بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

BioChemistry

﴿ وَلَقَدْ خَلَقْنَا ٱلْإِنسَٰنَ وَنَعْلَمُ مَا تُوَسْوِسُ بِهِۦ نَفْسُهُۥ ۖ وَنَحْنُ أَقْرَبُ إِلَيْهِ مِنْ حَبْلِ ٱلْوَرِيدِ ﴾

MID | Lecture 6

Carbohydrates Pt.1

Written by : Joud Alsafadi
Rand Alkhateeb

Reviewed by : Shahd Thamer

Carbohydrates

=

Saccharaides

Prof. Mamoun Ahram

Summer semester 2026

What are they?

- Carbohydrates are polyhydroxy aldehydes or ketones. They are the functional groups
- Saccharide is another name for a carbohydrate

Remember in organic chemistry that when you name a compound there is a priority in naming: (from lowest to highest priority)
Alkane → Alkene → Alkyne → Alcohol → Aldehyde → Ketone → Carboxylic acid

- Functions:
  - Source of energy (glycogen and starch) Carbohydrates are the quickest form of energy

    Glucose is stored in the form of polysaccharides as glycogen in animals and starch in plants.
  - Structure (cellulose and chitin)
  - Building blocks (glycosaminoglycans) Structural molecules inside our bodies
  - Cellular recognition (glycoproteins) Carbohydrates on the cell surface play important roles in cell signaling by transmitting signals from the outside of the cell to the inside. They also mediate cell recognition; for example, immune cells recognize whether a cell is self or non-self by detecting the carbohydrates present on its surface

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) Ribose&deoxyribose

Glycoprotein = Protein + short sugar → mostly protein
Proteoglycan =long GAG chains (huge sugar) + Protein → mostly carbohydrate
Glycolipid = Lipid + carbohydrate→ mostly lipid

Glycosides are carbohydrates in which the anomeric hydroxyl group is replaced by another functional group, such as methyl, ethyl, amino, or acetyl groups.

Mucopolysaccharides are the same as GAGs (glycosaminoglycans).

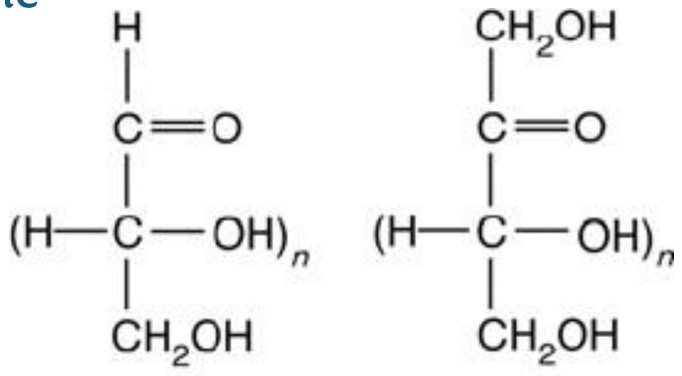
Monosaccharides

- Basic chemical formula: $(CH_2O)n$
- They contain two or more hydroxyl groups.

n:the number of carbon atoms ,so the ratio is always 1:2:1

“ose”: refers to sugars

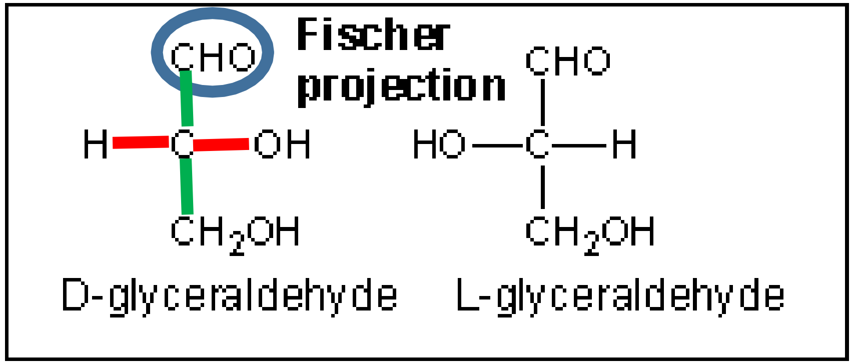
Notice that the aldoses have an aldehyde group on top and it always takes number one then we have carbon connected to hydrogen in one side and hydroxyl group in the other side and that might repeat and in the end we have CH2OH,while in ketoses the carbonyl group must be internal (It is always on carbon number 2)

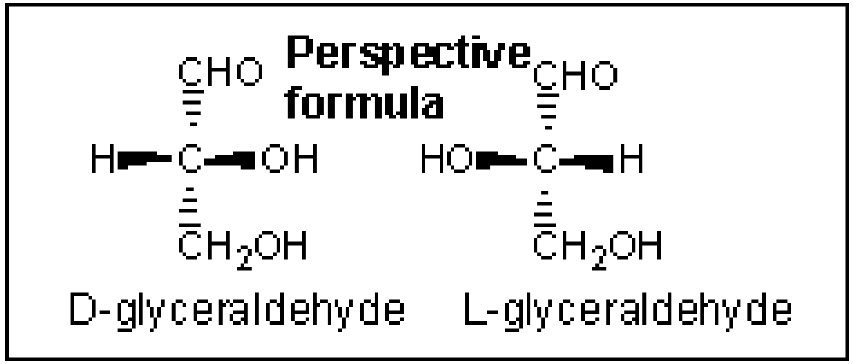


An aldose A ketose

This is Fischer projection

Fisher projections or perspective structural formulas.



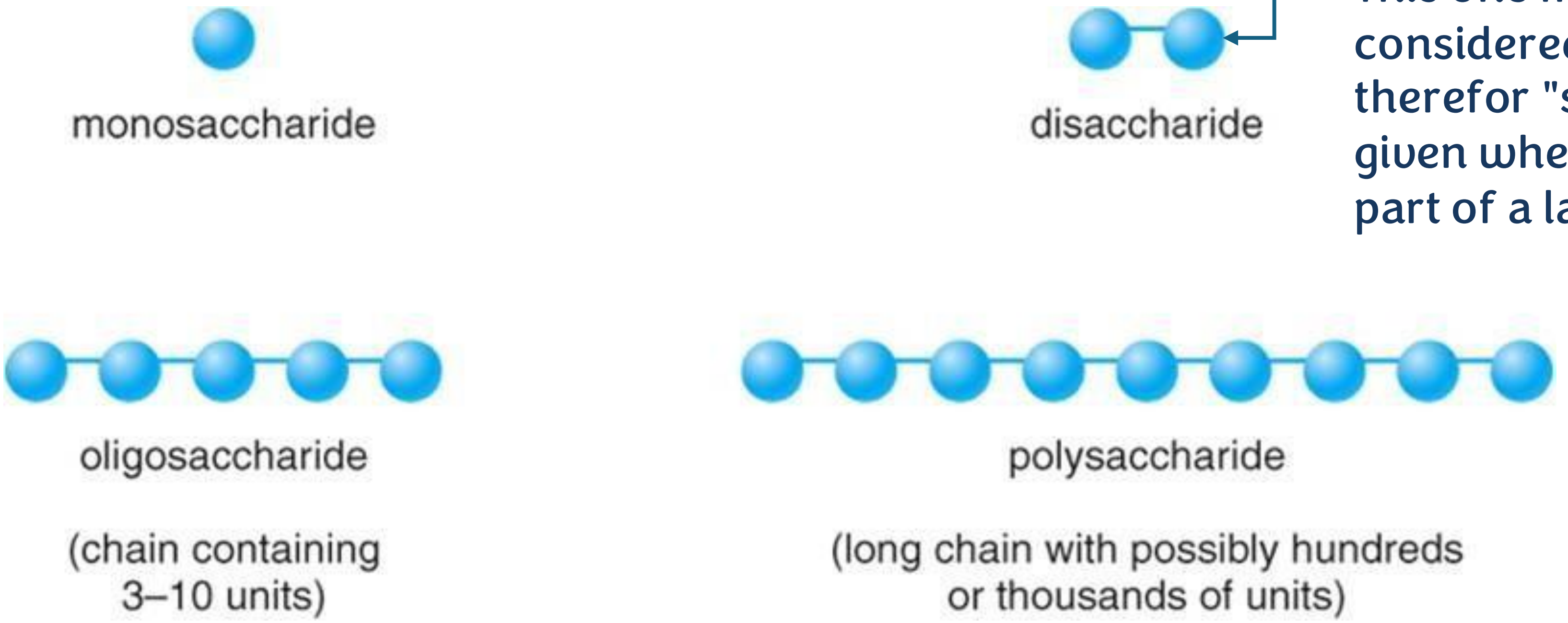


Forward **Backward** **Top (C1): Most highly oxidized C**

Classification I

- By the number of monosaccharides that constitute the molecule
  - Monosaccharides, Disaccharides, Oligosaccharides, Polysaccharides

