

- Carbohydrate Chemistry

Chapter Outline

- 5.1 Definition and classes of Carbohydrates
- 5.2 Biomedical importance of carbohydrates
- 5.3 Monosaccharides
- 5.4 Ring Formation— Monosaccharide Structure
- 5.5 Disaccharides
- 5.6 Polysaccharides
- 5.7 Properties & Practical chemistry

Definition

- Carbohydrates are defined as polyhydroxy aldehyde or ketones or compound which give them on hydrolysis.

Classifications:

- Major 4 classes based on number of monomeric units with two broad categories
- Sugars and non - sugars

I) Monosaccharides: Made up of single monomeric units

II) Disaccharides :Made up of 2 monomeric units

III) Oligosaccharides: Made up of 3 to 10 monosaccharides unit

IV) Polysaccharides: Made up of more than 10 monomeric units

Classifications:

- Monosaccharides can be further classify in 2 ways:
- A) Based on functional (aldehyde or ketone) group present
- Aldoses : Monosacchrides containing aldehyde group (CHO) are called aldoses.
- Ex Glucose, Galactose, Ribose etc
- Ketoses : monosaccharides containing keto (C=O) group are called ketoses
- Ex: Fructose, Ribulose, Xylulose etc

Monosaccharides:

- Based on number of carbon atoms present:
- Trioses: (3 c) Ex: Glyceraldehyde, DHA
- Tetroses: (4 c) Ex: Erythrose, Erythrulose
- Pentoses: (5 c) Ex: Ribose, Ribulose, Xylulose
- Hexose: (6 c) Ex: Glucose, Fructose, Galactose, Manose
- Heptose: (7 c) Ex: Aldoheptose, Sedoheptulose

Disaccharides:

- Contain 2 monosaccharide unit bonded by glycosidic bonds:
- Sucrose: 1 mole glucose+1mole fructose
- Lactose: 1 mole glucose+1mole galactose
- Maltose: 2 moles of glucose
- Trehalose, Isomaltose and cellobiose

Oligisaccharides:

- Contain 3 to 10 monomeric units bonded by glycosidic bonds:
- Maltotriose (Trisaccharide)
- Raffinose (Trisaccharide)
- Stachyose (Tetrasaccharide)
- Verbascose (Pentasaccharide)
- Oligosaccharides present in all cell membrane
- Blood group antigens are also oligosaccharides

Polysaccharides:

- Contain more than 10 monomeric units bonded by glycosidic bonds.
- Based on the type of monomeric units, they are classified into 2 groups:
- Homopolysaccharides and Heteropolysaccharides
- Homopolysaccharides: made up of only one type of monosaccharide units
- Ex:
- Starch: plant storage made up of only glucose molecules

Ex:

- Glycogen: Animal storage homopolysacch.
- Cellulose: Plants structural
- Inulin: Plant homopoly made up of fructose molecule
- Heteropolysaccharides (Heteroglycans): made up of more than one type of monosacchride units
- Ex: Agar
- Glycosaminoglycans (mucopolysaccharides) like hyaluronic acid, heparin, heparan sulphate, dermatan sulphate, chondroitin sulphate and keratan sulphate.

Biomedical importance of

- Energy source: **carbohydrates:**

Carbohydrates (glucose) are the major source of energy in the body. Erythrocytes and brain cells are almost completely dependant on glucose for energy.

- Energy storage:

Carbohydrates serves as storage form of energy Ex: glycogen in animals and starch in plants.

- Structural components:

Carbohydrates (glycoprotein/glycolipids) are components of cell membranes and involve in receptor, cell growth, cell adhesion, recognition etc

Biomedical importance of carbohydrates:

Matrix of connective tissues contains GAG which heteropolysaccharides in combination with proteins.

- Precursor:

Glucose is the precursor of all the carbohydrates in the body. Including, ribose and deoxyribose in Nucleic Acid, galactose in lactose of milk etc.

It is also precursor for the synthesis of fats and some amino acids.

