



# Carbohydrates

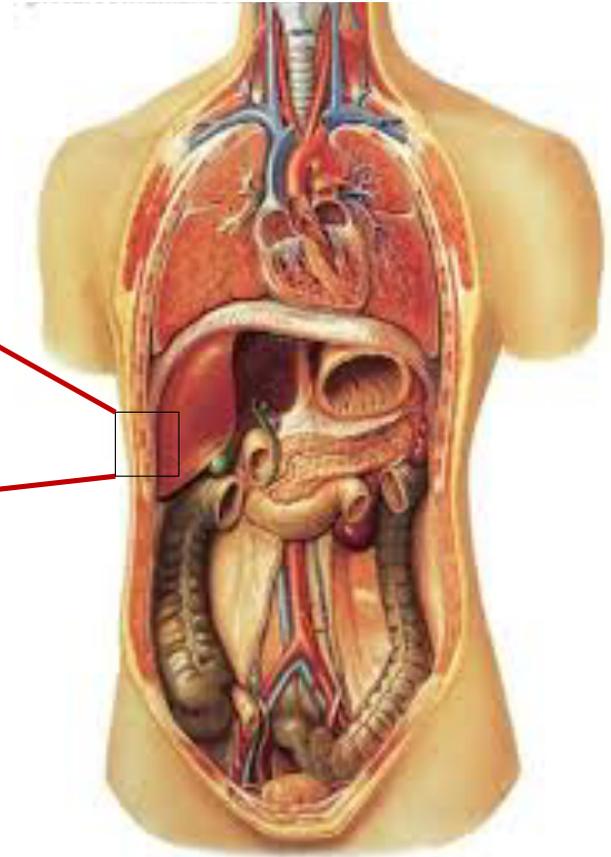
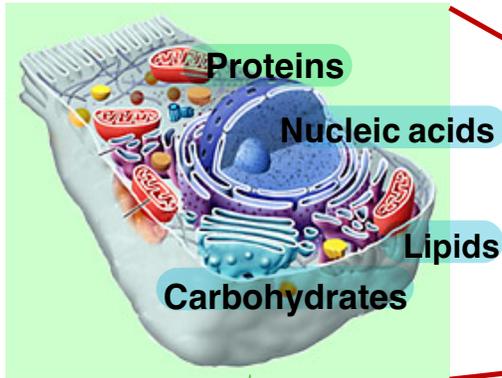


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# Major Types of Macromolecules



تحتوي خلايا الجسم على  
أي من هذه الجزيئات بالترتيب  
للإجابة على هذا السؤال

تصنيف

many food item that we eat every day contain

المجموعة الأكثر انتشاراً



# Classification of Carbohydrates

- Carbohydrates are "Sugars" or "Saccharides" consist of the empirical formula  $(CH_2O)_n$  where  $n \geq 3$ .
- Empirical formula, Molecular formula, Structural formula

كربوهيدرات

صان انا ما يعرف كم ال n

اذا عرفت ال n الكمي بيشير اسمها

لما رسم شكله بيسمى

Simpler type of carbohydrates  
الكربوهيدرات البسيطة

مائي

H2O في

## Carbohydrates

C

H2O

# Classification of Carbohydrates

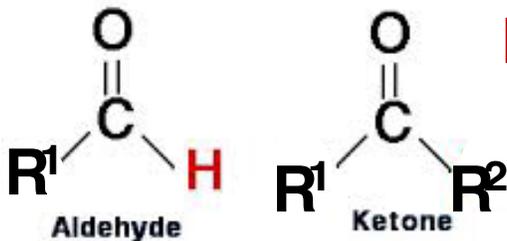


- ❑ Carbohydrates are “Sugars” or “Saccharides” consist of the empirical formula  $(CH_2O)_n$  where  $n \geq 3$ .
- ❑ Monosaccharides: The basic units of CHO which cannot be hydrolyzed into smaller sugars like glucose, galactose and fructose  
*مكونات*  
*ما يصير اليه صغرى الكاربوهيدرات*
- ❑ Disaccharides: contain two monosaccharides covalently linked by glycosidic bond like sucrose which consists of glucose and fructose
- ❑ Polysaccharides: are polymeric molecules composed of long chains of monosaccharides linked together via glycosidic bonds like starch, cellulose and glycogen  
*most complex*

# Monosaccharides



- They are classified according to the number of carbon atoms: trioses, tetroses, pentoses, **hexoses**...etc
- Also classified according to the chemical nature of the carbonyl group C=O either to **Aldoses** (the carbonyl group is an **aldehyde**) or **Ketoses** (the carbonyl group is a **ketone**)



**Aldehyde:**  $R^1 = \text{H}$ , alkyl or aryl

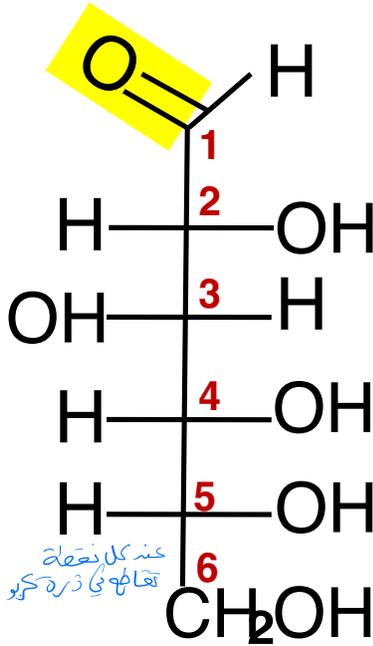
**Ketone:**  $R^1$  and  $R^2 =$  alkyl or aryl

# Monosaccharides



2 terminal group

Hexoaldose/Aldohexose



عند كل نقطة  
تقابلني ذرة كربون

terminal group

D-glucose

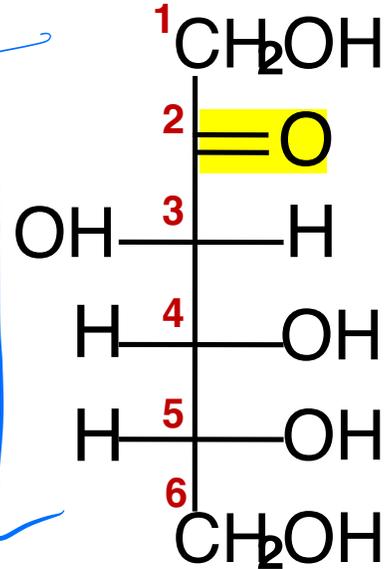
“grape or blood sugar”

Fischer projections

كلهم باليمين  
الا عند رقم 2  
بصير باليسار

اسم الطريقة الحرس

Hexoketose/Ketohexose



D-fructose

“fruit sugar” + honey

احلا طعم  
بكل الكاربوهيدرات

# Isomerization

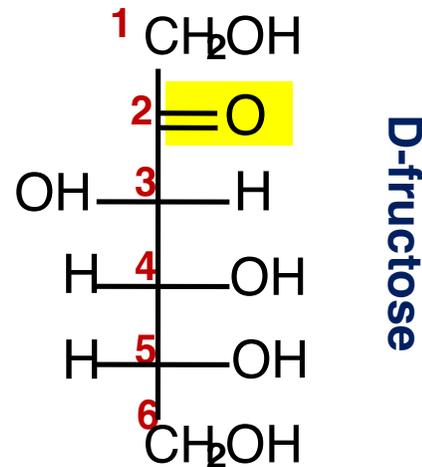
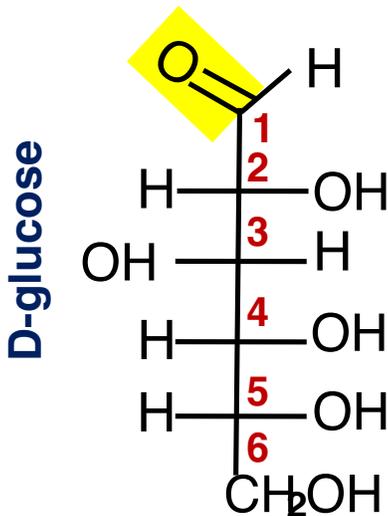


يعني عدد الـ n

? Isomers: are molecules with same molecular formula but different chemical structures

1. Constitutional (structural) isomers: atoms and functional groups bind together in different ways (e.g. glucose and fructose)