Keep in mind we don`t call a monosacharide a subunit



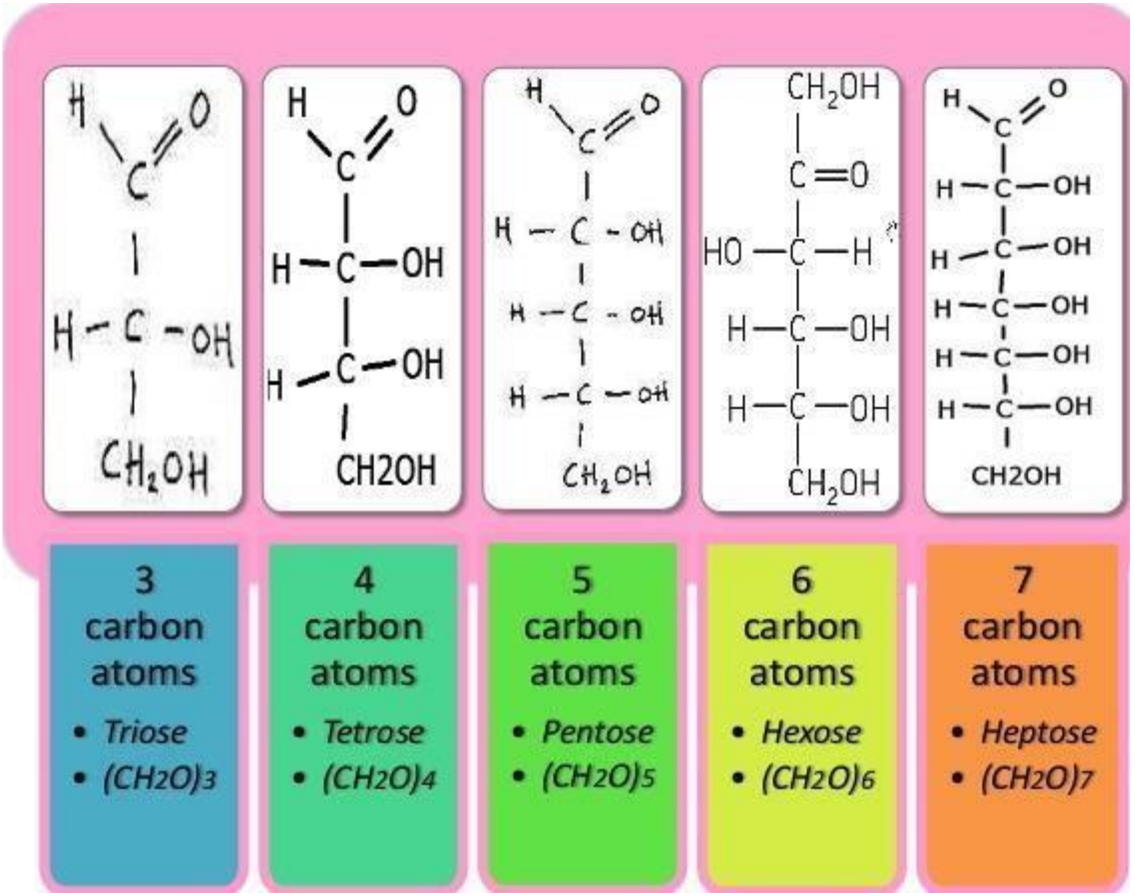
This one molecule is considered subunit, therefor "subunit" is only given when a molecule is part of a larger molecule

Oligo=Short

Classification 2

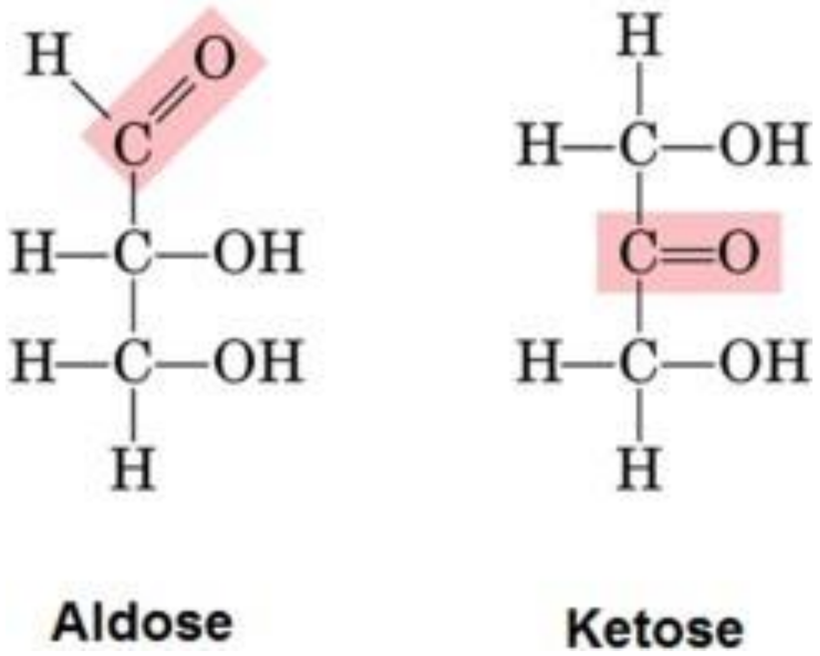
The smallest monosaccharides is made up of 3 carbons (there is no sugar made up of 1or 2 carbons)

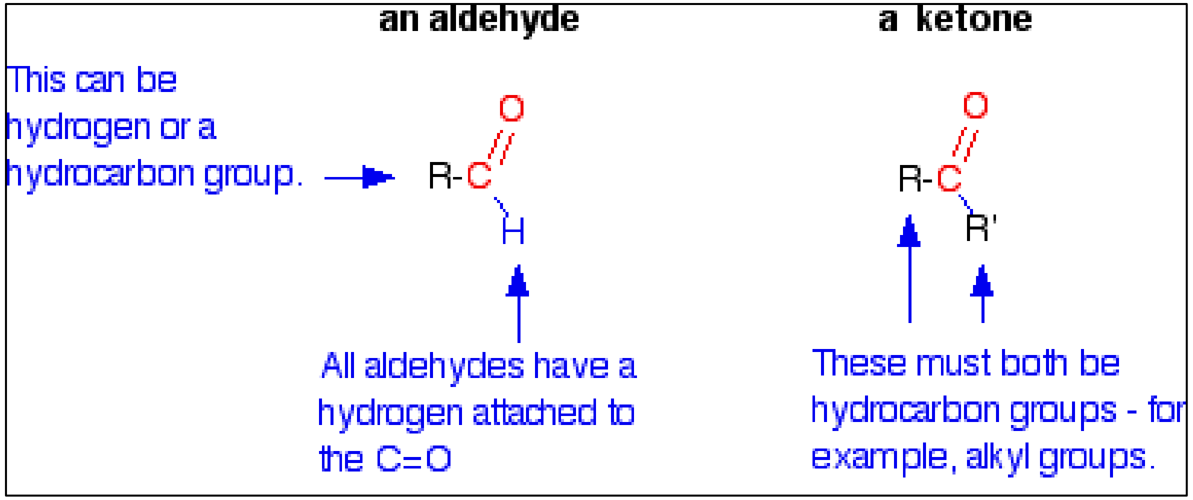
- By the number of carbon atoms monosahharides contain.
    - Triose
    - Tetrose
    - Pentose
    - Hexose
    - Heptose
    - …