Monosaccharides:

Introduction to Carbohydrates

- ***Carbohydrates*** are sugars and provide energy when consumed.
- Our bodies break down carbohydrates to extract energy. Carbon dioxide and water are released in the process.
- ***Glucose*** is the primary carbohydrate our bodies use to produce energy.
- Carbohydrates are classified as biomolecules.

Introduction to Carbohydrates, Continued

- ***Simple carbohydrates*** are referred to as ***simple sugars*** and are often sweet to the taste.
- Consumption of more sugar than is needed for energy results in conversion of these sugars to fat.
- ***Complex carbohydrates*** include starches and the plant and wood fibers known as ***cellulose***.

Introduction to Carbohydrates, Continued

- Carbohydrates are found on the surface of cells where they act as “road signs” allowing molecules to distinguish one cell from another.
- ***ABO blood markers*** found on red blood cells are made up of carbohydrates. They allow us to distinguish our body’s blood type from a foreign blood type.
- Carbohydrates in our body prevent blood clots. They are also found in our genetic material.

5.1 Classes of Carbohydrates

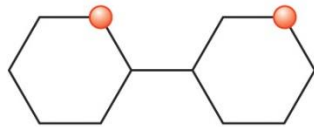
- ***Monosaccharides*** are the simplest carbohydrates. They cannot be broken down to smaller carbohydrates.
- ***Disaccharides*** consist of two monosaccharide units joined together; they can be split into two monosaccharides. Sucrose, table sugar, can be broken down into glucose and fructose.
- ***Oligosaccharides*** contain anywhere from three to nine monosaccharide units. ABO blood groups are oligosaccharides.

5.1 Classes of Carbohydrates, Continued

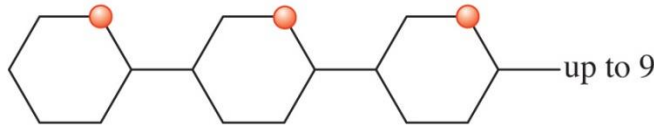
Polysaccharides are large molecules containing 10 or more monosaccharide units. Carbohydrate units are connected in one continuous chain or the chain can be branched.



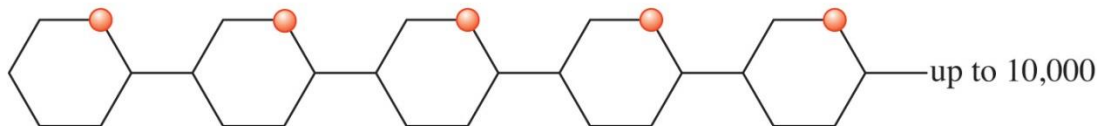
Monosaccharide



Disaccharide



Oligosaccharide



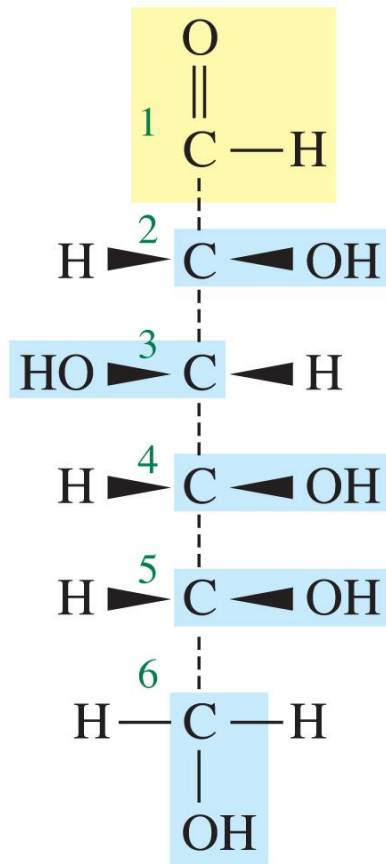
Polysaccharide

5.2 Monosaccharides

- Monosaccharides contain the elements carbon, hydrogen, and oxygen, and have the general formula $C_n(H_2O)_n$, where n is a whole number 3 or greater.
- Monosaccharides contain several functional groups. They contain the hydroxyl group represented as $-OH$. They also contain a **carbonyl group**, which is an oxygen double bonded to a carbon atom. The carbonyl group may be an aldehyde or a ketone.

