CARBOHYDRATES
&
LIPIDS

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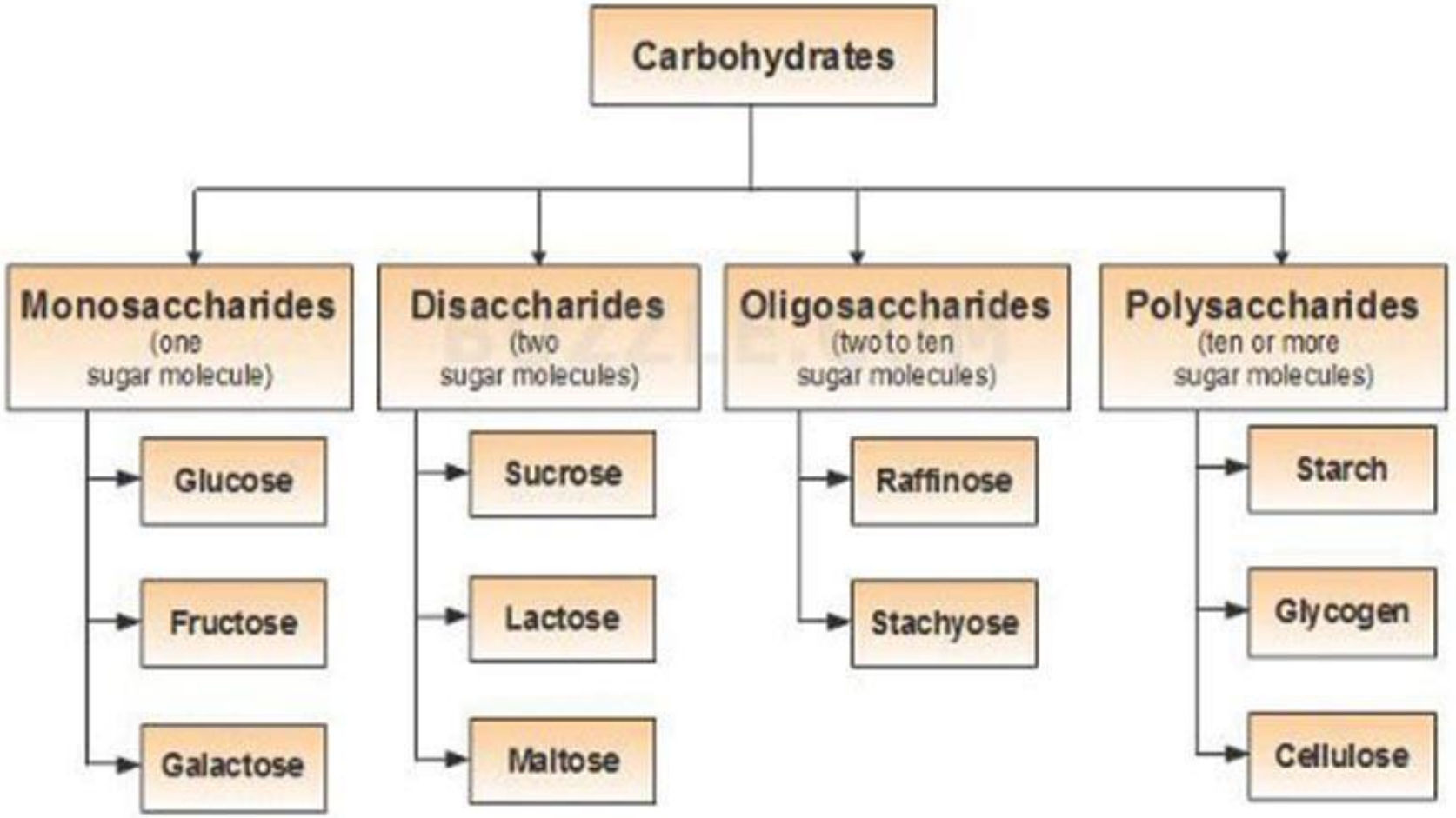
Carbohydrates

- Hydrates of carbon
- Carbohydrates are also called as saccharides.
- The word saccharides comes from Greek word sakchhron means sugar or something sweet.
- carbohydrates are energy provider.
- Carbohydrates are biological molecules made up of carbon, hydrogen and oxygen.
- Hydrogen and oxygen is Ratio 2:1 and carbon ratio may vary.
- So, technically, they are poly hydroxyl aldehydes and ketones.

Classification of carbohydrates



Monosaccharides

- Mono- one, saccharide- sugar
- Monosaccharides are single sugar molecules.
- They are colourless.
- They are crystalline solids.
- They are freely soluble in waters.
- Most of monosaccharides has a sweet taste.
- There compounds possess a free aldehyde or ketone group and two or more hydroxyl group.

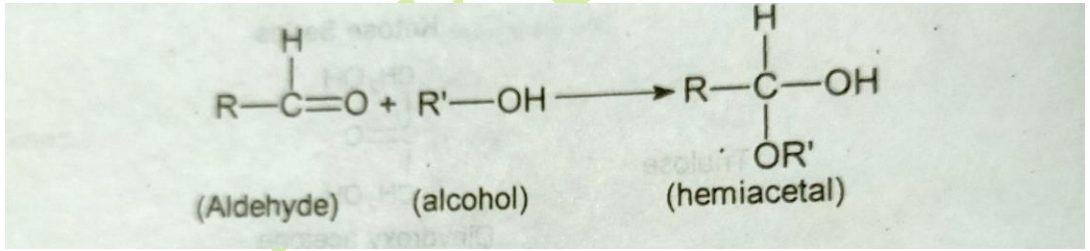
- Smallest unit of saccharides further joined together to form big size chain.
- The backbone off monosaccharides is an unbranched carbon chain wherein all the carbon atoms linked by single bonds.
- One of the carbon atoms is double bonded to an oxygen atom to form a carbonyl group, each of the carbon atoms has a hydroxyl group.
- In aldoses the carbonyl group is at an end of the carbon chain.
- In ketoses the carbonyl group is at any other position than extreme end of carbohydrates chain.