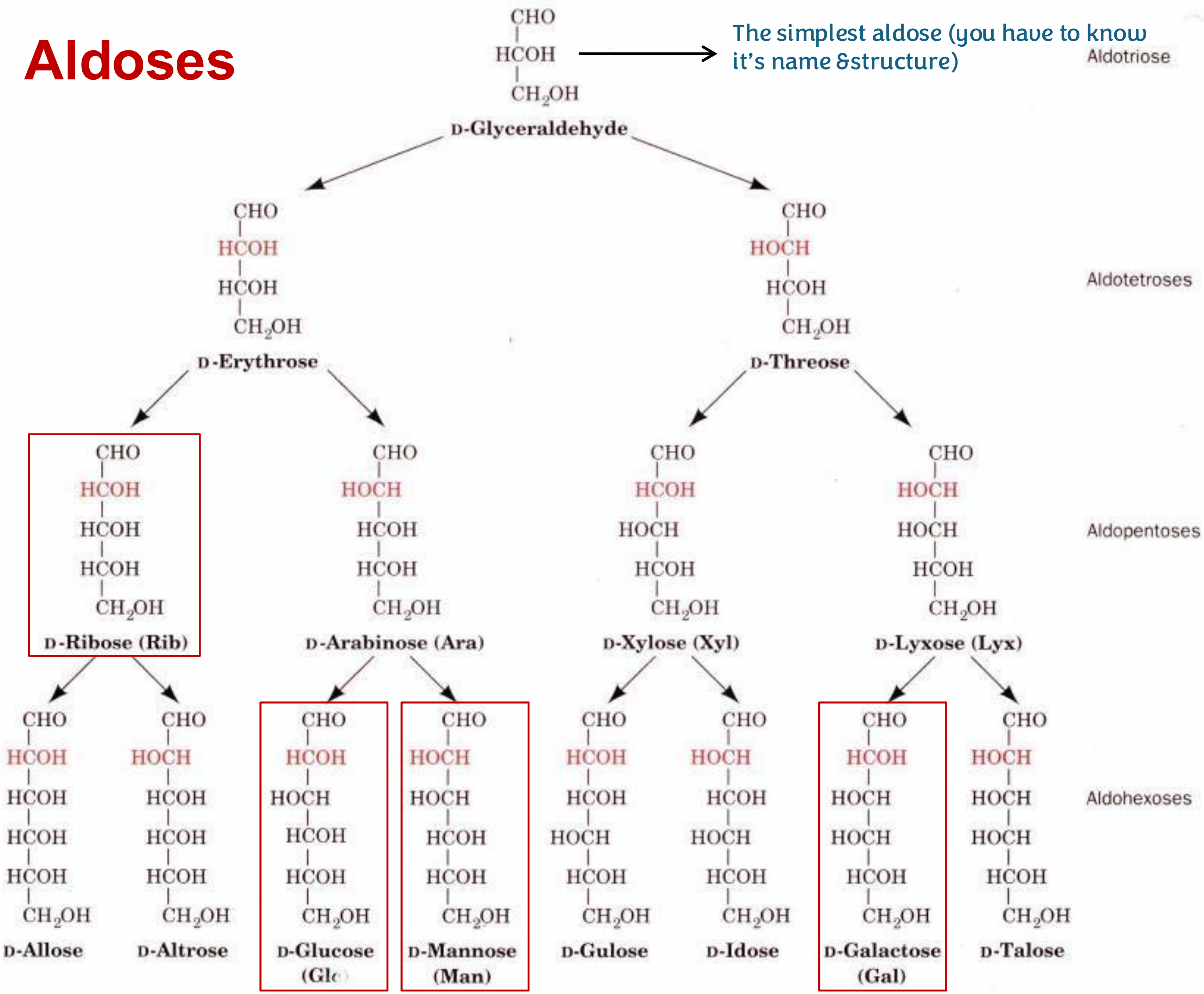
Classification III

- By the functional group monosaccharides have





Aldoses

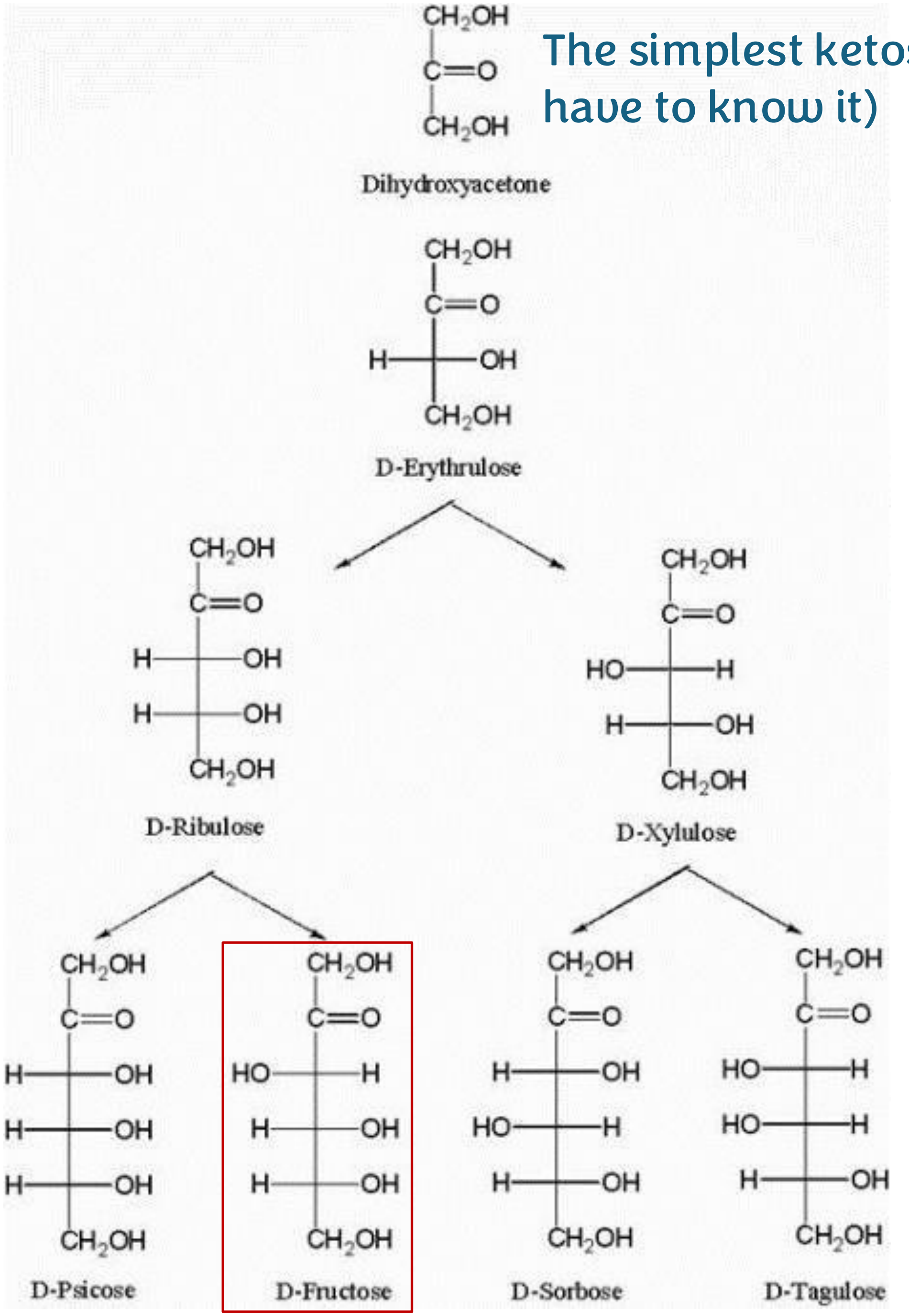


Memorize the ones in boxes.

The ones in the boxes are required. You've to know there name and structures

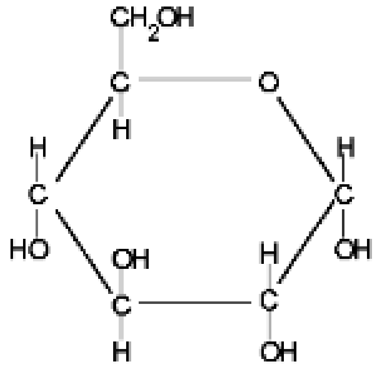
Ketoses

The simplest ketose (You have to know it)

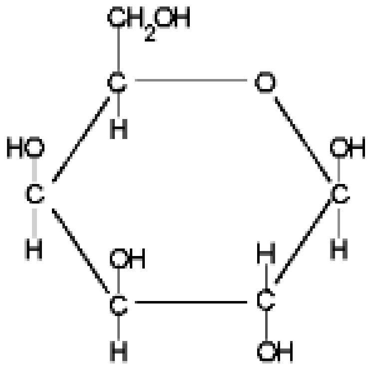


Memorize the ones in boxes.

Common Monosaccharides



Glucose



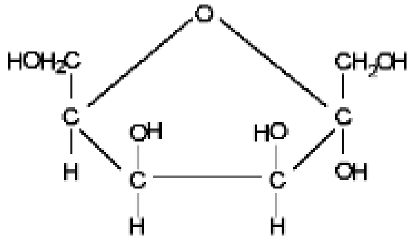
Galactose

- Glucose:
  - Mild sweet flavor
  - Known as blood sugar
  - Essential energy source
  - Found in every disaccharide and polysaccharide

When we measure the blood sugar we're measuring the glucose level

Whenever you have a disaccharide, oligosaccharide, or polysaccharide, it is a must that the glucose is one of the subunits

- Galactose:
  - Hardly tastes sweet & rarely found naturally as a single sugar
- Fructose:
  - Sweetest sugar, found in fruits and honey
  - Added to soft drinks, cereals, desserts



Fructose

Fructose is the sweetest naturally occurring monosaccharide. Because of its high sweetness, it is widely used as a sweetening agent in many foods and beverages.

High-fructose syrup (such as high-fructose corn syrup) is commonly used in products like pancake syrup, waffle syrup, soft drinks, candies, and chewing gum. It provides a strong sweet taste and is therefore a common ingredient in processed foods.

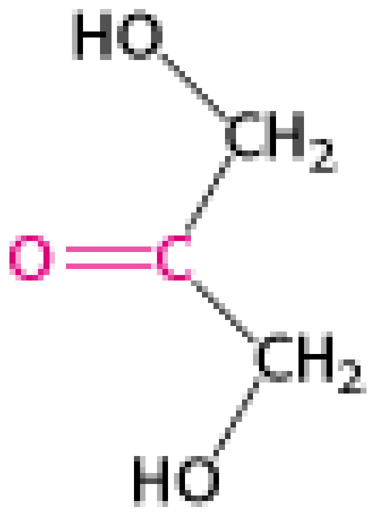
Trioses

Notice that the middle carbon (carbon 2) in glyceraldehyde is a chiral carbon because it is bonded to four different attachments.

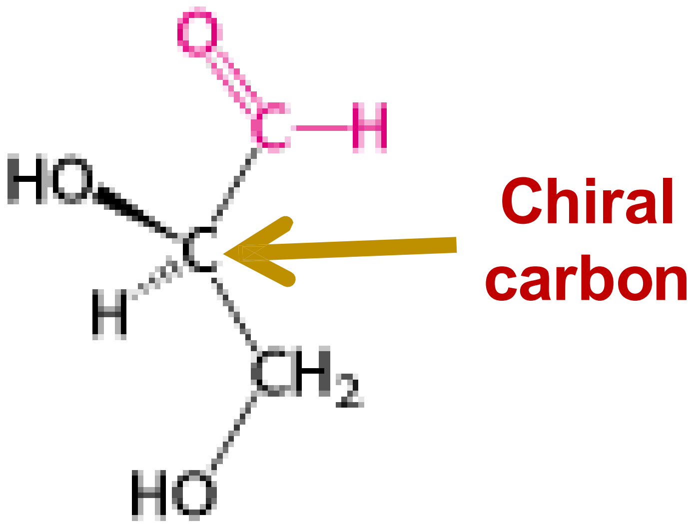
The presence of this chiral carbon makes glyceraldehyde a chiral molecule, which exists as two enantiomers (D- and L-glyceraldehyde).

These enantiomers are mirror images of each other but are not superimposable, meaning they cannot be placed on top of each other to become identical, even though they have the same molecular formula

What is a chiral carbon?



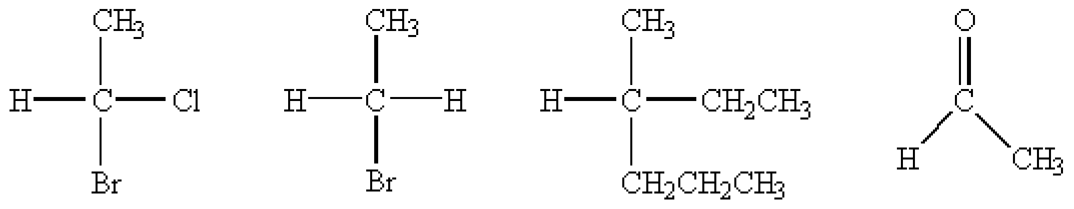
Dihydroxyacetone
(a ketose)



D-Glyceraldehyde
(an aldose)

Dihydroxyacetone does not contain a chiral carbon; therefore, it is achiral and does not have enantiomers (mirror-image isomers).

Note what a chiral carbon is…



chiral

Has 4 differnt atoms bonded to the carbon

achiral

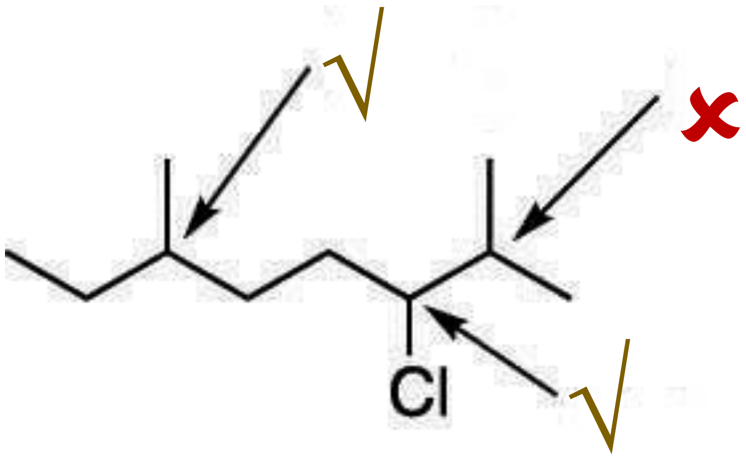
Does not have 4 different atoms or groups bonded to the carbon (2 hydrogens)

chiral

Has 4 differnt groups bonded to the carbon

achiral

Only has 3 atoms bonded to the carbor.