ما الهم ثلاثة بيعة هما بس  
من نفس العائلة



# Isomerization



? Isomers: are molecules with same molecular formula but different chemical structures

1. Constitutional (structural) isomers: atoms and functional groups bind together in different ways (e.g. glucose and fructose)

2. Stereroisomers (spatial isomers): differ in the configuration of atoms in space rather than the order of atomic connectivity

الانزيمات الجسدية  
تتميز

? Chiral carbon: asymmetric carbon atom attached to 4 different groups of atoms

one chiral center leads to two stereoisomers  
يمكن أن يكون مركز كيرال واحد  
↓

? The number of stereoisomers for any given molecules =  $2^n$  where n represents the number of chiral centers

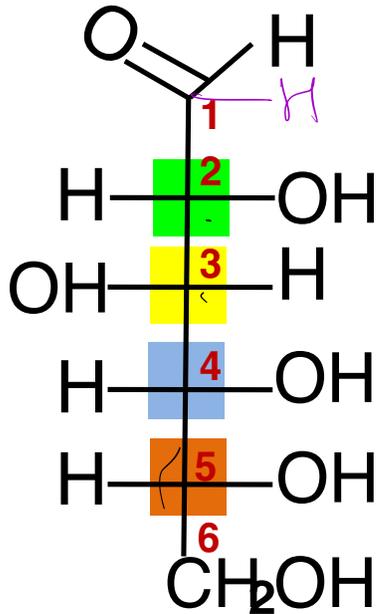
Chiral center → هي اذرة ياتى بتكون  
كله روابطها مختلفة يعني وحدة H, OH, R1, R2  
→ chiral carbon

# Isomerization



يعد الكربون الكيرالي هو ذرة الكربون التي  
Chiral carbon ذرة الكربون الكيرالي

$2^n \rightarrow n$   
عدد الكيرال center



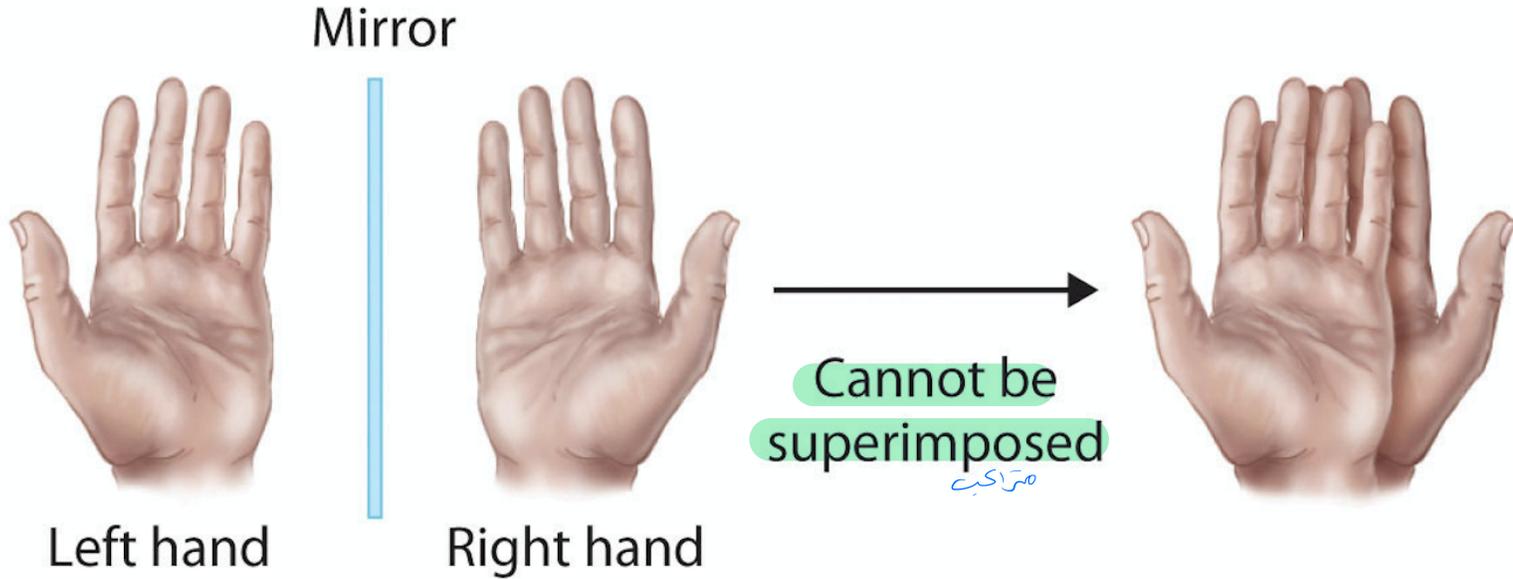
D-glucose

$$\begin{aligned} \text{Number of stereoisomers} &= 2^4 \\ &= 16 \end{aligned}$$

کلمة یونا کے معنی ہاتھ ہوتے ہیں

# Chirality & Chiral Object

لہذا ایسا کمال ہے

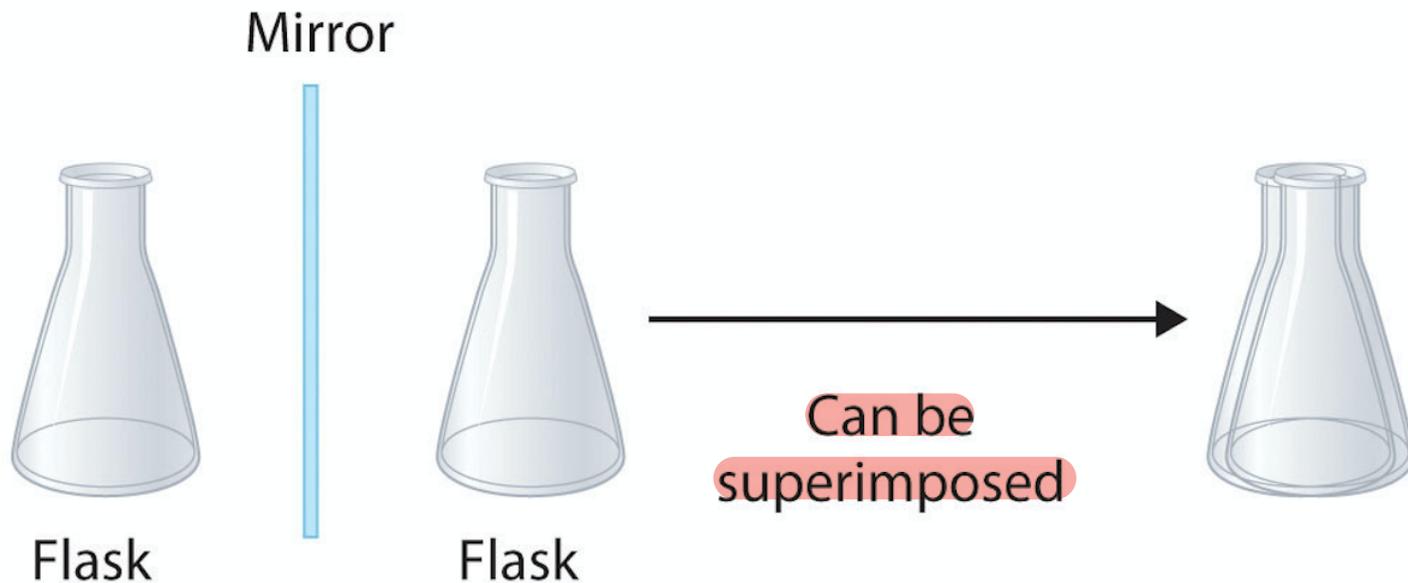


(a) **Chiral objects**

ایسی ہی صورت میں متراکیب نہیں ہو سکتے۔  
chiral objects کے superimposed



# Chirality & Chiral Object



## (b) Achiral objects

نوعی

- Chiral molecules should contain at least one chiral center (**usually a carbon atom**)

# Stereoisomers



- ❓ Enantiomers: are two stereoisomers that are mirror images to each other but not superimposable



