Chapter 7
Carbohydrates

Definition of Carbohydrates

<u>carbohydrate</u>: "hydrate of carbon"; $C_n(H_2O)_m$

Examples: glucose ($C_6H_{12}O_6$ or $C_6(H_2O)_6$),
sucrose ($C_{12}H_{22}O_{11}$ or $C_{12}(H_2O)_{11}$)

<u>saccharide</u>: "simple sugar" group

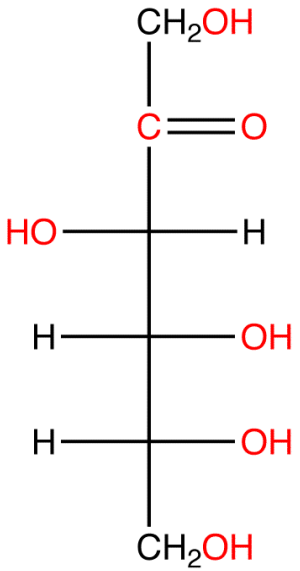
*mono*saccharides, *di*saccharides, *poly*saccharides…

monosaccharides are $C_nH_{2n}O_n$

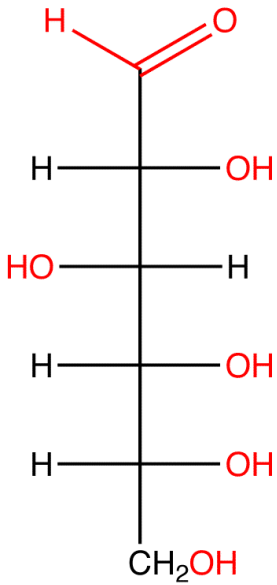
Functional Groups

Carbohydrates can be classified as:

- <u>Polyhydroxyaldehydes</u>: many alcohols and an aldehyde
- <u>Polyhydroxyketones:</u> many alcohols and a ketone



D-fructose
(a polyhydroxy ketone)

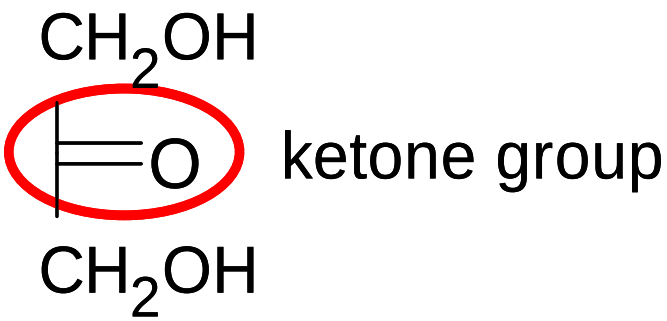


D-glucose
(a polyhydroxy aldehyde)

Structure and Nomenclature

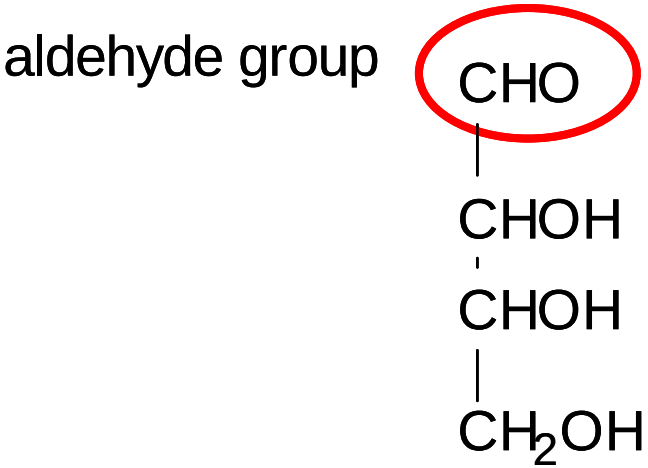
Named by the functional group + number of carbons