Isomerism

Isomers are molecules that have the same molecular formula, meaning they contain the same number of carbon, hydrogen, and oxygen atoms, but they differ in the arrangement of these atoms.

An *isomer* is a molecule with the same molecular formula as another molecule, but with a different chemical structure.

- Isomers
  - Stereoisomers
    - Enantiomers
      - L-isomers
      - D-isomers
    - Diastereomers
      - Epimers
  - Constitutional isomers

Isomers that have the same molecular formula and sequence of bonded atoms (constitution) but differ in the three-dimensional orientations of their atoms in space.

Stereo means space

Thus, stereoisomers have identical connectivity but different three-dimensional structures.

Constitutional isomers = structural isomers.

Molecules with the same molecular formula but have different bonding patterns and atomic organization.

Isomers of glucose

2^n (n is the number of chiral carbons in a sugar molecule)

Search for: Glucose, Galactose Mannose

A molecule with four chiral centers (four chiral carbons) can have a maximum of 16 stereoisomers.

The maximum number of stereoisomers is calculated using the formula:

Number of stereoisomers = 2^n

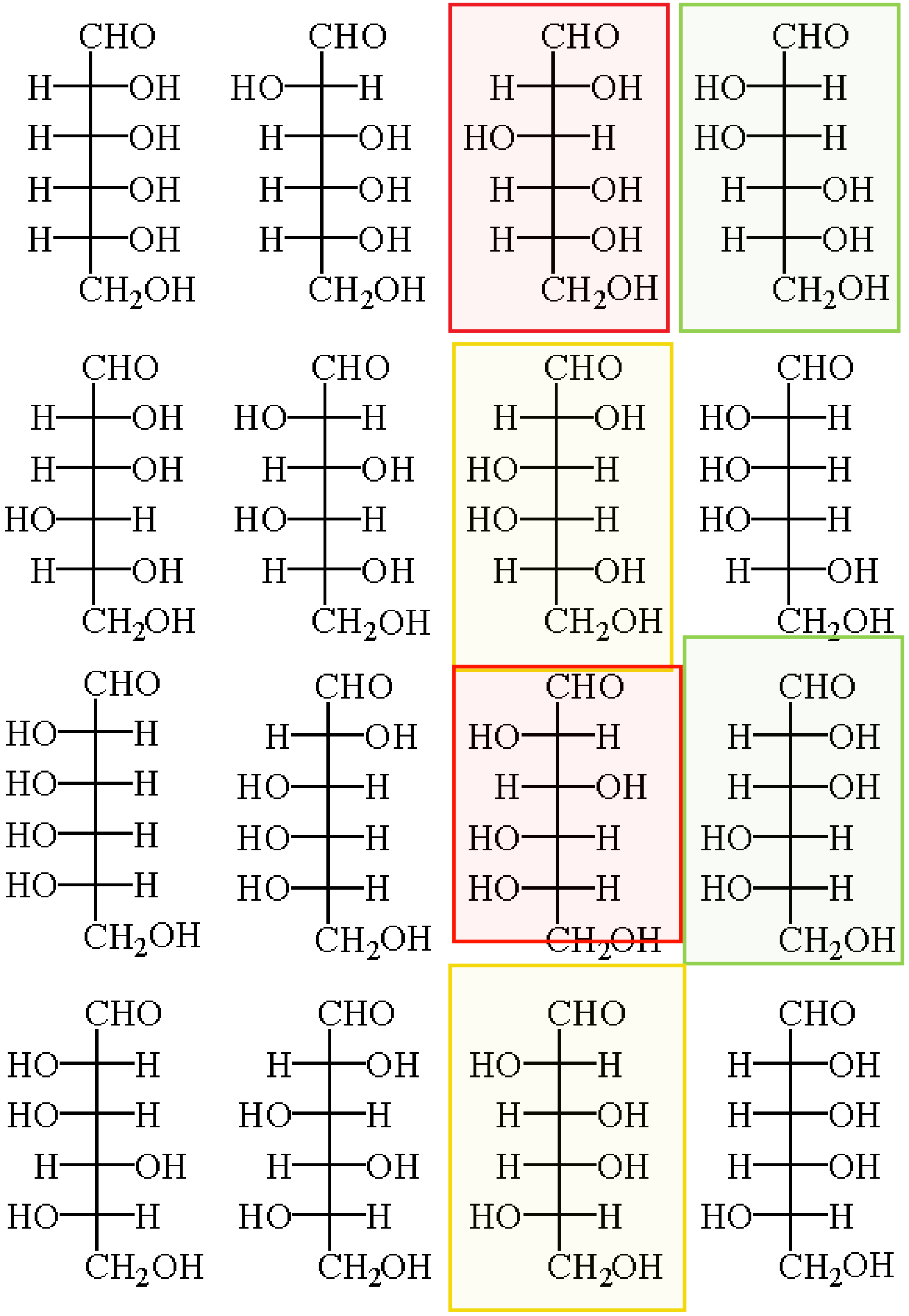
where n is the number of chiral centers.

Since this molecule has 4 chiral centers ($n = 4$):

$2^4 = 16$ stereoisomers.

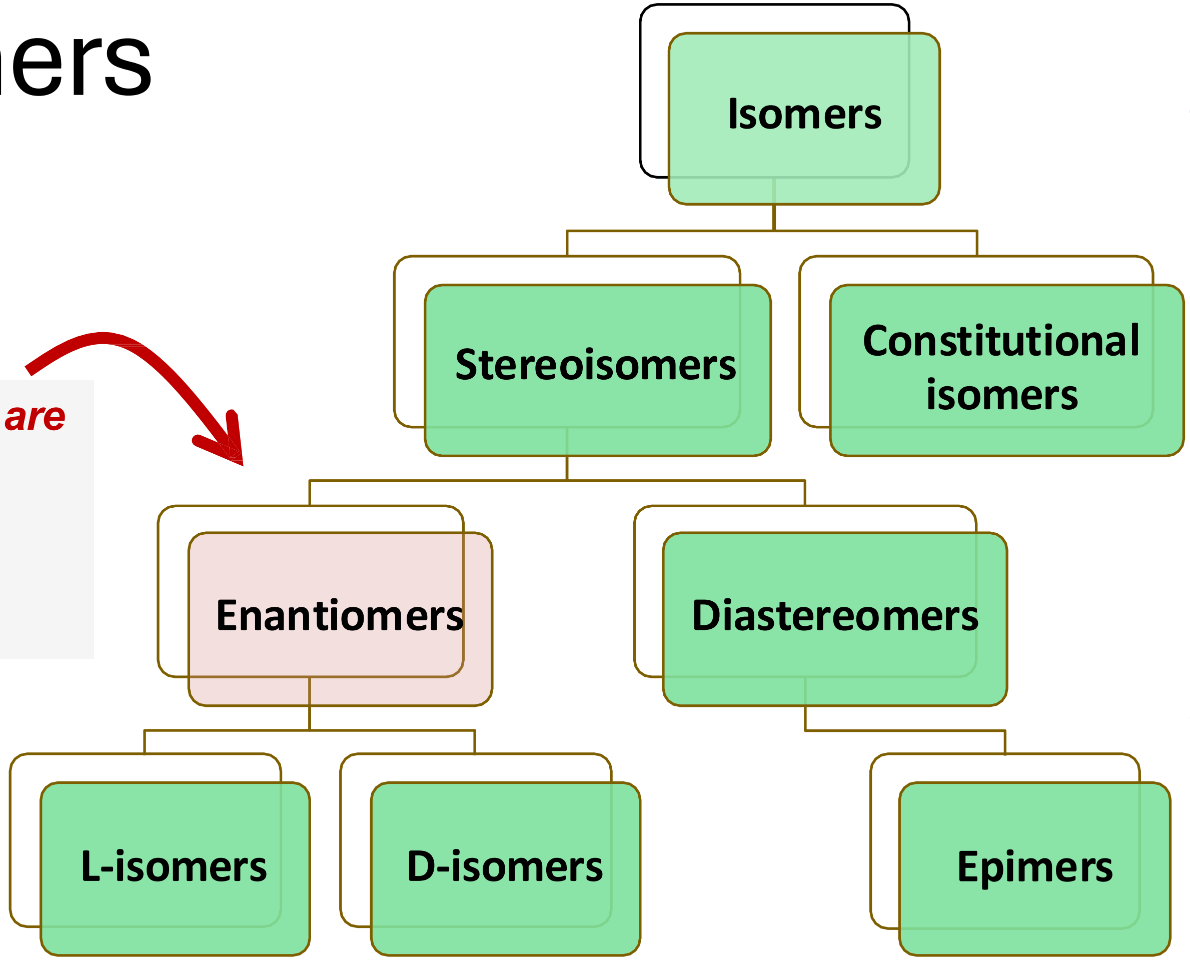
Red Boxes: GlucoseTop (1st row, 3rd structure): D-Glucose Bottom (3rd row, 3rd structure): L-Glucose Yellow Boxes: Galactose Top (2nd row, 3rd structure): D-Galactose Bottom (4th row, 3rd structure): L-Galactose Green/Teal Boxes: Mannose Top (1st row, 4th structure): D-Mannose Bottom (3rd row, 4th structure): L-Mannose

16 Aldohexoses



Enantiomers

Two stereoisomers that are mirror images of each other and are non-superimposable (not identical)



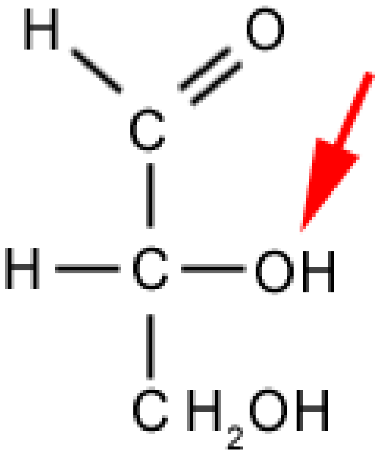
Diastereomers are stereoisomers that are not mirror images of each other.

They have the same molecular formula and the same connectivity between atoms.

