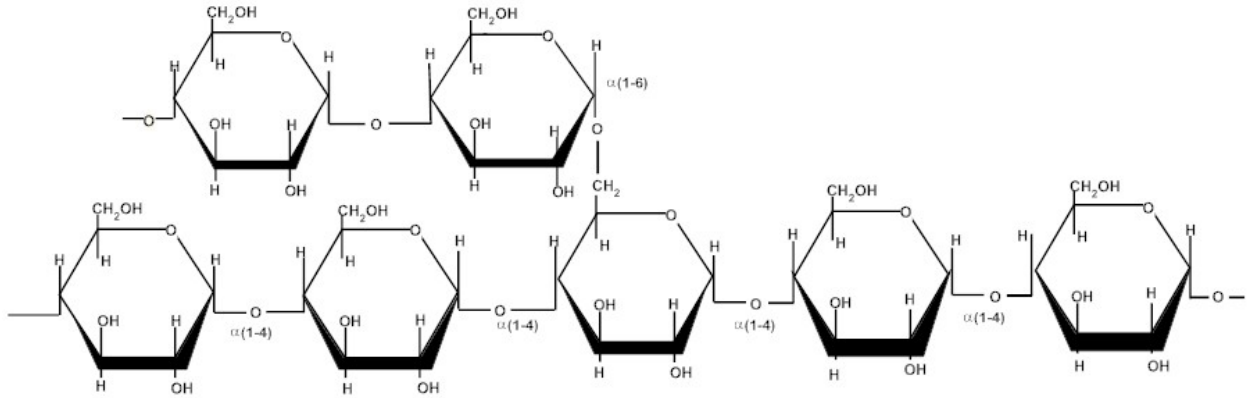
Starch

Starch is a polymer of glucose. It yields only glucose on hydrolysis and hence is a **homopolysaccharide** and is called a **glucosan** or **glucan**. The two chief constituents of starch are **amylose** (15-20%), which has a non branching helical structure, with **glucose** units linked by **$\alpha(1-4)$ -glucosidic bond** in the chains and **amylopectin** (80-85%), which consists of branched chains composed of 24-30 glucose residues united by **$\alpha(1-4)$ glucosidic linkages** in the chains and by **$\alpha(1-6)$ glucosidic linkages** at the branch points.



Structure of Amylose

Structure of Amylopectin



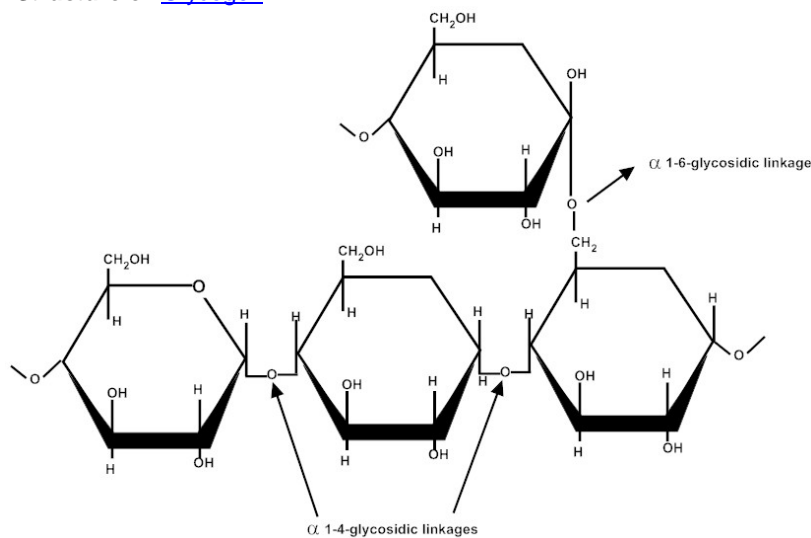
Structure of Amylopectin

Starch is the most important food source of carbohydrate and is found in cereals, potatoes, legumes, and other vegetables. Rich sources of starch are grains such as wheat, rice, corn, oats, millets and barley, legumes such as peas, beans and lentils and tubers such as potatoes, yam and cassava.