(keto-) or (aldo-) + (tri-, tetr-, pent-) + -ose



ketotriose

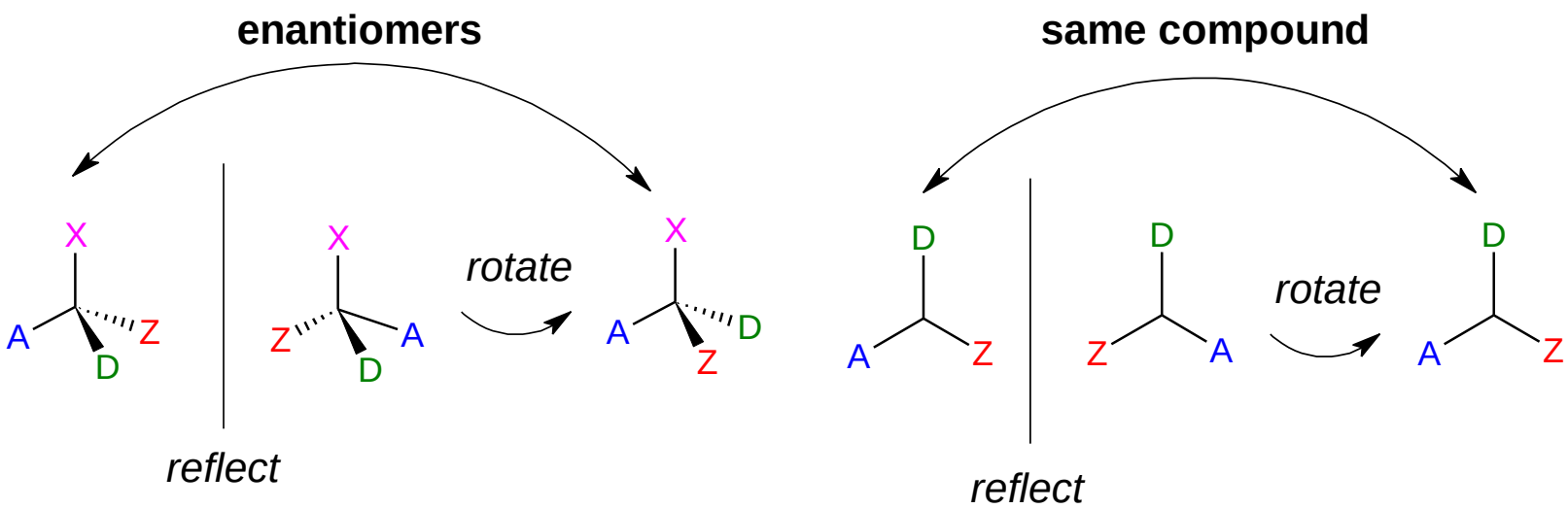
aldotetrose



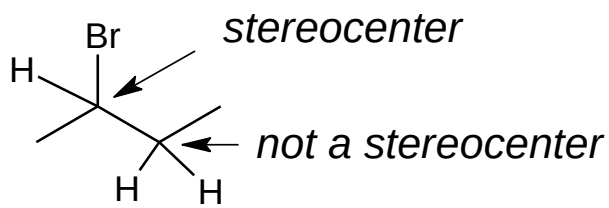
Chirality

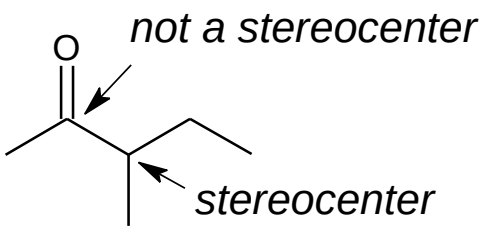
<u>Stereocenter:</u> tetrahedral carbon with four different substituents

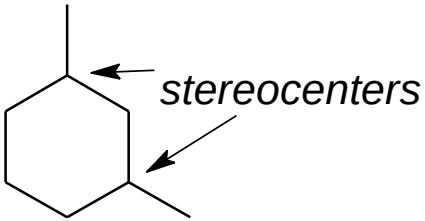
chiral carbon
or *asymmetric* center



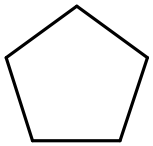
Stereocenters

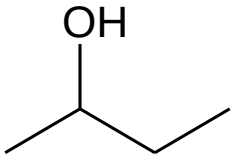


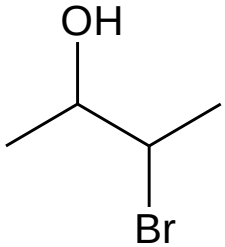


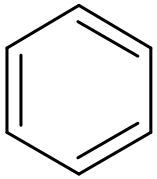


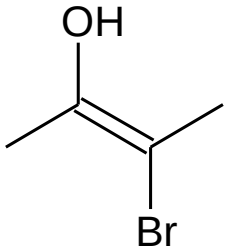
How many chiral carbons are in:

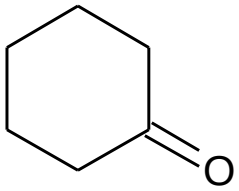


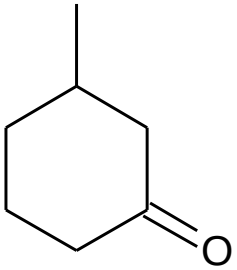






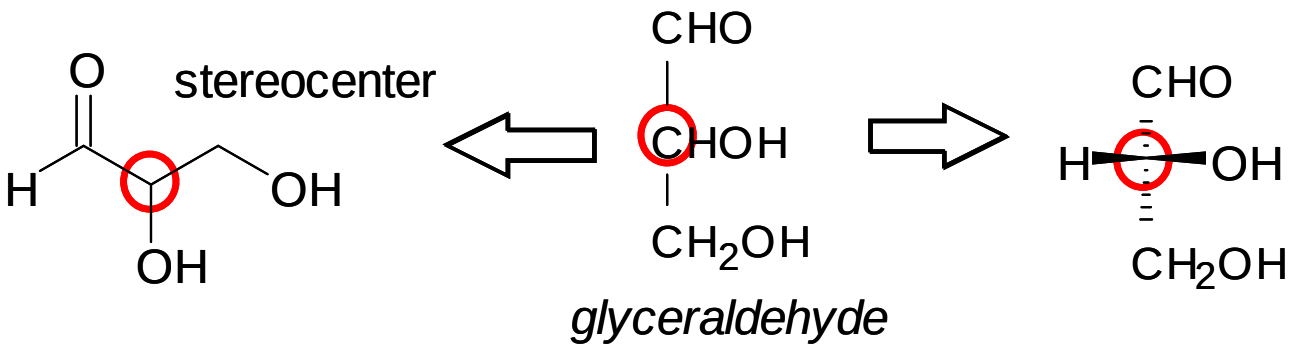






Fisher Projections

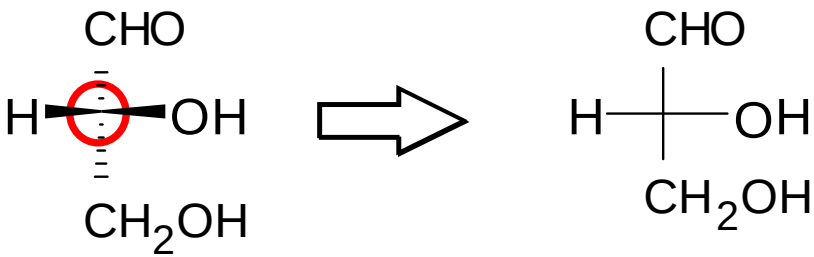
Glyceraldehyde: an aldotriose



Fisher Projection: two-dimensional representation of stereocenters as the only atoms in plane

