SBT1102 – BIOCHEMISTRY

UNIT 1 CARBOHYDRATES

Introduction. Classification, Properties and Biological importance. Isomers, epimers, enantiomers,mutarotation, open chain and closed chain structures of glucose.

UNIT 2 AMINOACIDS AND PROTEINS

Aminoacids: classification- essential and non-essential amino acids, protein and non-protein amino acids, Zwitter ions. Proteins: Classification- based on i) shape and solubility and ii) increasing complexity of structure. Structure of proteins: primary, secondary, tertiary and quaternary, biological significance. Concept of isoelectric point and its significance.

UNIT 3 LIPIDS

Introduction, Classification, Properties and Biological importance. Fatty acid nomenclature and structure, Lipids in cell membrane Cholesterol and Steroids, Hormones - structure and function

UNIT 4 NUCLEIC ACIDS

Introduction- Nitrogeneous bases - Purines and Pyrimidines - Nucleosides and Nucleotides -- Structure of nucleic acids - DNA, RNA: m-RNA, t-RNA, r-RNA - Biological importance of nucleic acids. 16s rRNA and its significance.

UNIT 5 VITAMINS AND MINERALS

Vitamins: fat soluble and water soluble vitamins. Minerals: Micro and Macro minerals. Biological importance of vitamin and minerals, deficiency symptoms

CARBOHYDRATES

Carbohydrates are the most abundant biomolecules on earth. Oxidation of carbohydrates is the central energy-yielding pathway in most non-photosynthetic cells.

Definition: Carbohydrates are polyhydroxy aldehydes or ketones, or substances that yield such compounds on hydrolysis.

carbohydrates have the empirical formula $(CH_2O)_n$.

There are three major classes of carbohydrates:

1. **Monosaccharides**

Monosaccharides, or simple sugars, consist of a single polyhydroxy aldehyde or ketone unit. The most abundant monosaccharide in nature is the six-carbon sugar D-glucose, sometimes referred to as dextrose.

2. **Oligosaccharides**

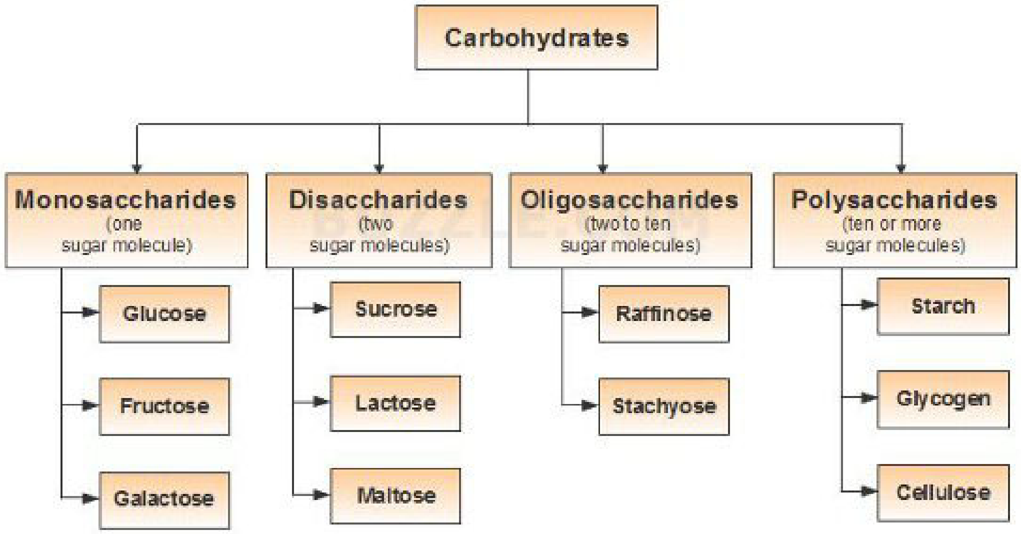
Oligosaccharides consist of short chains of monosaccharide units, or residues, joined by characteristic linkages called glycosidic bonds. The most abundant are the disaccharides, with two monosaccharide units. Example: sucrose (cane sugar).

3. **Polysaccharides**

The polysaccharides are sugar polymers containing more than 20 or so monosaccharide units, and some have hundreds or thousands of units. Example: starch.

Polysaccharides are of two types based on their function and composition. Based on function, polysaccharides of two types storage and structural.

A. Storage polysaccharide - starch.
B. Structural polysaccharide - cellulose.



General properties of carbohydrates

- Carbohydrates act as energy reserves, also stores fuels, and metabolic intermediates.
- Ribose and deoxyribose sugars forms the structural frame of the genetic material, RNA and DNA.
- Polysaccharides like cellulose are the structural elements in the cell walls of bacteria and plants.
- Carbohydrates are linked to proteins and lipids that play important roles in cell interactions.
- Carbohydrates are organic compounds, they are aldehydes or ketones with many hydroxyl groups.

Physical Properties of Carbohydrates

- Steroisomerism - Compound shaving same structural formula but they differ in spatial configuration. Example: Glucose has two isomers with respect to penultimate carbon atom. They are D-glucose and L-glucose.
- Optical Activity - It is the rotation of plane polarized light forming (+) glucose and (-) glucose.
- Diastereoisomeers - It the configurational changes with regard to C2, C3, or C4 in glucose. Example: Mannose, galactose.

- Annomerism - It is the spatial configuration with respect to the first carbon atom in aldoses and second carbon atom in ketoses.

Biological Importance

- Carbohydrates are chief energy source, in many animals, they are instant source of energy. Glucose is broken down by glycolysis/ kreb's cycle to yield ATP.
- Glucose is the source of storage of energy. It is stored as glycogen in animals and starch in plants.
- Stored carbohydrates acts as energy source instead of proteins.
- Carbohydrates are intermediates in biosynthesis of fats and proteins.
- Carbohydrates aid in regulation of nerve tissue and is the energy source for brain.
- Carbohydrates gets associated with lipids and proteins to form surface antigens, receptor molecules, vitamins and antibiotics.
- They form structural and protective components, like in cell wall of plants and microorganisms.
- In animals they are important constituent of connective tissues.
- They participate in biological transport, cell-cell communication and activation of growth factors.
- Carbohydrates that are rich in fibre content help to prevent constipation.
- Also they help in modulation of immune system.

