Lecture 2

CARBOHYRATES

Chemical Constituents of Life

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INTRODUCTON

- Carbohydrates are the most abundant organic molecules in nature. They are primarily composed of the elements **carbon**, **hydrogen and oxygen**. The name carbohydrate literally means '**hydrates of carbon**'. With formula $(CH_2O)_n$
- **Carbohydrates may be defined as polyhydroxy aldehydes or ketones or compounds which produce them on hydrolysis**.
- The term 'sugar' is applied to carbohydrates soluble in water and sweet to taste.

FUNCTIONS

- They are the most abundant dietary **source of energy** (4 Cal/g) for all organisms.

- Carbohydrates are precursors for many organic compounds (fats, amino acids).

- Carbohydrates participate in the structure of cell membrane and cellular functions.

FUNCTIONS

- They are structural components of many organisms. These include the fiber (cellulose) of plants, exoskeleton of some insects and the cell wall of microorganisms.

- Carbohydrates also serve as the storage form of energy (glycogen) to meet the immediate energy demands of the body.

Classification of carbohydrate

- **Monosaccharides** – carbohydrates that cannot be hydrolyzed to simpler carbohydrates; eg. Glucose or fructose.
- **Disaccharides** – carbohydrates that can be hydrolyzed into two monosaccharide units; eg. Sucrose, which is hydrolyzed into glucose and fructose.
- **Oligosaccharides** – carbohydrates that can be hydrolyzed into a few monosaccharide units.
- **Polysaccharides** – carbohydrates that are polymeric sugars; eg Starch or cellulose.

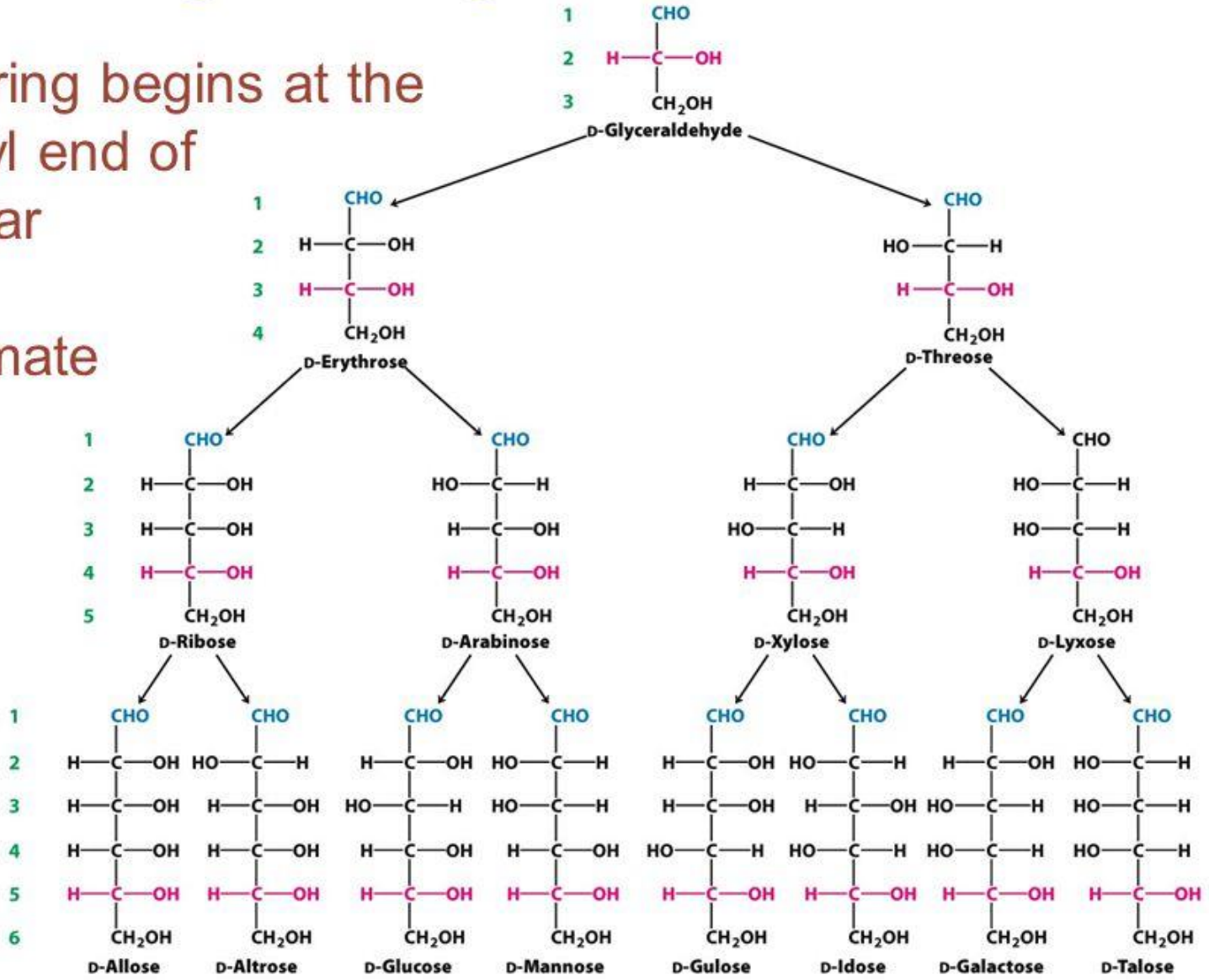
MONOSACCHARIDES—STRUCTURAL ASPECTS

- The monosaccharides are divided into different categories, based on the functional group and the number of carbon atoms
- **Aldoses** : Sugars that contain an aldehyde group
- **Ketoses** : Sugars that contain a keto group.