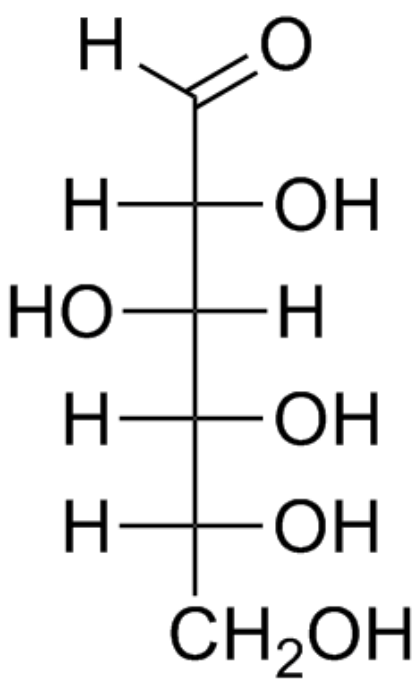
Wedges (toward you) are *horizontal*

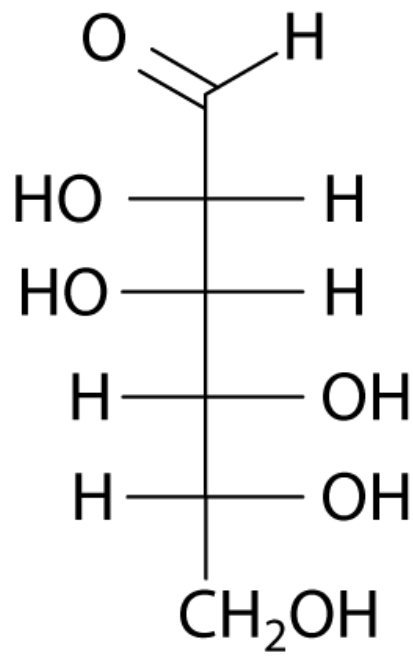
Dashes (away from you) are *vertical*



Chirality in Carbohydrates

How many chiral carbons are present?

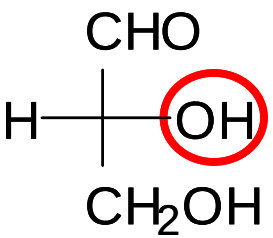




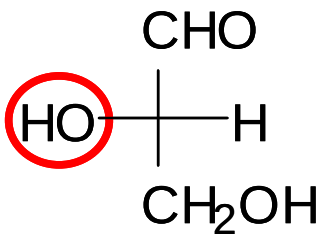
Are these structures (1) enantiomers, (2) constitutional isomers, or (3) neither?

D and L Configuration

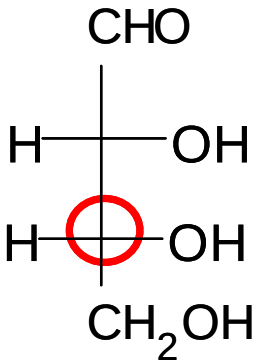
Sugars are designated with **D** (right) and **L** (left).



D-glyceraldehyde

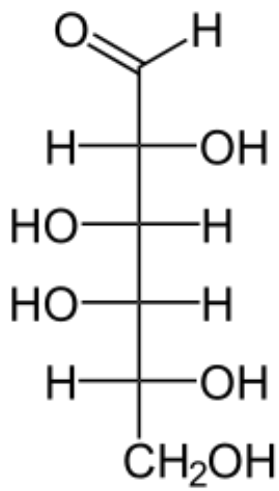


L-glyceraldehyde

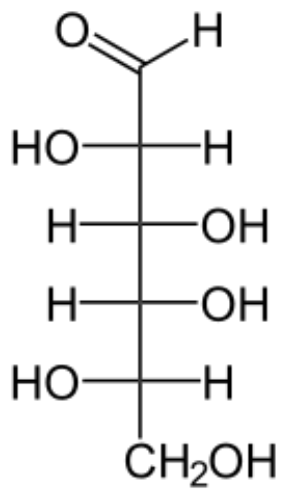


D-erythrose

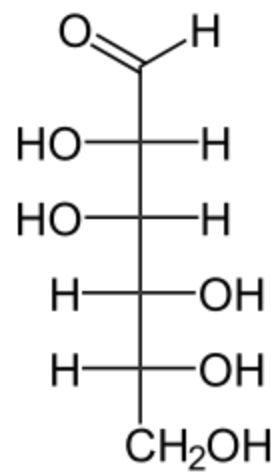
D and L Configuration



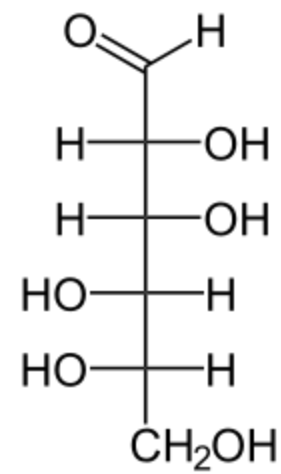
D-Galactose



L-Galactose



D-Mannose



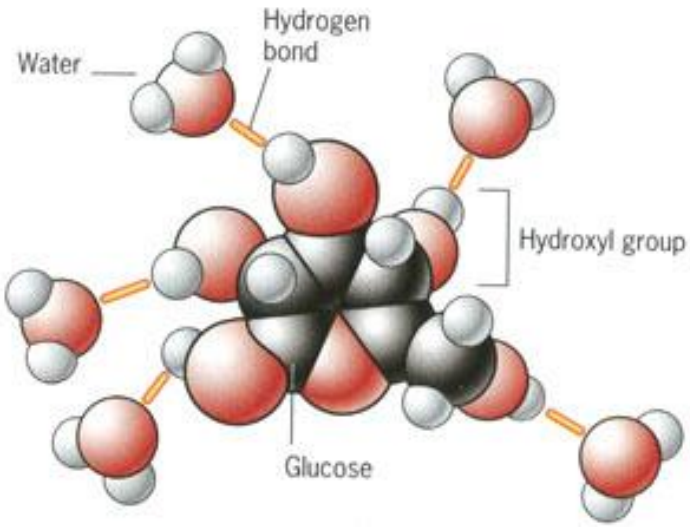
L-Mannose

Physical Properties

Most are colorless, crystalline solids with a sweet taste (sugars).