Glycogen

Glycogen is a **homopolysaccharide** containing only glucose units. **Glycogen** is the storage polysaccharides of the animals. It is often called animal starch. It is a highly branched structure similar to amylopectin and has chains of 12-14 α -D-glucopyranose residues (in **α [1-4]- glycosidic linkage**) with branching by means of **α (1-6) - glycosidic bonds** . Skeletal muscle and the liver are the two important sites of **glycogen** storage.

Structure of Glycogen

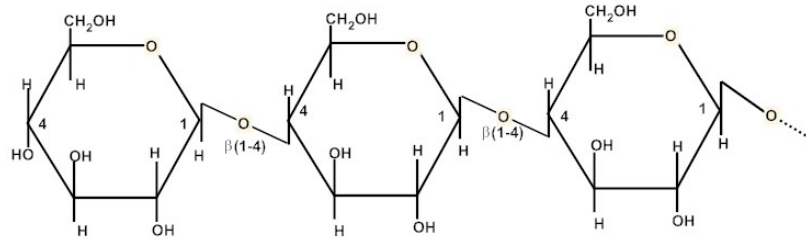


Dextrins

Dextrins are substances formed in the course of the hydrolytic break down of starch. Limit dextrins are the first formed products as hydrolysis reaches certain degree of branching. They form sticky solutions in water and are used as adhesive.

Cellulose

Cellulose is the structural component of plant cell walls, it the most abundant naturally occurring polysaccharide. It is insoluble and consists of D-glucopyranose units linked by **β (1-4) glycosidic bonds** to form long, straight chains strengthened by cross-linked hydrogen bonds.

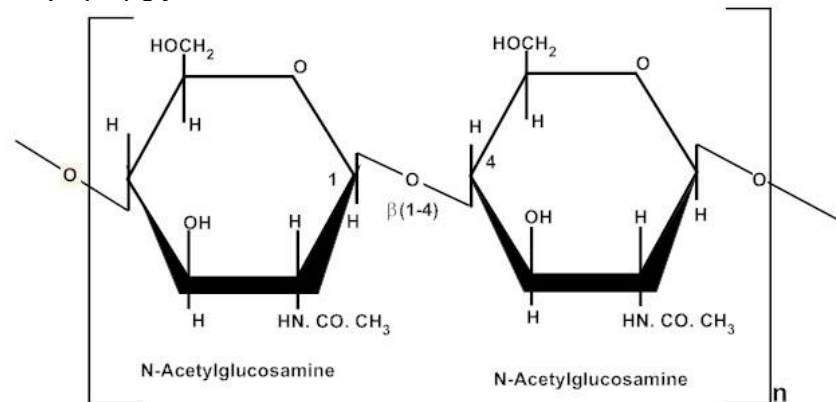


Cellulose structure,
4-D-glucopyranosyl- β -D-glucopyranoside linkages

Cellulose cannot be digested by many mammals, including humans, because of the absence of an enzyme that attacks the β linkages. But, it is an important source of “bulk” in the diet. In the stomach of ruminants and other herbivores, there are microorganisms that can attack the β linkage, making cellulose available as a major calorogenic source.

Chitin

Chitin is a polysaccharide that is similar to cellulose in both function and structure. Structurally, chitin consists of **N - acetyl - D - glucosamine units** joined by **$\beta(1-4)$ -glycosidic bond**.



Structure of Chitin units

Its function is to give rigidity to the exoskeletons of crabs, lobsters, shrimp, insects, and other arthropods. It also occurs in the cell walls of fungi.

Pectins

Pectin occurs widespread in nature. Pectin is combined with cellulose in the cell walls. The combined, **insoluble pectin** is referred to as **protopectin**. It may be released by mild hydrolysis or other means and converted into **soluble pectin**. When soluble pectin is boiled with dilute acid, it is slowly hydrolyzed to pectic acid and methyl alcohol. Purified pectin accordingly is the **methyl ester (many methyl groups per molecule) of pectic acid**. Pectic acid is a chain of at least 200 of (1-4) linked β -D galactopyranosyl uronic acid units. It is found especially in the pulp of citrus fruits, apples, beets and carrots

Uses: Pectin is used commercially in the preparation of jellies, jams, and marmalades. Its thickening properties also make it useful in the confectionery, pharmaceutical, and textile industries. Pectin also has several health benefits in humans. Included among these are its ability to reduce low density lipoprotein (LDL) levels, thereby lowering cholesterol levels, and its ability to slow the passage of food through the intestine, relieving diarrhea. Pectin can also activate cell death pathways in cancer cells, indicating that pectin may play an important role in preventing certain types of cancer.