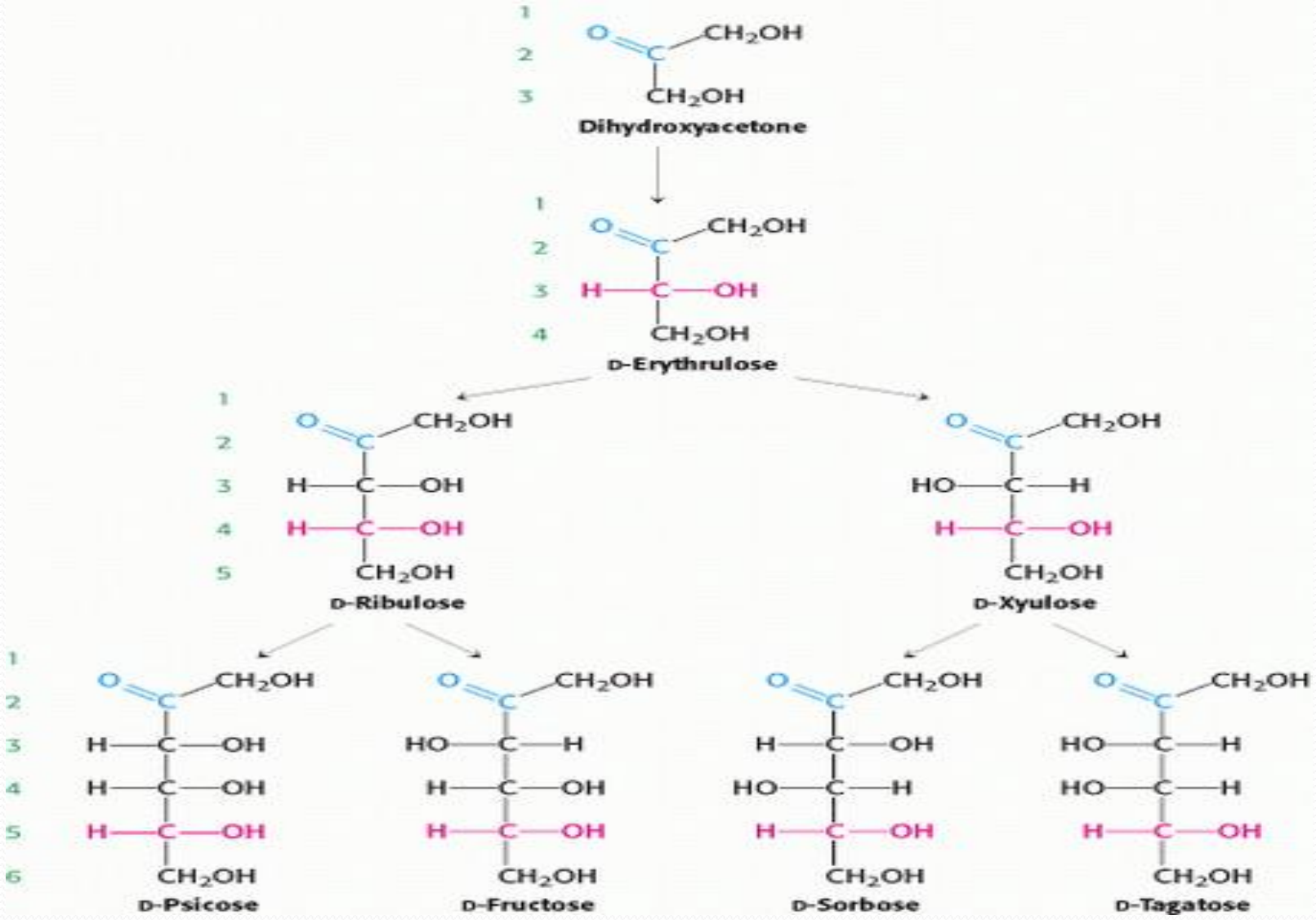
D-Aldose Sugar Configurations

Numbering begins at the carbonyl end of the sugar

Penultimate carbon (pink) sets L- versus D-form



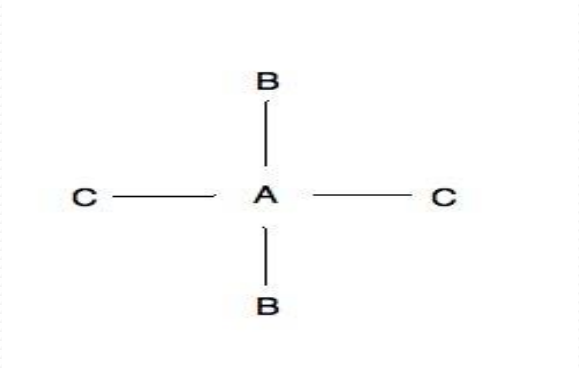
Ketoses sugars

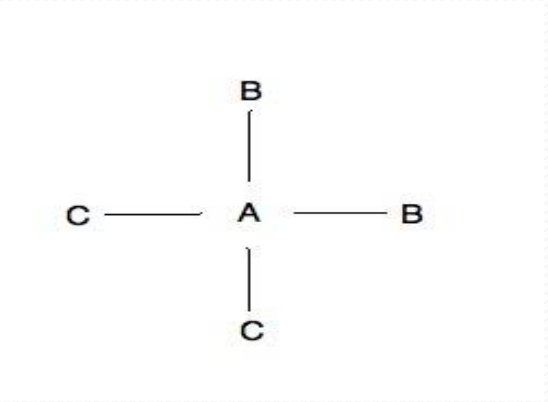


Isomers

- Isomers are molecules that have the same molecular formula, but have a different arrangement of the atoms in space. (different structures).

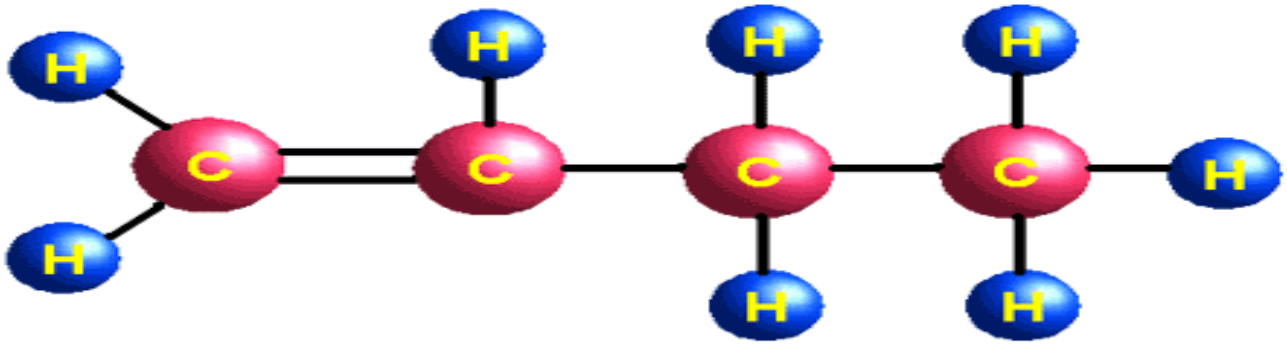
- For example, a molecule with the formula AB_2C_2, has two ways it can be drawn:



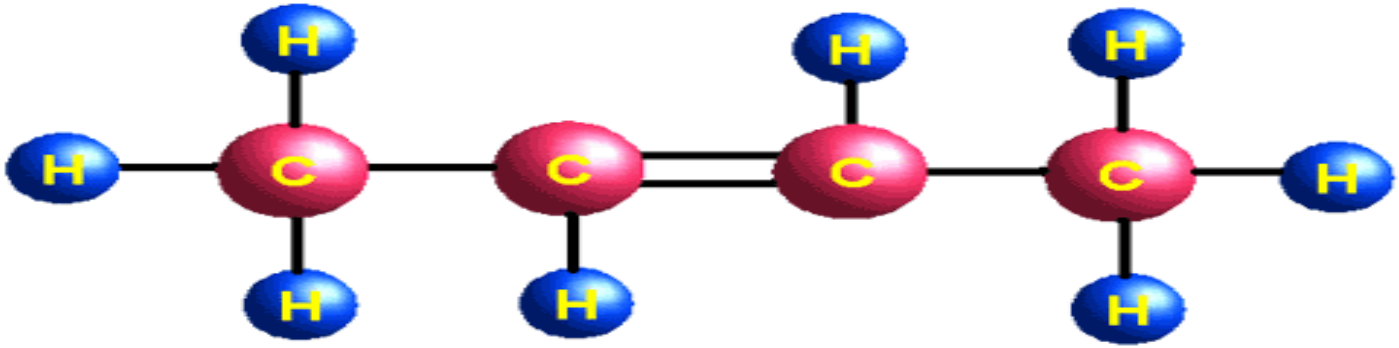


Isomers

Structural Isomer 1



Structural Isomer 2



Isomers

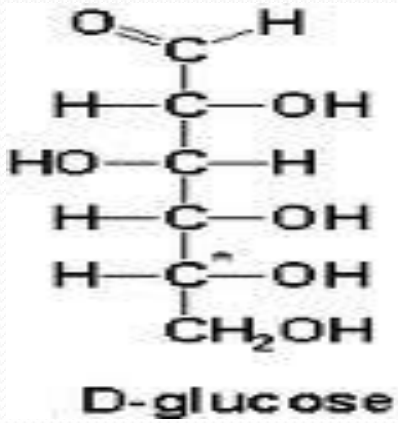
Examples of isomers:

