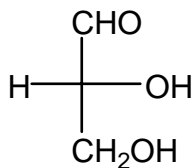


The R,S system was adopted for sugars and, by coincidence, the D-isomer was determined to have the R-configuration as drawn by Fischer!

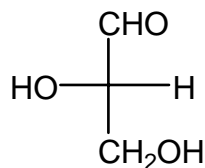
(R)-glyceraldehyde



$$[\alpha]_D^{25} = +13.5^\circ$$

dextrorotatory isomer

(S)-glyceraldehyde



$$[\alpha]_D^{25} = -13.5^\circ$$

levorotatory isomer

D-glyceraldehyde

L-glyceraldehyde

Now glyceraldehyde serves as a reference for all other carbohydrates:

The penultimate carbon is the highest numbered carbon (using conventional rules for nomenclature).

The penultimate carbon is the stereocenter lowest on the backbone.

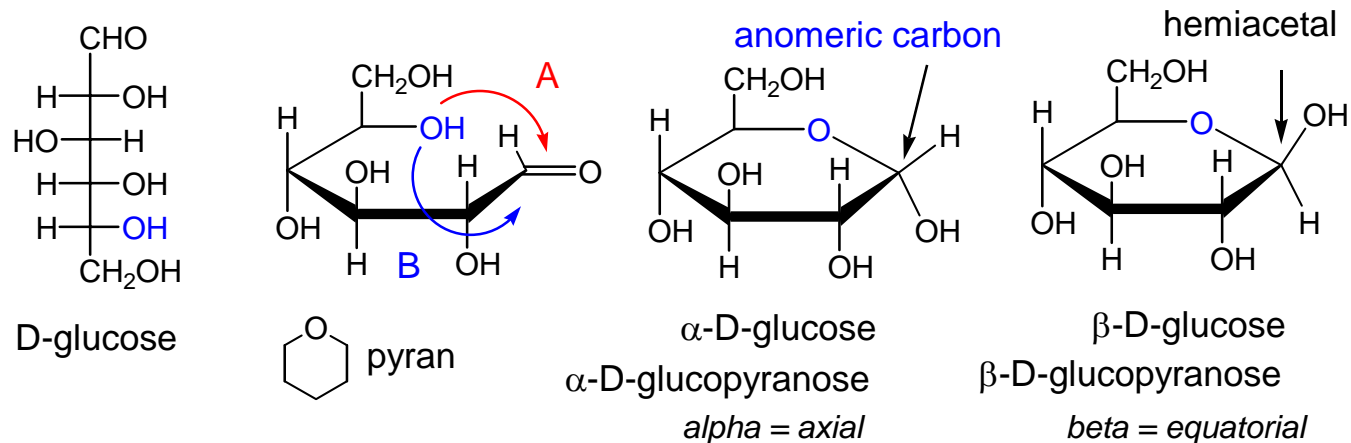
- At the penultimate carbon, all D-sugars have the OH group on the right; the same configuration as D-glyceraldehyde.
- There is no correlation between D and L with R and S!
- A sugar with R configuration at the penultimate carbon may rotate P-P light to the right or the left; i.e., it may be a D or an L sugar.

The most abundant monosaccharide is D-glucose.

Recall: aldehydes + alcohol → hemiacetal

Glucose cyclizes into a hemiacetal using the penultimate OH group as the alcohol.

The result is a cyclic hemiacetal. These structures are called Haworth formulas.