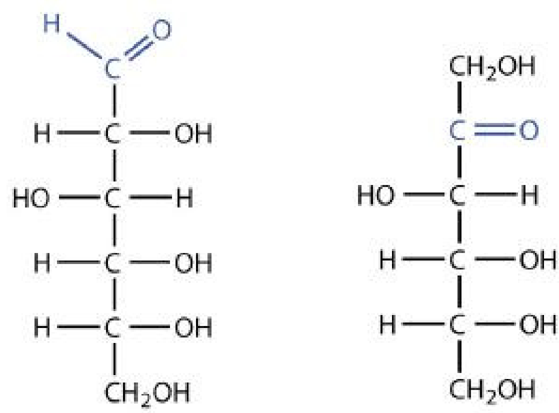
Monosaccharides

- The word “Monosaccharides” derived from the Greek word “Mono” means Single and “saccharide” means sugar
- Monosaccharides are polyhydroxy aldehydes or ketones which cannot be further hydrolysed to simple sugar.
- Monosaccharides are simple sugars. They are sweet in taste. They are soluble in water. They are crystalline in nature.
- They contain 3 to 10 carbon atoms, 2 or more hydroxyl (OH) groups and one aldehyde (CHO) or one ketone (CO) group.

Classification of Monosaccharides

Monosaccharides are classified in two ways. (a) First of all, based on the number of carbon atoms present in them and (b) secondly based on the presence of carbonyl group.

The naturally occurring monosaccharides contain three to seven carbon atoms per molecule. Monosaccharides of specific sizes may be indicated by names composed of a stem denoting the number of carbon atoms and the suffix -*ose*. For example, the terms *triose*, *tetrose*, *pentose*, and*hexose* signify monosaccharides with, respectively, three, four, five, and six carbon atoms. Monosaccharides are also classified as aldoses or ketoses. Those monosaccharides that contain an aldehyde functional group are called aldoses; those containing a ketone functional group on the second carbon atom are ketoses. Combining these classification systems gives general names that indicate both the type of carbonyl group *and* the number of carbon atoms in a molecule. Thus, monosaccharides are described as aldotetroses, aldopentoses, ketopentoses, ketoheptoses, and so forth. Glucose and fructose are specific examples of an aldohexose and a ketohexose, respectively.



Glucose (an aldohexose) Fructose (a ketohexose)

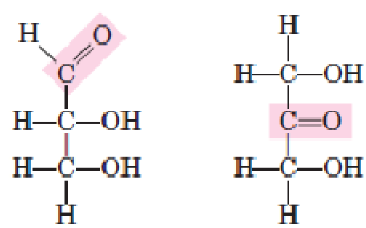
Name	Formula	Aldose	Ketose
Triose	$C_3H_6O_3$	Glycerose	Dihydroxy acetone
Tetrose	$C_4H_8O_4$	Erythrose	Erythrulose
Pentose	$C_5H_{10}O_5$	Ribose	Ribulose
Hexose	$C_6H_{12}O_6$	Glucose	Fructose
Heptose	$C_7H_{14}O_7$	Glucoheptose	Sedo heptulose

Trioses

Trioses are "Monosaccharides" containing 3 carbon atoms. The molecular formula of triose is C3H6O3

Characteristics

- Trioses are simple sugars
- They are soluble in water
- They are sweet in taste.
- The triose may contain an aldehyde group (aldotriose) or a ketone group (ketotriose). Example Glycerose and Dehydroxyacetone



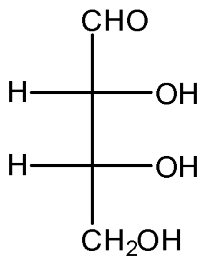
Glyceraldehyde, an aldotriose   Dihydroxyacetone, a ketotriose

Tetroses

Tetroses are "Monosaccharides" containing 4 carbon atoms. The molecular formula of tetrose is C4H8O4

Characteristics

- Tetroses are simple sugars
- Tetroses are soluble in water
- They are sweet in taste.
- They are *crystalline* forms.
- The tetroses may contain an aldehyde group (aldotetrose) or a ketone group (ketotetrose).



Ervthrose

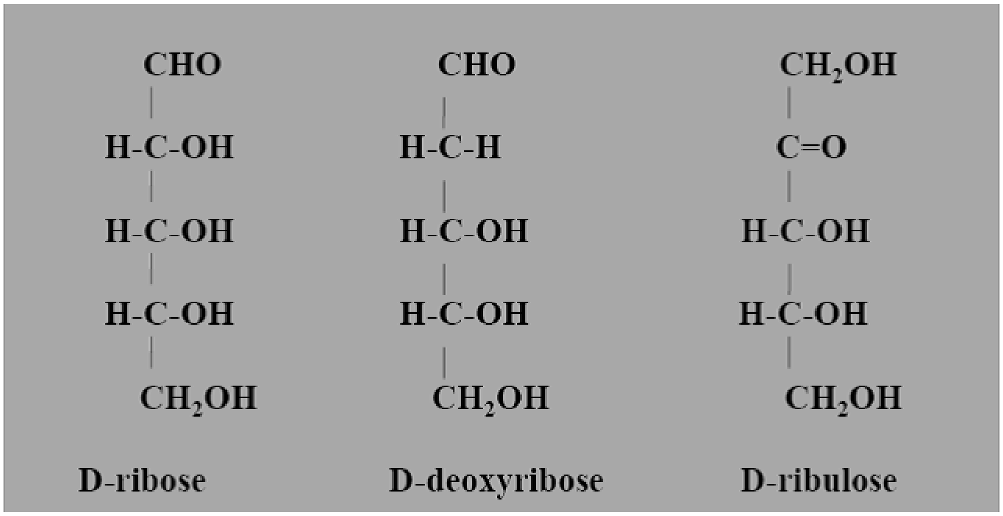
D-Erythrulose

Pentoses

Pentoses are “Monosaccharides” containing 5 carbon atoms. It is an important component of “nucleic acid”. The molecular formula of Pentose is C5H10O5

Characteristics

- Pentoses are simple sugars
- Pentoses are soluble in water
- They are sweet in taste.
- They are *crystalline* forms.
- The pentoses may contain an aldehyde group (aldopentose) or a ketone group (ketopentose).