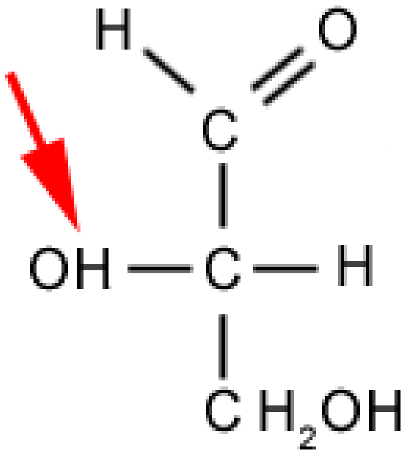
However, they differ in the configuration of one or more (but not all) chiral centers.

As a result, diastereomers have different physical and chemical properties.

Sugar enantiomers (D- vs. L-)

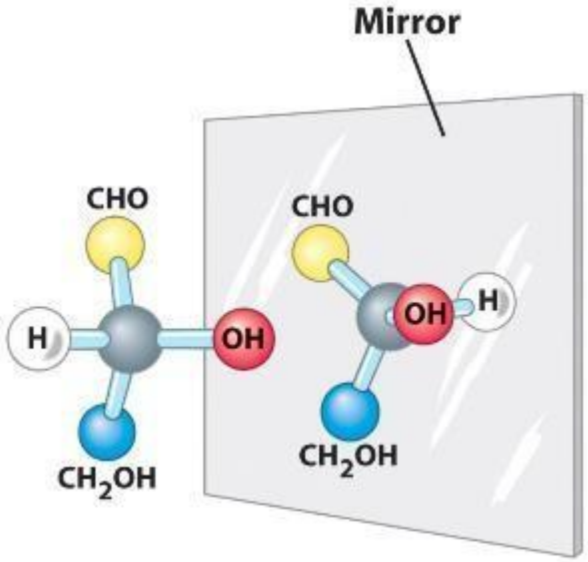


D-Glyceraldehyde



L-Glyceraldehyde

Our enzymes don't recognize it, therefore we can't digest it



Ball-and-stick models

Explanation to the previous slides

Sugars can be classified as D-isomers or L-isomers based on the configuration of the chiral carbon farthest from the carbonyl group (using the Fischer projection).

Glyceraldehyde is the reference molecule for assigning the D and L configuration because it contains one chiral carbon.

If the hydroxyl group (-OH) attached to the chiral carbon is oriented to the right, the sugar is classified as a D-sugar (D-glyceraldehyde).

If the hydroxyl group (-OH) attached to the chiral carbon is oriented to the left, the sugar is classified as an L-sugar (L-glyceraldehyde).

D-glyceraldehyde and L-glyceraldehyde are enantiomers because they are non-superimposable mirror images of each other.

The D and L designations describe the configuration of the molecule and do not indicate the direction of optical rotation.

Most naturally occurring sugars in humans are D-sugars.

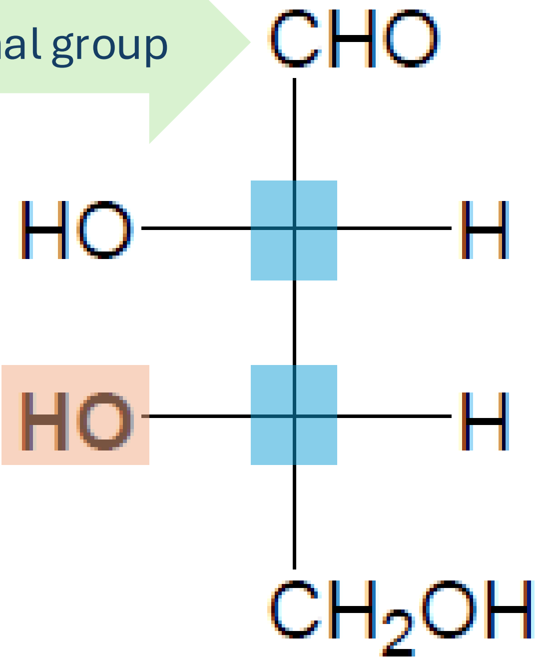
Human enzymes are highly stereospecific and are adapted to recognize and metabolize D-sugars.

Therefore, L-sugars are generally not metabolized efficiently by the human body, although some microorganisms, including certain bacteria, can utilize L-sugars

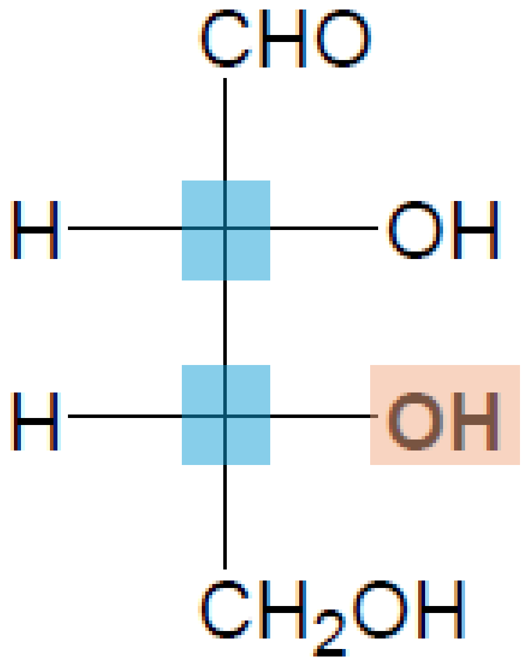
Which one(s) is a chiral carbon?

Functional group

2 chiral carbons & 4 possible stereoisomers



L-erythrose

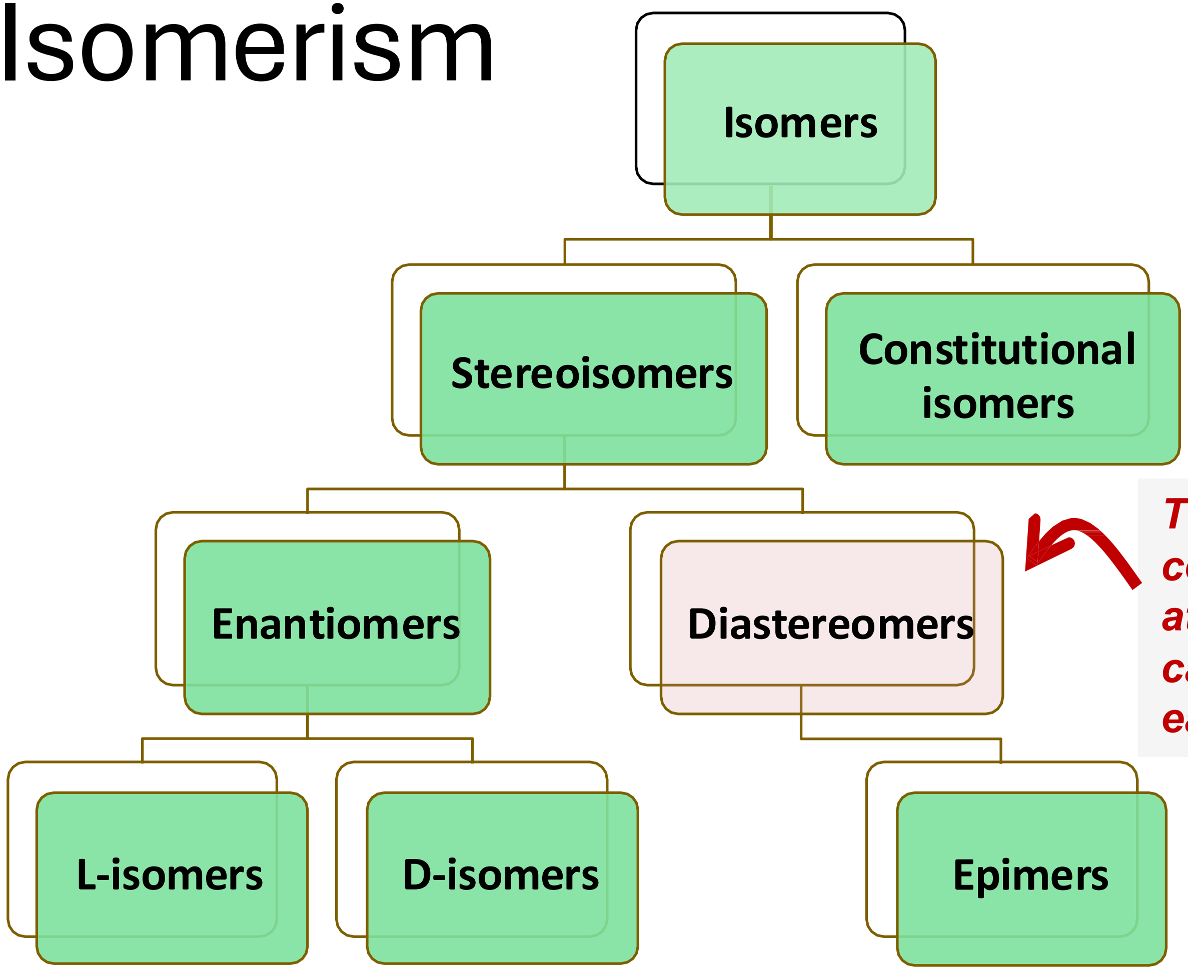


D-erythrose

We look at the orientation of the hydroxyl group that is connected to the farthest chiral carbon from the functional group

