- Number :

6

- Done by :

Tasneem Shawar

- Corrected by :

Osama Fraij

- Doctor :

Nafith Abu-tarbosh

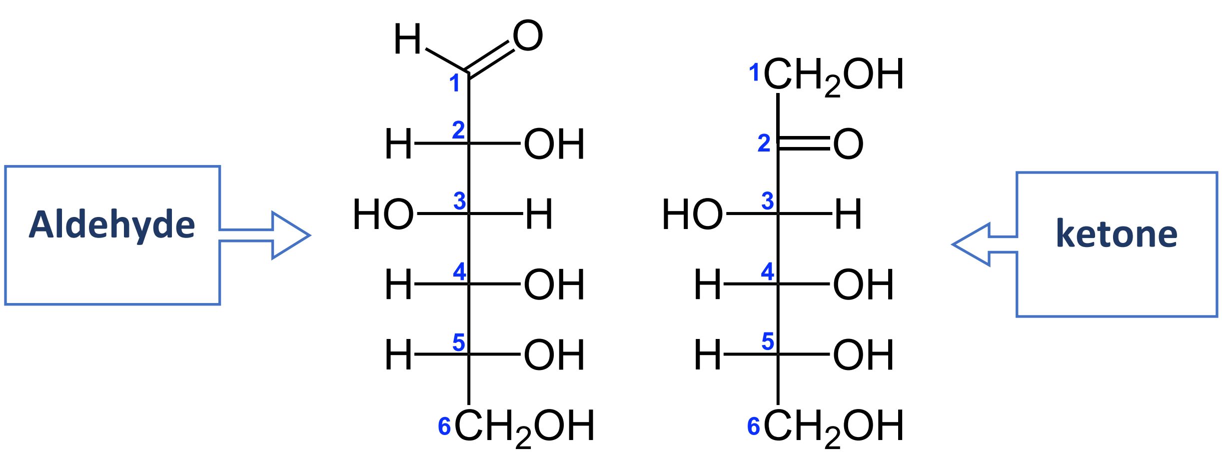
Carbohydrates

-What are they?

Carbohydrates are polyhydroxy molecules (chain of carbon atoms with multiple hydroxyl groups) aldehydes or ketones, and as the name implies, they are molecules that are made of carbon and H_2O (hydrating carbon= adding H_2O).

-When we add water to each carbon atom how will it distribute on each one?

At each C we will have (OH, H), the C on one terminal will bind to CH2OH and the other C terminal will bind to a functional group which is aldehyde (carbonyl group). Other molecules may have a ketone group (carbonyl group) that is not attached on a terminal carbon.



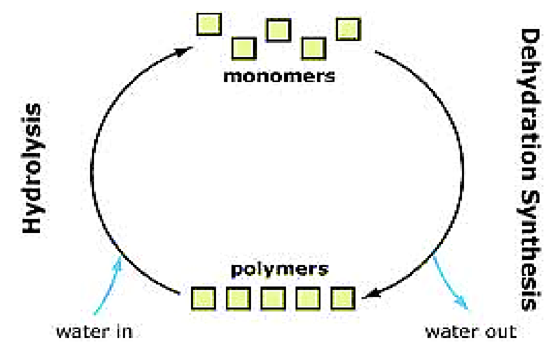
Notice that: the carbonyl group in aldose is attached to carbon no.1. Whereas in ketose it is attached to carbon no.2.

Biomacromolecules:

- Subunits: the small building blocks (precursors) used to make macromolecules
- Macromolecules: large molecules made of subunits.
  - ✓ **Carbohydrates (monosaccharides)**
  - ✓ **Proteins (amino acids)**
  - ✓ **Nucleic acids (nucleotides)**
  - ✓ **Lipids (fatty acids)**

Except for lipids, these macromolecules are also considered polymers.

- All these macromolecules are being formed by dehydration reaction (connecting 2 molecules by removing water) and are getting degraded to their subunits through hydrolysis reaction (adding water so subunits come apart).



Main functions of carbohydrate:

- Major energy source: as we have it on large quantities, we call them as **main** source of energy, but any molecule which can be broken down can serve as an energy source.
- Building blocks: they are used to form larger molecules.

- Structural tissues: they are essential structural components of several classes of organisms. For example, cellulose is the major component of stem in plants. In addition to, chitin in insects.
- On cells surfaces: Cellular recognition, cellular transduction, cell-cell adhesion and activation of growth factor. (lipids and proteins do have attachments with carbohydrates forming glycolipids, glycoproteins and proteoglycans, so cells can recognize other cells by looking at these molecules on the surface of these cells).
- Intermediates in biosynthesis of other basic biochemical structures (fats and proteins).