Glucose

- Glucose is a monosaccharide, and it is one of a group of carbohydrates known as simple sugar.
- Glucose (from Greek *glyky*- sweet) has the molecular formula $C_6H_{12}O_6$.
- It is found in fruits and honey and is the major free sugar circulating in the blood of higher animals.
- glucose is the most important source of energy in all organisms.
- Glucose circulates in the blood of animals as blood sugar.
- The naturally occurring form of glucose is D-glucose, while L-glucose is produced synthetically in comparatively small amounts.
- Glucose is a monosaccharide containing six carbon atoms and an aldehyde group, and is therefore an aldohexose.

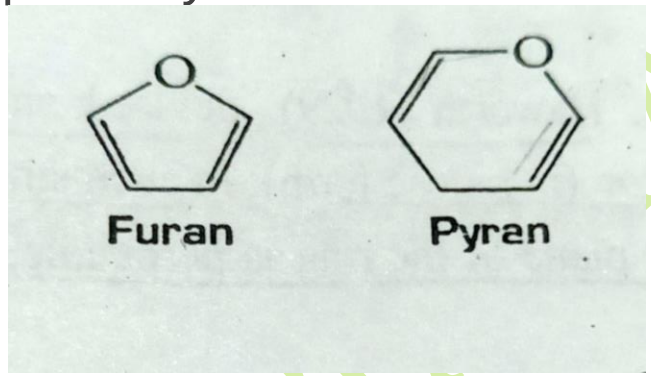
Open chain structure of glucose

- 6 carbon atoms of glucose are arranged in a straight line. It is also called as open chain structure.
- Sugars can exist L-glucose and D-glucose, but only D-glucose is biologically active form of glucose.
- Open chain structure of glucose is unable to explain two forms of glucose.
- Which can be explained by Fisher's formula by using hemiacetal group.
- The aldehyde group of glucose can react with hydroxyl groups of alcohols within the same molecules to form a 5 or 6 membered ring.



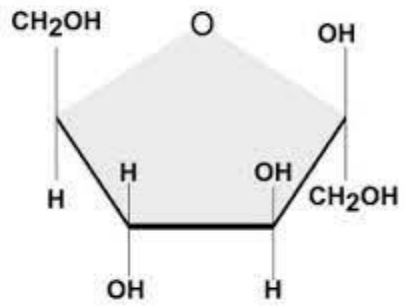
Formation of hemiacetal-

- A six membered ring of cyclic hemiacetal is called a pyranose and a five membered ring of cyclic hemiacetal is called a furanose.
- The terminology furanose and pyranose is derived from the name of the 5 membered cyclic compound furan and the 6 membered cyclic compound pyran respectively.



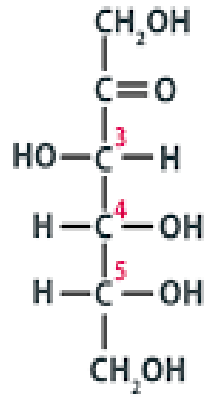
Fructose

- Fructose is also known as laevulose which is found in many foods.
- Pure dry fructose is a very sweet, white.
- They are odorless. They are crystalline solids.
- They are the most water soluble of all the sugars.
- Fructose is found in honey, sugar, vine fruits, flowers, berries, and most root vegetables such as beet, Sweet potatoes, and onions.
- Fructose is the sweetest naturally occurring sugar, estimated to be twice as sweet as sucrose.

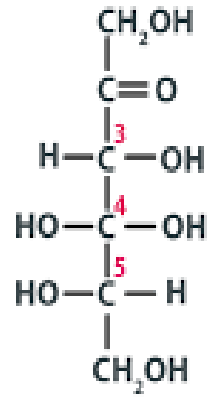


FRUCTOSE

Chain structure of fructose

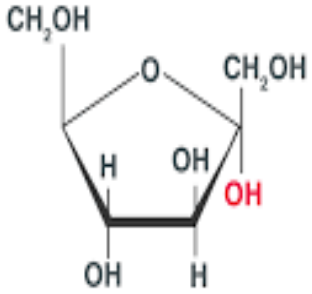


D- Fructose

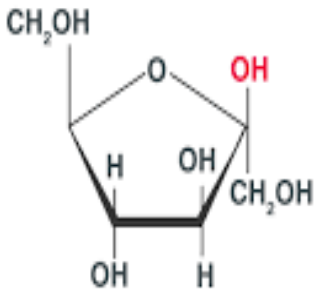


L- Fructose

Ring or cyclic structure of fructose



α-D- Fructose



β-D- Fructose

Oligosaccharides

- Contains less numbers of sugars. Usually two to ten sugar units are present there.
- Oligosaccharides can be homo oligosaccharides or hetero oligosaccharides.