Seaweed polysaccharides

Significant amounts of **seaweed polysaccharides** are used in food, pharmaceuticals and other products for human consumption. Commercially important are,

1. Agar

2. Agarose
3. Carrageenan
4. Alginic acid

Agar

Agar is a polymer made up of subunits of the sugar galactose. The word **agar** comes from the Malay word **agar-agar** (meaning jelly). It is also known as **kanten** or **agal-agal** (Ceylon agar).

Structure: It is an unbranched polysaccharide obtained from the cell walls of some species of red algae or seaweed. Agar polysaccharides serve as the primary structural support for the algae's cell walls.

Uses: *Gracilaria*, *Gelidium*, *Pterocladia* and other red algae are used in the manufacture of the all-important agar. Agar can be used as a vegetarian gelatin substitute, a thickener for soups, in jellies, ice cream and desserts, as a clarifying agent in brewing, a laxative and for paper sizing fabrics. It is used widely as a growth medium for microorganisms and for microbiological and biotechnological applications.

Agarose

Agar is a heterogeneous mixture of two classes of polysaccharide: **agaropectin** and **agarose**. Although both polysaccharide classes share the same galactose-based backbone, agaropectin is heavily modified with acidic side-groups, such as sulfate and pyruvate. The neutral charge and lower degree of chemical complexity of agarose make it less likely to interact with biomolecules, such as proteins.

Uses: Gels made from purified agarose have a relatively large pore size, making them useful for size-separation of large molecules, such as proteins or protein complexes >200 kilo Daltons, or DNA fragments >100 base pairs. Agarose can be used for electrophoretic separation in agarose gelelectrophoresis or for column-based gel filtration.

Carrageenan

Carrageenans or **carrageenins** are a family of linear sulphated [polysaccharides](#) extracted from red [seaweeds](#). The name is derived from a type of seaweed that is abundant along the [Irish](#) coastline near the village of [Carrageen](#). **Carrageenan** consists of alternating **3-linked- β -D-galactopyranose** and **4-linked- α -D-galactopyranose units**. Carrageenan is a collective term for polysaccharides prepared by alkaline extraction (and modification) from red seaweed (*Rhodophyceae*), mostly of genus *Chondrus*, *Euclima*, *Gigartina* and *Iridaea*. Different seaweeds produce different carrageenans.

Uses: Carrageenans are used mainly for thickening, suspending and gelling. κ - and ι -carrageenans form thermoreversible gels on cooling in the presence of appropriate counterions. κ -Carrageenan stabilizes milk -casein products due to its charge interaction with the casein micelles (~200 nm diameter); their incorporation into the network preventing whey separation. Such complexes are soluble when both have same charge and are held together by counterions or oppositely charged patches. Carrageenan is also used as a binder in cooked meats, to firm sausages and as a thickener in toothpaste and puddings.

Alginic Acids

Alginic acid is a linear **copolymer** with **homopolymeric blocks of (1-4)-linked β -D-mannuronate (M)** and its **C-5 epimer α -L-guluronate (G)** residues, respectively, covalently linked together in different sequences or blocks. It is (alginate, alginic acid) is a viscous gum that is abundant in the cell walls of brown algae. Brown Seaweeds are used for extraction of alginic acid. Commercial varieties of alginate are extracted from brown seaweed, including the giant kelp *Macrocystis pyrifera*, *Ascophyllum nodosum* and various types of *Laminaria*, *Sargassum* sp, *Turbinaria ornata*, *Padina* sp etc.

Uses: **Alginic acid** is used in the food industry, for thickening soups and drinks, ice cream, tinned meats and jellies. Alginate absorbs water quickly, which makes it useful as an additive in dehydrated products such as slimming aids, and in the manufacture of paper and textiles is used commercially for toothpastes, soaps, fabric printing, and a host of other applications. It forms a stable viscous gel in water, and its primary function in the above applications is as a

binder, stabilizer, emulsifier, or moulding agent. It is also used for waterproofing and fireproofing fabrics, as a gelling agent, and cosmetics, and as a detoxifier that can absorb poisonous metals from the blood. Alginate is also produced by certain bacteria, notably *Azotobacter* species.