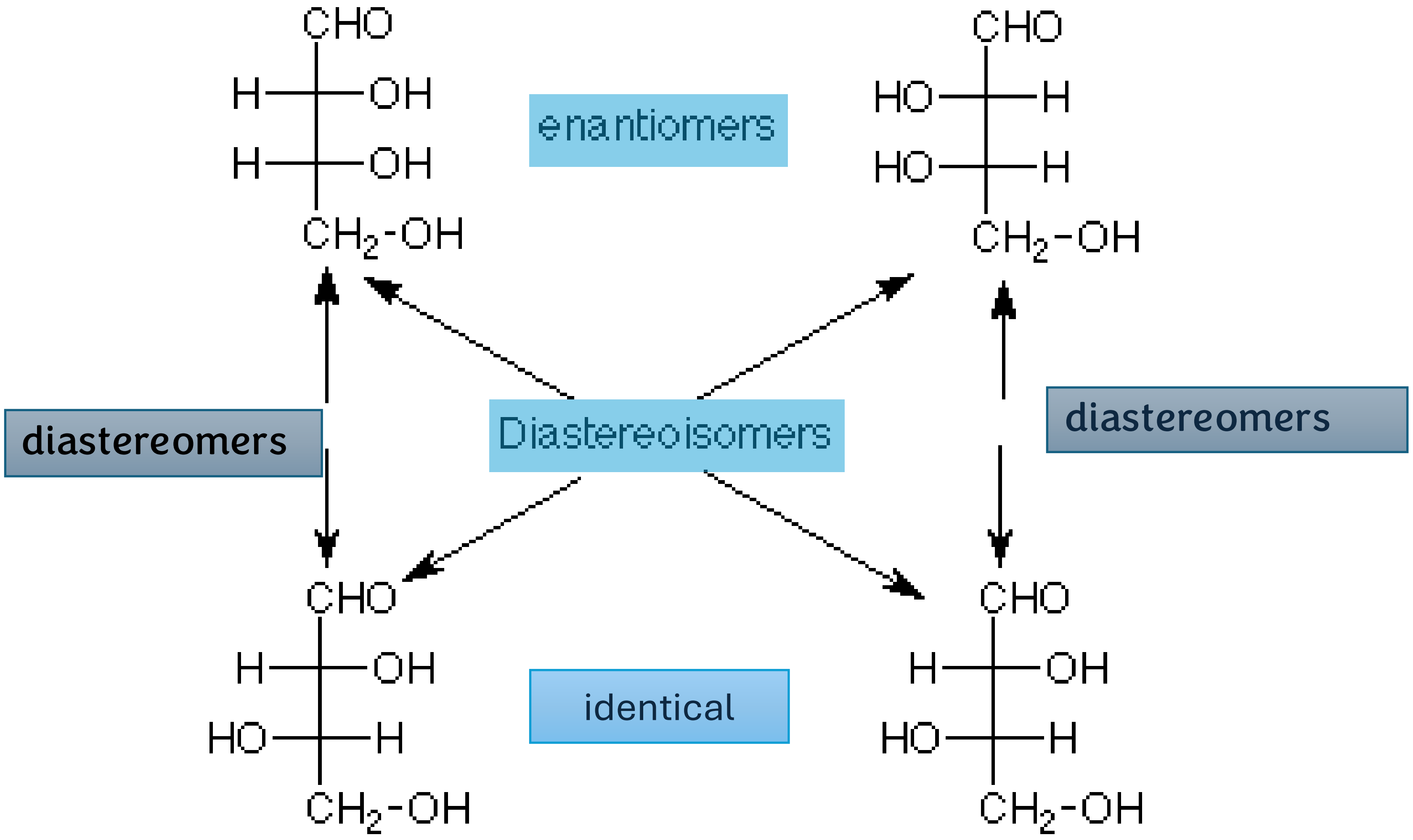
Do not memorize but study them.

Isomerism

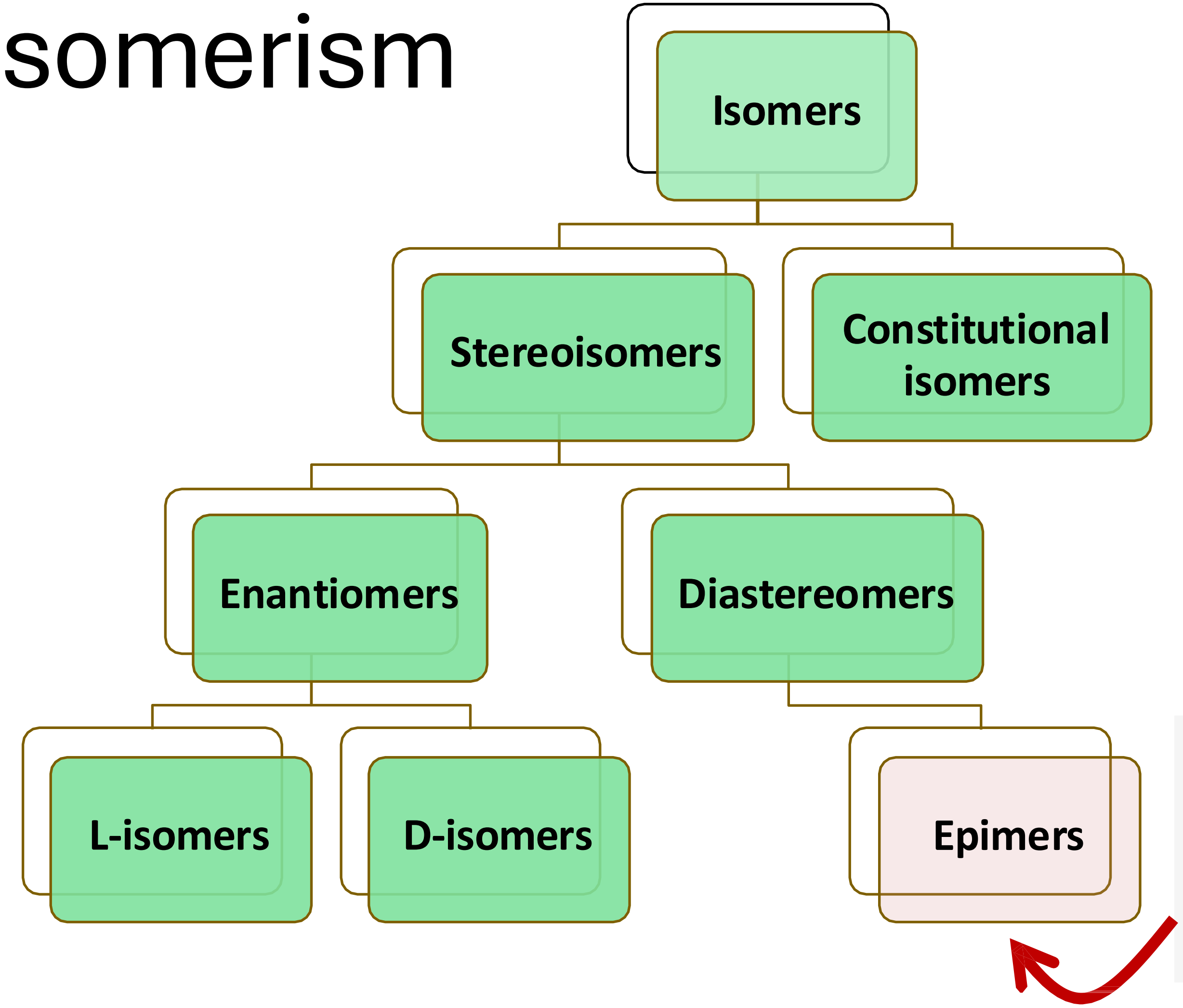


Two or more stereoisomers of a compound having different configurations at one or more (but not all) of the chiral carbons and are not mirror images of each other.

Stereoisomers, but non-mirror images and non-superimposable, then…*diastereomers*



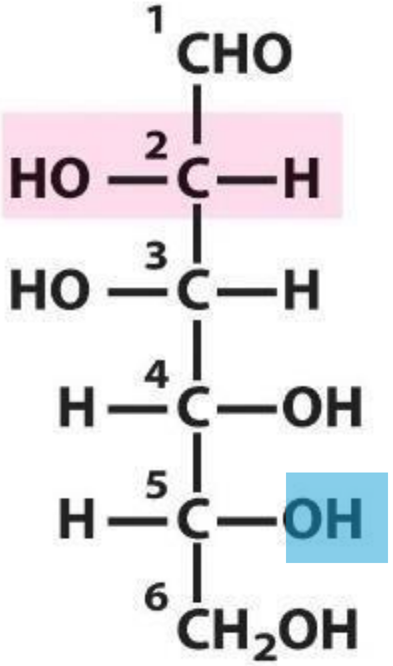
Isomerism



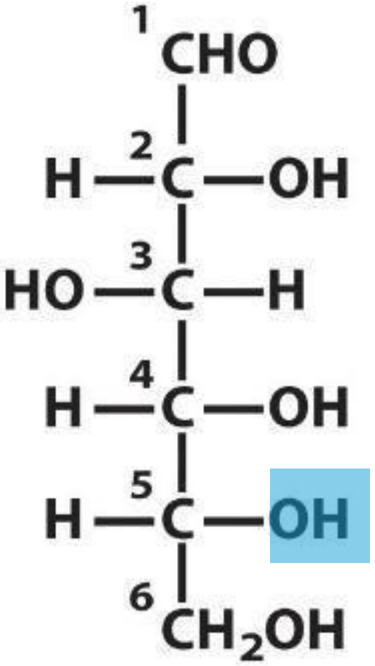
Epimer refers to one of a pair of stereoisomers whereby two isomers differ in configuration at only one chiral carbons.

Diastereomers with different orientations of one chiral carbon are … *epimers*

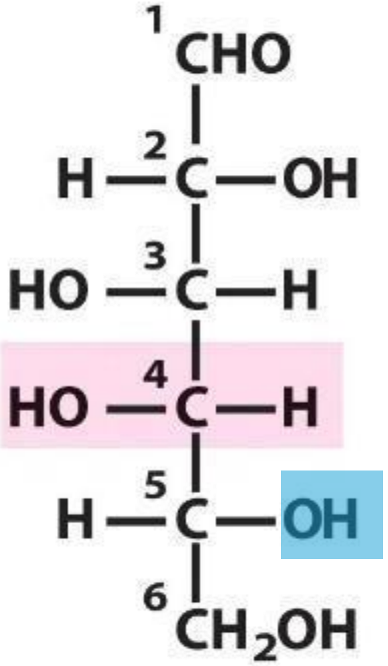
Memorize and study them.