# D/L Monosaccharides

Simplest sugar أبسط سكر

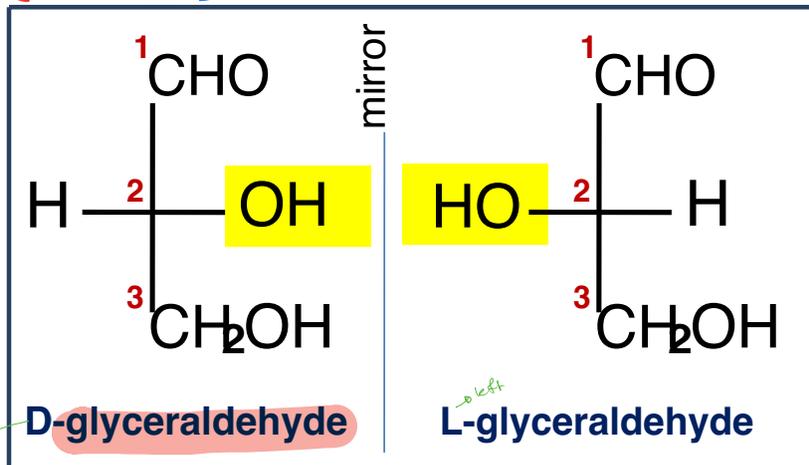
glyceraldehyde أبسط سكر

2 stereoisomers 2 صور

1 chiral center 1 مركز كيرالي

Chiral center 1 مركز كيرالي  
 one stereoisomer 1 صورة  
 $2^1 = 2$

صاحب مركز كيرالي ما يتغير كثير بالشكل بسا ليهنا بكون  
 موصوف نوع واحد منهم يرتبطن عليه يكون كيرالي  
 لو هو موجود باليمين وده الي يسمونه

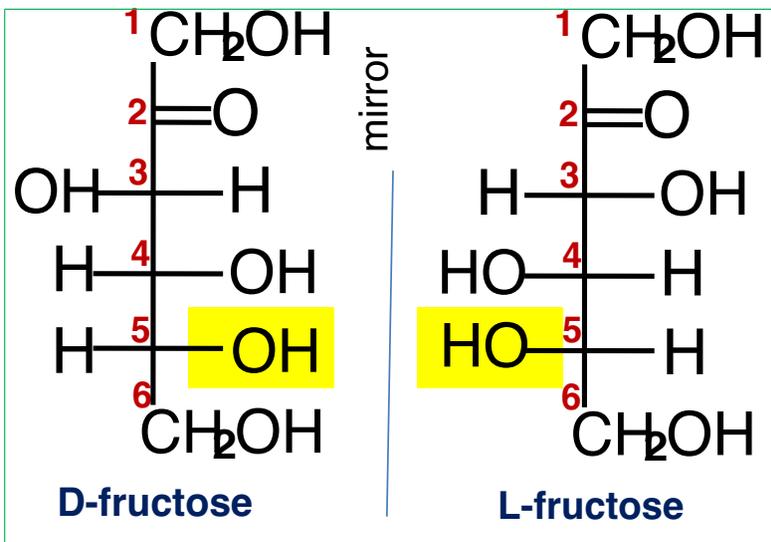


right

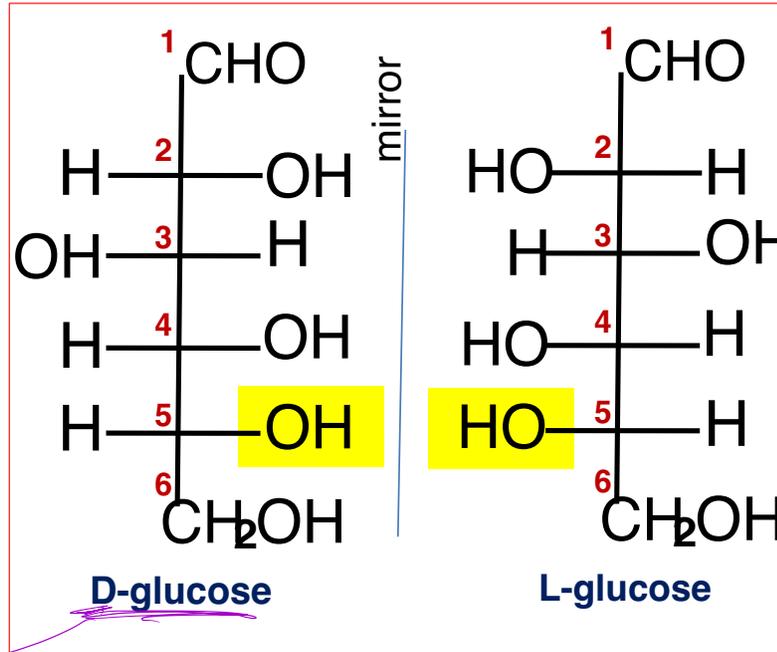
left

$2^3 = 8$  stereoisomers

تامة تامة تامة التسمية  
 انه دالعا بنسبها بالرفق بالمكان  
 Chiral center OH الي اليمين  
 من اليمين اذ كانت في اليمين  
 تكون D او left تكون L  
 اذ الي اليمين اليمين



# D/L Monosaccharides



biologically active inside a human body  
 وهو الذي نستخدمه لرفع نسبة السكر في الدم  
 وبنفسه هو الذي لا يرفع نسبة السكر في الدم

# Isomerization



- ❑ **Enantiomers**: are two stereoisomers that are mirror images to each other but not superimposable
- ❑ **D- (dexter)/L- (laevus) Nomenclature system**: commonly used to assign the configurations in sugars and amino acids
  - ❑ As a rule of thumb: if the farthest chiral atom from the highest oxidized carbon (i.e. carbonyl group) has –OH group on the right-hand side, the configuration is assigned as **D** but if it is on the left-hand side, the sugar is designated as **L**
- ❑ Most naturally occurring sugars are **D-isomers** (biologically active form)

ال 2 باقته على شكل دوا

# Monosaccharides

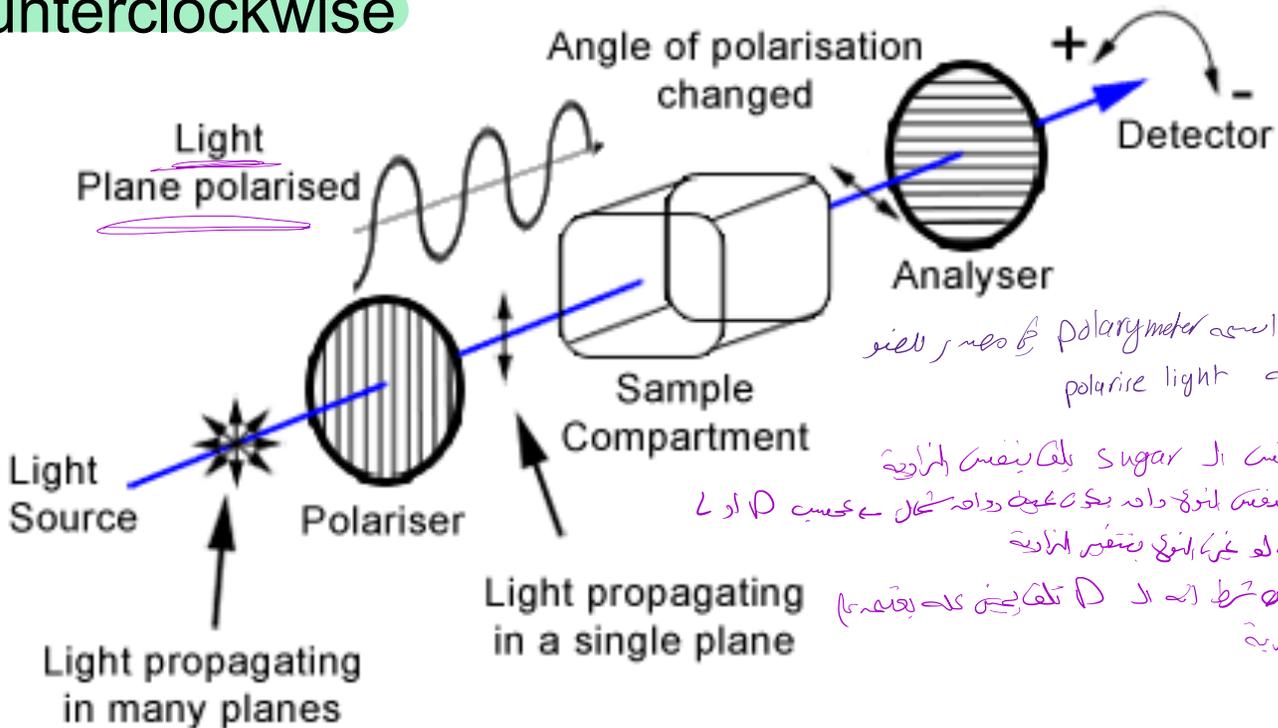


دنيا لو مخطط بالجهز وانه بلفل plane polarised light

استدارة

Enantiomers are optically active and can rotate the polarized light plane either clockwise or counterclockwise