1. Glucose
2. Fructose
3. Galactose
4. Mannose

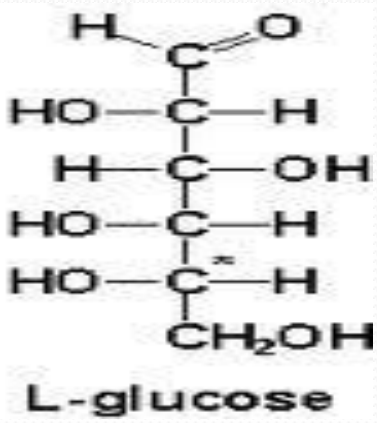
Same chemical formula $C_6H_{12}O_6$

D and L forms of sugars

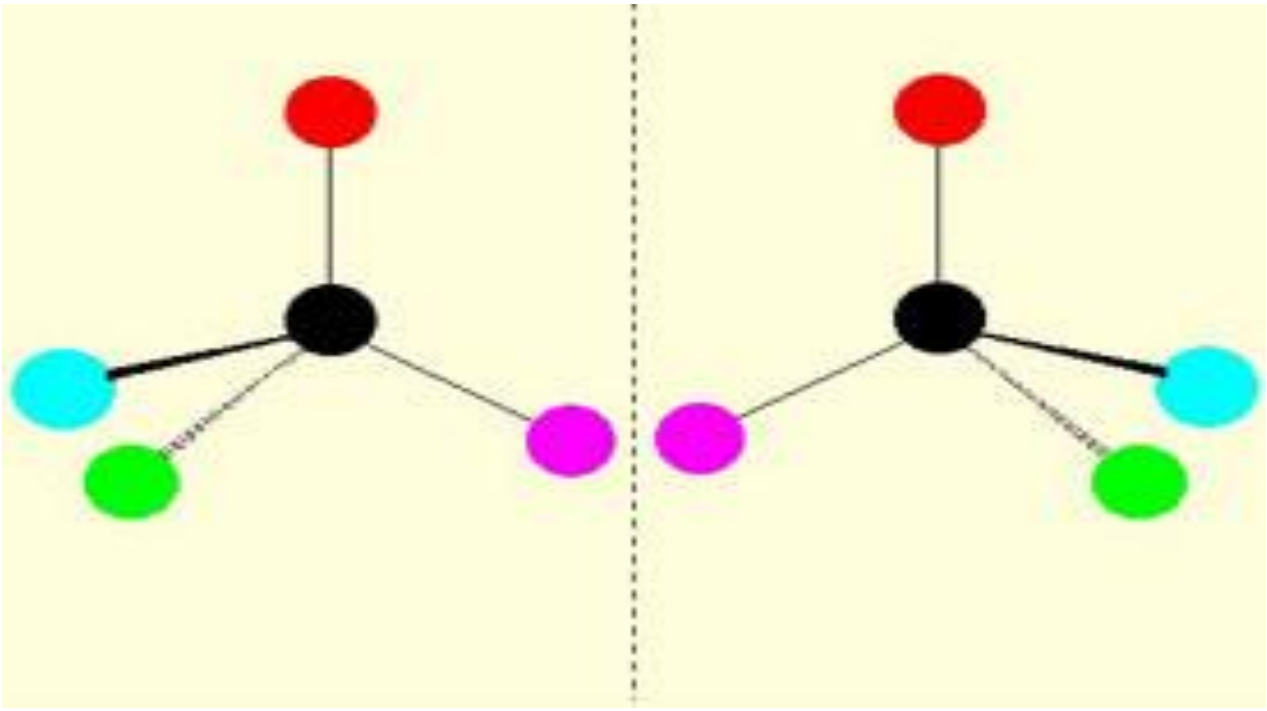
- The D and L isomers are mirror images of each other. The spatial orientation of H and OH groups in the sugars . Examples
- In **D** form the OH group on the asymmetric carbon is on the **right**
- In **L** form the OH group is on the **left side**