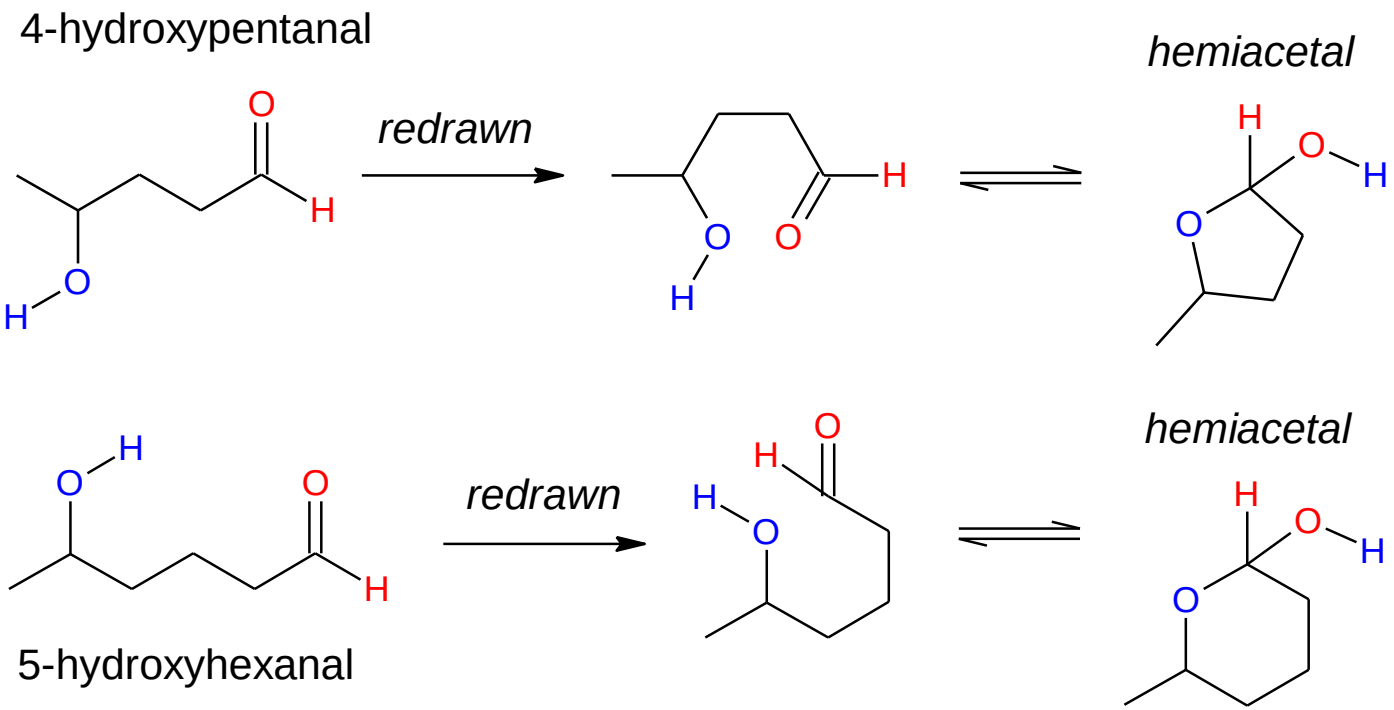
The many alcohols make the compounds extremely polar.

- All three intermolecular forces
- Very water-soluble



Hemiacetals

Hydroxyaldehydes will form *hemiacetals*.



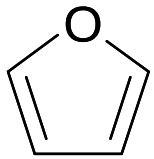
Are these isomers or different compounds?

How many stereocenters are in the hydroxyaldehydes?

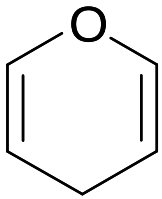
How many are in the hemiacetals?

Furanose and Pyranose

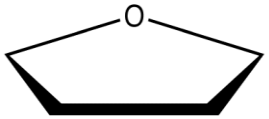
The cyclic hemiacetal forms are *particularly* stable when forming a 5- or 6-membered ring.