ايجاد اختبار السامية

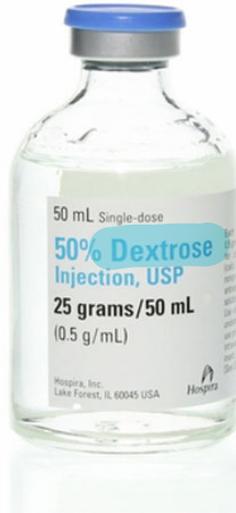


الجهز اسمه polarimeter لقياس ر لانيو  
اسم polarise light

تقسيم ال sugar بلفل بنفس الاماوية  
لنفس الاماوية وانه بيكون كجذب وانه كجذب  
بانه لو غير الاماوية يتغير الاماوية  
دونه شرط انه ال D تكافؤ كانه يقسم  
القياسية



# Monosaccharides



- **Dextrose** is the commercial/trade name of **D-glucose**
- **Laevulose** is the the commercial name of **D-fructose**

# Monosaccharides



Enantiomers are optically active and can rotate the polarized light plane either clockwise or counterclockwise

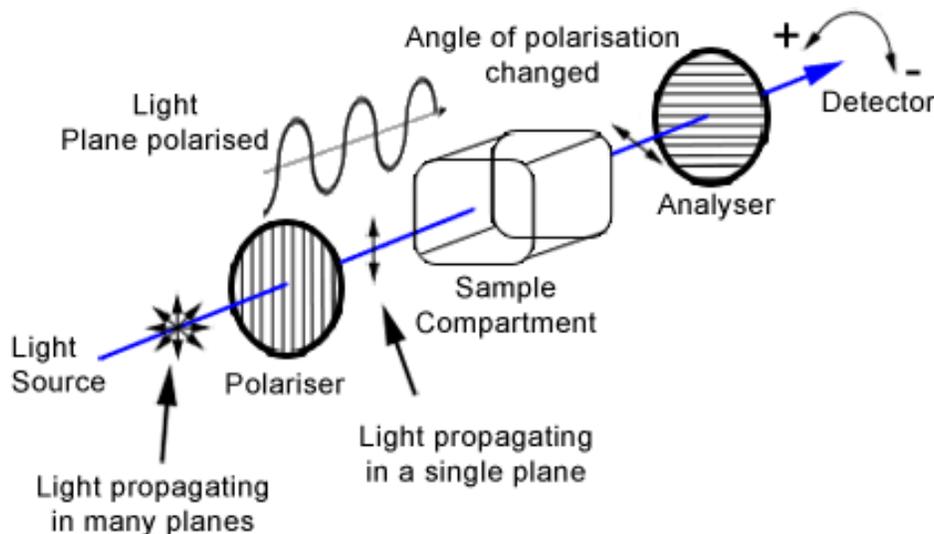
مختلطة الكيرال من المتساوية Racemic mixture

الحلقة solution مذبذب كيرال مع متساوية

من ال D-glucose

وال L-glucose

التي تسمى من ال D-glucose  
التي تسمى من ال L-glucose  
والتي تسمى من ال D-glucose



ال D-glucose  
وال D-fructose  
بل أن من نفس الكيرال بلعوا منها

كل واحد من الكيرال مختلفة يكون

**Racemic mixture** contains equal amounts of each enantiomer (net rotation is zero)

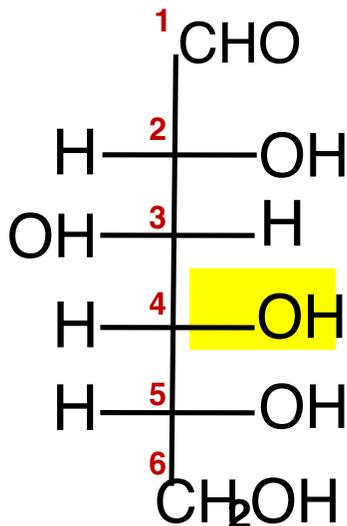
# Monosaccharides



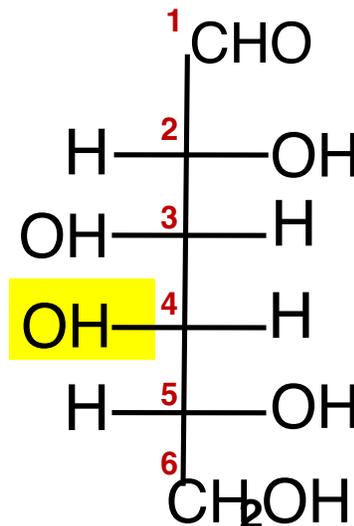
pair of → same molecular formula → differ in structural formula

Epimers: are stereoisomers that differ in the configurations of atoms at only one chiral center (i.e. chiral carbon in CHO). They are not mirror image isomers.

Enantiomers all → not superimposed → لا في صورة طبيعية

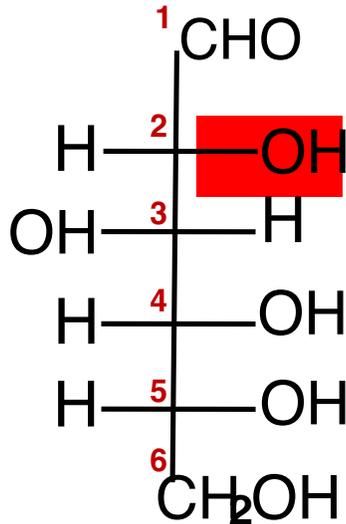


D-glucose

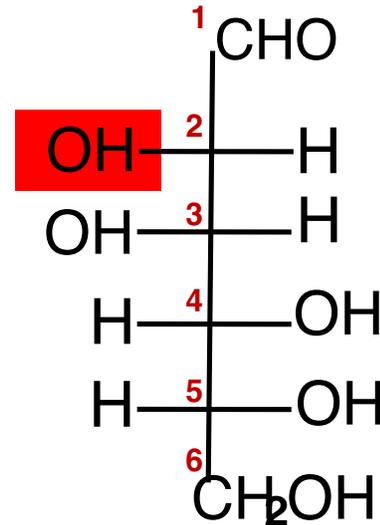


D-galactose

# Monosaccharides



D-glucose



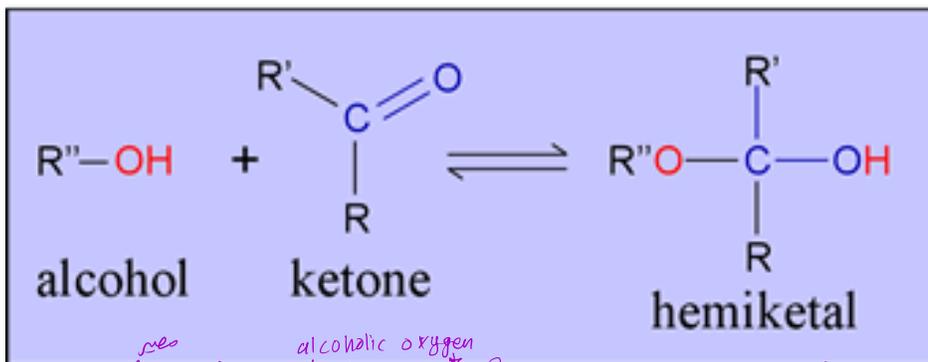
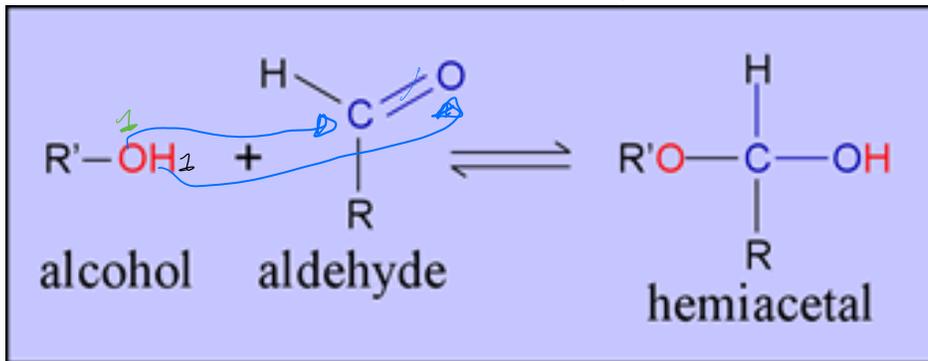
D-mannose