Classification of Oligosaccharides

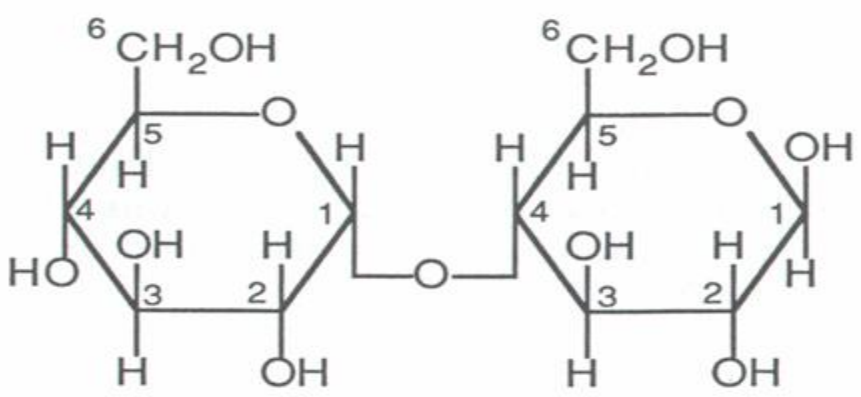
	No "C"	Examples	Type of monosaccharide
Disaccharides	2	Maltose	Glucose + Glucose
		Lactose	Glucose + Galactose
		Sucrose	Glucose + Fructose
Trisaccharides	3	Raffinose	Glu + Fruc + Galactose
Tetra saccharides	4	Stachyose	2 Galactose + Glucose + Fructose
Penta saccharides	5	Verbascose	3 Galactose + Glucose + Fructose

Disaccharides

- Consists 2 monosaccharides molecules linked by glycosidic bond.
- Sucrose, lactose, and maltose are three most abundant disaccharides.
- Disaccharides can be homo disaccharides (similar sugar molecule) or hetero disaccharides(different sugars).
- Maltose is a homo disaccharides (glucose + glucose)
- Sucrose and lactose are hetero disaccharides.

Maltose

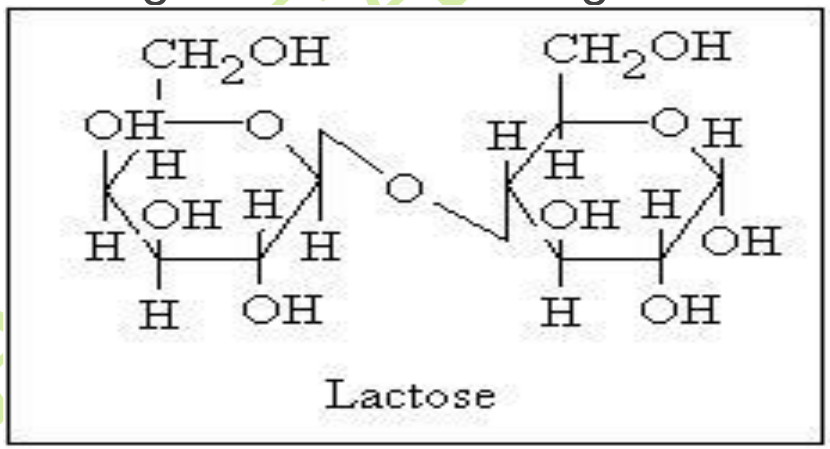
- It is a disaccharides formed from two units of glucose joined with an alpha(1-4) linkage.
- Maltose also known as maltobiose or malt sugar.
- Malt preparing from sprouting barely, is a source of maltose.
- Maltose found in germinating seeds as they break down their starch as their starch stores to use for food. The same process happens in living organisms by the enzyme maltase.
- Maltose can be broken down into two glucose molecules by hydrolysis.



Maltose

lactose

- Lactose also referred to as milk sugar.
- Lactose is a sugar, which is found most notably in milk.
- The name comes from latin word, lacto-for milk, and the ose ending used to name sugars.
- Lactose is a disaccharide that consists of one unit of galactose and one unit of glucose bonded through a beta 1-4 linkage.



- Lactose has a molecular structure consisting of galactose and glucose.
- It is formed by eliminating of a molecule of water from the glycosidic –OH group of D-galactose and alcoholic –OH group of carbon atom 4 of D-glucose.
- As D-glucose exists in three forms alpha beta and aldehyde form, there are three forms of lactose alpha form, beta form, and aldehyde form.

- Lactose is found in the milk of mammals.
- It is a product of mammary gland.
- Lactose makes up around 2-8% of milk.
- Lactose is the only significant sugar or carbohydrate of animal origin.
- Characteristics of lactose:
- It is milk sugar.
- Lactose has about one third the sweetness of sucrose. It is readily digested to glucose and galactose.
- Lactose has a free carbonyl group on carbon atom 1 of glucose unit.

- Hydrolysis of lactose:
- Upon hydrolysis of enzyme lactase, it yields an mixture of glucose and galactose.
- Lactose itself cannot be absorbed from intestine into blood stream unless it is first hydrolyzed into monosaccharide units.
- The enzyme lactase is secreted by intestinal mucosal cell in suckling infants and therefore the lactose, in form of milk suckled by them, is easily hydrolyzed to the component monosaccharide units, thus effecting absorption by intestinal tract.

- Although milk is universal food of humans, many adult humans cannot digest milk because they are deficient in intestinal lactase, the enzyme that hydrolyze milk sugar lactose.
- Such individuals therefore, show lactose intolerance.
- Lactose intolerance is characterized by abdominal bloating, cramps, colic pains, abdominal intestinal flow, nausea and diarrhea.
- All these symptoms appear within 30 to 90 minutes after ingesting milk and unfermented by products.