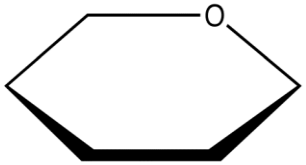
furan



pyran

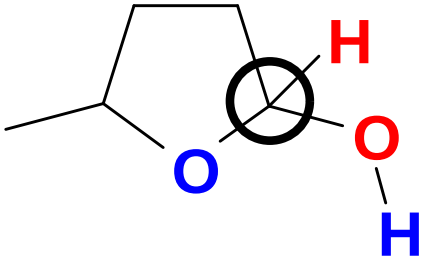


furanose ring



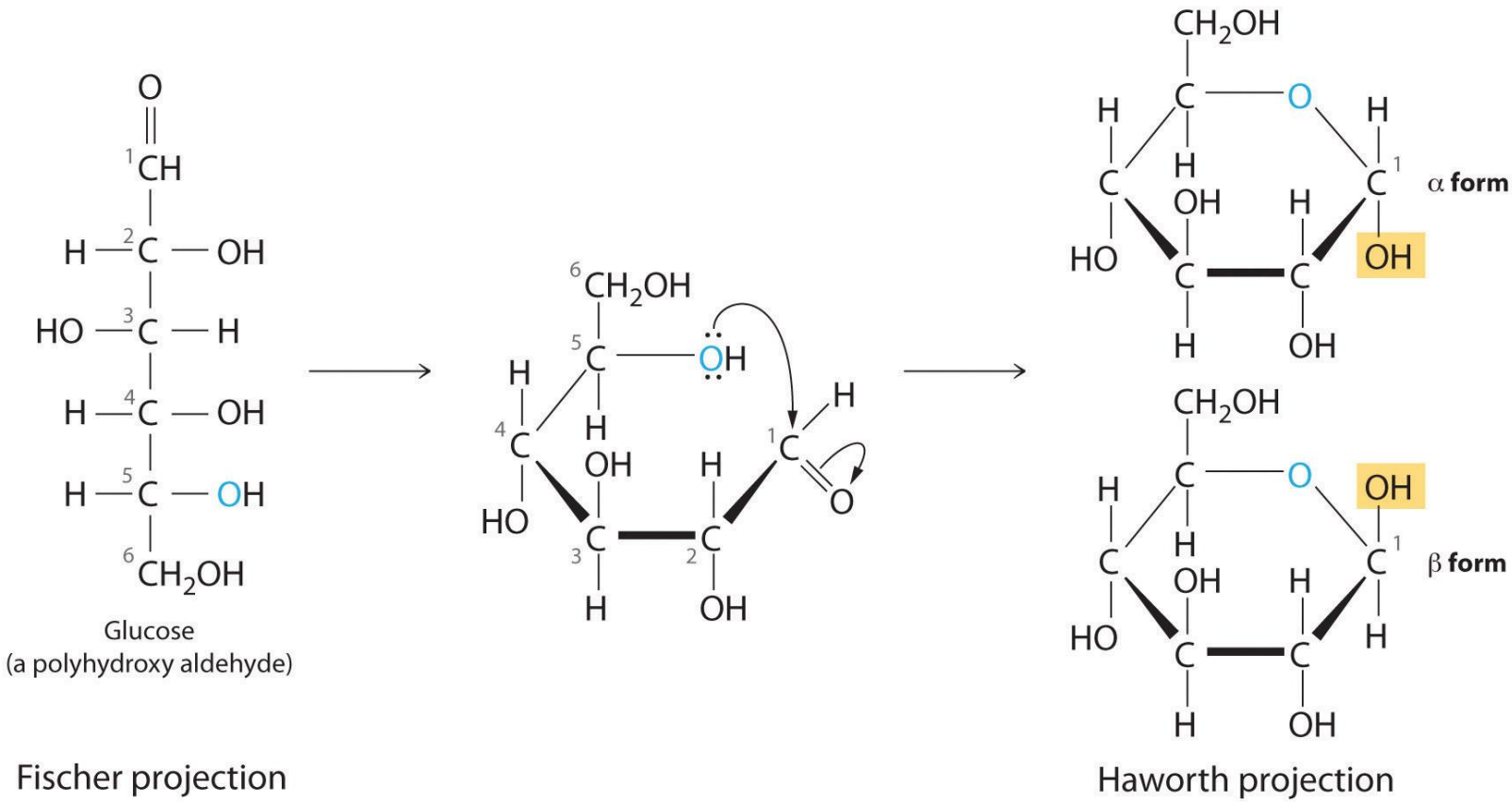
pyranose ring

<u>Furanose</u>: 5-membered
<u>Pyranose</u>: 6-membered



<u>anomeric carbon</u>: *new* stereocenter created in forming the cyclic hemiacetal

Haworth Projections

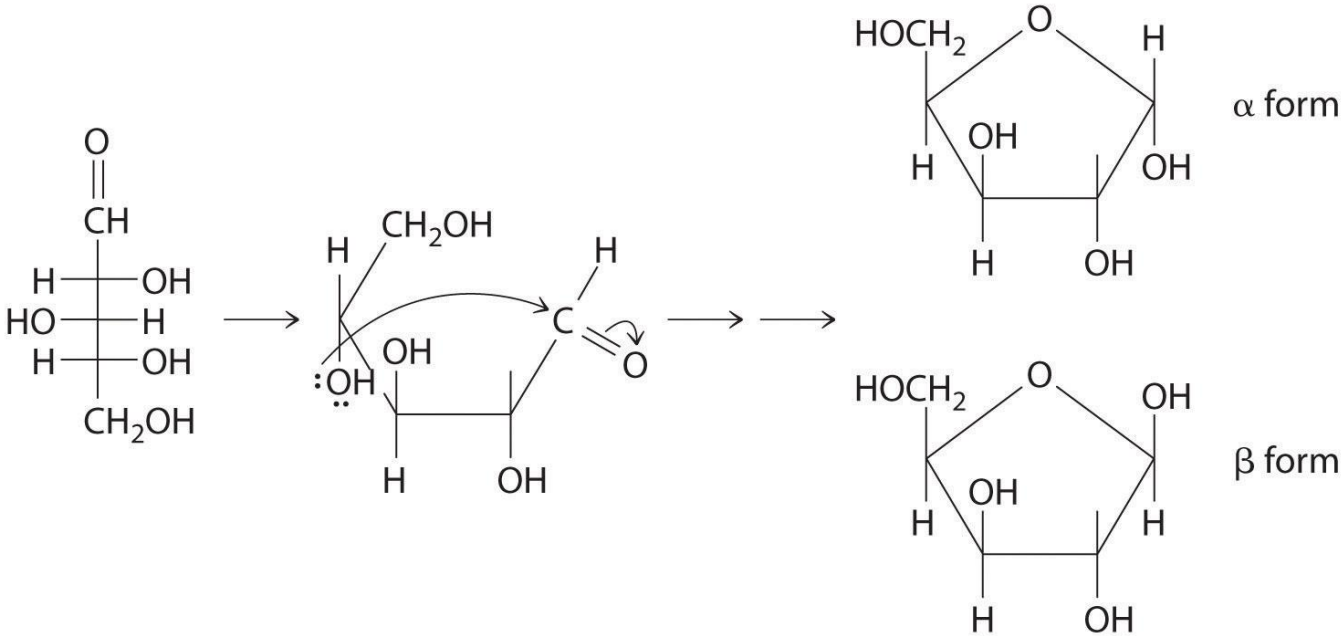


Left in Fisher → up from ring

Right in Fisher → down from ring

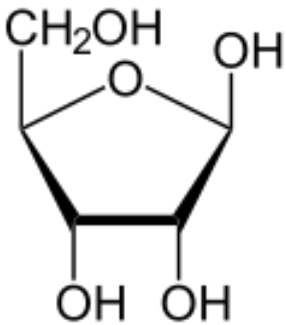
Anomeric carbon's alcohol can be *either* up or down.

Haworth Projections

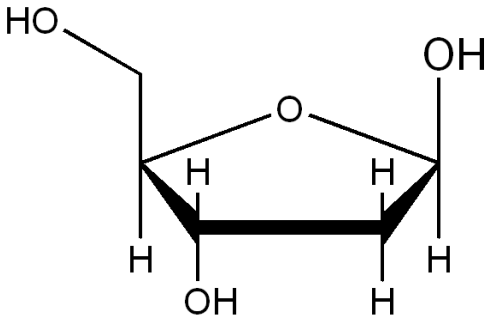


Oxygen in the ring is always pointed *backwards*.
Anomeric carbon is always to the *right*.
All three isomers exist in in equilibrium.