- Glucose and galactose are C4 epimers while glucose and mannose are C2 epimers



# Hemiacetal & Hemiketal

١- الرابطة بين ال C و H تتكسر  
 ٢- الرابطة بين ال C تتكسر الرابطة بين ال O و H تتكسر  
 ٣- ال H في ال C تتكسر الرابطة بين ال C و O تتكسر  
 ٤- ال H في ال O تتكسر الرابطة بين ال O و H تتكسر  
 ٥- ال H في ال R تتكسر الرابطة بين ال C و R تتكسر



what is the fate of hydroxyl oxygen?  
 it will be ethere groups in hemiacetal  
 what is the fate of carbonic carbon?  
 chiral carbon center

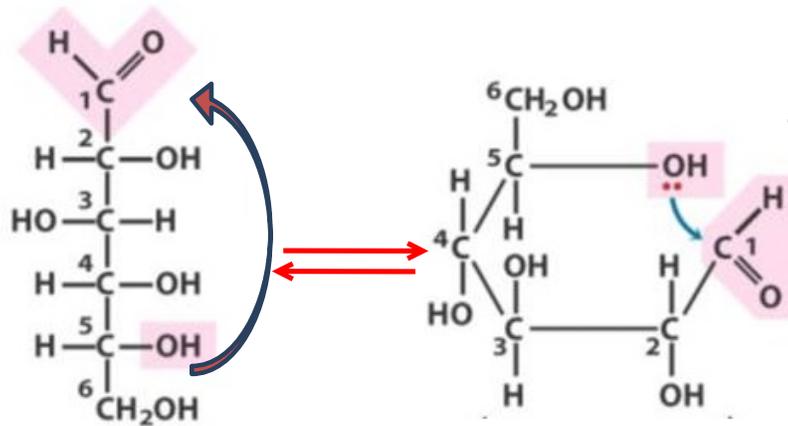
what is the fate of carbonyl oxygen?  
 alcoholic / hydroxyl group

# Monosaccharide cyclization

intra molecular cyclization



## Linear form



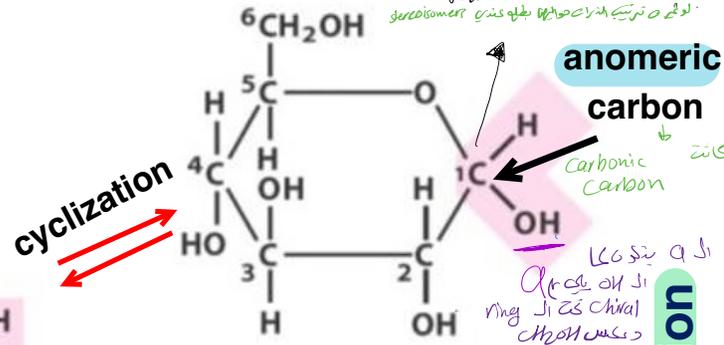
D-glucose

linear form

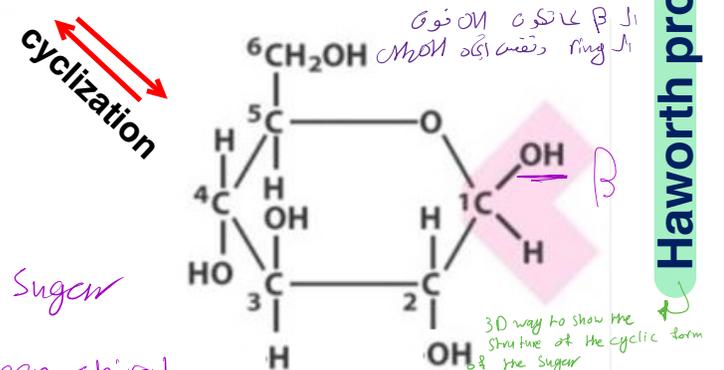
## Fisher projection

anomers is found in cyclic form of the sugar

happen because carbonel carbon have been chiral center because of cyclization



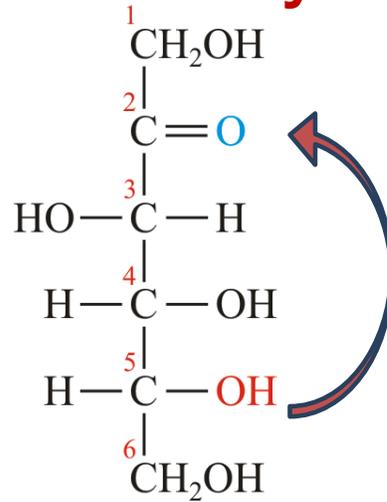
$\alpha$ -D-glucose



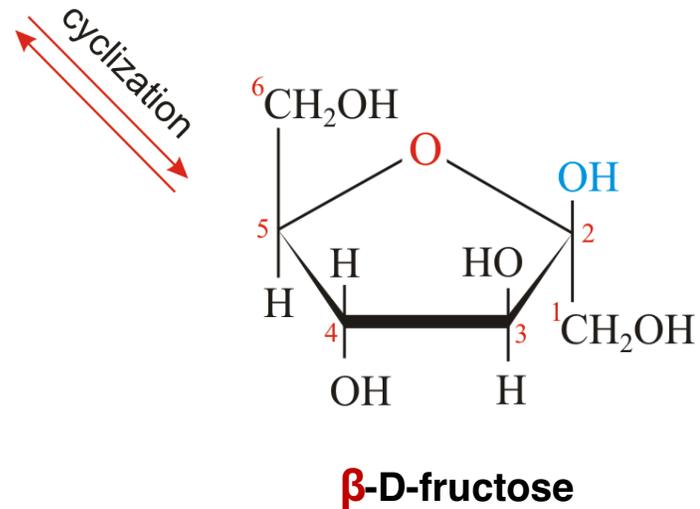
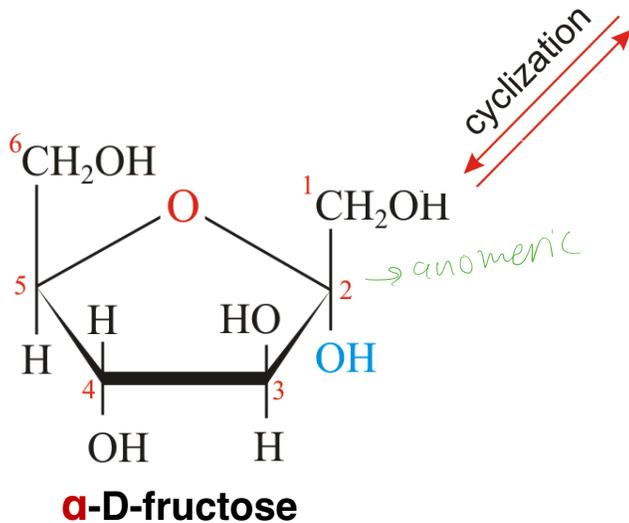
$\beta$ -D-glucose

كيف يسهل الامر اذا الشكل D اول في شكله كحللهم لهم  
عند C4 في CH2OH انهم يتكونون في انما يكون مكانه في يتكون في واما فيشرون ال D داعج

# Monosaccharide cyclization



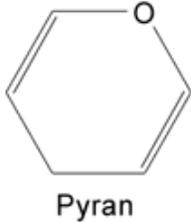
**D-fructose**  
**Linear form**



# Pyranoses & Furanoses

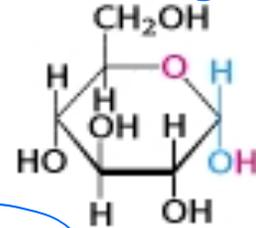


- ? Sugars with six-membered rings are known as pyranoses (e.g. glucopyranose) as they resemble the heterocyclic compound pyran.