5.2 Monosaccharides, Continued

The functional groups of glucose are shown in the figure below.



Aldehyde

Alcohol



Carbonyl

5.2 Monosaccharides, Continued

Functional Groups in Monosaccharides—Alcohols, Aldehydes, and Ketones

Alcohols

- ***Alcohol*** is an organic compound containing the -OH group.
- Ethanol is one of the simplest alcohols and is prepared from the fermentation of simple sugars in grains and fruits. Ethanol is present in beer and liquors, and is used as an alternative fuel blend, such as gasohol and E85 (85% ethanol and 15% gasoline).

5.2 Monosaccharides, Continued

Alcohols

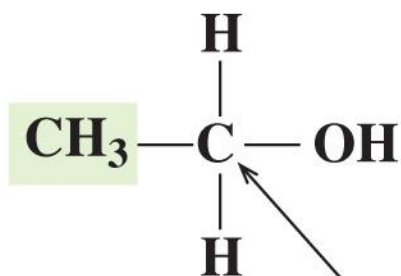
- Alcohols are classified by the number of alkyl groups attached to the carbon atom containing the hydroxyl group. The number of alkyl groups impacts the reactivity of the alcohol.
- ***Primary (1°) alcohols*** have one alkyl group attached to the alcoholic carbon.
- ***Secondary (2°) alcohols*** have two alkyl groups attached to the alcoholic carbon.
- ***Tertiary (3°) alcohols*** have three alkyl groups attached to the alcoholic carbon.

5.2 Monosaccharides, Continued

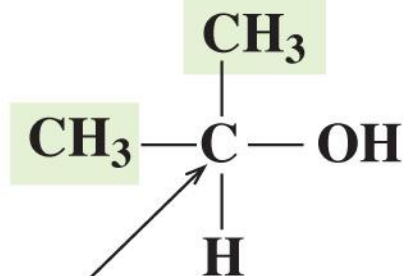
Alcohols

- Monosaccharides contain both primary and secondary alcohols.