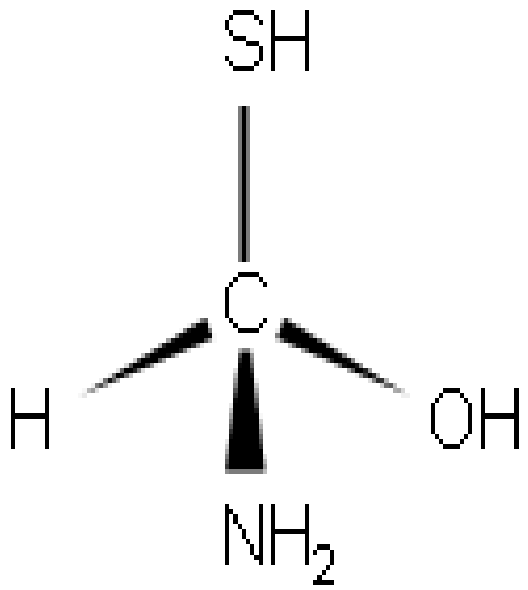


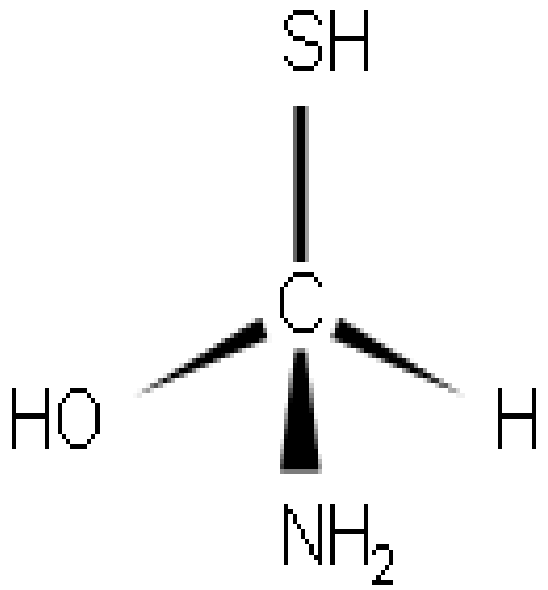
D-glucose

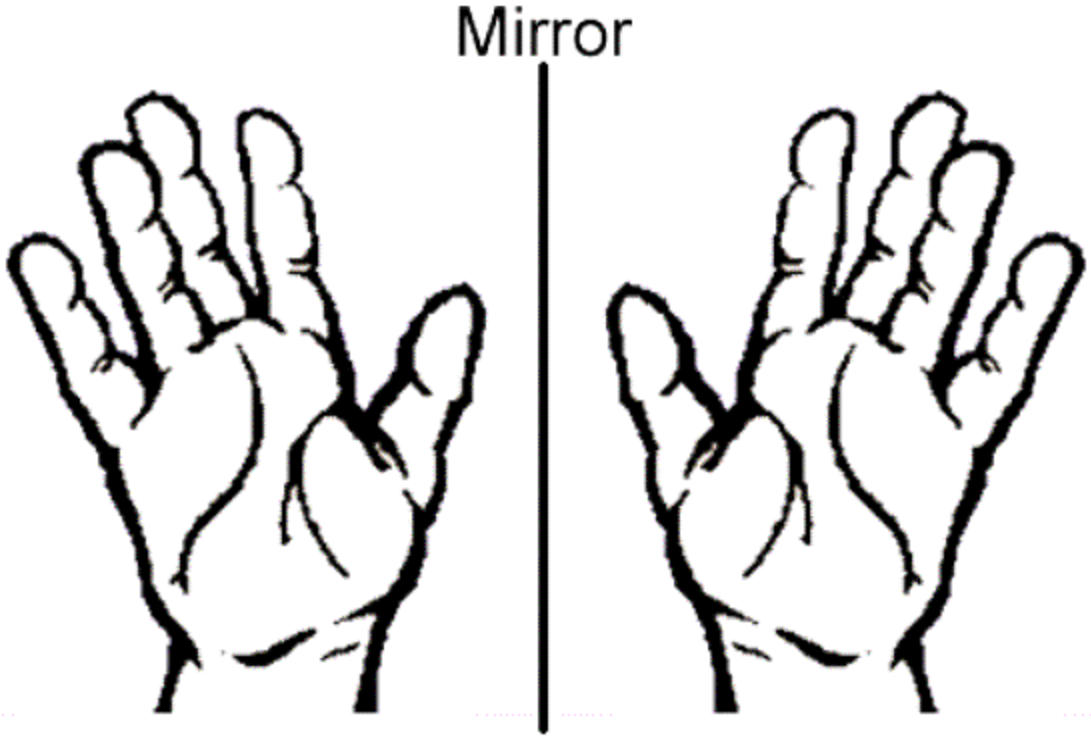


L-glucose




SH
C
H
OH
NH2


SH
C
HO
H
NH2

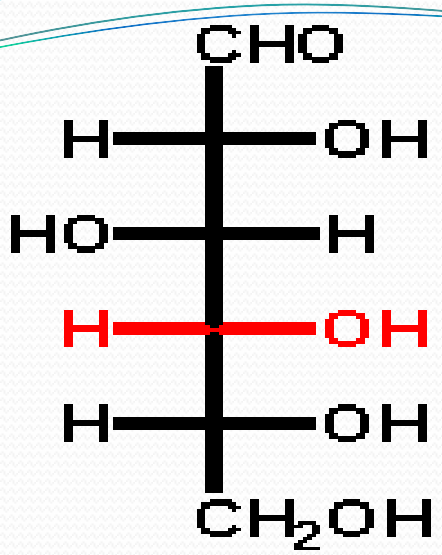


The mirror image of a chiral substance cannot be superimposed on the original image. Hands are chiral, as are sugars and amino acids.

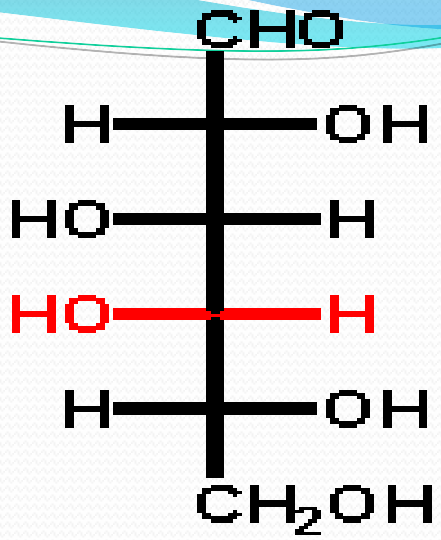
EPIMERS

- If two monosaccharides **differ** from each other in their **configuration around a single specific carbon** atom, they are referred to as epimers to each other .

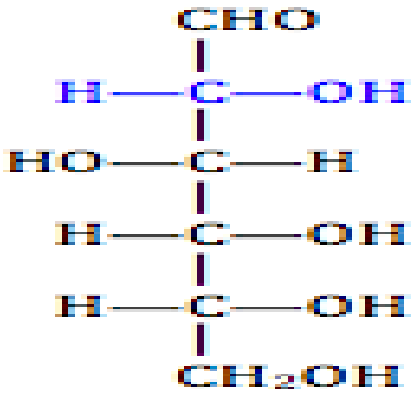
- Examples **glucose and galactose are epimers** with regard to carbon 4 (C4-epimers). Glucose and mannose are epimers with regard to carbon 2 (C2-epimers).



