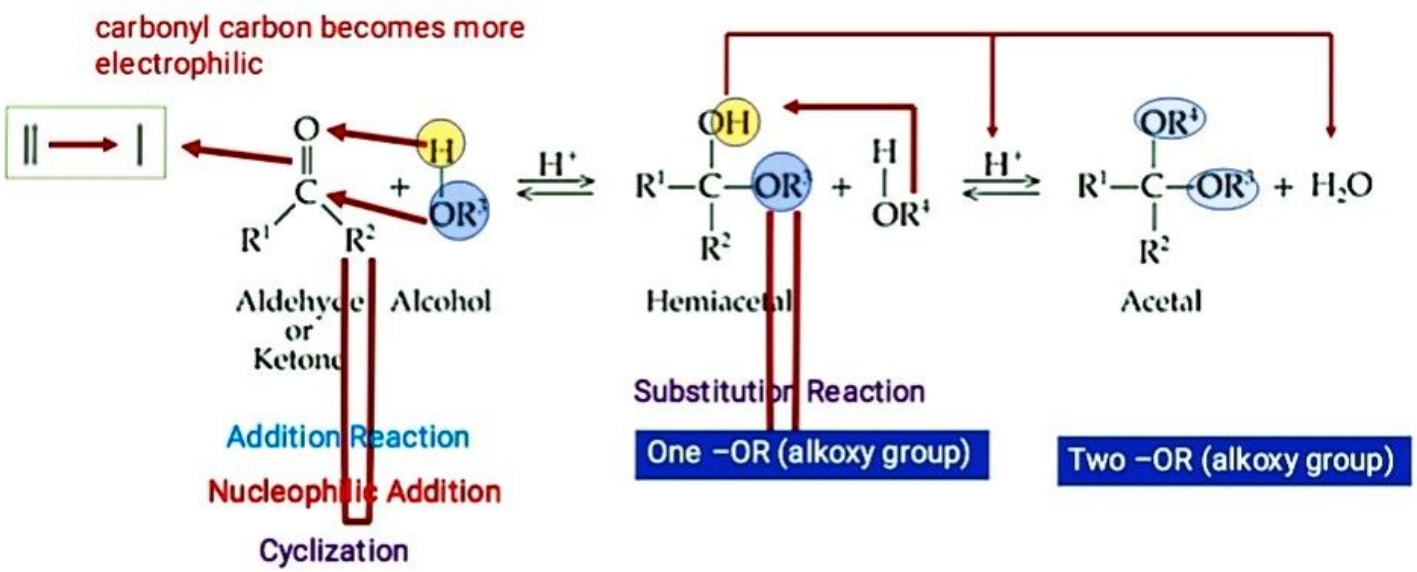
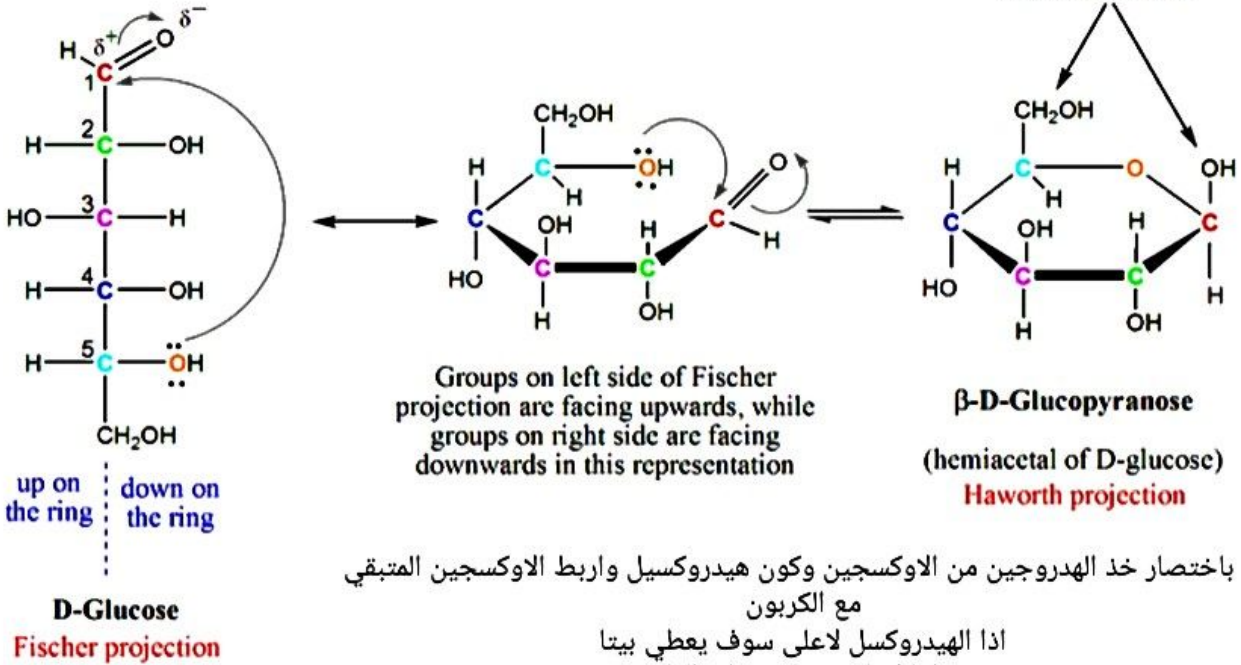
Ring (cyclic) structure