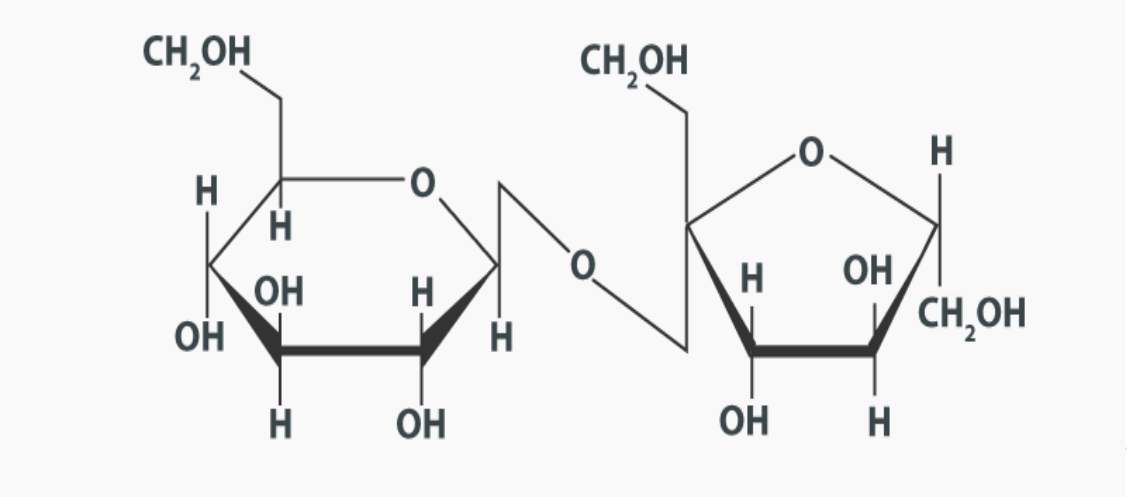
Sucrose

- Sucrose is a commonly known as a table sugar.
- Also called as saccharose.
- It is a disaccharide, composed of one unit of fructose and one unit of glucose which covalently linked through alpha 1-2 glycosidic bond.
- Sucrose as a pure carbohydrate, has a energy content of 3.94 kilocalories per gram.
- High sucrose consumption increase the risk for chronic disease such as defect in glucose metabolism or diabetes mellitus.

- Occurrence
  - Sucrose is present in all photosynthetic plants.
  - It is the chief constituent of sugarcane.
  - Sucrose is present in different plant organs such as fruits, seeds, flowers, and roots.
  - Sucrose is ordinary table sugar refined from sugar cane or sugar beets.

- Characteristics
  - Sucrose is a white crystalline solid.
  - Soluble in water.
  - It is dextrorotatory.
  - It is sweetest among the disaccharides.
  - It is sweeter than glucose.
  - Sucrose is a major calorie sweetener for commercial or home use.

- It is formed by condensation of glucose and fructose.
- It is formed by elimination of a molecule of water from glycosidic hydroxyl groups or alpha D glucose and beta D fructose.
- Fructose possesses the furanose ring structure in the sucrose molecule.
- The glycosidic linkage of the two monosaccharide units of sucrose is between C1 of glucose and C2 of fructose.
- Molecular formula: $C_{12}H_{22}O_{11}$
- It can be seen from the formula of sucrose that both the carbonyl groups one from glucose and other from fructose are involved in the formation of glycosidic bond.



- Hydrolysis
- Enzyme sucrase hydrolyzes sucrose to glucose and fructose in acid solution.
- Sucrose upon hydrolysis by sucrase yields mixture of glucose and fructose. This mixture is called invert sugar.
- This mixture is called invert sugar because the levorotary fructose, produced on hydrolysis of sucrose changes the previous dextrorotatory action of sucrose.
- The invert sugar is levorotary.
- The reaction by which invert sugar is produced is called inversion of sucrose.

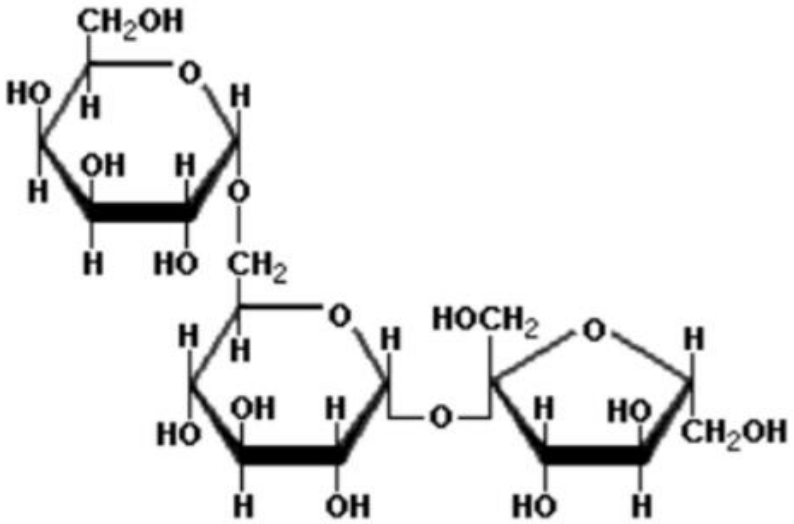
Trisaccharides

- A trisaccharides consists of three monosaccharides molecules linked by glycosidic bond.
- Example: Maltotriose, Raffinose

Raffinose

- Molecular formula: $C_{18}H_{32}O_{16}$
- raffinose is also called as melitriose.
- It is widely found in legume and cruciferous vegetable including sugar beet, beans, peas, cabbage, brussels, sprouts, broccoli, asparagus, other vegetables and whole grain.
- Raffinose is a trisaccharide composed of galactose, fructose, and glucose.
- The raffinose families of oligosaccharides are alpha-galactosyl derivatives of sucrose, and the most common are the trisaccharide raffinose, the tetrasaccharide stachylose, and the pentasaccharise verbascose.