Hexoses

Hexoses are “Monosaccharides” containing 6 carbon atoms. The molecular formula of Hexose is C6H12O6

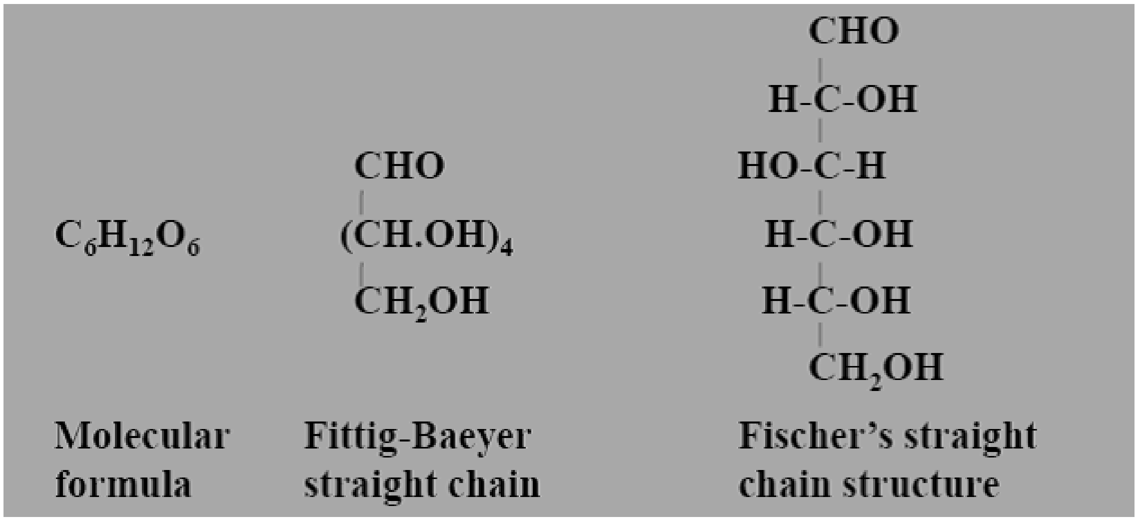
Characteristics

- Hexoses are simple sugars
- Hexoses are soluble in water
- They are sweet in taste.
- They are *crystalline* forms.
- The pentoses may contain an aldehyde group (aldohexose) or a ketone group (ketohexose).

Structure of Monosaccharides

1. **Straight or Open Chain Structure**: Here 6 carbon atoms of glucose are arranged in a straight line. It is also called open chain structure because the two ends remain separate and they are not linked. Open chain structure are of two types –

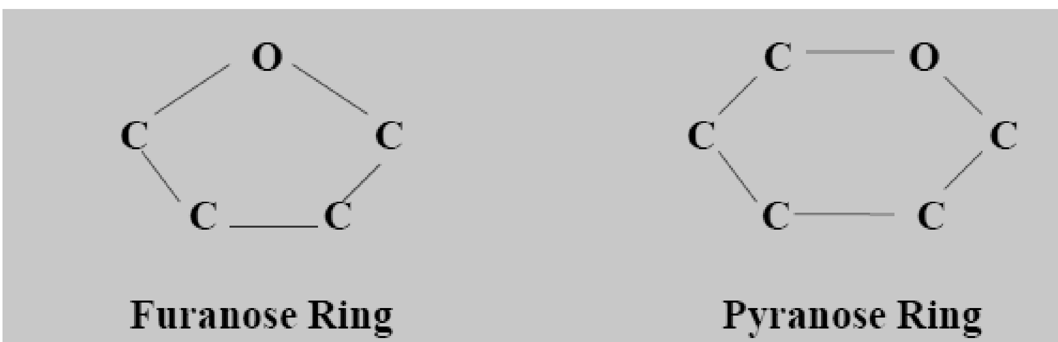
- (a)Structure proposed by Fittig and Baeyer
- (b)Structure proposed by Fischer known as Fischer’s Projection Formula.



2. Cyclic or Ring Structure: Here the atoms are arranged in the form of a ring. Haworth (1929) proposed this formula and hence the name Haworth's Projection Formula. The sugar molecules exist in two type of rings which are as follows –

(a)Furanose Ring – 5 membered ring

(b)Pyranose Ring- 6 membered ring



Properties of Monosaccharides

1.Colour - colourless

2.Shape - crystalline

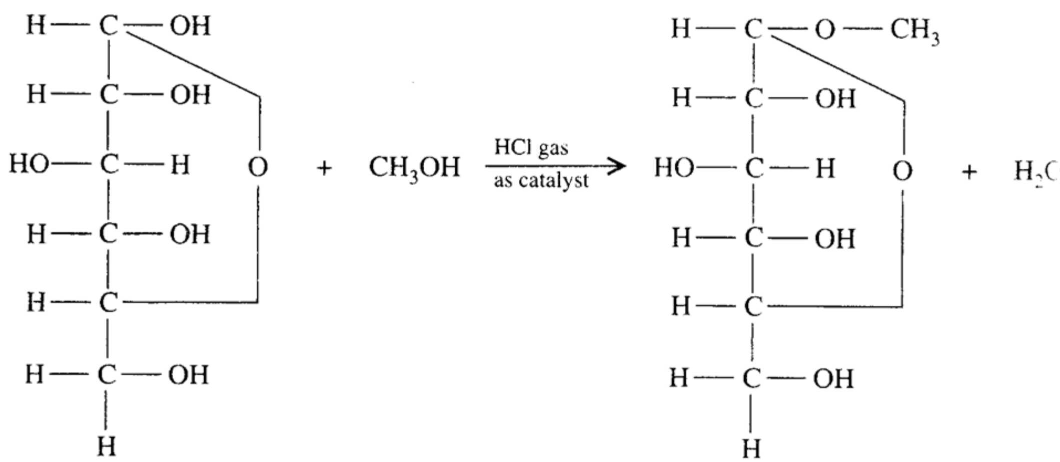
3.Solubility – water soluble

4.Taste - sweet

5.Optical activity – Optically active. (a) Dextrorotatory (‘d’ form) and (b) Levorotatory (‘l’ form)