D-Mannose
(epimer at C-2)



D-Glucose



D-Galactose
(epimer at C-4)

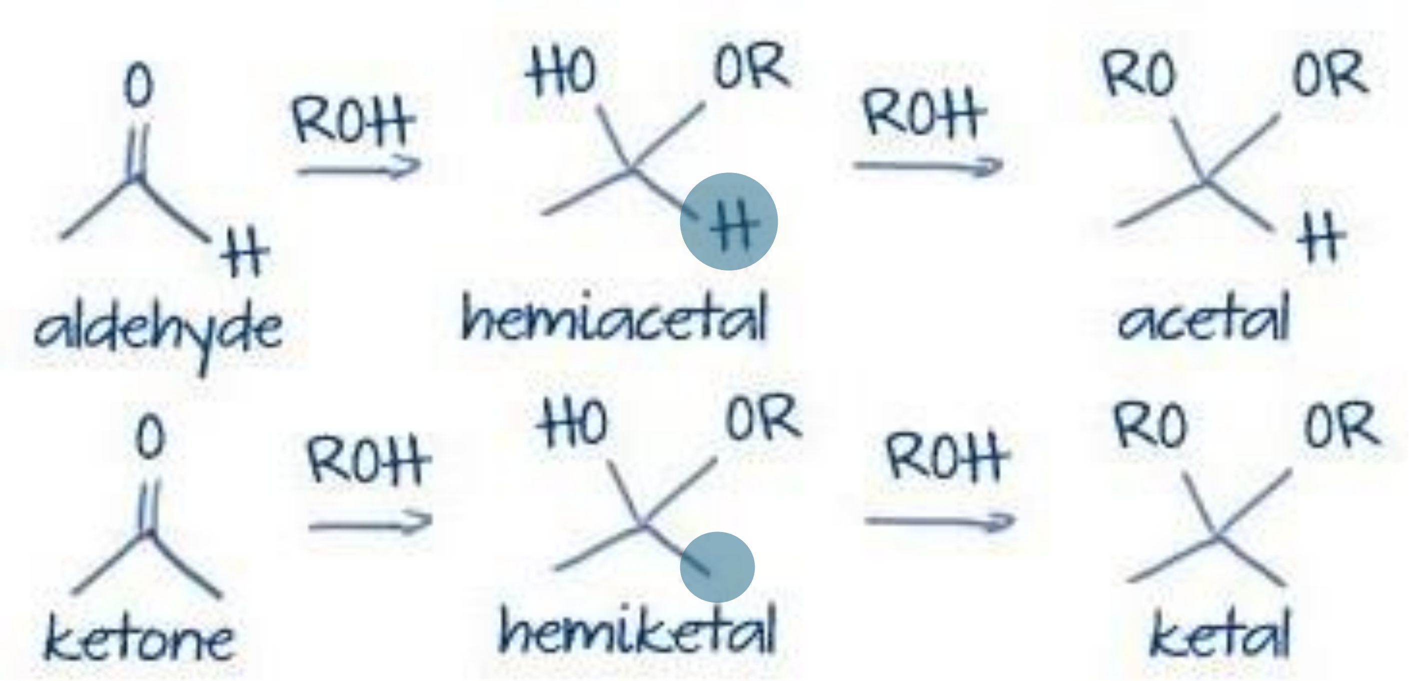
What about mannose & galactose, are they :
- Isomers – yes
- Stereoisomers – yes
- Mirror images – no
- Diastereomers – yes
- Epimers – no

Is L-glucose an epimer with D-mannose and D-galactose? No

Acetal/ketal vs. hemiacetal/hemiketal

- Hemiacetal and hemiketal: ether and alcohol on same carbon
- Acetal and ketal: two ethers on same carbon

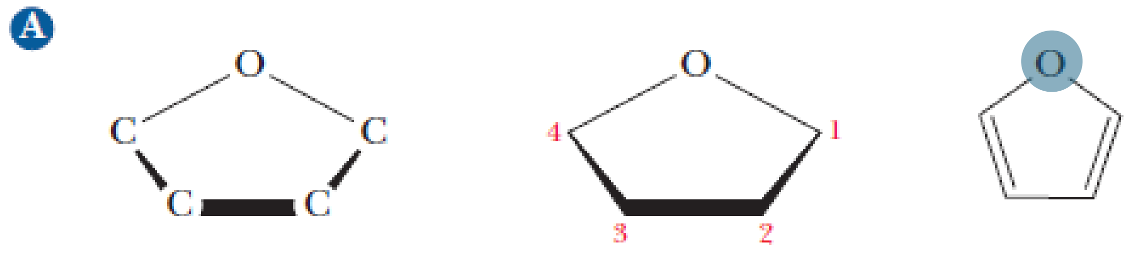
Aldehyde & ketone groups are very active



- *Know the difference between hemiacetal and hemiketal*
- *Know the difference between acetal and ketal*

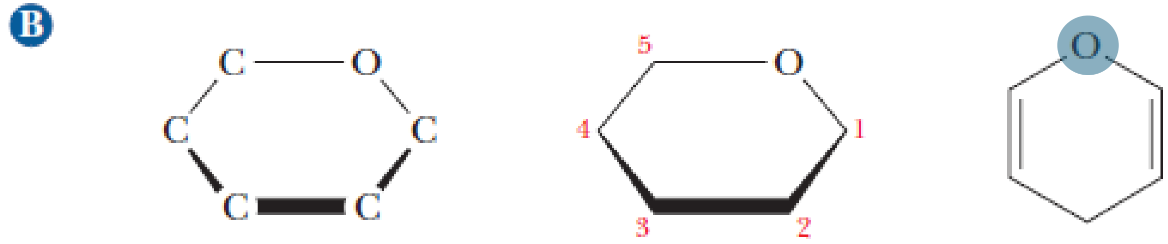
Formation of a ring structure

Ring structure for sugar molecules (-ose)



Haworth representations of furanose structures

Furan

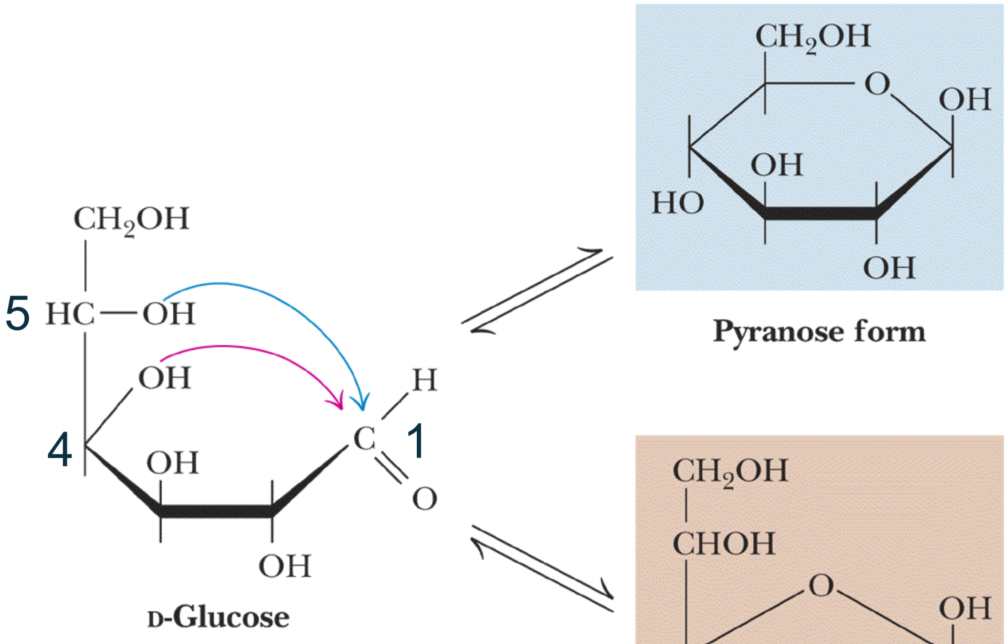


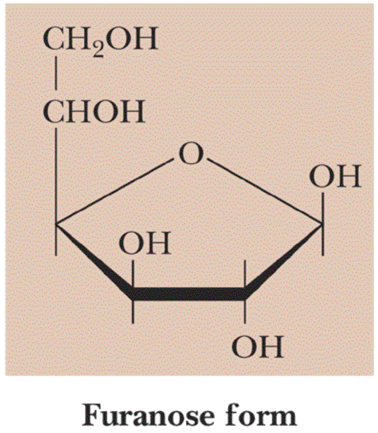
Haworth representations of pyranose structures

Pyran

- If we put glucose in a solution, 99% of this glucose will be in the cyclic form, because it is more stable.
- Bigger rings are more stable than small rings, because repulsion on small rings reduces the stability of them
- you can have different molecules with the same shape of a ring, they'll just differ in the additions and the three dimensional structure

With carbon 5





With carbon 4

This kind of reaction can`t happen with carbon 3 because repulsion will happen

Furan: five membered ring including the oxygen.
Pyran: six membered ring including the oxygen.

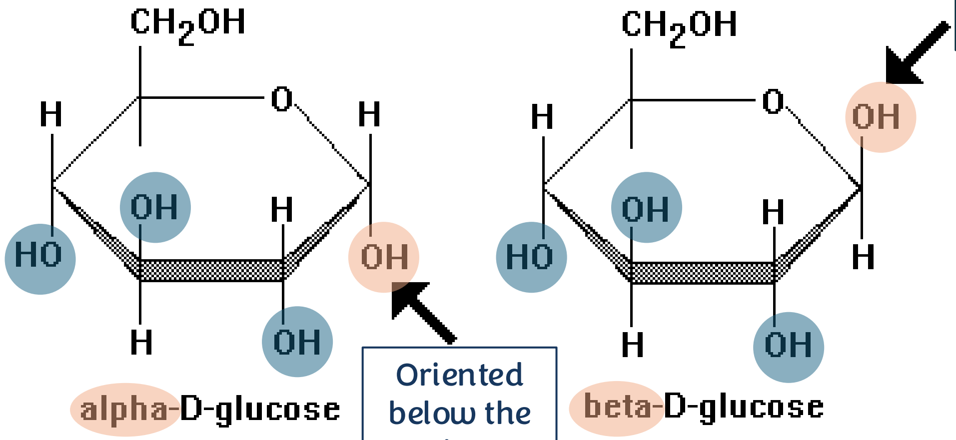
Anomers

Fixed hydroxyl groups

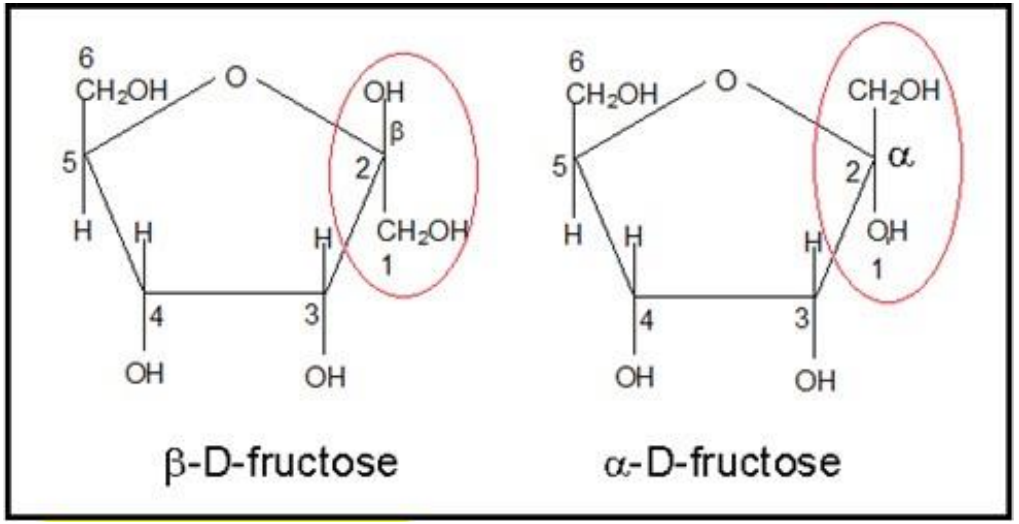
To exchange between alpha and beta, the ring opens up, and when it closes again the orientation will change