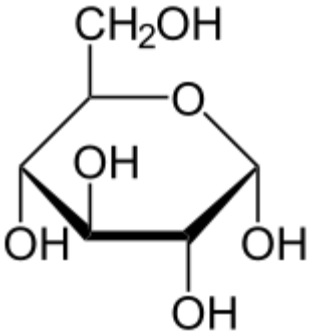
Important Monosaccharides



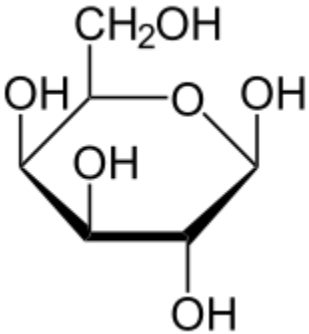
β-ribose



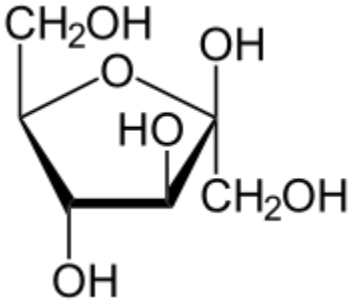
β-deoxyribose



β-glucose



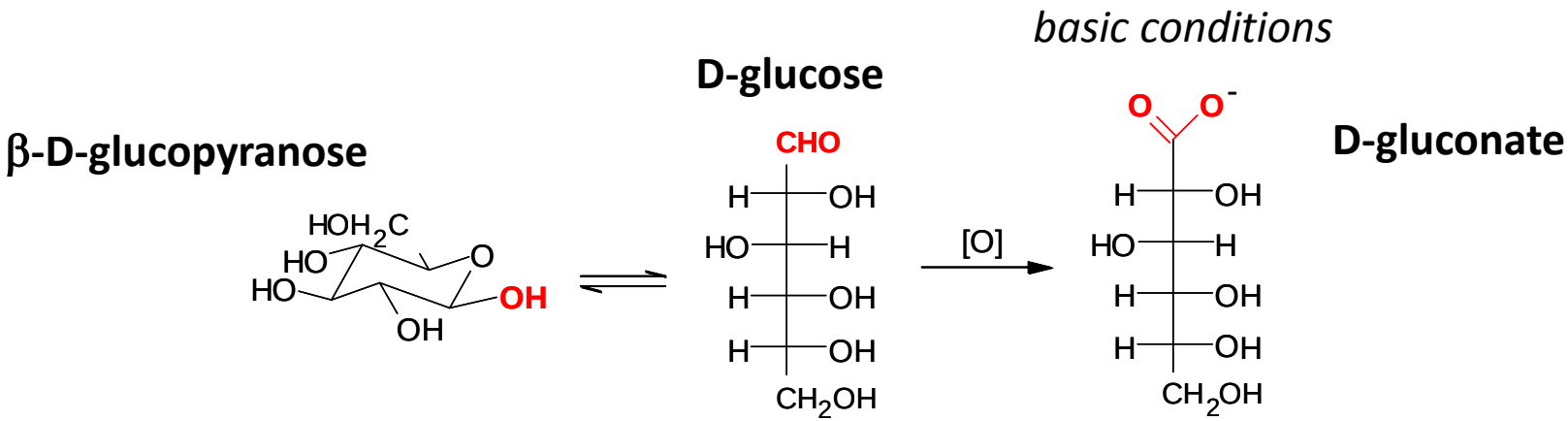
β-galactose



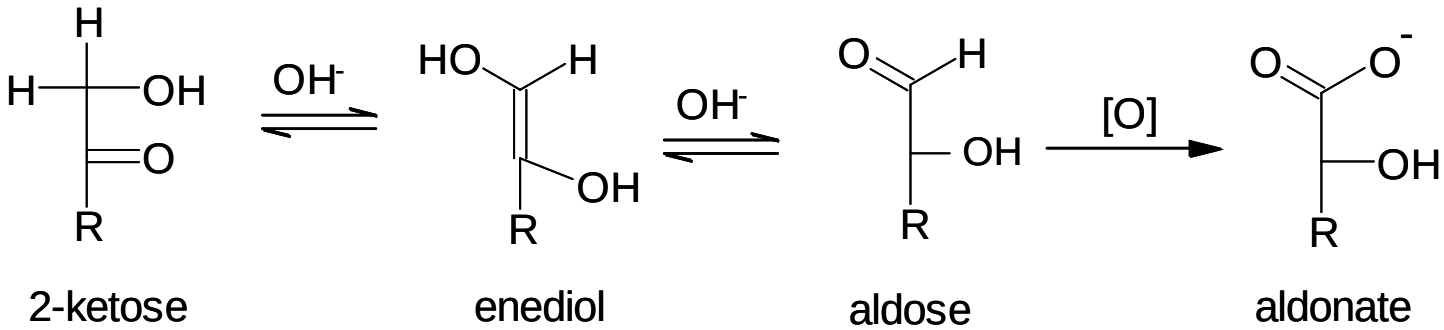
β-fructose

Oxidation

<u>reducing sugar</u>: carbohydrate that reacts with an oxidizing agent



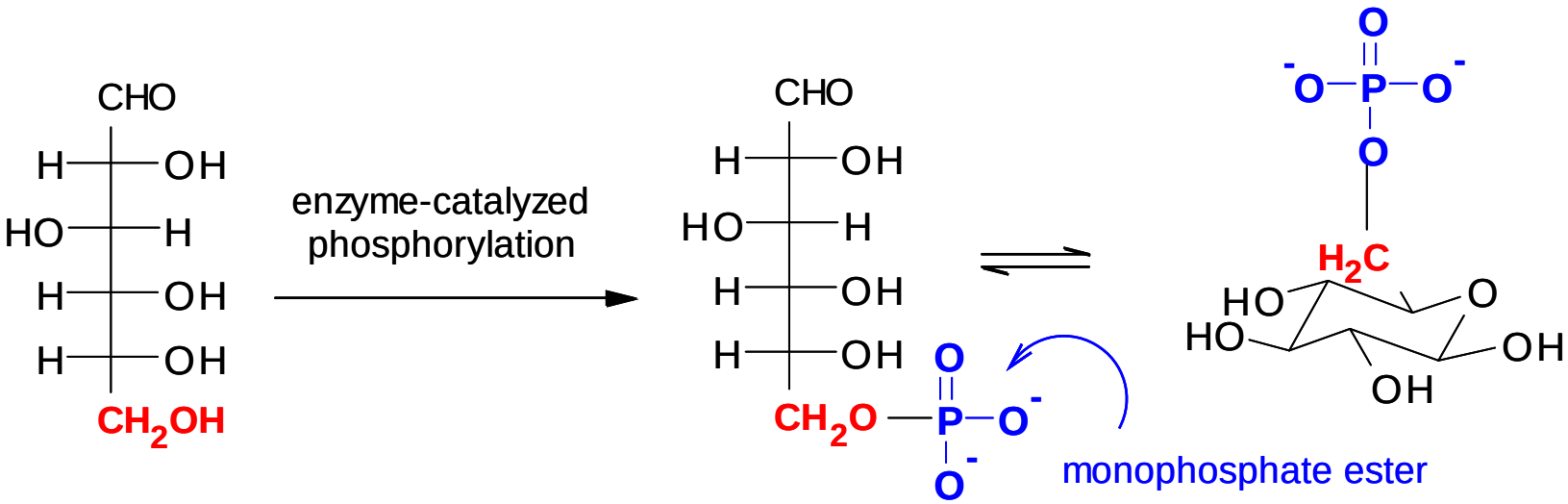
2-ketoses are also reducing sugars.