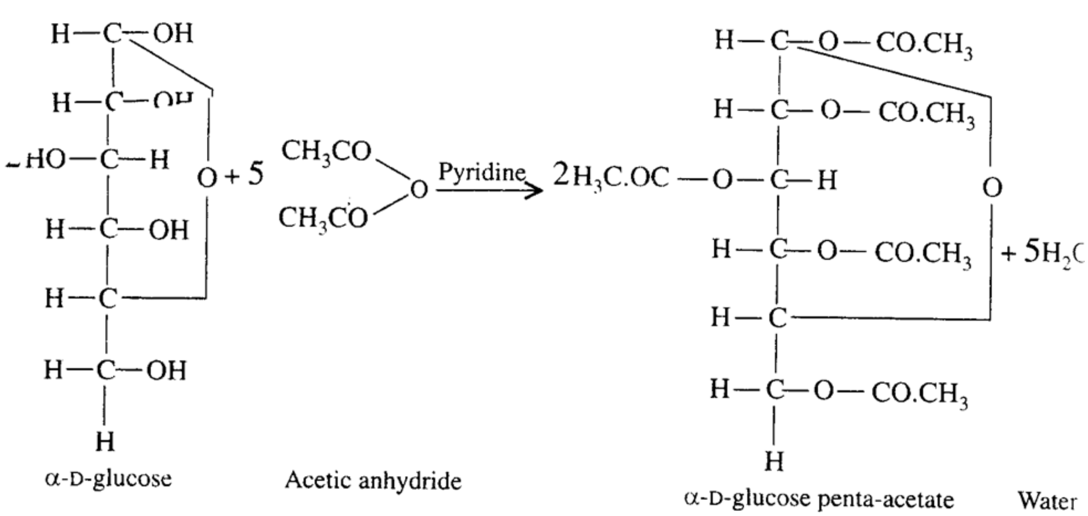
6.Mutarotation – The change in specific rotation of an optically active compound is called mutarotation. +1120 +52.50 +190 α-D-glucose β -D-glucose

7. Glucoside formation -



Glucose + Methyl alcohol = Methyl glucoside

8. Esterification –



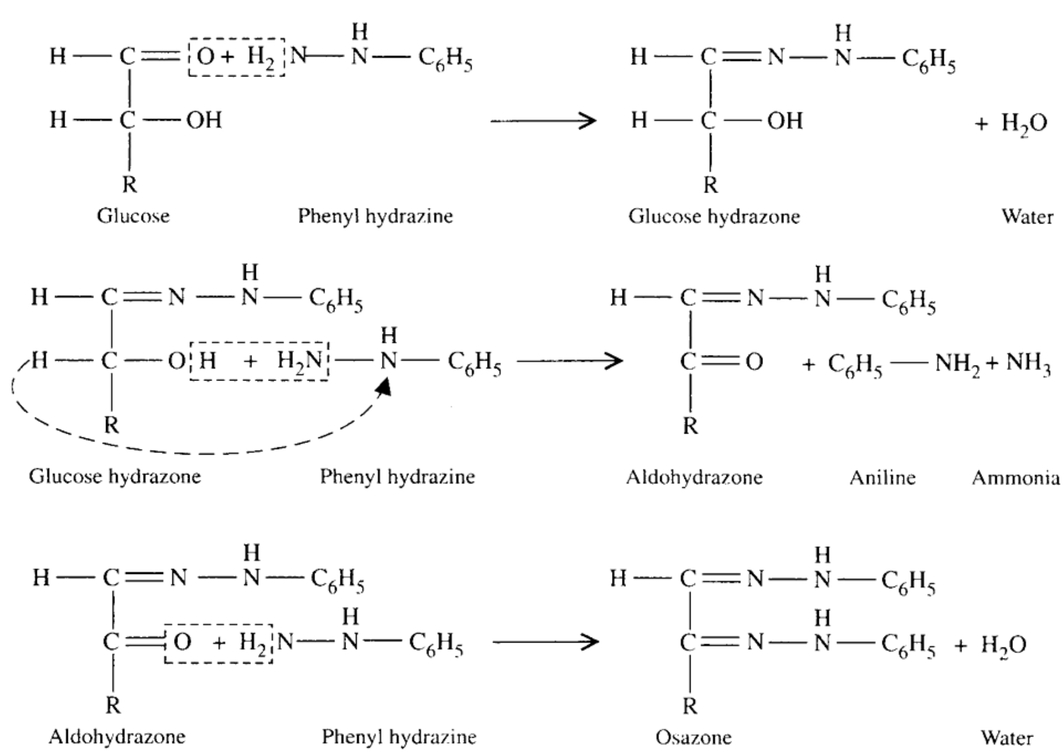
9. Reducing agents –

Monosaccharides reduce oxidizing agent such as hydrogen peroxide. In such reaction, sugar is oxidized at the carbonyl group and oxidizing agent becomes reduced.

$C_6H_{12}O_6 + 2\ Cu(OH)_2 \rightarrow C_6H_{12}O_7 + Cu_2O + 2H_2O$

Glucose Fehling's GluconicCuprous
solutionacid oxide

10. Formation of Osazone –



Disaccharides

Disaccharides consist of two sugars joined by an **O**-glycosidic bond.