Carbohydrates –Natural forms:

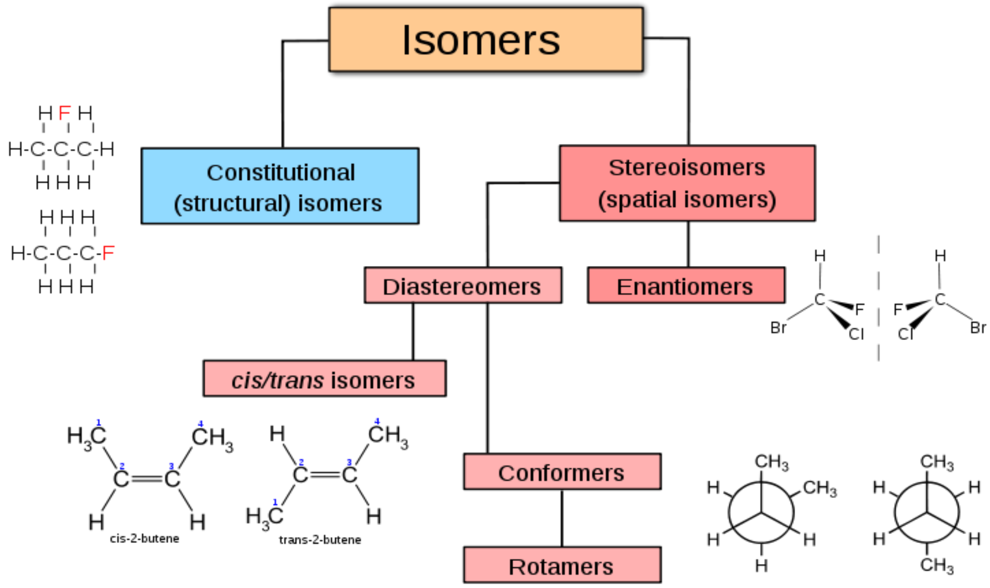
- Most carbohydrates are found naturally in bound form rather than as simple sugars:
  - ✓ Polysaccharides (starch, cellulose, inulin, gums).
  - ✓ Glycoproteins and proteoglycans (hormones, blood group substances, antibodies).
  - ✓ Glycolipids (cerebrosides, gangliosides).
  - ✓ Glycosides.
  - ✓ Mucopolysaccharides (hyaluronic acid).
  - ✓ Nucleic acids (DNA, RNA).

Carbohydrates – Forms:

- **Monosaccharides** – carbohydrates that cannot be hydrolyzed to simpler carbohydrates (glucose & fructose).
- **Disaccharides** – made of two monosaccharides, that can be hydrolyzed into two monosaccharide units (sucrose → glucose + fructose).
- **Oligosaccharides** – they are made of 3-10 monosaccharides, that can be hydrolyzed into a few monosaccharide units (fructo-oligosaccharides (FOS), found in many vegetables)
- **Polysaccharides** – carbohydrates that are polymeric sugars (starch or cellulose).

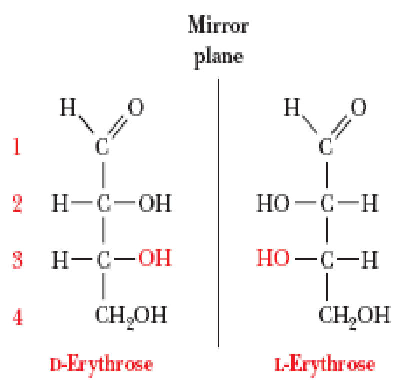
Isomers:

- Compounds with similar molecular formula but different structural formulas.
- Isomers do not necessarily share similar properties.
- Two main forms:
  - ✓ Structural isomerism: molecules with the same molecular formula but have different bonding patterns
  - ✓ Stereoisomerism (geometric isomers): where they differ from each other in the orientation of functional groups in space.