Formation of Phosphate Esters

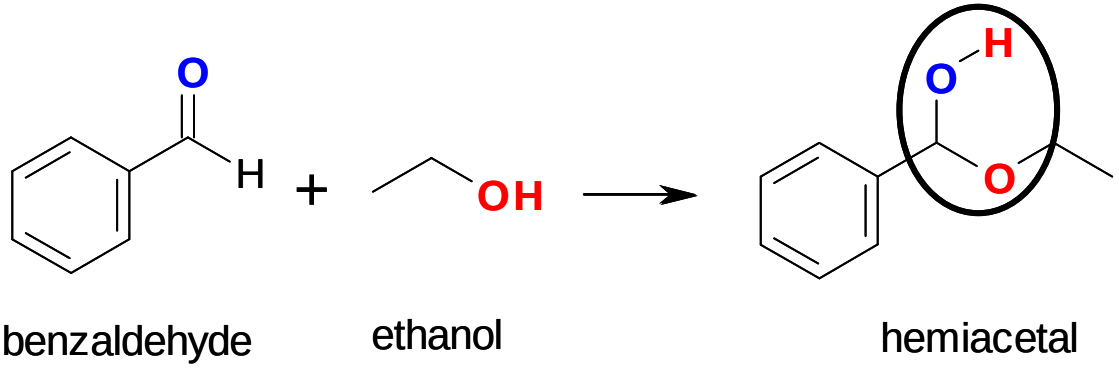
Mono- and diphosphoric esters serve as intermediates in the metabolism of monosaccharides.

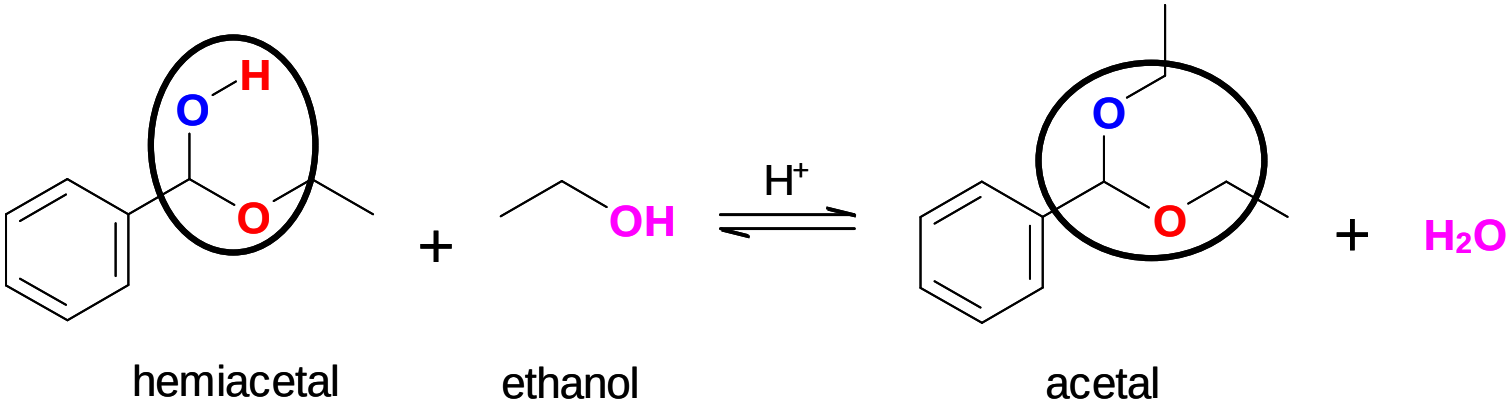
<u>phosphorylation</u>: addition of a phosphate ester



Formation of Acetals

Recall: aldehyde or ketone + alcohol → hemiacetal

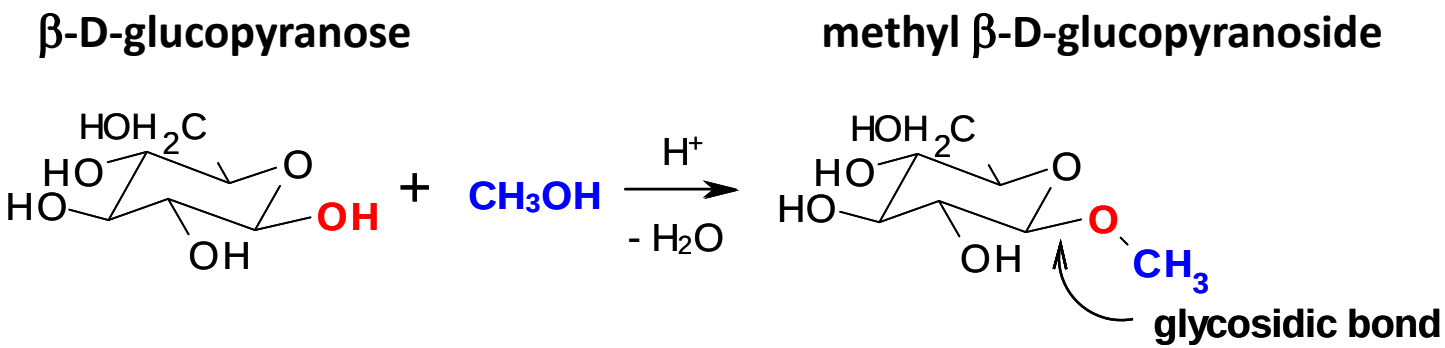




Glycosides

Addition of an alcohol to a monosaccharide in acidic conditions will form a *glycoside.*