The most abundant disaccharides are sucrose,lactose and maltose.

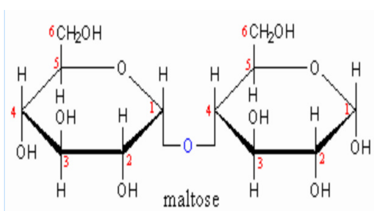
Other disaccharides include isomaltose, cellobiose and trehalose.

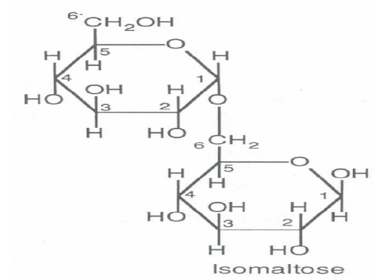
The disaccharides can be classified into:

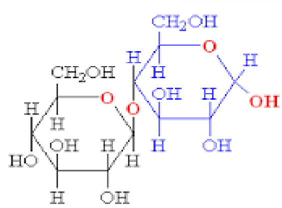
1. Homodisaccharides

2. Heterodisaccharides.

Hommodisaccharides	**Maltose (malt sugar)**	**Isomaltose**	**Celebiose**
structure	2α-glucose	2 α-glucose	2β-D-glucose
Type of bond	α-1-4 glucosidicbond	α1-6 glucosidicbond	β1-4 glucosidicbond.
Anomeric Carbon	Free	Free	Free
Reducing Property	Reducing	Reducing	Reducing
Produced by	It is produced from starch by the action of amylase	by the hydrolysis of some polysaccharides such as dextran	by the acid hydrolysis of cellulose





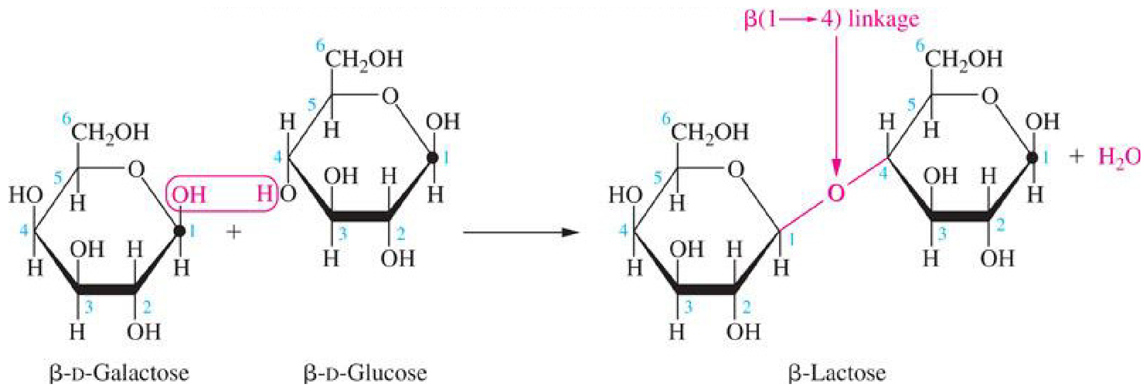


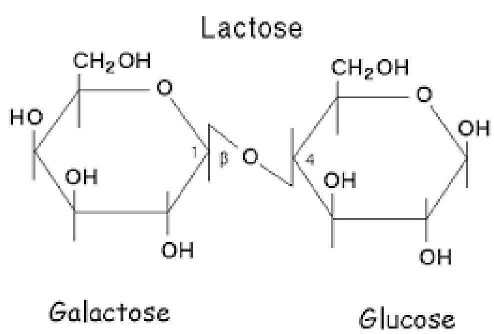
cellobiose
4-(β-D-glucopyranosyl)-D-glucose

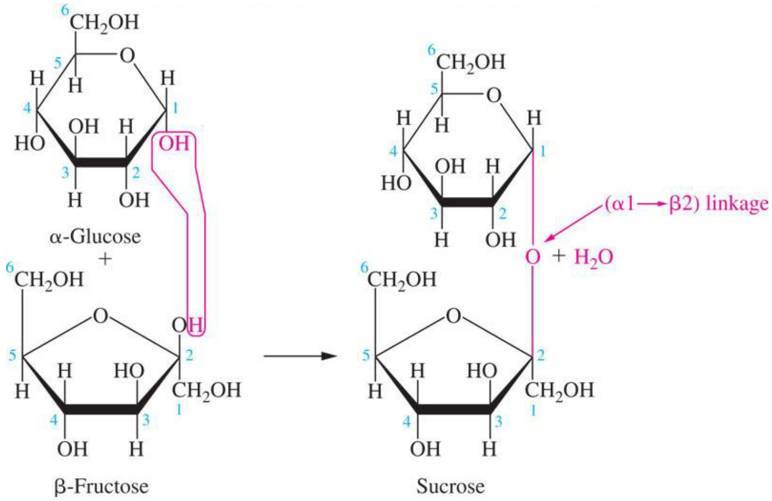
Heterodisaccharides: are formed of 2 different monosaccharide units

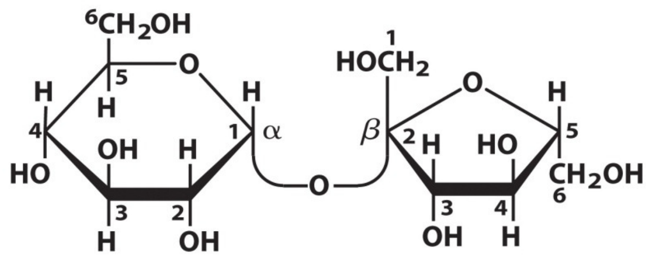
Heterodisaccharides	**Sucrose**	**Lactose**
Composition	α-D-glucose+ β–D-fructose	β-D-galactoseand β-D-glucose
Type of bond	α-1-β-2 glucosidic bond OR β 2-α-1 fructosidic bond	a β (1□4) galactosidicbond
AnomericC	no free aldehydeor	free

	ketonegroup	
Reducing property	is not a reducing sugar	Reducing
Composition	α-D-glucose**+**β–D-fructose	β-D-galactoseandβ-D-glucose
AnomericC	nofreealdehydeorketonegroup	free
Effectofhydrolysis	The hydrolysis of sucrose to glucose and fructose is catalysed by sucrose (also called invertase),	Hydrolysed by the intestinal lactase enzyme into galactose and glucose
Present in	Table sugar Cane sugar, beet sugar	Milk sugar It may appear in urine in late pregnancy and during lactation









Sucrose
α-D-glucopyranosyl β-D-fructofuranoside
Glc(α1↔2β)Fru

Polysaccharides

Polysaccharides contain hundreds or thousands of carbohydrate units.