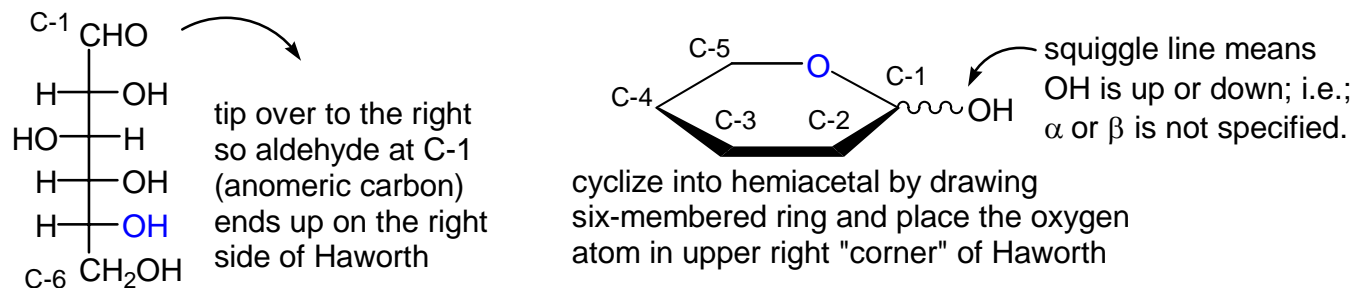


Stereoisomers that differ in configuration at the anomeric center are called anomers.

The anomeric carbon of aldoses is C-1 and the anomeric carbon of ketoses is C-2

α -D-glucose and β -D-glucose are anomers.

Conversion of Fischer projection into Haworth formula and then into chair.

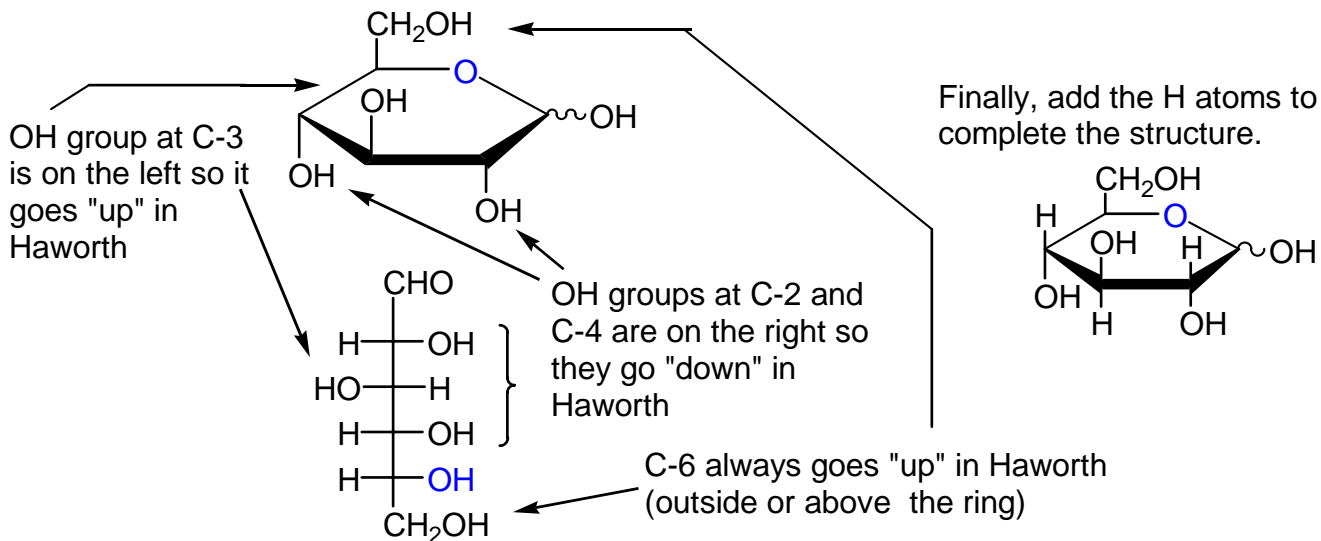


Now add the OH and H atoms on the ring.