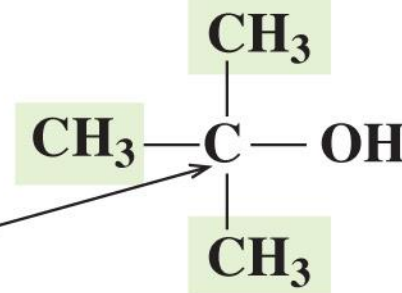
Primary (1°) alcohol



Secondary (2°) alcohol



Tertiary (3°) alcohol

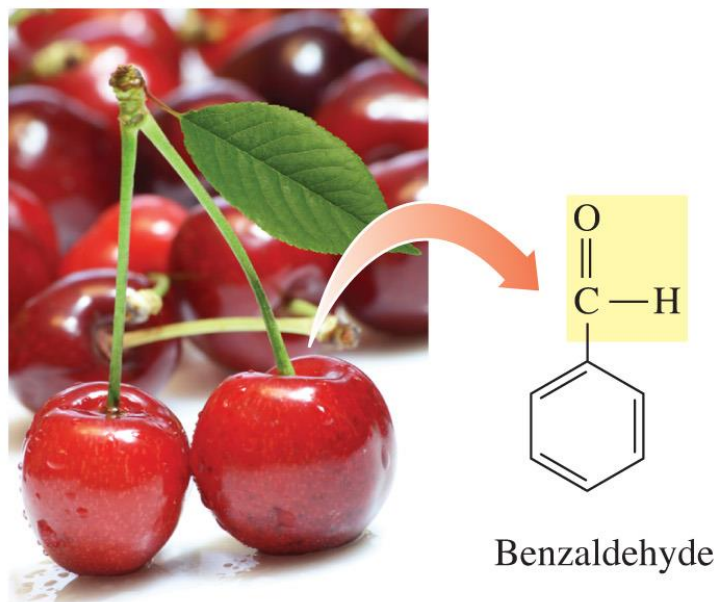


Carbon attached
to OH group

5.2 Monosaccharides, Continued

Aldehydes

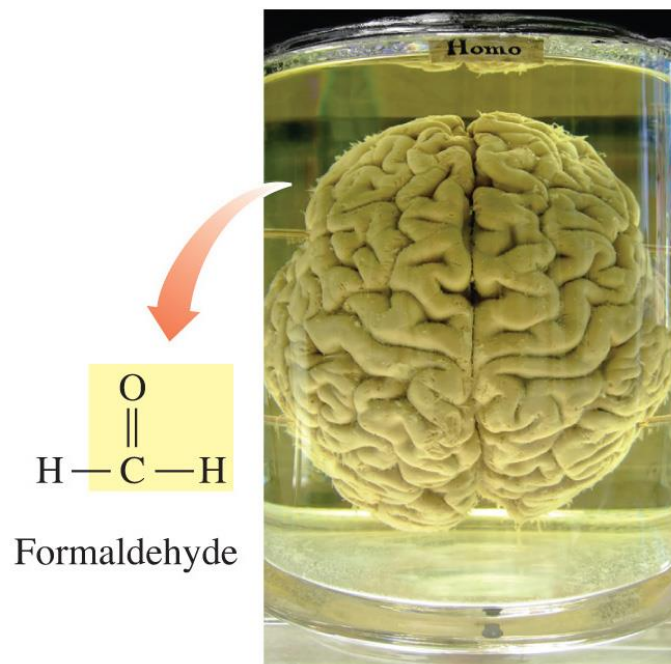
- An ***aldehyde*** is an organic compound containing the carbonyl group.
- Benzaldehyde, a compound responsible for the aroma of almonds and cherries, is one example.



5.2 Monosaccharides, Continued

Aldehydes

- Members of this family always contain a carbonyl group with a hydrogen atom bonded to one side and an alkyl or aromatic bonded to the other. An exception is formaldehyde (a preservative), which has two hydrogens bonded to the carbonyl group.

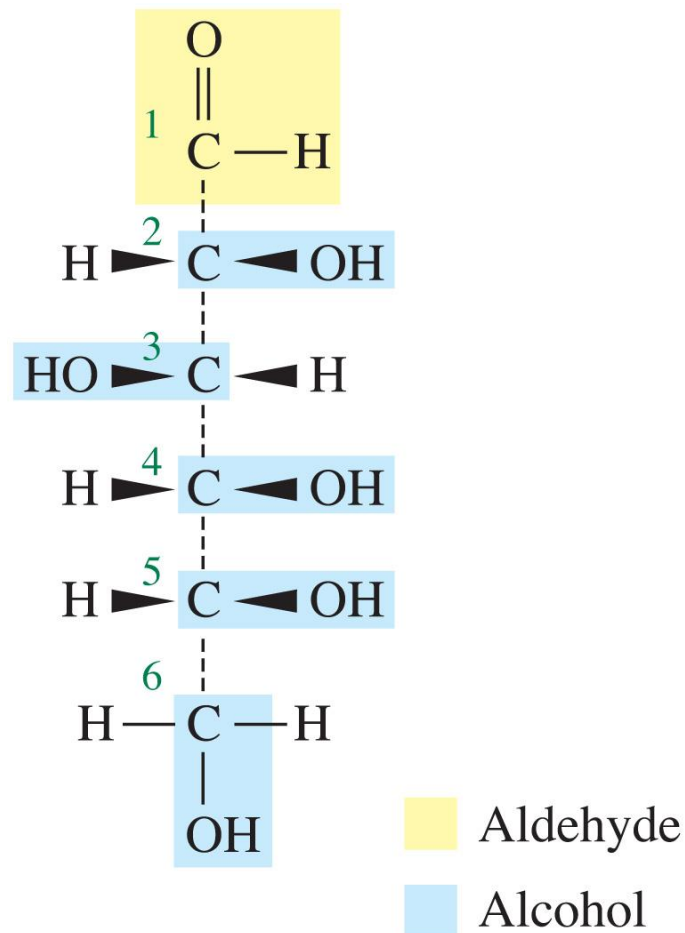


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5.2 Monosaccharides, Continued

Aldehydes

- Monosaccharides can contain an aldehyde group on one end of the molecule in addition to multiple hydroxyl groups.