- Polysaccharides are *not* reducing sugars, since the anomeric carbons are connected through glycosidic linkages.
- **Nomenclature:**

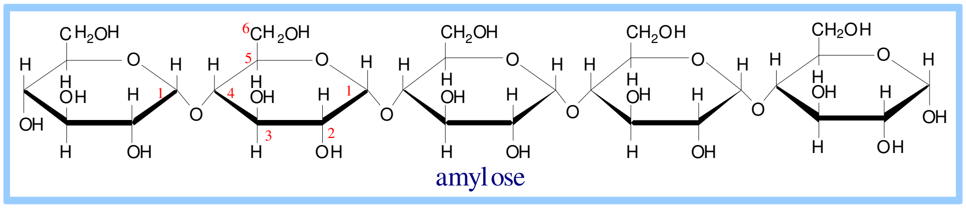
Homopolysaccharide- a polysaccharide is made up of **one type** of monosaccharide unit

Heteropolysaccharide- a polysaccharide is made up of more than **one type** of monosaccharide unit

Starch

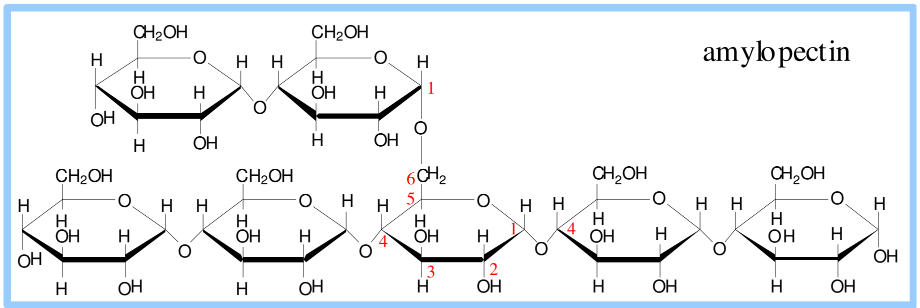
- Starch is a polymer consisting of D-glucose units.
- Starches (and other glucose polymers) are usually insoluble in water because of the high molecular weight, but they can form thick colloidal suspensions with water.

- Starch is a **storage** compound in plants, and made of glucose units
- It is a homopolysaccharide made up of two components: **amylose** and **amylopectin**.
- Most starch is 10-30% amylose and 70-90% amylopectin.
- **Amylose** – a straight chain structure formed by **1,4 glycosidic bonds** between **α-D-glucose** molecules.



Structure of Amylose Fraction of Starch

- The amylose chain forms a helix.
- This causes the blue colour change on reaction with iodine.
- Amylose is poorly soluble in water, but forms micellar suspensions
- Amylopectin-a glucose polymer with mainly α -(1→4) linkages, but it also has branches formed by α -(1→6) linkages. Branches are generally longer than shown above.



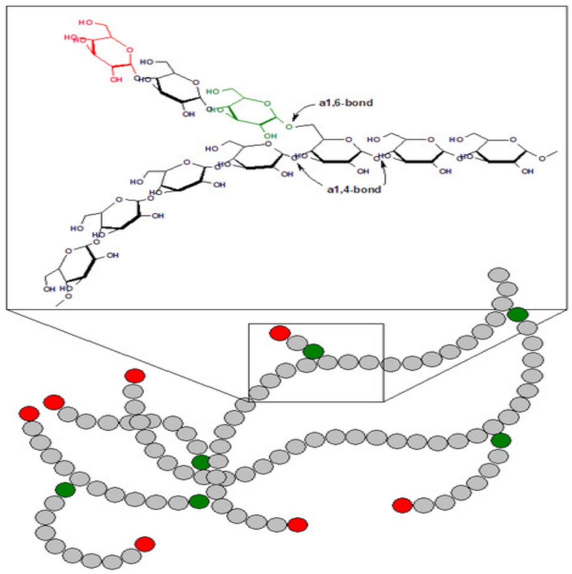
Structure of Amylopectin Fraction of Starch

- Amylopectin causes a red-violet colour change on reaction with iodine.
- This change is usually masked by the much darker reaction of amylose to iodine.

Glycogen

- Storage polysaccharide in animals
- Glycogen constitutes up to 10% of liver mass and 1-2% of muscle mass

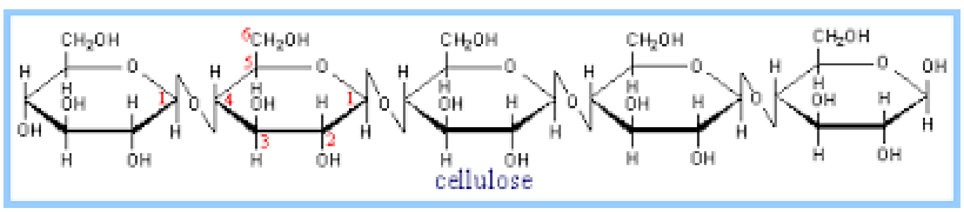
- Glycogen is stored energy for the organism
- Similar in structure to amylopectin, only difference from starch: number of branches
- Alpha(1,6) branches every 8-12 residues
- Like amylopectin, glycogen gives a red-violet color with iodine



Cellulose

- The β-glucose molecules are joined by condensation, i.e. the removal of water, forming β-(1,4) glycosidic linkages.
- The glucose units are linked into straight chains each 100-1000 units long.
- Weak hydrogen bonds form between parallel chains binding them into cellulose microfibrils.
- Cellulose microfibrils arrange themselves into thicker bundles called microfibrils. (These are usually referred to as fibres.)
- The cellulose fibres are often “glued” together by other compounds such as hemicelluloses and calcium pectate to form complex structures such as plant cell walls.
- Because of the β-linkages, cellulose has a different overall shape from amylose, forming extended straight chains which hydrogen bond to each other, resulting in a very rigid structure.