<u>glycoside</u>: cyclic acetal derived from a monosaccharide

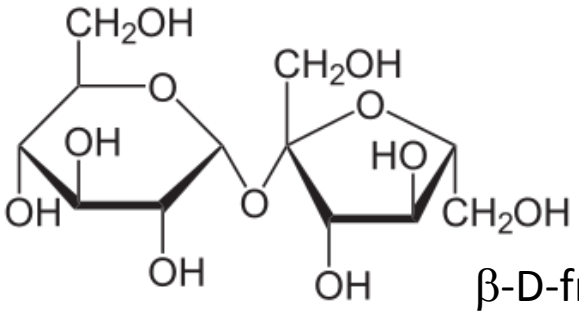


<u>glycosidic bond:</u> bond between the anomeric carbon and the new –OR group formed during the conversion to an acetal

Disaccharides

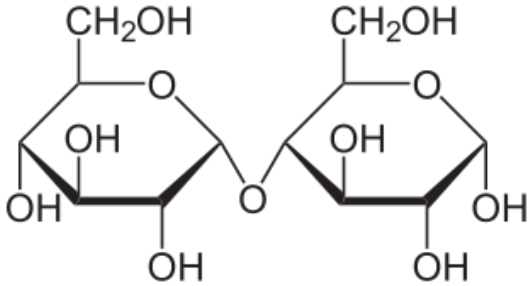
<u>disaccharide</u>: two sugar units linked through a glycosidic bond

α-D-glucose



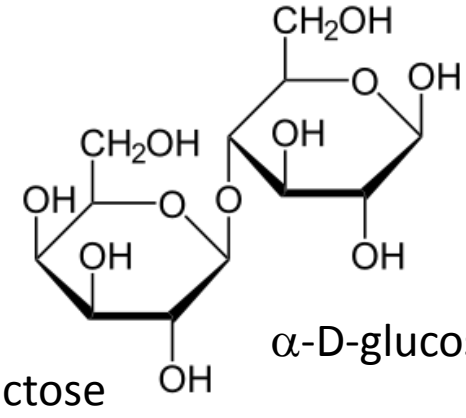
β-D-fructose

sucrose: α(1→2) glycosidic bond



α-D-glucose α-D-glucose

maltose: α(1→4) glycosidic bond

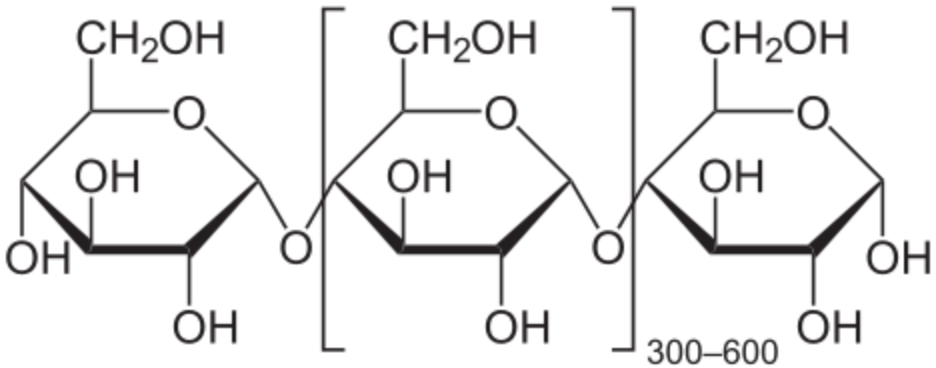


lactose: β(1→4) glycosidic bond

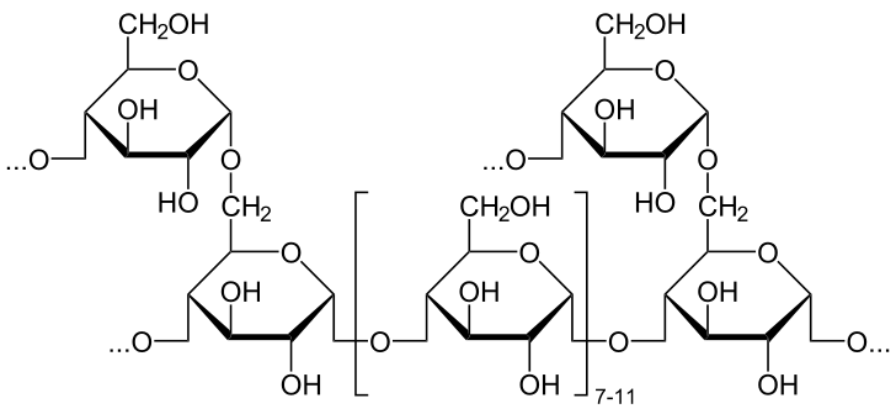
α-D-glucose

β-D-galactose

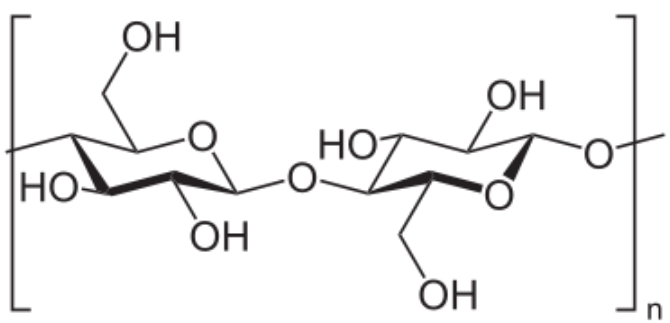
Polysaccharides



starch: polymer of D-glucose units connected with $\alpha(1\rightarrow4)$ linkages



glycogen: polymer of D-glucose units connected with $\alpha(1\rightarrow4)$ and $\alpha(1\rightarrow6)$ linkages



cellulose: polymer of D-glucose units connected with $\beta(1\rightarrow4)$ linkages