- It consists of alpha D-galactose connected to sucrose via alpha 1-6 glycosidic linkage.
- Raffinose is also used as a base substance for sucralose.



- When hydrolyzed completely, raffinose yields one molecule each of fructose, glucose and galactose.
- Raffinose can be hydrolyzed to D-galactose and sucrose by the enzyme alpha-galactosidase an enzyme not found in humans.
- Human cannot digest saccharides with this linkage and the saccharides are fermented in the large intestine by gas producing bacteria.
- Tablet containing the enzyme alpha galactosidase, are frequently used as digestive aids to prevent gas.
- This enzyme is derived from selected strains of the food grade fungus *Aspergillus niger*.
- Animals can digest raffinose because intestinal bacteria of herbivorous animals can produce enzymes to hydrolyze it.

Polysaccharides

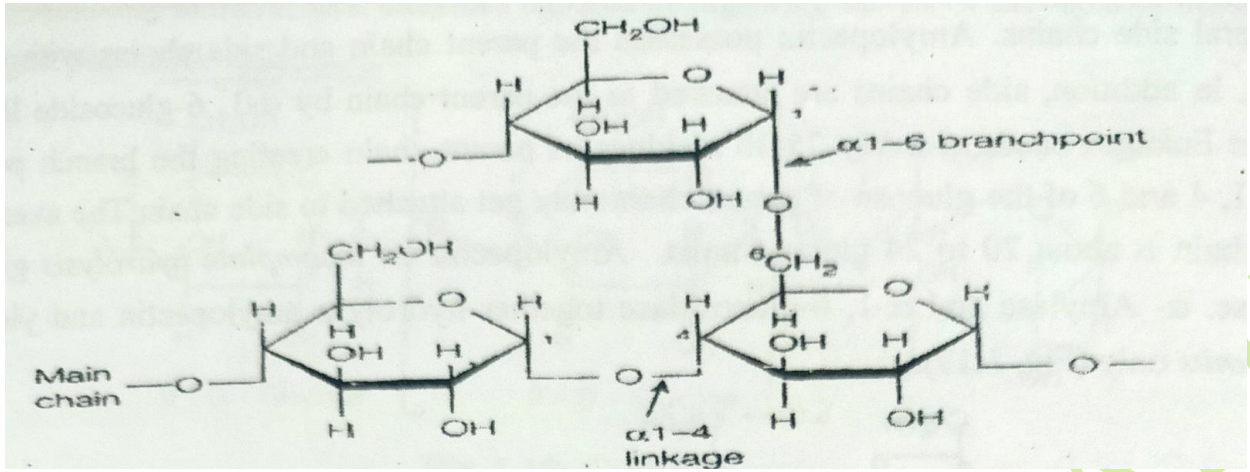
- Polysaccharides are polymers made up of many monosaccharides linked by glycosidic bond.
- They are large macromolecule either linear or branched.
- They yield more than 10 molecules of monosaccharides on hydrolysis.
- They are tasteless, insoluble in water, and amorphous.
- The structural diversity among polysaccharide includes different sequence of sugars, kinds and proportion of sugars, ring size, anomeric configuration, site of the glycosidic linkage and the presence of noncarbohydrate components.
- Depending on composition, polysaccharide are categorized as homopolysaccharides and heteropolysaccharides.

- Homopolysaccharides
- Homopolysaccharides are polysaccharides with same type of monosaccharide molecules by glycosidic linkage.
- Example: starch, glycogen, cellulose, etc.

- Heteropolysaccharides
- Heteropolysaccharides are polysaccharides with two or more type of monosaccharide molecules linked by glycosidic linkage.
- Example: Hyaluronic acid

Starch

- It is a homopolysaccharide. These yield on hydrolysis , a single type of monosaccharide.
- Starch is major food material of the higher plants. Main starch containing foods are cereals, legumes, potatoes, corn, wheat, rice.
- Starch is naturally occurring homopolymer of glucose.
- Pure starch exists as white amorphous powder without sweet taste.
- It is not soluble in water, alcohol and ether at ambient temperature.
- Starches from different sources vary in structure. It is most abundant polysaccharides in plants, it is stored in the some fruits, seeds, roots.



- Mutual action of salivary alpha amylase, pancreatic alpha amylase and alpha glucosidase in the intestinal mucosa, starch hydrolyzed to glucose.
- The alpha amylase cleaves the alpha 1-4 linkages only that catalyze hydrolysis of starch to maltose, maltotriose, maltotetrose, and oligosaccharides called alpha limit dextrins, that include at least four glucose units and alpha 1-6 linked branch points.
- These limits dextrins are then converted to glucose by the alpha 1-4 and alpha 1-6 glucosidases, glucosidic linkages that can be hydrolyzed by human digestive enzymes.