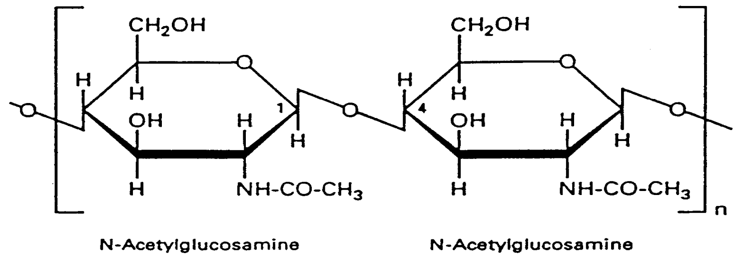
- Cellulose is an important structural polysaccharide, and is the single most abundant organic compound on earth. It is the material in plant cell walls that provides strength and rigidity; wood is 50% cellulose.
- Most animals lack the enzymes needed to digest cellulose, although it does provide needed roughage (dietary fiber) to stimulate contraction of the intestines and thus help pass food along through the digestive system
- Some animals, such as cows, sheep, and horses, can process cellulose through the use of colonies of bacteria in the digestive system which are capable of breaking cellulose down to glucose; ruminants use a series of stomachs to allow cellulose a longer time to digest. Some other animals such as rabbits reprocess digested food to allow more time for the breakdown of cellulose to occur.
- Cellulose is also important industrially, from its presence in wood, paper, cotton, cellophane, rayon, linen, nitrocellulose (guncotton), photographic films (cellulose acetate), etc.



CHITIN

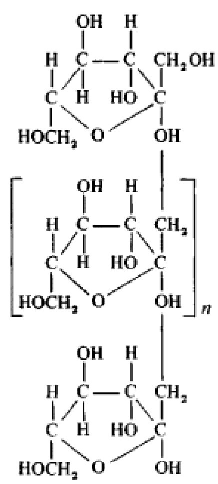
- Chitin is a polymer that can be found in anything from the shells of beetlesto webs of spiders. It is present all around us, in plant and animal creatures.
- It is sometimes considered to be a spinoff of cellulose, because the two are very molecularly similar.
- Cellulose contains a hydroxy group, and chitin contains acetamide.
- Chitin is unusual because it is a "natural polymer," or a combination of elements that exists naturally on earth.
- Usually, polymers are man-made. Crabs, beetles, worms and mushrooms contain large amount of chitin.
- Chitin is a very firm material, and it help protect an insect against harm and pressure

Chitin



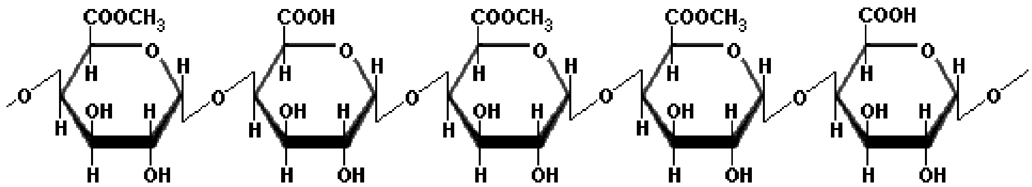
Inulin

- Inulin is stored in the tubers of the dahlia and artichoke and in the roots of dandelion. It is also found in onion and garlic.
- Inulin (Fig. 8–4) has a molecular weight of about 5,000 and consists of about 30–35 fructose units per molecule.
- It is formed in the plants by eliminating a molecule of water from the glycosidic OH group on carbon atom 2 of one β-D-fructose unit and the alcoholic OH group on carbon atom 1 of the adjacent β-D-fructose unit.



Pectin

- Pectins are found as intercellular substances in the tissues of young plants and are especially abundant in ripe fruits such as guava, apples and pears.
- Pectin is a polysaccharide of α-D-galacturonic acid where some of the free carboxyl groups are, either partly or completely, esterified with methyl alcohol and others are combined withcalcium or magnesium ions. Chemically, they are called polygalacturonides



Mucopolysaccharides

Polysaccharides that are composed not only of a mixture of simple sugars but also of derivatives of sugars such as amino sugars and uronic sugars are called mucopolysaccharides.

Hyaluronic acid

- It is the most abundant member of mucopolysaccharides and is found in higher animals as a component of various tissues such as the vitreous body of the eye, the umbilical cord and the synovial fluid of joints.
- It is a straight-chain polymer of D-glucuronic acid and N-acetyl- D-glucosamine (NAG) alternating in the chain. Its molecular weight approaches approximately, 5,000,000. linkages invloved, β-1 → 3 and β-1 → 4.

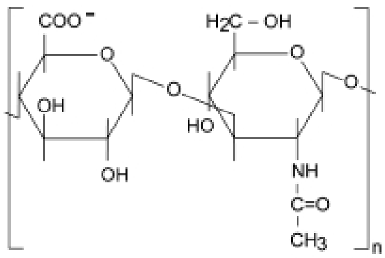
Chondroitin

- Chondroitin is of limited distributioin. It is found in cartilage and is also a component of cell coats. It is a parent substance for two more widely distributed mucopolysaccharides, chondroitin sulfate A and chondroitin sulfate B.
- Chondroitin is similar in structure to hyaluronic acid except that it contains galactosamine rather than glucosamine. It is, thus, a polymer of β-Dglucuronido- 1, 3-N-acetyl-D-galactosamine joined by β- 1 → 4 linkages.