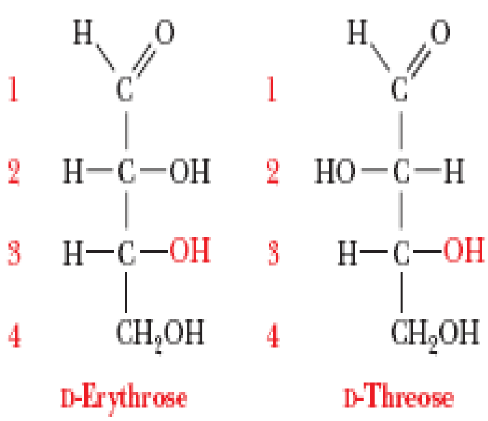


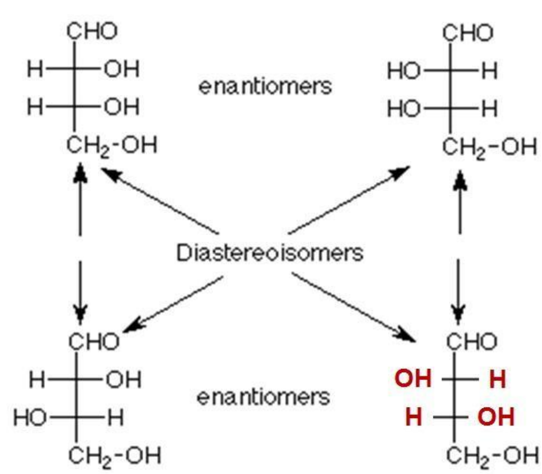
There are two types of stereoisomers:

1. Enantiomers: Two stereoisomers that are mirror images of each other and are non-superimposable.

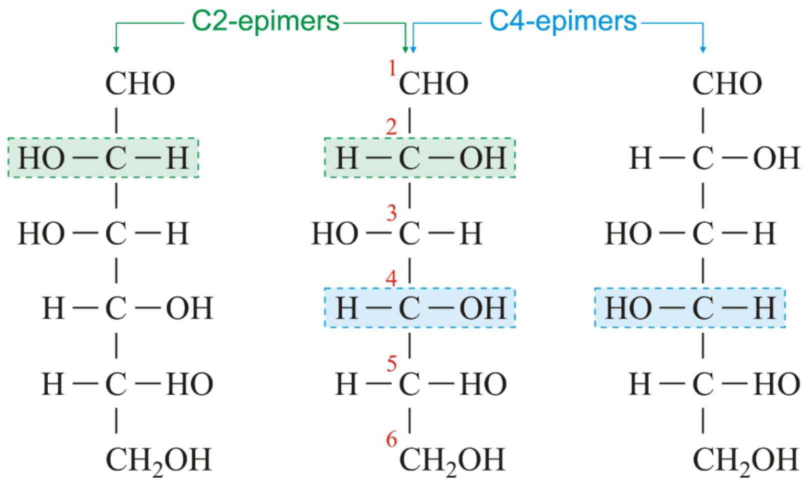


2. Diastereomers: **NOT** mirror-images but still they are stereoisomers.





-Epimers: are diastereomers that differ in configuration at only one chiral center (the following example is only for clarification).



D-mannose D-glucose D-galactose

Note: every epimer is a diastereomer but not every diastereomer is an epimer.

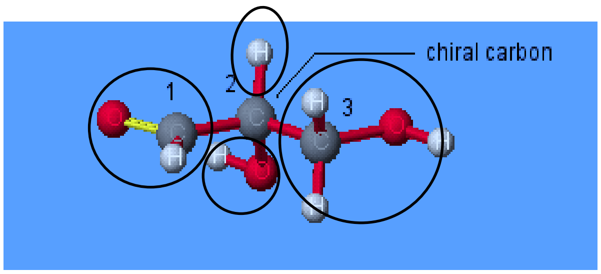
D-mannose and D-glucose are epimers at carbon no.2 (OH group is directed to the left in D-mannose while it's directed to the right in D-glucose) whereas D-glucose and D-galactose are epimers at carbon no.4. D-mannose and D-galactose are ONLY diastereomers (they are not epimers).

Chirality:

Chiral carbon: is a carbon atom that is attached to four different groups **NOT** four different atoms (no double bonds)

-How to determine whether this carbon is chiral or achiral?

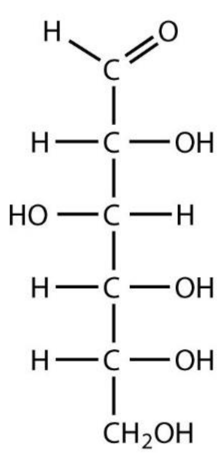
By looking at a specific carbon, anything to the right of it you deal with it as a one group (the same principle is applied to all aspects).



After determining all the attached groups to carbon 2, it seems that it is a CHIRAL center as it's attached to 4 different groups.