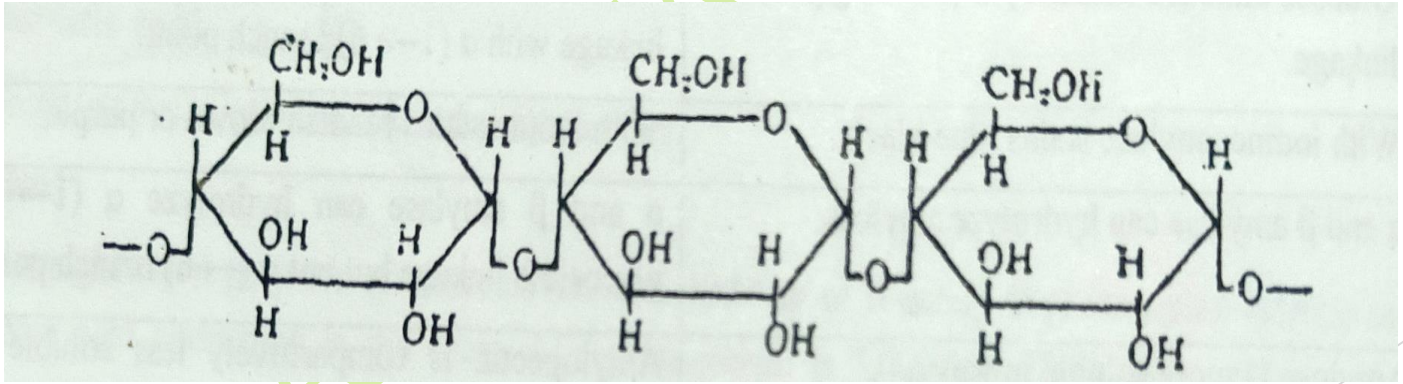
Natural starch consists of two sugar components

- Amylose :
- A long unbranched (linear) straight chain polysaccharide formed by alpha 1-4-d- glucan.

- Amylopectin :
- A branched chain polysaccharide formed by alpha 1-4-d-glucan with branches linked to C6 of glucose.

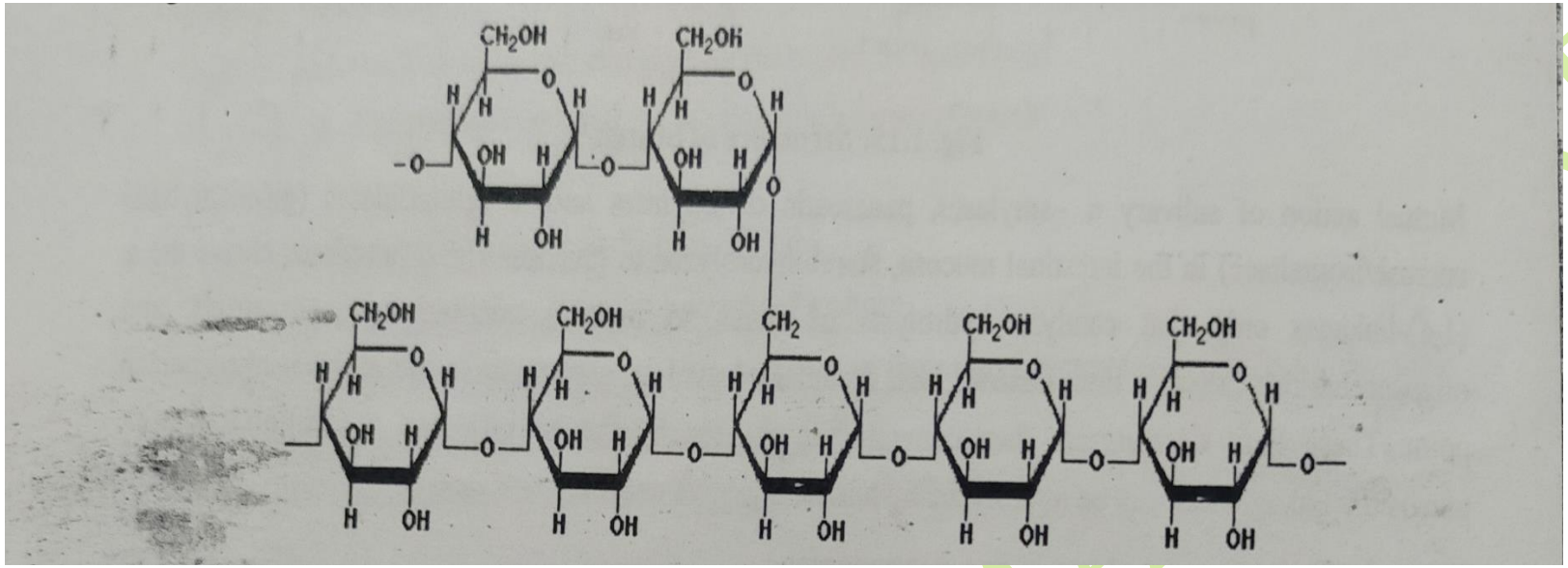
Amylose (alpha-Amylose)

- Amylose is an unbranched long chain of glucose linked through alpha 1-4 glycosidic linkages.
- It may be formed in plants cells by elimination of a molecule of water from glycosidic –OH group of one alpha D- glucose molecule and alcoholic –OH group on carbon 4 of the adjacent alpha D glucose molecule.
- Enzyme hydrolysis of amylose with beta- amylase, yields maltose units only.
- The amylose structure may also be considered as a repeated maltose structure with a free acetal group at one end, which is also known as the reducing end, whereas the first residue is referred as the non-reducing end.