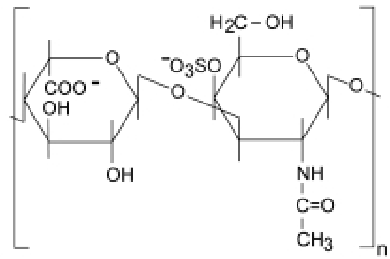
- The two chondroitin sulfate A and C are widely distributed and form major structural components of cartilage, tendons and bones.

- Chondroitin sulfates may be regarded as derivatives of chondroitin where, in thegalactosamine moiety, a sulfate group is esterified either at carbon 4 as in chondroitin sulfate A or at carbon 6 as in chondroitin sulfate C

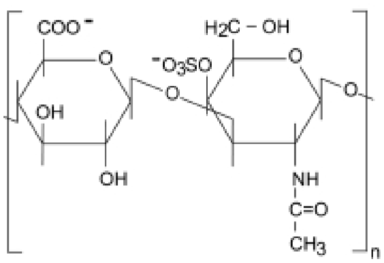
- The two linkages involved in both types of chondroitin sulfate would, obviously, be the same. These are β-1 → 3 and β-1 → 4.



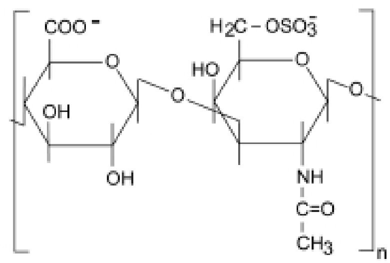
Hyaluronan



Dermatan Sulfate



Chondroitin-4-Sulfate



Chondroitin-6-Sulfate

Dermatan Sulfate

- Dermatan sulfate is a mucopolysaccharide structurally similar to chondroitin sulfate A except that the D-glucuronic acid is replaced by L-iduronic acid
- The two linkages involved are α-1 → 3 and β-1 → 4. Dermatan sulfate is also known byits conventional name, **chondroitin sulfate B**.

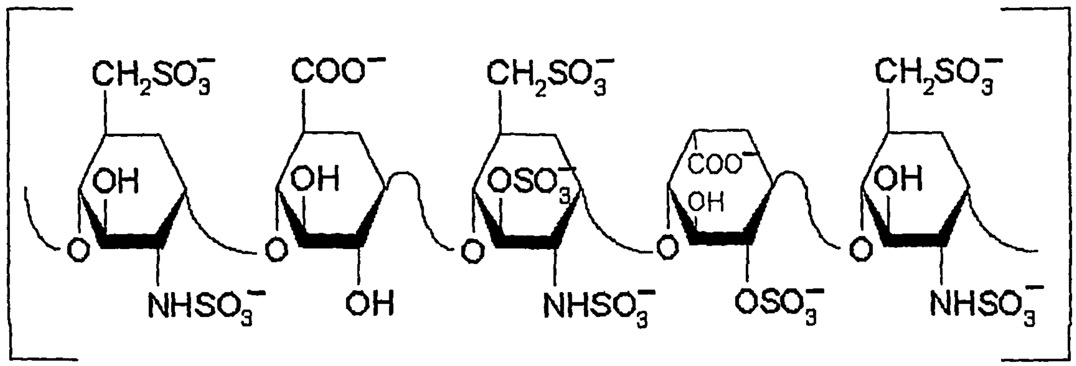
Keratosulfate

- Keratosulfate differs from other mucopolysaccharides in that the uronic acid component is replaced by D-galactose. Here, the second acetylated amino sugar component (which is N-acetyl-D-glucosamine in this case) is esterified by a sulfate group at carbon 6. Although, the two alternating linkages involved are β-1 → 4 and β-1 → 3, in this case the linkage between the repeating disaccharide units is β-1 →3 rather than β-1 → 4.

Heparin

- composed of D-glucuronic acid units, most of which (about 7 out of every 8) are esterified at C2 and D-glucosamine-N-sulfate (= sulfonylaminoglucose) units with an additional O-sulfate group at C6. Both the linkages of the polymer are alternating α-1 → 4. Thus, the sulfate content is very high and corresponds to about 5–6 molecules per tetrasaccharide repeating unit.

- Heparin acts as an anticoagulant. It prevents coagulation of blood by inhibiting the prothrombin thrombin conversion. This eliminates the effect of thrombin on fibrinogen.



Heparin

The following table is the list of biologically important polysaccharides and their functions. Polysaccharides are complex carbohydrates.

Name of the Polysaccharide	Composition	Occurrence	Functions
Starch	Polymer of glucose containing a straight chain of glucose molecules (amylose) and a branched chain of glucose molecules (amylopectin)	In several plant species as main storage carbohydrate	storage of reserve food
Glycogen	Polymer of glucose	Animals (equivalent of starch)	Storage of reserve food
Cellulose	Polymer of glucose	Different regions of plant, in sieve tubes of phloem	Cell wall matrix
Insulin	Polymer of fructose	In roots and tubers (like Dahlia)	Storage of reserve food

Pectin	Polymer of galactose and its derivatives	Plant cell wall	Cell wall matrix
Hemi cellulose	Polymer of pentoses and sugar acids	Plant cell wall	Cell wall matrix
Lignin	Polymer of glucose	Plant cell wall (dead cells like sclerenchyma)	Cell wall matrix
Chitin	Polymer of glucose	Bodywall of arthropods. In some fungi also	Exoskeleton Impermeable to water
Murein	Polysaccharide cross linked with amino acids	Cell wall of prokaryotic cells	Structural protection
Hyaluronic acid	Polymer of sugar acids	Connective tissue matrix, Outer coat of mammalian eggs	Ground substance, protection
Chrondroitin sulphate	Polymer of sugar acids	Connective tissue matrix	Ground substance
Heparin	Closely related to chrondroitin	Connective tissue cells	Anticoagulant
Gums and mucilages	Polymers of sugars and sugar acids	Gums - bark or trees. Mucilages - flower	Retain water in dry seasons