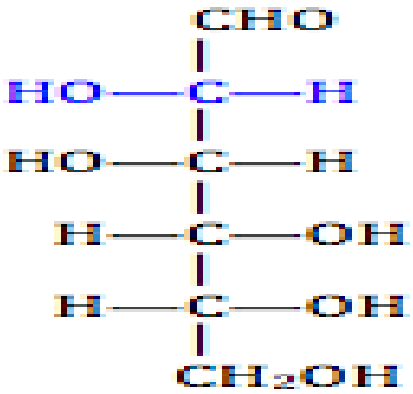
D-glucose



D-galactose



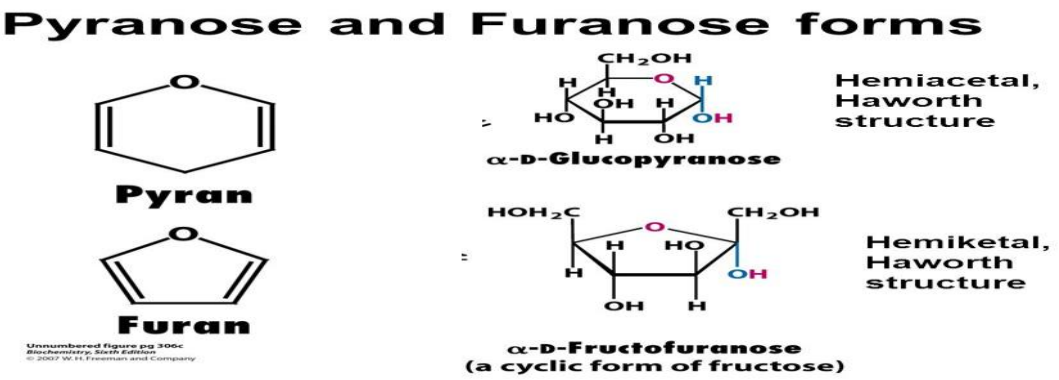
D-Glucose



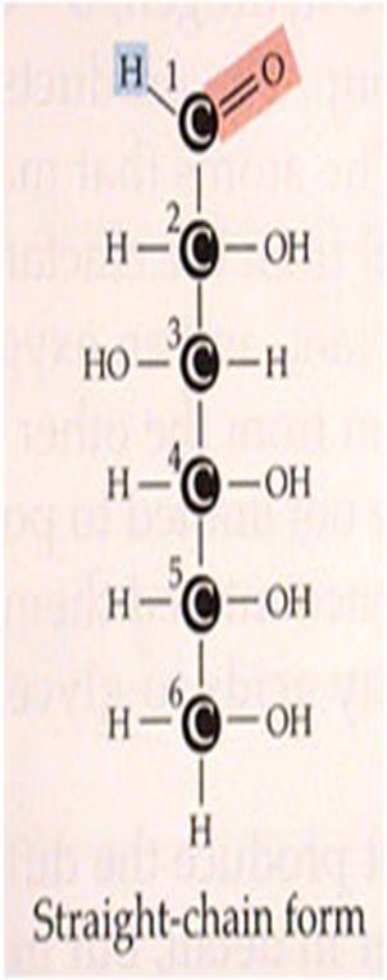
D-Mannose

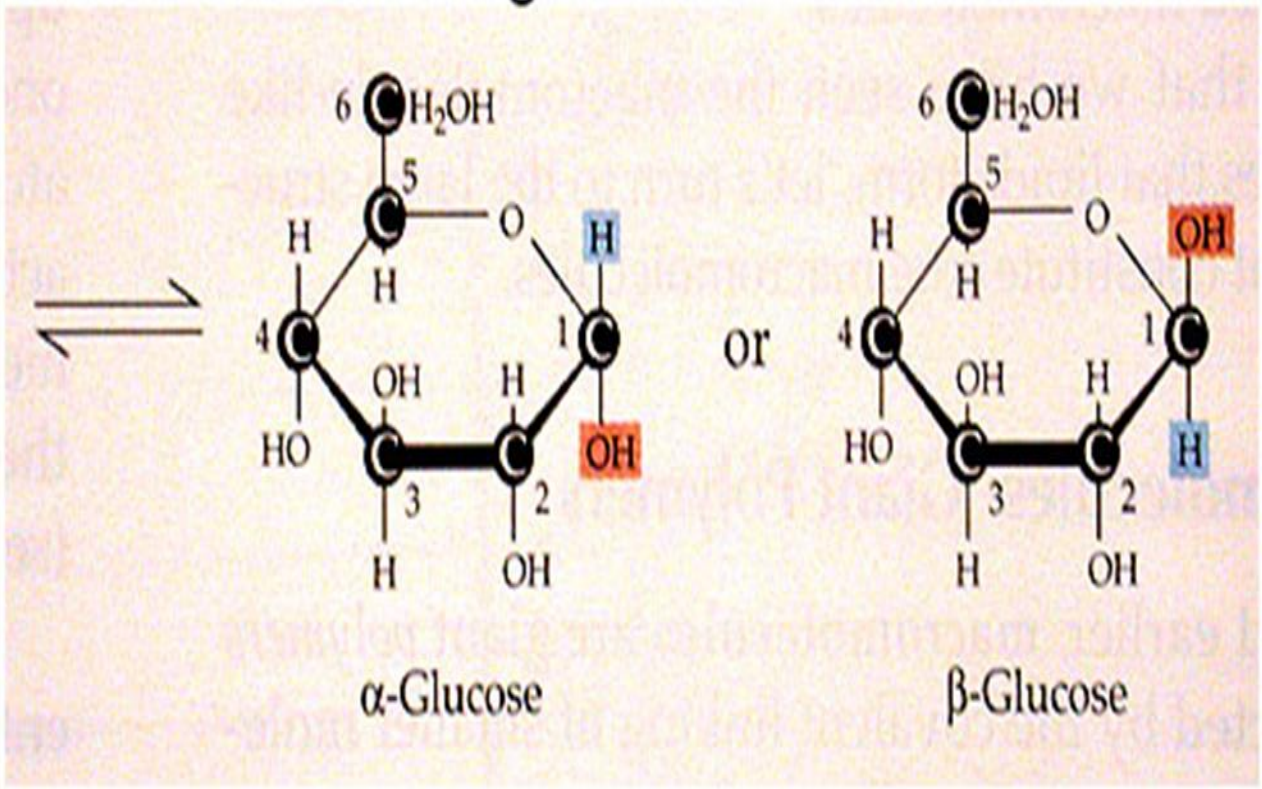
cyclization

- Less then 1% of CHO exist in an open chain form.
- Predominantly found in **ring form**.
- involving reaction of C-5 OH group with the C-1 aldehyde group or C-2 of keto group.
  - Six membered ring structures are called **Pyranoses .**
  - Five membered ring structures are called **Furanoses**



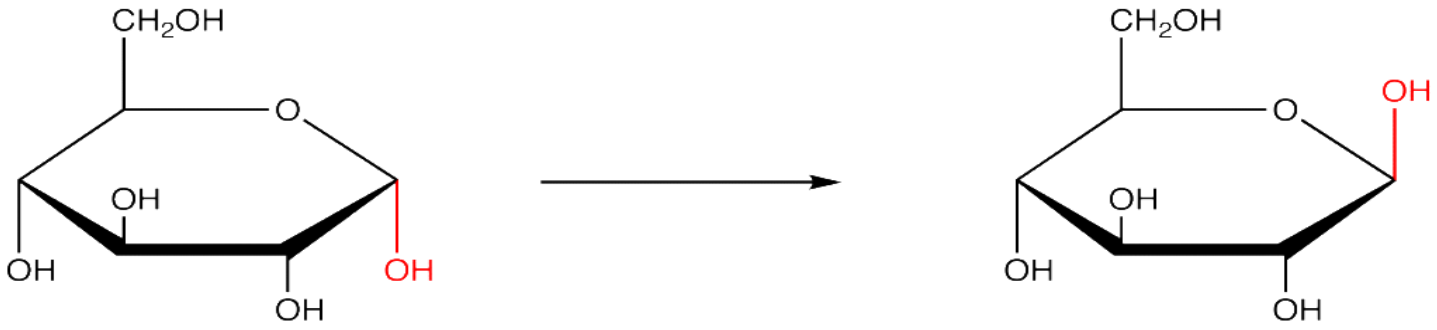
ring form





Anomeric carbon

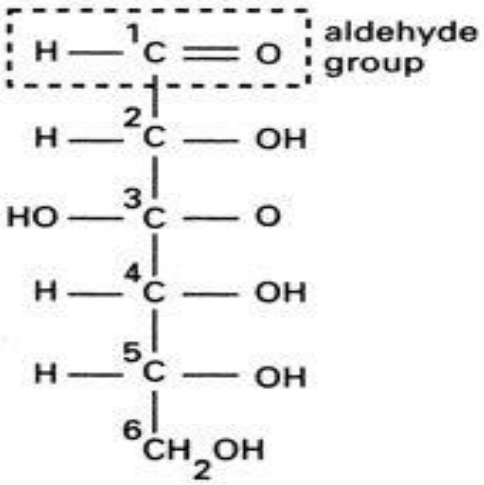
- The carbonyl carbon after cyclization becomes the anomeric carbon.
- This creates **α** and **β** configuration.



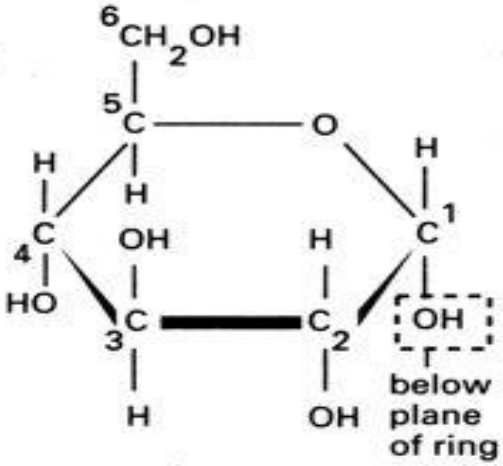
α-D-glucose

β-D-glucose

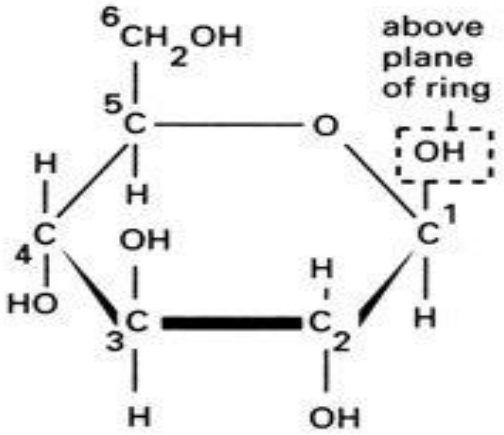
Glucose (an aldohexose)