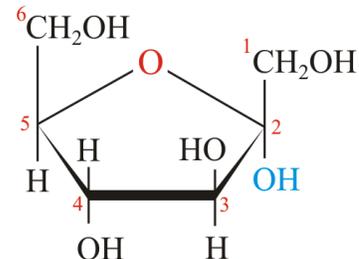
كل السكر sugar التي يتكون طبقا له هي pyranose  
تسمى

خطوط ايضا من كل اية كربون في ذرة O



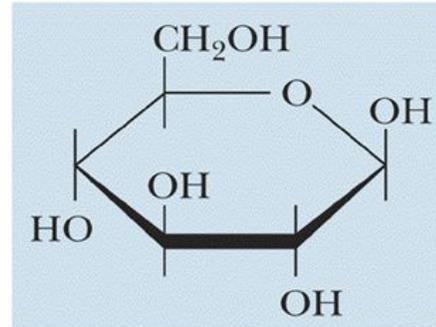
**α-D-glucopyranose**

- ? Sugars with five-membered rings are known as furanoses (e.g. fructofuranose) as they resemble the heterocyclic compound furan.

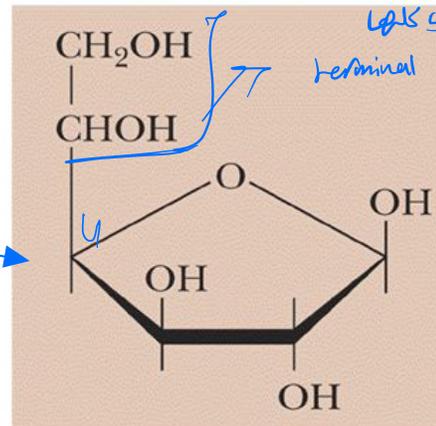


**α-D-fructofuranose**

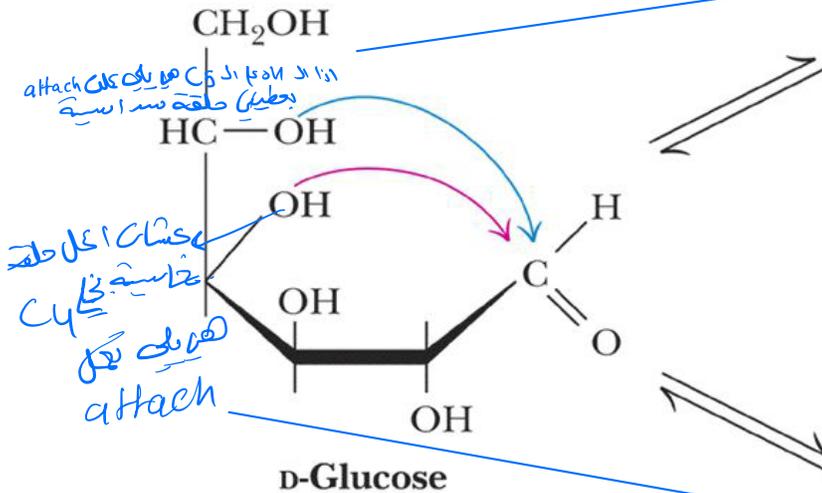
# Pyranoses & Furanoses



**Pyranose form**  
 $\beta$ -D-glucopyranose



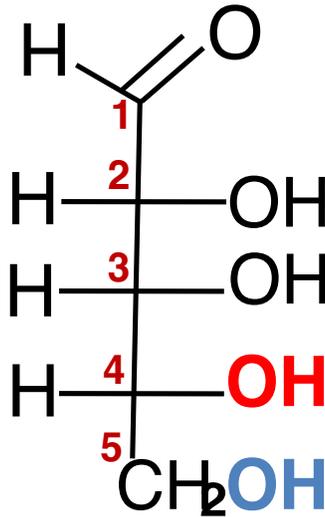
**Furanose form**  
 $\beta$ -D-glucofuranose



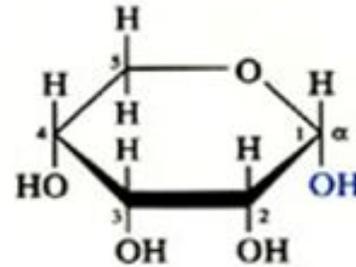
**D-Glucose**

D-glucose can cyclize in two ways forming either furanose or pyranose structures

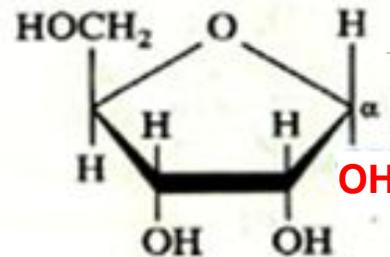
# Pyranoses & Furanoses



D-ribose  
Fisher projection



$\alpha$ -D-Ribopyranose  
(Haworth projection)



$\alpha$ -D-Ribofuranose  
(Haworth projection)

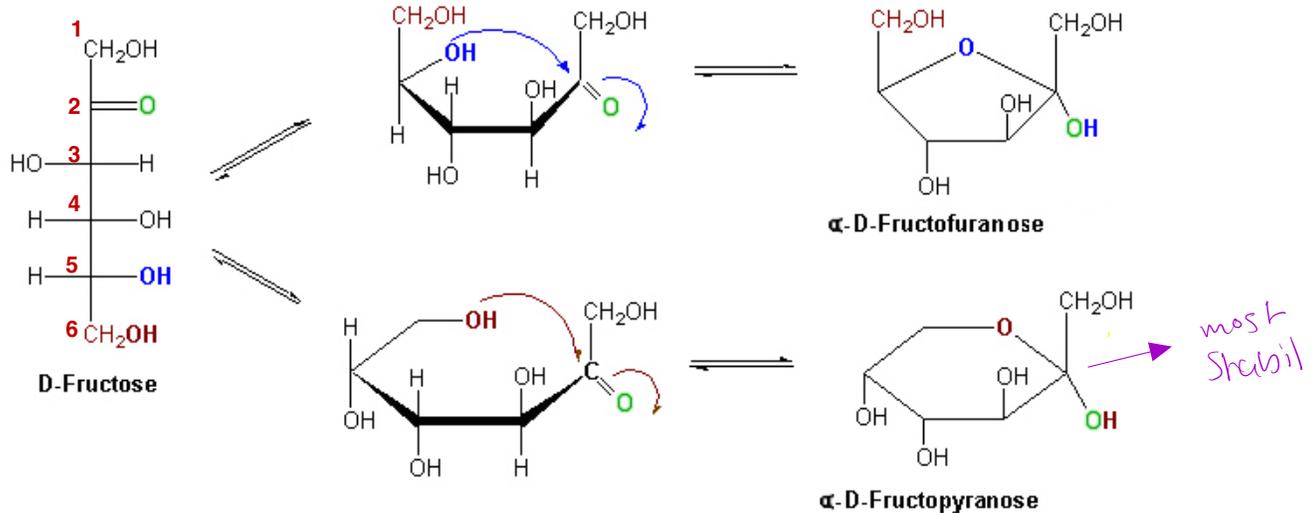
most stable

# Pyranoses & Furanoses



داخلي كيمي ما بلادي  
 Howarth بلادي  
 لعمري

## Isomeric Forms of Fructose



**?** Hexose or pentose can exist in pyranose and furanose forms (the most stable rings).

e.g. in solution, glucose and fructose are mostly pyranoses whereas ribose is mostly furanose

الكتابه الاكبره د صبيح موجوده والاكبره د تاربه د  
 pyranose & furanose most stable كبره د

هذا الشكل في المساحة زاوية الجليد والسكر كغوز ال  
Pyranoses هو المهم هو most stabil

في الكريات الخماسية مثل البرايوز ال furanoses هو most stabil

# Anomers

most stabil  
يحي less energy  
السكر استقرار



- ❑ In cyclic sugars, the carbonyl carbon becomes a chiral center (asymmetric carbon) with two possible configurations:  $\alpha$  and  $\beta$ . This new carbon is called anomeric carbon.
- ❑ Anomers are pair of stereoisomers that differ in spatial arrangement of atoms at the anomeric carbon. In  $\alpha$ -anomer, the OH group of the anomeric carbon is projecting down the plane of the ring and on the opposite side of the terminal  $\text{CH}_2\text{OH}$  group (in Fisher projection) and vice versa in  $\beta$ -anomer.
- ❑ The anomers freely interconvert in aqueous solution, e.g. at equilibrium D-glucose is a mixture of  $\beta$ -anomer (63.6%),  $\alpha$ -anomer (36.4%) and extremely tiny amounts of the straight chain.