If there are 2 different molecules, we call them anomers to each other (exist in the ring structure with a difference in the orientation of the non-fixed hydroxyl group)

Oriented above the ring

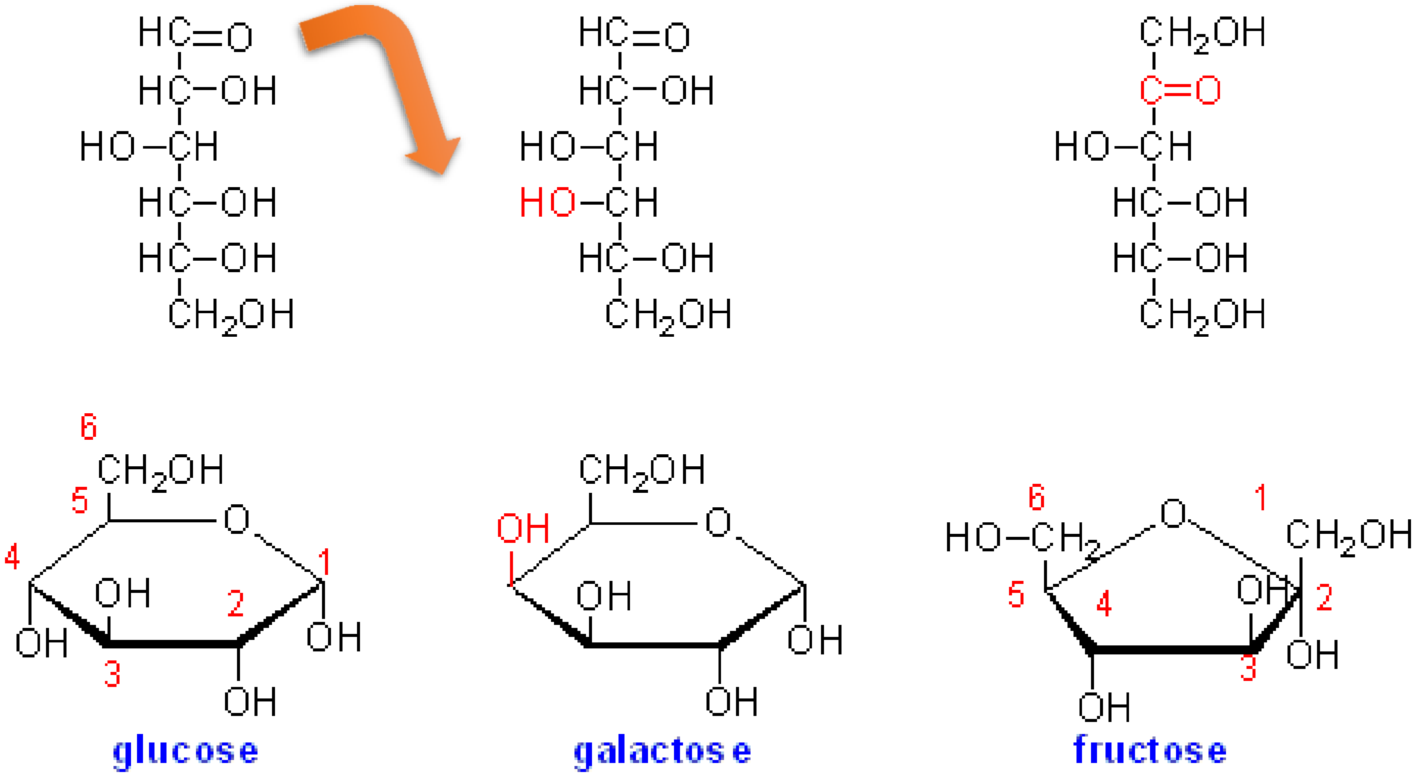


Oriented below the ring



Chain to ring
Left-up, right-down

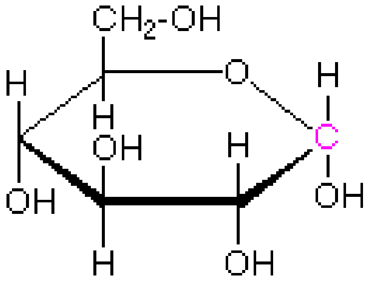
Face the sugar and go down to <u>YOUR</u> right



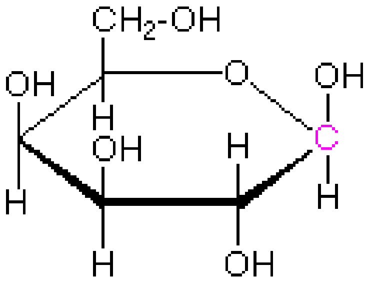
Cyclic aldohexoses

Almost all sugars we will study are D sugars(but you still need to understand what L sugars are).

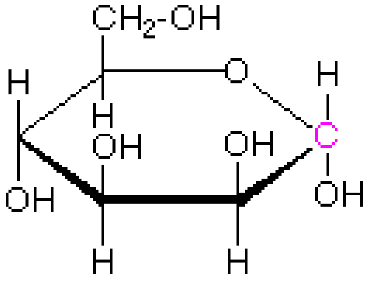
Examples of Some Pyranose Forms of Hexoses



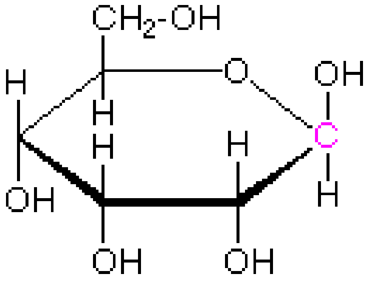
α-D-glucopyranose



β-D-galactopyranose



α-D-mannopyranose



β-D-allopyranose

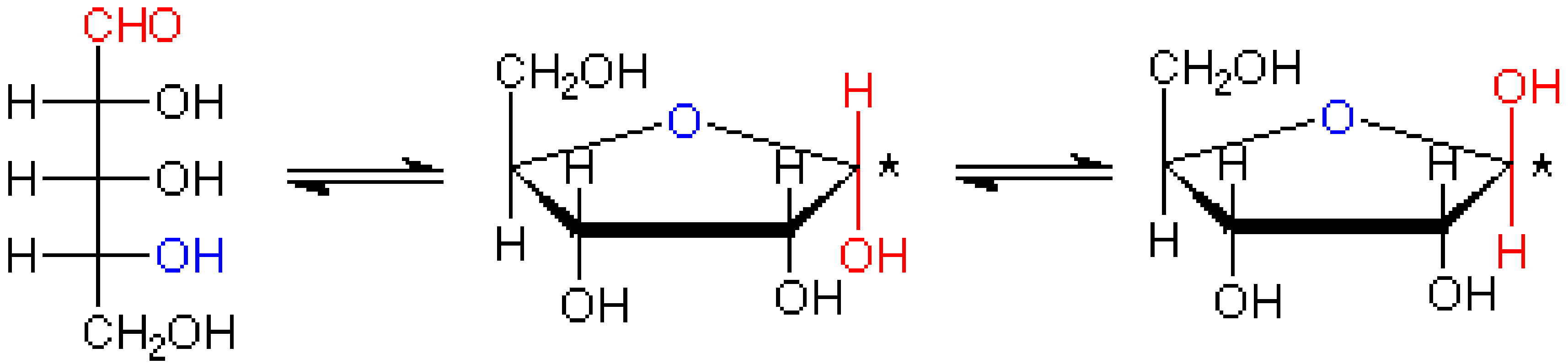
It is α because OH below the ring.
Pyran ring (6 membered)
In C2:OH below the ring
In C4:OH below the ring
Therefore glucose structure.

It is β because OH is above the ring.
Pyran ring.
In C2: OH below the ring
In C4: OH above the ring
Therefore galactose structure

Recall,
The relation between mannose and glucose:
Isomers: yes
Stereoisomers: yes
Enantiomers : no
Diastereomers: yes
Epimers: yes(at C2)

Cyclic ribofuranose

* anomeric carbon



D-ribose

α-D-ribose
OH at anomeric carbon down

β-D-ribose
OH at anomeric carbon up

Furan ring

Notice all hydroxyl groups are fixed except the one on the anomeric carbon.

Test your study !

https://gemini.google.com/app/af7b39328f4cf6e5?canvas-id=c_af7b39328f4cf6e5_biochem-lec6-quiz&full-screen=true&hl=en

For any feedback, scan the code or click on it.

Corrections from previous versions:

Versions	Slide # and Place of Error	Before Correction	After Correction
V0 → V1			
V1 → V2			

Additional Resources:

رسالة من الفريق العلمي:

Reference Used:
Prof. Mamoun Ahram recorded lecture
https://drive.google.com/file/d/1DMGwLKahWhbrBk3Iz0H9REHHTngAFv_T/view?usp=drivesdk

Extra References for the Reader to Use:
Marks' Basic Medical Biochemistry (6th edition)

اللَّهُمَّ إِنِّي أَسْأَلُكَ عِلْمًا نَافِعًا، وَرِزْقًا طَيِّبًا، وَعَمَلًا مُتَقَبَّلًا.. اللَّهُمَّ لاَ سَهْلَ إِلاَّ مَا جَعَلْتَهُ سَهْلاً، وَأَنْتَ تَجْعَلُ الْحَزْنَ إِذَا شِئْتَ سَهْلاً. تَمَّتْ بِحَمْدِ اللَّهِ وَتَوْفِيقِهِ.