straight-chain form



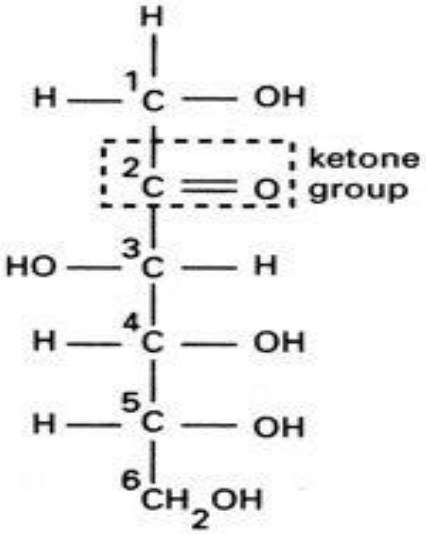
α-glucose



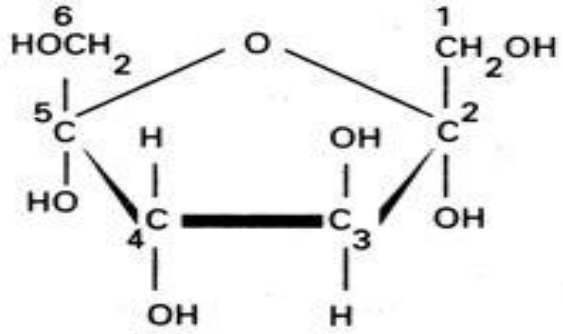
β-glucose

ring forms

Fructose (a ketohexose)



straight-chain form



ring form

Anomeric carbon

- Such **α** and **β** configuration are called diastereomers and they are not mirror images.

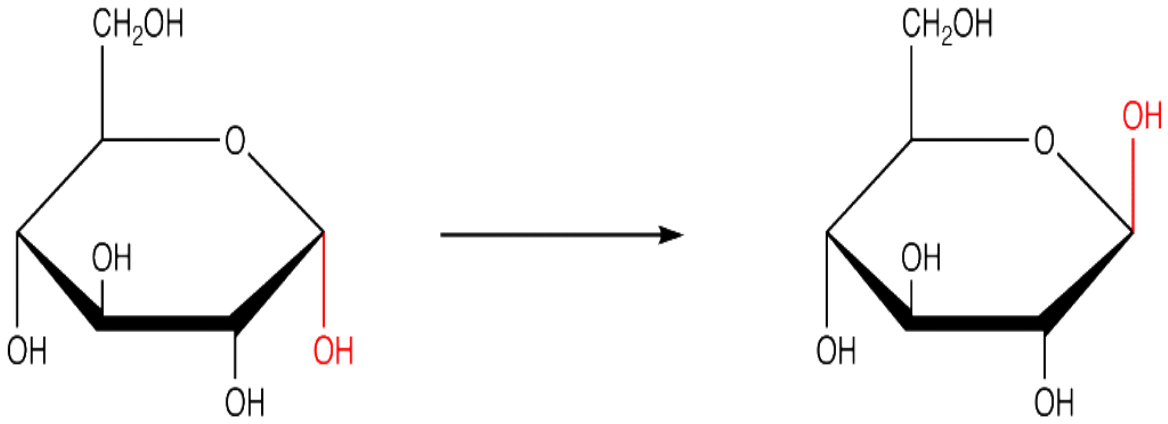
Enzymes can distinguished between these two forms:

- Glycogen is synthesized from **α-D glucopyranose**

- Cellulose is synthesized from **β -D glucopyranose**

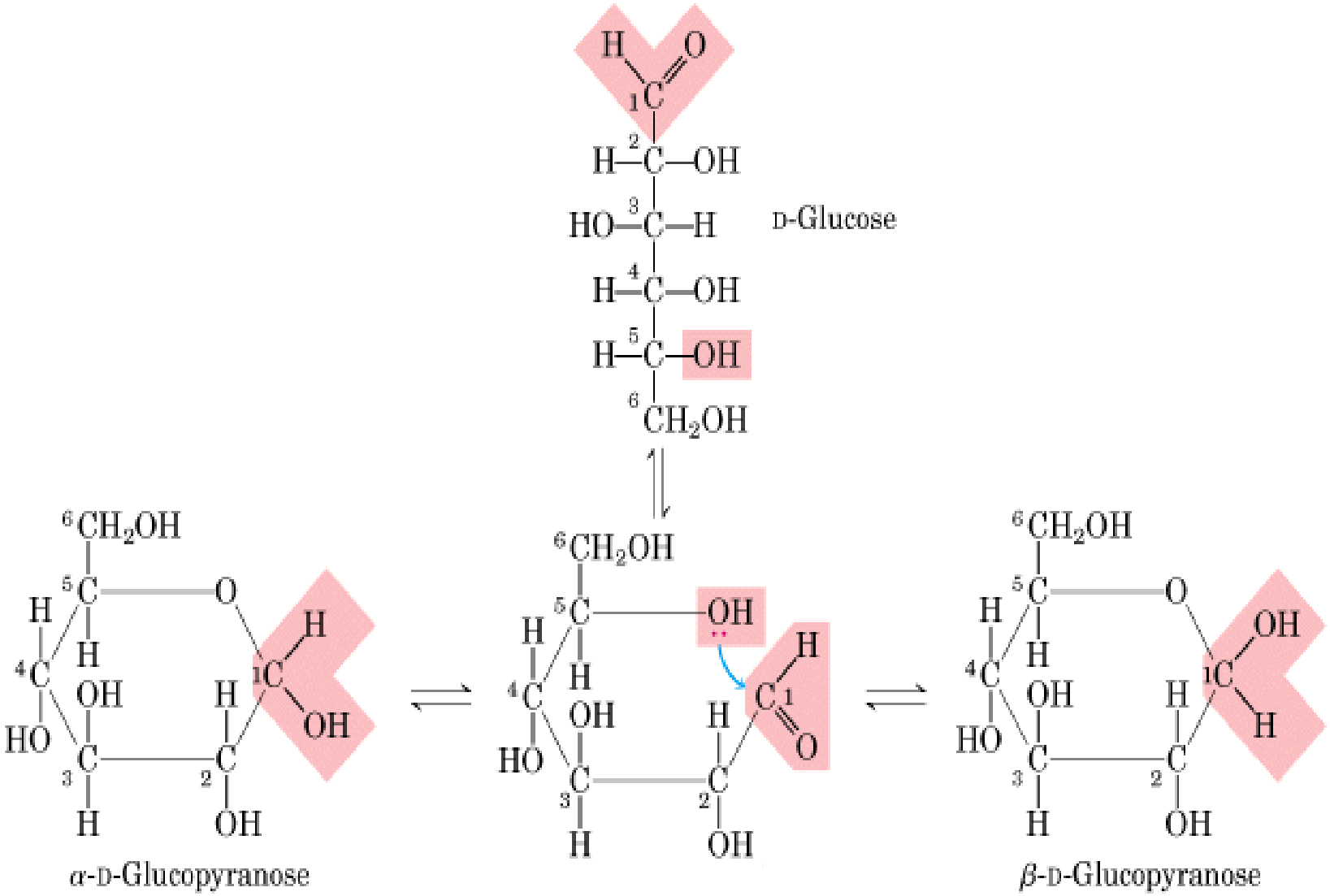
MUTAROTATION

- Unlike the other stereoisomeric forms, **α** and **β** **anomers** spontaneously interconvert in solution.
- This is called mutarotation.