تحويل داخلي

مائي

حالة التوازن

less than 0.1% linear

يحي يتسوفهم بانفسه الى تداي linear

حرفه کیمیا

الخطوة هنا بشكل عام وفيه ال chiral carbon

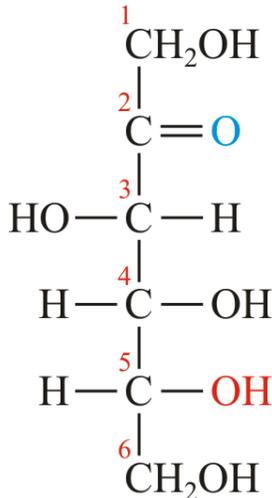
# Haworth Projection

والترميز  
بالأدوية

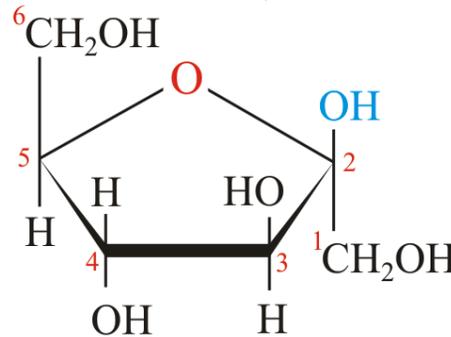


? Haworth projection is a simple 3D way to represent the cyclic monosaccharides. The OH groups on the right-hand side of Fisher projection are down in Haworth projection and vice versa. The dark line indicates atoms that are closer to the observer.

Fisher projection



D-fructose



$\beta$ -D-fructose

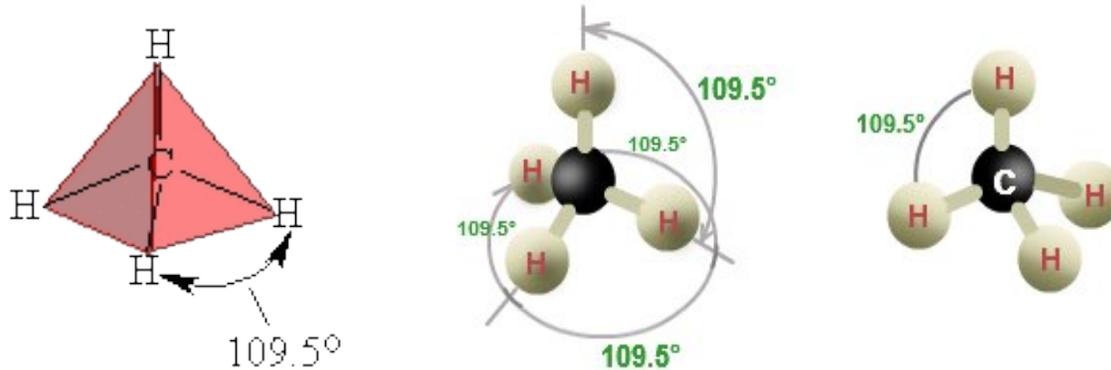
Haworth projection

# المركبات Conformers

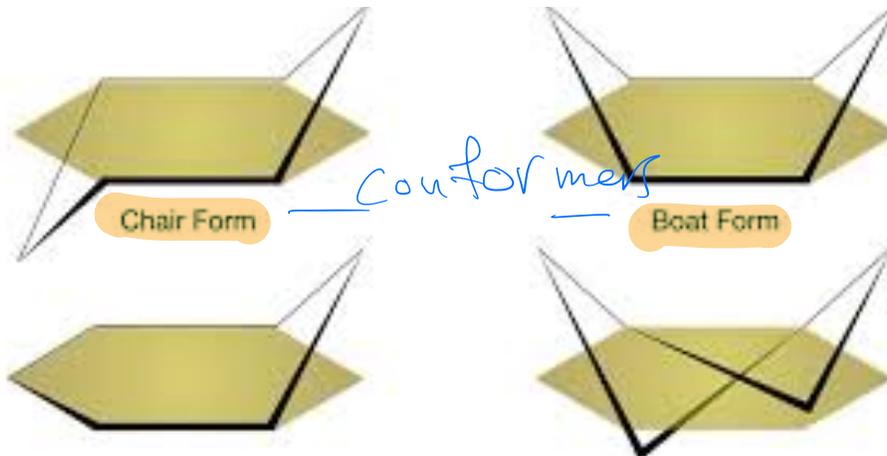


- ❓ The geometry of the carbon atoms of monosaccharide ring is tetrahedral (bond angles are close to  $109.5^\circ$ ), so sugar rings are not actually planar. For example, pyranoses take on either Chair or Boat conformations (conformational isomers or conformers).

# Conformers



**Carbon atoms are tetrahedral**

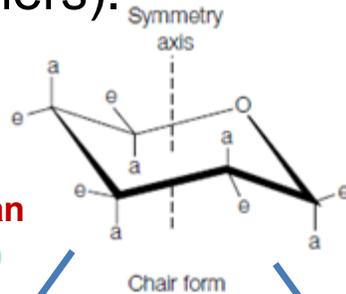


**Conformers are stereoisomers with different rotations about single bonds**

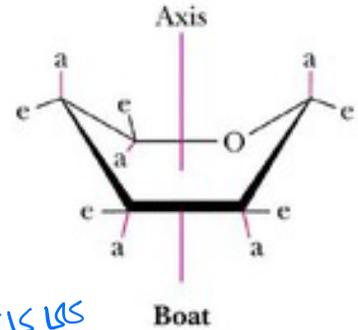
# Conformers



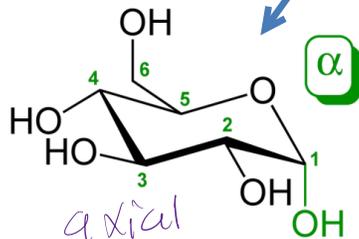
☐ The geometry of the carbon atoms of monosaccharide ring is tetrahedral (bond angles are close to  $109.5^\circ$ ), so sugar rings are not actually planar. For example, pyranoses take on either **Chair** or **Boat** conformations (conformational isomers or conformers).



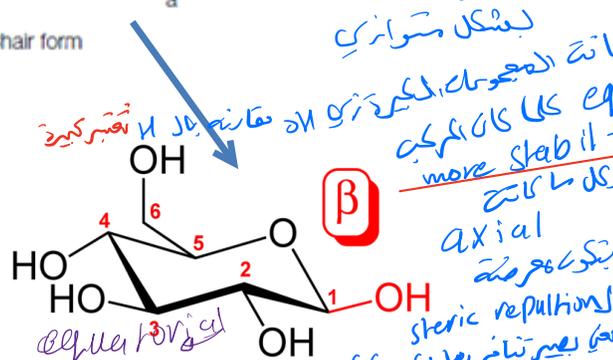
a: axial  
e: equatorial



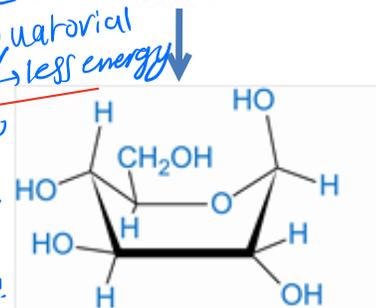
$\alpha$  is Less stable than  $\beta$  due to steric repulsion



Chair form of  $\alpha$ -D-glucose



Chair form of  $\beta$ -D-glucose



Boat form of  $\beta$ -D-glucose

فوقاً ادركت

ليشكل متوازني

مقارنة بين الـ  $\alpha$  و  $\beta$  تعتبر كبيرة

كلما كانت المجموعات الكبرية في الـ equatorial  
كلما كان المركب more stable  $\rightarrow$  less energy

كل ما كانت axial  
تكون غير مستقرة  
لست repulsive  
بعضها ليس متنازها يكون المركب stabil