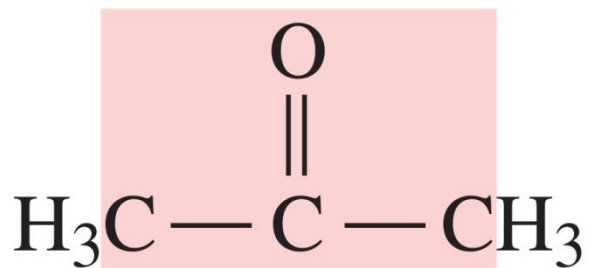


5.2 Monosaccharides, Continued

Ketones

- A **ketone** also contains the carbonyl group, but has an alkyl or aromatic group on both sides of the carbonyl group.
- Acetone is the simplest ketone. It is the main component of fingernail polish remover.

 Ketone

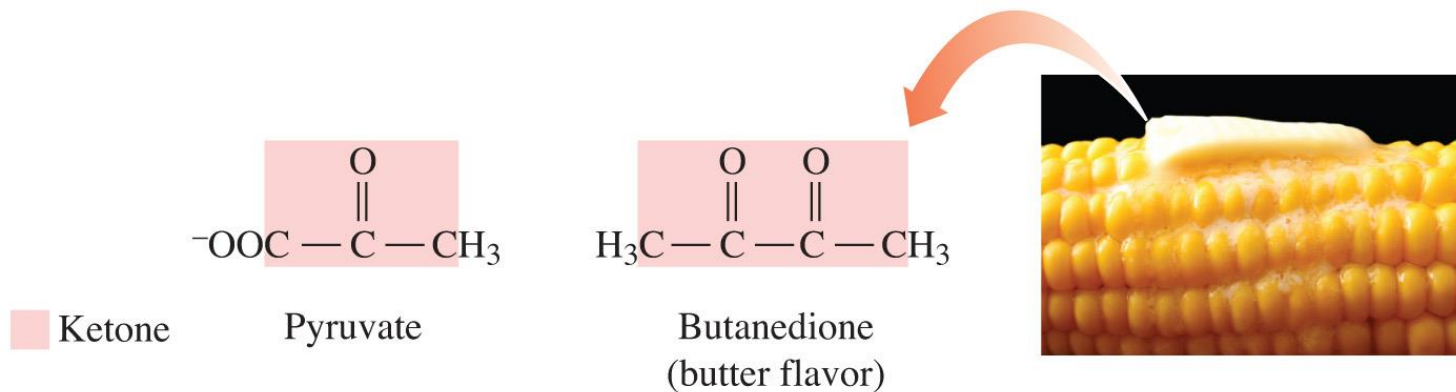


Acetone

5.2 Monosaccharides, Continued

Ketones

- A wide variety of biologically important compounds contain a ketone group.
- Pyruvate is a ketone-containing compound formed during the breakdown of glucose.
- Butanedione, the flavor of butter, contains two ketone groups.



5.2 Monosaccharides, Continued

- Monosaccharides that contain an aldehyde group are referred to as an ***aldose***. Those that contain a ketone group are referred to as a ***ketose***.
- Monosaccharides are classified according to the number of carbon atoms. Most common monosaccharides have three to six carbon atoms.
 - *Triose* contains three carbons Ex Glycceralde.
 - *Tetrose* contains four carbons Ex Erythrose.
 - *Pentose* contains five carbons Ex Ribose.
 - *Hexose* contains six carbons Ex Glucose.

5.2 Monosaccharides, Continued

- Carbohydrates are further classified on whether they contain an aldehyde or ketone group.
- For example, glucose, the most abundant monosaccharide found in nature, contains six carbons and an aldehyde group. It is classified as an ***aldohexose***.
- Fructose, known as fruit sugar, contains six carbons and a ketone group. It is classified as a ***ketohexose***.