Amylopectin (alpha-Amylose)

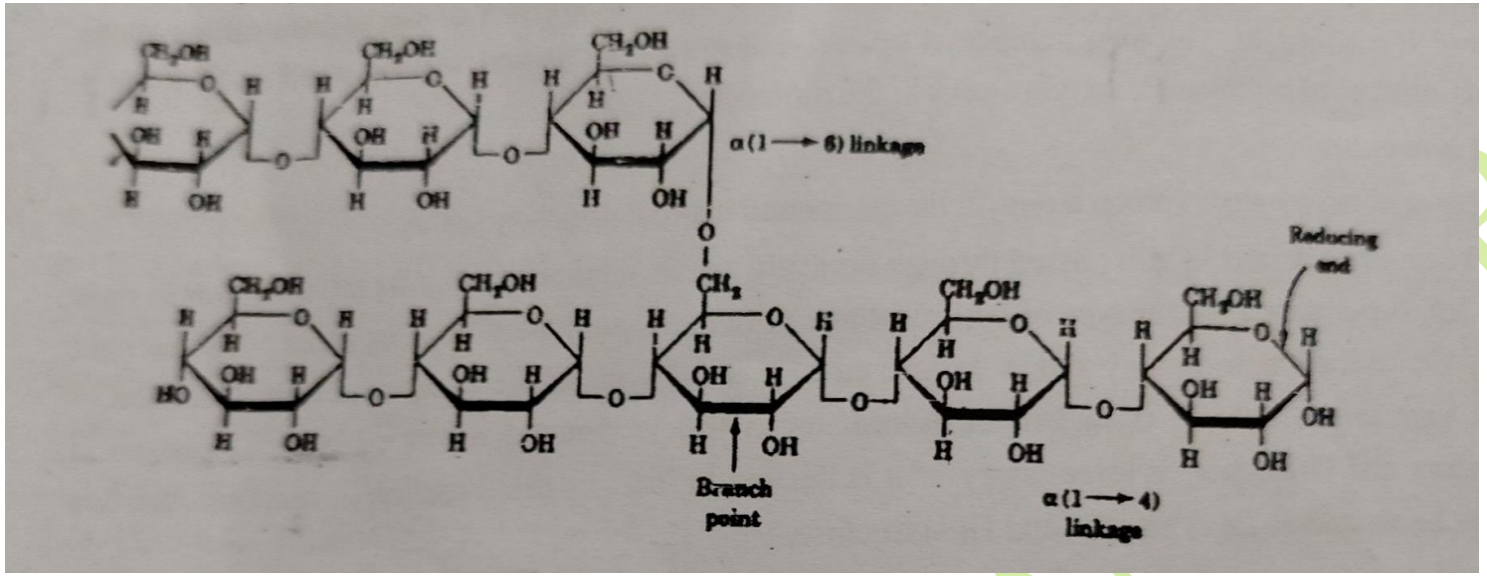
- Amylopectin is also made up of chains of glucose, but the chains are highly branched.
- Amylopectin has a present chain and several side chains.
- Amylopectin possesses the parent chain and side chains with alpha 1-4 glucoside linkages, in addition, side chains are attached to the parent chain by alpha 1-6 glucoside linkages.
- Alpha 1-6 glucoside linkages occur at every 25-30 residues of parent chain creating the branch points.
- The carbon number 1, 4, and 6 of the glucose of parent chain may get attached to side chain.
- The average chain length of side chain is about 20 to 24 glucose units.
- Amylopectin on incomplete hydrolysis gives disaccharide isomaltose.
- Alpha amylase and alpha 1-6 glucosidase together hydrolyze amylopectin and yields maltose and glucose units only.



- Typical starch contain 20% to 30% amylose and 70% to 80% amylopectin but the ratio can vary and depend on sucrose.
- Amylose and amylopectin give reactions with iodine, amylose products a blue-black color whereas, amylopectin gives reddish brown or purple color.

Glycogen

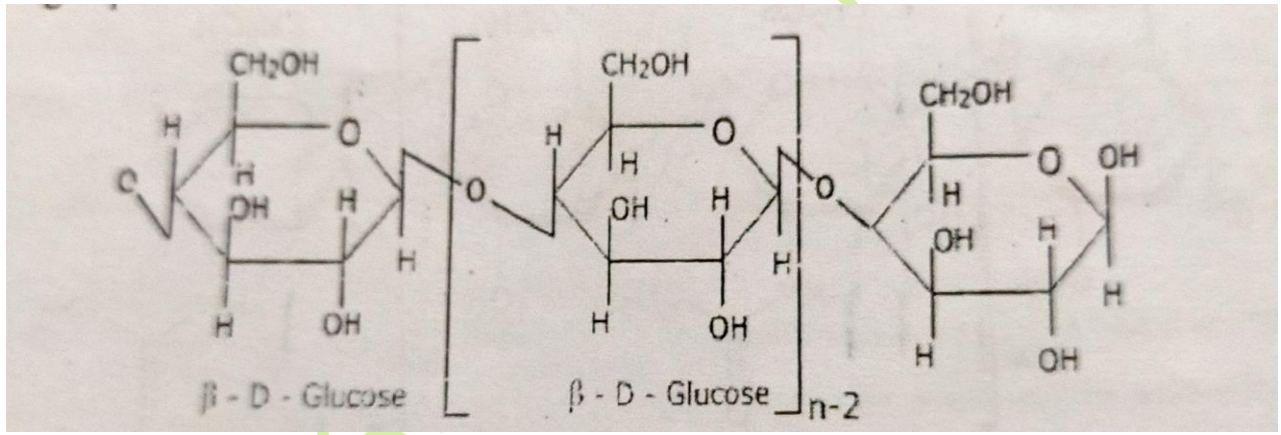
- It acts as a major reserve food in animals and thus it is also referred as animal starch.
- It is found in the liver and muscles of the animals.
- Glycogen constitute up to 10% of the human liver.
- It exists as a white powder when pure and exhibit more solubility in water than amylopectin, because of its greater degree of branching in comparison with amylopectin.
- Glycogen is readily soluble in cold water and gives solutions of relatively low viscosity.
- Ethyl alcohol is used to precipitate glycogen from aqueous solution.
- Glycogen is quite stable in hot solution of alkali.
- Acids completely hydrolyze glycogen into glucose however maltose is produced upon incomplete hydrolysis by alpha 1-4 glucanmaltohydrolase.