α-D-glucose

β-D-glucose


D-Glucose
α-D-Glucopyranose
β-D-Glucopyranose

Disaccharides

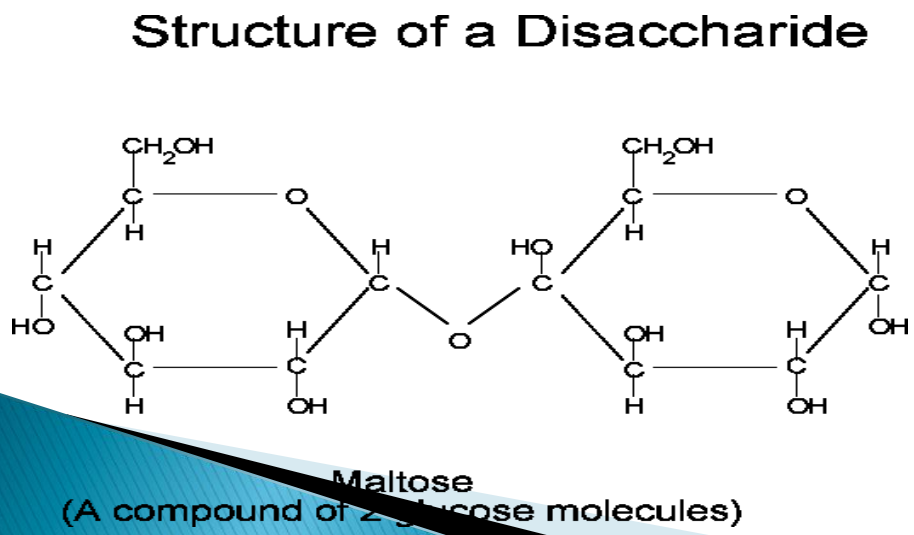
- As is evident from the name, a disaccharide consists of two monosaccharide units (similar or dissimilar) held together by a **glycosidic bond**.
- They are crystalline, water-soluble and sweet to taste.

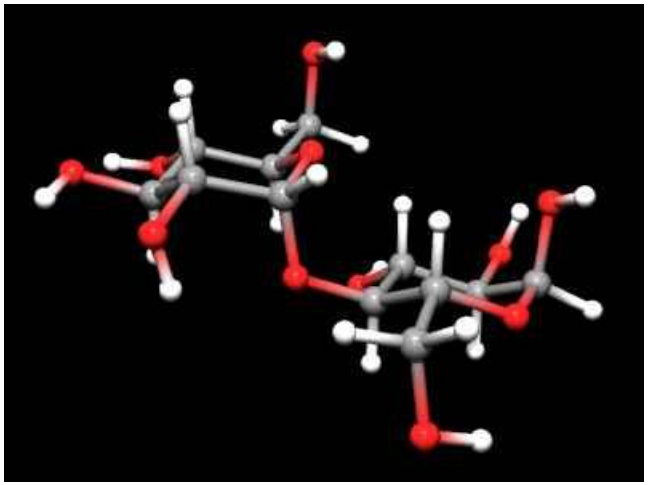
Disaccharides

- pairs of the monosaccharides
  - glucose is always present
  - 2nd of the pair could be fructose, galactose or another glucose
  - taken apart by hydrolysis
  - put together by condensation
  - hydrolysis and condensation occur with all energy nutrients
  - maltose, sucrose, lactose

Maltose

- 2 glucose units
- produced when starch breaks down
- not abundant



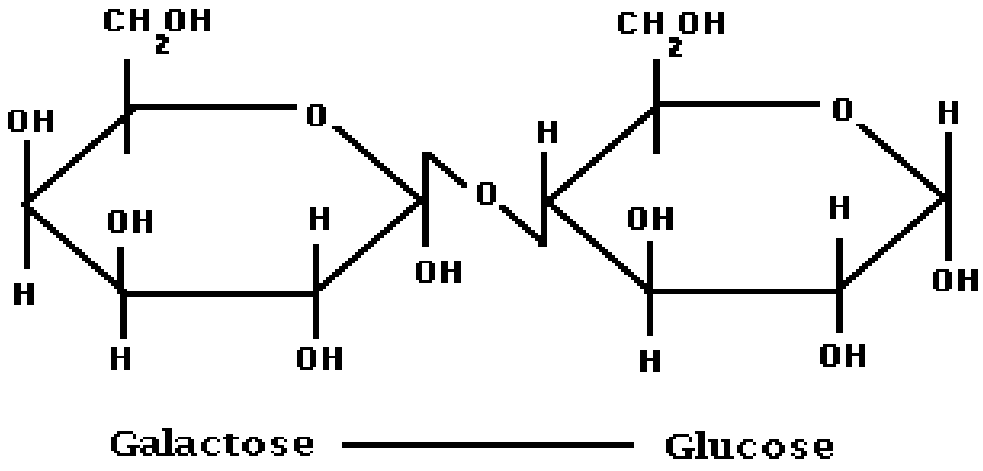


Sucrose

- fructose and glucose
- tastes sweet
  - fruit, vegetables, grains
- table sugar is refined sugarcane and sugar beets
- brown, white, powdered

Lactose

- glucose and galactose
- main carbohydrate in milk
  - known as milk sugar

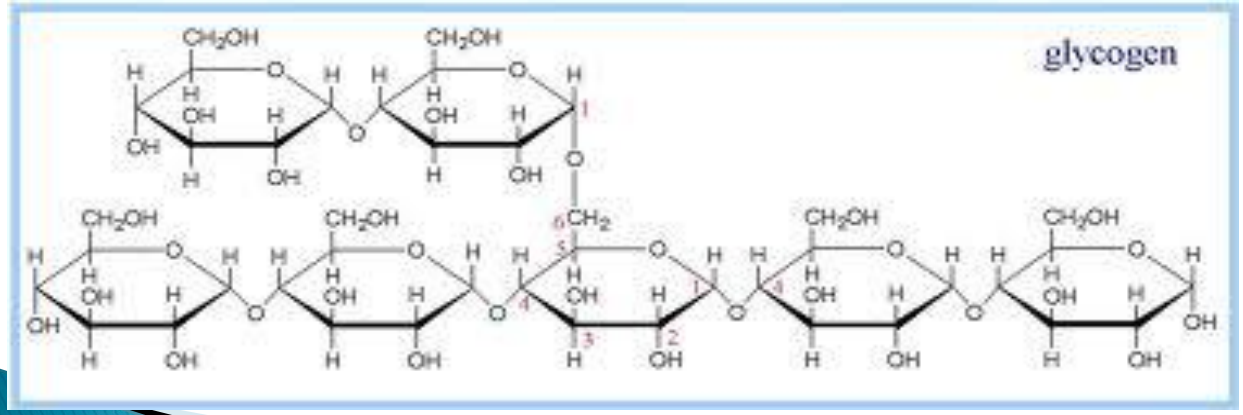


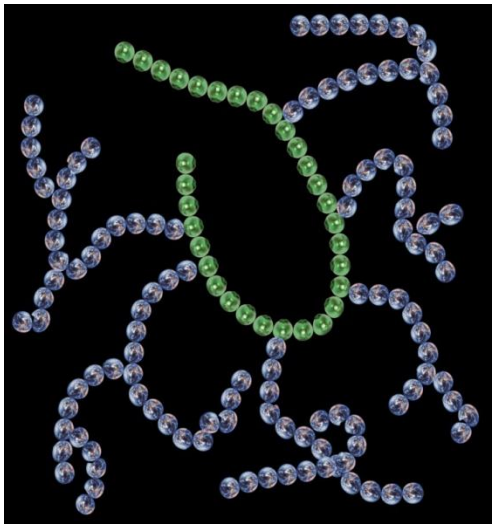
Complex Carbohydrates

- polysaccharides
  - glycogen and starch
    - built entirely of glucose.
  - fiber
    - variety of monosaccharides and other carbohydrate derivatives