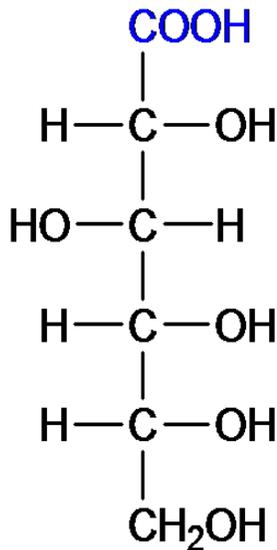


# Sugar Modification



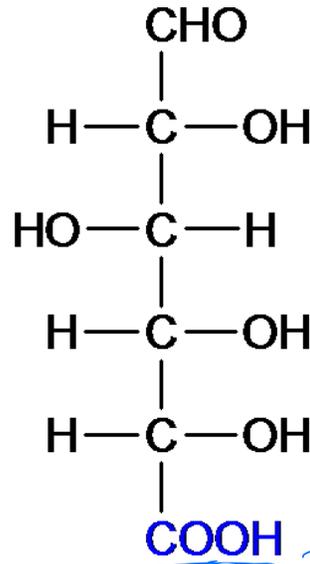
reduction *تخفيض*

1. Aldonic acids : oxidation of aldehyde (C1) to carboxylic acid; e.g. D-gluconic acid



2. Uronic acids : oxidation of OH at (C6) to carboxylic acid; e.g. D-glucuronic acid

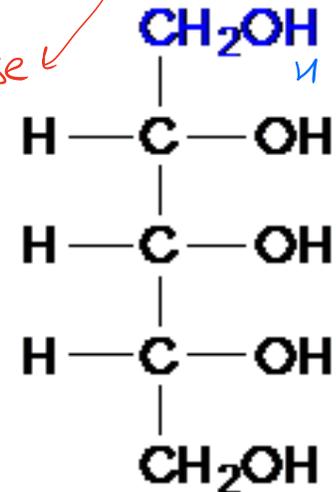
*derivative from glucose*



*terminal group*

3. Alditols : reduction of carbonyl group to alcohol; e.g. D-ribitol, D-glycerol and D-sorbitol (sweetener)

*reduction aldehyde*



D-ribitol

*D-ribose*  
*D-glyceroldehyde*  
*D-glucose*

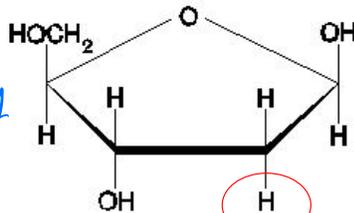
*١١ سكريات*

# Sugar Modification

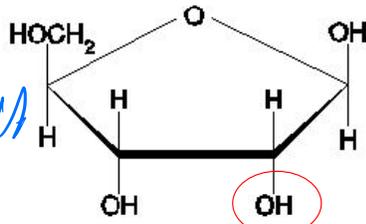


منزوح الاكسجين

4. **Deoxy sugars** : OH group is replaced by H; e.g.  $\beta$ -D-2-deoxyribose



Deoxyribose



Ribose

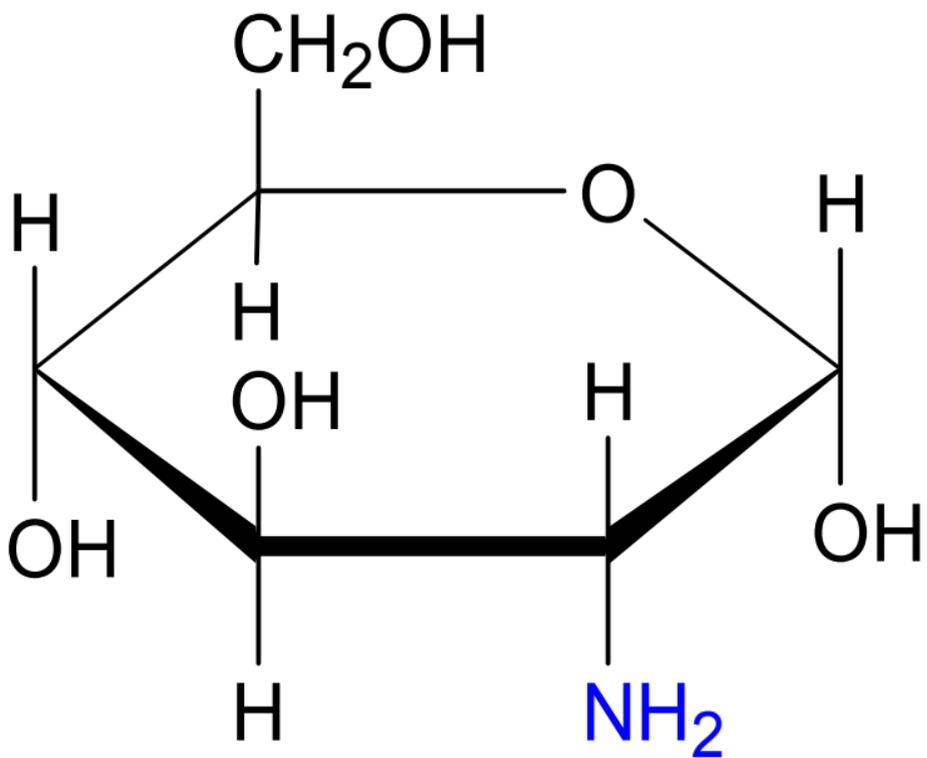
4. **Amino sugars** : one or more OH groups are replaced by **amino group** which is often **acetylated**; e.g.  $\alpha$ -D-glucosamine (rebuild cartilage in osteoarthritis & osteoporosis) and  $\alpha$ -D-N-acetylglucosamine (both are derivatives of  $\alpha$ -D-glucose)

بمساعدة الحرارة

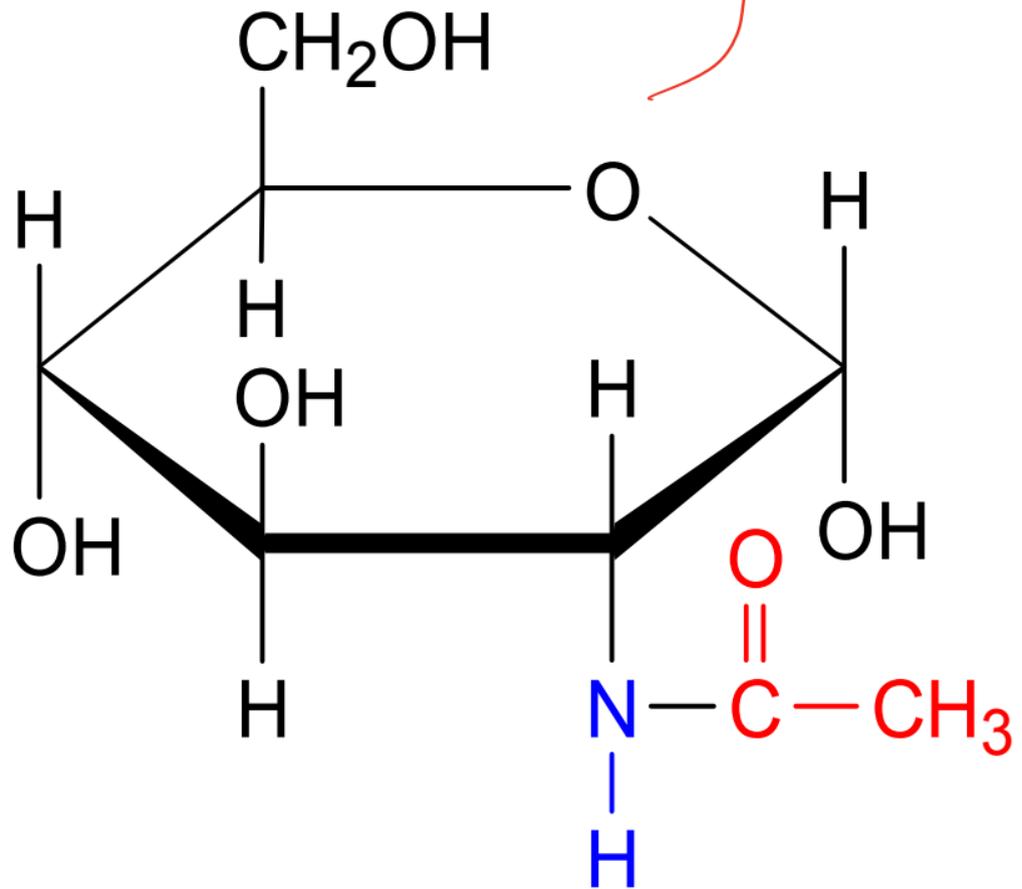
$\alpha$ -D-glucosamine



اعتبرها قوام



*acetyl group adds to C2* →  
 $\alpha$ -D-glucosamine



$\alpha$ -D-N-acetylglucosamine