- Glycogen is branched chain polysaccharide and its structure is very much similar to the structure of amylopectin, accept that the chain are shorter (10-20 glucose units).
- It consists of linear chains of glucose monomers with branching to every 8 to 2 glucoses.
- An alpha (1-4) glycosidic bonds links the glucose and branching off by alpha (1-6) glycosidic but have greater degree of branching in comparison with amylopectin.

Cellulose

- Cellulose is an anomeric compound with general formula $(C_6H_{10}O_5)_n$.
- Cellulose is homopolysaccharide consisting of beta (1-4) linked.
- D-glucose monomers is a linear chain.
- Cellulose is a straight chain polymer ,no coiling or branching occur.
- The cellulose is formed by taking out a molecule of water from the glycosidic –OH group on carbon atom 1 of one beta D-glucose molecule and the alcoholic –OH group on carbon atom 4 of the adjacent beta D-glucose molecule.



- It is the principal component of the fibrous parts of plants,.
- Cellulose occurs in the cell walls of plants.
- Cellulose is tasteless, odorless, hydrophilic, biodegradable, is insoluble in water and most other organic solvents.
- It is a white solid, insoluble in water but soluble in cellulose is soluble in Schweizer's reagent, cupricethylenediamine (CED), cadmiumethylenediamine (Cadoxen), N-methylmorphine N-oxide, and lithium chloride/ dimethylacetamide.
- Cellulose has no nutritive value because of the lack of chemical reactivity.
- Cellulose is more crystalline than starch.
- It yields glucose when treated with conc H_2SO_4 or HCL or with conc NaOH.
- Mammals including humans, lack enzymes capable of digesting the beta 1-4 linkages of cellulose and so cannot digest plant cell walls.
- Cellulose is homopolysaccharide consisting of beta 1-4 linkage linked D-glucose in linear chain.
- The cellulose is formed by taking out a molecule of water.
- Small D-glucose chain release during breakdown of cellulose are known as cellodextrins.

Heteropolysaccharides

- There are two major groups of heteropolysaccharides. One group consists of sugars and the other group includes mucopolysaccharides.

- Neutral sugars :
- The polysaccharides of this group yields more than one type of sugar on hydrolysis, and sometimes non sugar components also. This group includes hemicellulose and gum.

- Mucopolysaccharides:
- It consists of amino sugar and some their derivatives.
- They are gelatinous substances, they are structural polysaccharide and are mainly found in connective tissues of animals and as blood components.
- The mucopolysaccharides include hyaluronic acid, heparin and chondroitin.

Lipids

- Bloor in 1943 used the term lipid.
- The word lipids is derived from the Greek word lipos - meaning fat.
- Lipids comprise the group of compound which are insoluble in water and soluble in organic solvents such as chloroform, acetone, alcohol,etc.
- These are variously called lipins or lipoids.
- In plants and animals lipids serves in storage.
- Meat and vegetables contains structural lipids in animals and plants.
- Lipids supplies the essential fatty acids which essential for growth .
- Lipids are essential for the absorption of fat soluble vitamis A,D,E and K.

Simple lipids

- These are esters of fatty acids with glycerol.
- Neutral fats: Chemically, the fats are defined as the esters of glycerol and fatty acids or as the glycerides of fatty acids.
- The triglyceride are the most abundant of all lipids.
- The triglyceride constitutes dietary lipids, and other phospholipids and cholestrol and its esters.
- In plants and animal triglyceride are the major components of storage fats.
- Most fats and oils, upon hydrolysis, yields several fatty acids as well as glycerol.
- In normal man weighing 70 kg , at least 10 to 20 percent of body weight is lipid, the bulk of which is triglycerol.

Compound lipids

- These are the esters of fatty acids with alcohol and possess additional groups also.
- The conjugated lipids are classified as follows:
- 1. phospholipids

Phospholipids are esters of glycerol, fatty acids, nitrogenous base and other substituents.

a. Glycerophospholipids –lecithin, cephalin, plasmalogens

b. Sphingophospholipids

- 2. Glycolipids

These are the compounds of fatty acids with carbohydrates and contain nitrogen.

a. Cerebroside

b. Gangliosides

Derived lipids

- Derived lipids include products obtained from hydrolysis of simple or conjugated lipids and various compounds like steroids, terpenes, etc.
- Steroids

a. Sterol

b. Cholesterol

c. Phytosterol- stigmasterol, sitosterol

❖ Other steroids:

1. Carotenoids
2. Adrenal corticosteroid
3. Vitamin D
4. Ergosterol
5. Steroid hormones
6. Bile acid