Hemiacetal and hemiketal formation is the correct and standard explanation for sugar cyclization. The aldenol description is not commonly used in modern biochemistry.



- Cyclization of sugars occurs by nucleophilic addition forming a hemiacetal, while glycosidic bond formation occurs by substitution converting the hemiacetal into an acetal

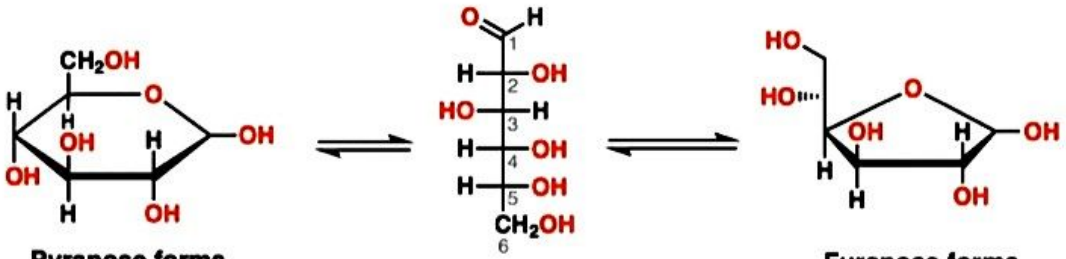


باختصار خذ الهدروجين من الاوكسجين وكون هيدروكسيل واربط الاوكسجين المتبقي
مع الكربون
اذا الهيدروكسل لاعلى سوف يعطي بيتا
اما لاعلى سوف يعطي الفا

Summary: Pyranoses, Furanoses, and Ring-Chain Tautomerism

- Sugars exist in equilibrium between their open-chain and various closed-chain forms. (This is called "ring-chain tautomerism")
- This is particularly important for **hexoses** (e.g. glucose) and **pentoses** (e.g. ribose)

e.g. D-glucose (below)



Pyranose forms (α + β)

Open-chain form

Furanose forms (α + β)

99% **0.02%** **< 1%**

- The **six-membered** cyclic form is generally referred to as the "**pyranose**" form, and the **five-membered** cyclic form is called the "**furanose**" form
- Closure of the ring creates a chiral center at C-1, resulting in two diastereomers (sometimes called "**anomers**") - the alpha (α) and beta (β) forms

Term	Word Breakdown	Simple Meaning	Definition	Example
Isomers	Iso = same mer = parts	Same parts, different arrangement	Same molecular formula, different structures	Glucose vs Fructose
Epimers	Epi = upon/on mer = part	Differ at ONE position	Differ at only one carbon	Glucose vs Galactose (C4)
Enantiomers	Enantio = opposite mer = part	Opposite forms (mirror images)	Mirror images of each other	D-glucose vs L-glucose
Anomers	Ano = up/down mer = part	Differ at anomeric carbon	Differ at the anomeric carbon (α and β)	α-glucose vs β-glucose
Mutarotation	Muta = change rotation = optical rotation	Change in rotation	Interconversion between α and β forms	α ⇌ β glucose

Mutarotation

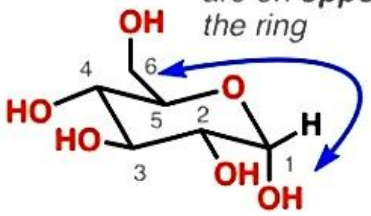
- Mutarotation is the change in optical rotation observed when pure α- or β-anomers are dissolved in water.
- Each of these two forms can be synthesized and isolated as pure compounds.
  - The alpha (α) anomer of D-glucose has a specific rotation of +112 degrees in water.
  - The beta (β) anomer of D-glucose has a specific rotation of +18.7.