{you can practice more by referring to slide no.6}

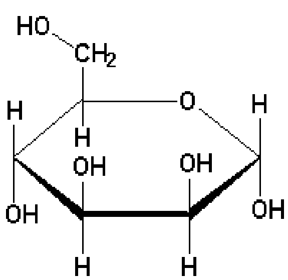
We are interested about chiral and Achiral centers to know the number of isomers for each molecule, because isomers occur out of chirality "when it is bind to four different groups" so to know the number of isomers you can create out of each molecule then you have to identify chiral centers in each molecule and use this formula 2^n (where n is the number of chiral carbons)



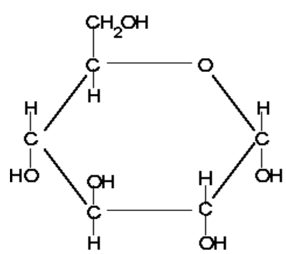
For example, glucose has 4 chiral carbons accordingly the number of isomers is: $\mathbf{2^4}$ =16

Monosaccharides:

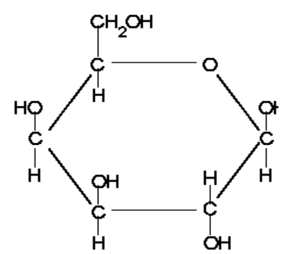
- They are the simplest form of sugar, following basic formula: **$(CH_2O)_n$** (n varies from 3-8)
- The simplest number of carbons is 3 to 8 carbons in each monosaccharide.
- The most common monosaccharide are pentoses (5 carbons) and hexoses (6 carbons) and here are the most common monosaccharides:
  - ✓ Glucose, fructose, galactose, mannose: All are 6 carbon hexoses: **6 Cs, 12 Hs, 6 Os.**



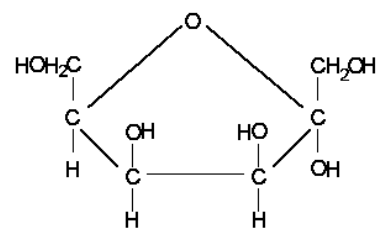
Mannose



Glucose



Galactose



Fructose

  - ✓ They are isomers to each other, as the arrangement of groups & atoms differs and thus lead to different functions and properties for each molecule.

➢ Glucose:

- ▪ Mild sweet flavor.
- ▪ Known as blood sugar.
- ▪ Essential energy source.
- ▪ Found in every disaccharide & polysaccharide.

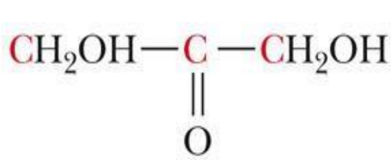
- Fructose:
  - Sweetest sugar, found in fruits & honey.
  - Added to soft drinks, cereals, and deserts.

- Galactose:
  - Hardly tastes sweet & rarely found naturally as a single sugar. (it is found in milk and that's why it tastes less sweet unless you add some sugar).

Note: we add the suffix -ose to designate a carbohydrate (triose, pentose…) and in each class we could have either an aldehyde or ketone.

Carbon Atoms	General terms	Aldehydes	Ketones
3	Triose	Aldotriose	Keto triose
4	Tetrose	Aldotetrose	Ketotetrose
5	Pentose	Aldopentose	Ketopentose
6	Hexose	Aldohexose	Ketohexose
7	Heptose	Aldoheptose	Ketoheptose

- Trioses (aldehyde/ketone) are simplest carbohydrate monosaccharides. Examples:



Dihydroxyacetone

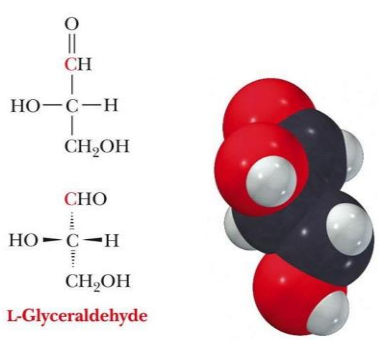
This molecule is a ketotriose, with no chiral carbon so it doesn't have any isomers.

Glyceraldehyde

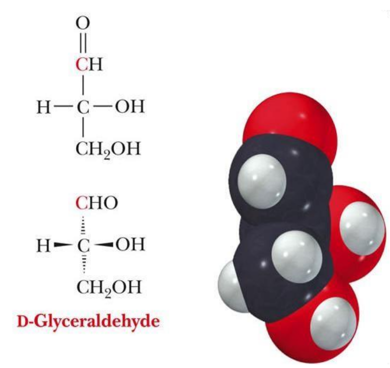
This molecule is an aldotriose, with one chiral carbon so $\mathbf{2^1} = 2$ isomers

-Any molecule which is a stereoisomer to another molecule, if you put it in a solution and project it with light, it can start rotating resulting in either a left-handed molecule (L-levorotatory) or right-handed molecule (D-dextrorotatory).

3 The structure of L-glyceraldehyde and a space-filling model of L-glyceraldehyde.



2 The structure of D-glyceraldehyde and a space-filling model of D-glyceraldehyde.



Good luck