Glycogen

- limited in meat and not found in plants
  - not an important dietary source of carbohydrate
  - Glucose is stored as glycogen inside the body
  - long chains allow for hydrolysis and release of energy





Starches

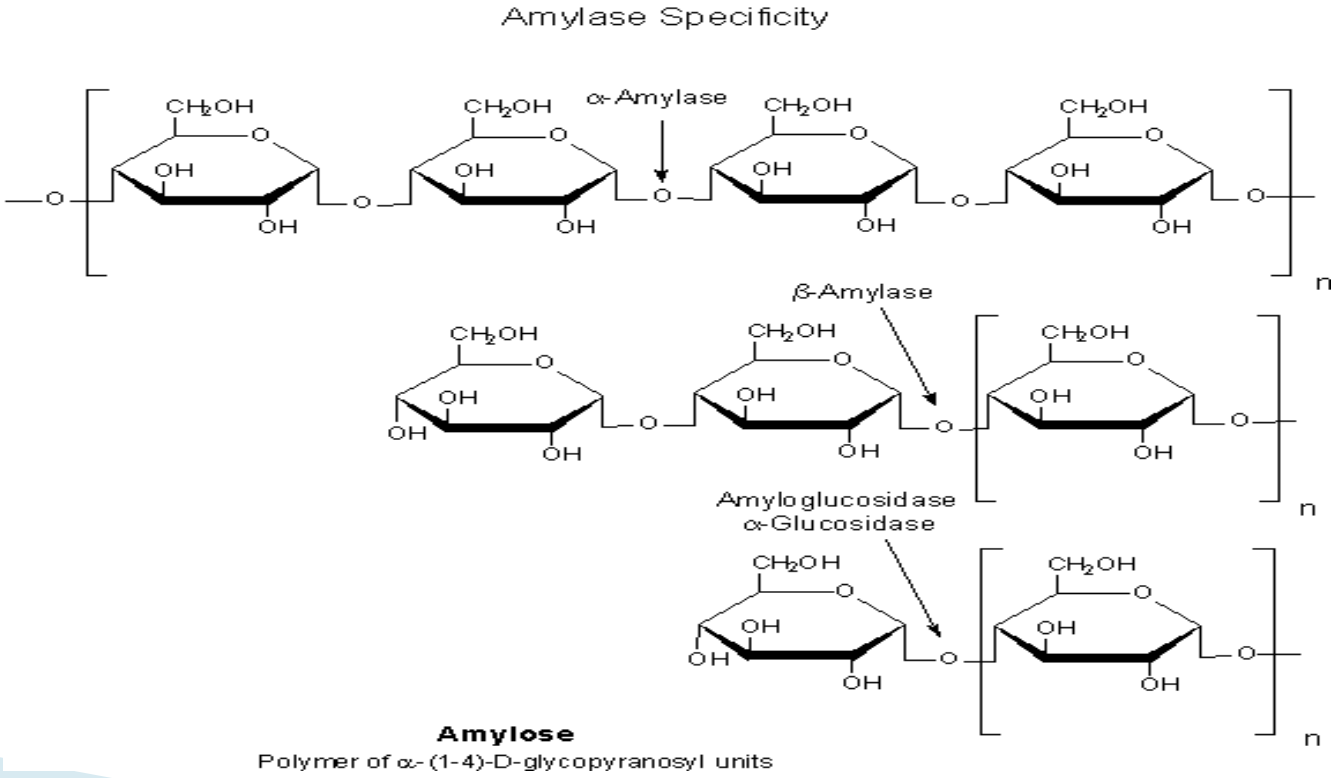
- stored in plant cells
- body hydrolyzes plant starch to glucose
- Starch consist of :

-20% amylose (water soluble)

-80% amylopectin (water insoluble)

starch

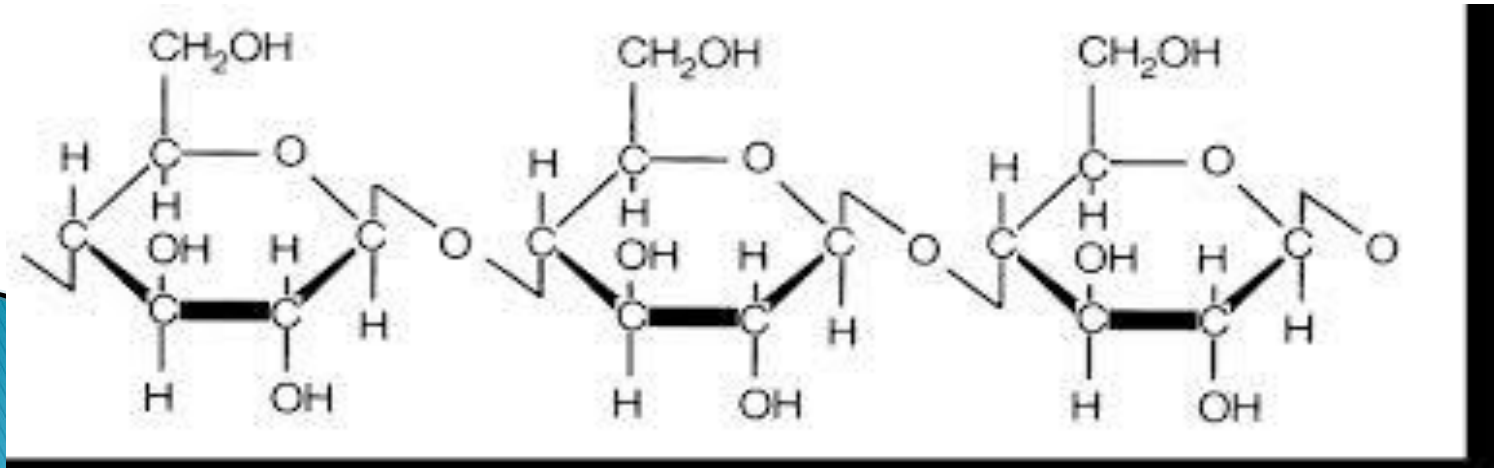
- Starch
- 20% amylose (water soluble)
- 80% amylopectin (water insoluble)



Cellulose

cellulose

- Cellulose is the most abundant natural polymer on earth
- Cellulose is the principal strength and support of trees and plants
- Cellulose can also be soft and fuzzy – in cotton



Home work

- Write essay about homopolysaccharide and heteropolysaccharide

Thank you for listening