Alpha (α) and beta (β) isomers ("anomers") differ in the orientation of the OH at the C-1 hemiacetal carbon

Example: D-glucose

"alpha" (α) isomer:

*C_5-CH_2OH (up) and C_1-OH (down) are on **opposite** faces of the ring*

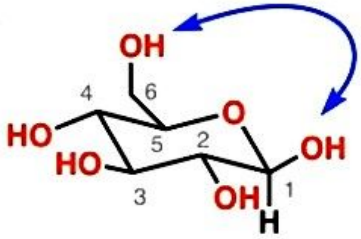


α-D-Glucose drawn as "chair"

Specific rotation: $[\alpha]_D^{20}$ + 112°

"beta" (β) isomer:

*C_5-CH_2OH (up) and C_1-OH (up) are on the **same** face of the ring*



β-D-Glucose drawn as "chair"

Specific rotation: $[\alpha]_D^{20}$ + 18.7°

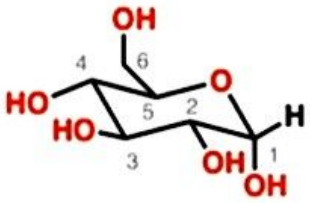
Note different specific rotations!

Why β is more abundant?

Mutarotation

- When either anomer is dissolved in water, **the value of the specific rotation changes over time, eventually reaching the same value of +52.5°.**
  - The specific rotation of α-D-glucopyranose decreases from +112° to +52.5°.
  - The specific rotation of β-D-glucopyranose increases from +19° to +52.5°.
- This behavior is called **mutarotation** (literally, "change in

When 100% pure α-D-glucopyranose is dissolved in water, the specific rotation slowly changes from +112° to + 52.5° over a few hours.



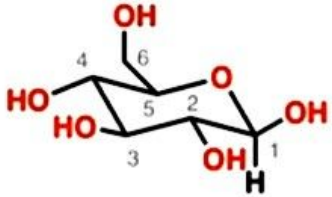
Dissolve in water →

specific rotation decreases over several hours, until reaching stable value of +52.5°

α-D-Glucose (pyranose form)

Specific rotation: $[\alpha]_D^{20}$ + 112°

Similarly, when 100% pure β-D-glucopyranose is dissolved in water, the specific rotation slowly changes from + 18.7° to + 52.5°.



Dissolve in water →

specific rotation increases over several hours, until reaching stable value of +52.5°

β-D-Glucose (pyranose form)

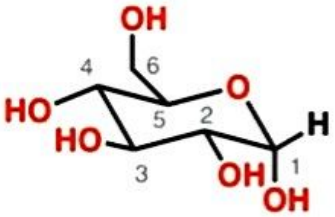
Mutarotation

- When the rotation reaches **+52.5°**, the system has reached **equilibrium**, and the ratio of **α : β is about 36 : 64**.
- No matter if you start with α or β, the sugar opens and recloses until it reaches a stable mixture of 36% α and 64% β.

Why the change in specific rotation?

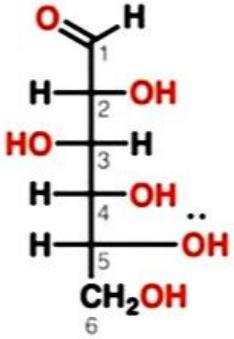
The alpha and beta anomers are each in equilibrium with the "linear" form, and therefore with each other.

"alpha" (α) isomer:



α-D-Glucose

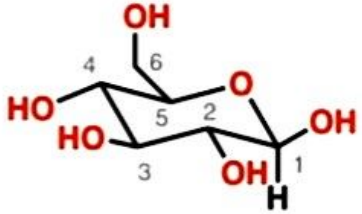
36%
(at equilibrium)



D-Glucose

("linear" form)

"beta" (β) isomer:



β-D-Glucose

64%
(at equilibrium)

At equilibrium the mixture consists of 36% α-D-Glucose, 64% β-D-Glucose, and traces of the linear and furanose forms.

Mutarotation is a general property of cyclic sugars bearing a free anomeric carbon.

Sugar	Mutarotation	Reason
Glucose	Yes	Has a **free anomeric carbon** (hemiacetal)
Fructose	Yes	Has a **free anomeric carbon** (hemiketal)
Maltose	Yes	Has **one free anomeric carbon**
Sucrose	No	**No free anomeric carbon** (both involved in glycosidic bond)

- Fructose also shows mutarotation, changing from about −133° to −92° as different ring forms interconvert