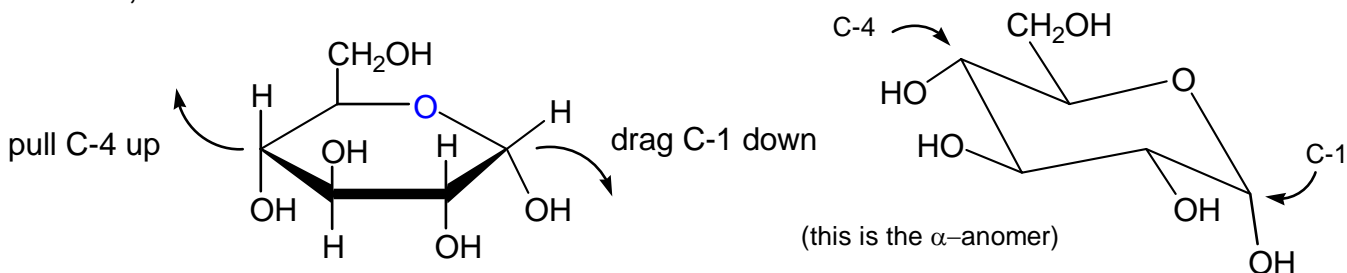
If the OH is on the right side of Fischer then it ends up "down" in Haworth.

Only consider OH at C-2, C-3 and C-4; the OH group at C-5 is part of the acetal.

The C-6 carbon (CH_2OH group) is always drawn "up" in Haworth.

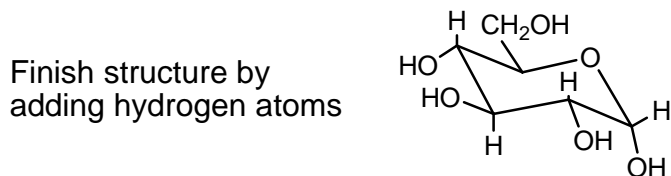


To form chair, move "end" carbons:



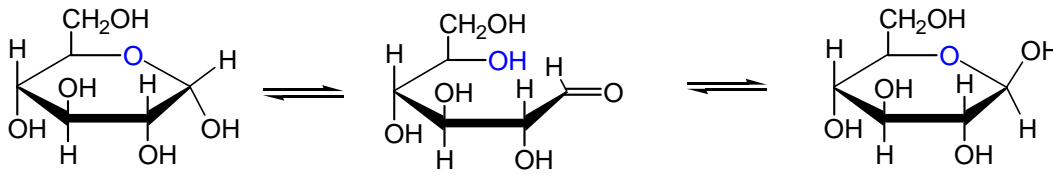
Notice that OH groups (and CH_2OH group at C-6) are all equatorial positions.

OH group at C-1 is axial in the α -D-glucopyranose and equatorial in β -anomer.



Mutarotation- equilibration between α and β hemiacetals.

mutarotation shown for glucose

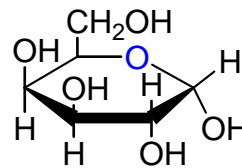
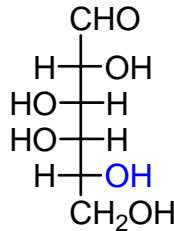


The hemiacetals are in equilibrium with open-chain aldehyde.

Galactose- one more important monosaccharide.

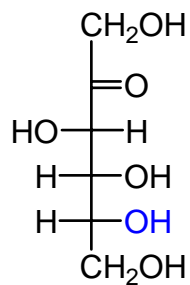
D-galactose

Similar to glucose except for configuration at C-4



α -D-galactose

Fructose is another abundant monosaccharide- it is a ketohexose.



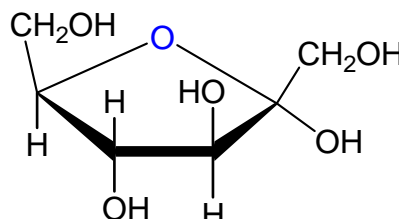
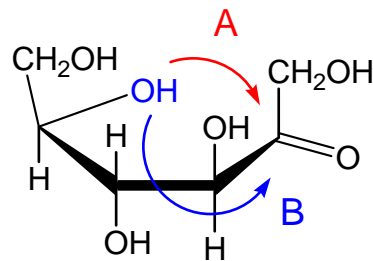
D-fructose

cyclic hemiacetal formation gives a furanose



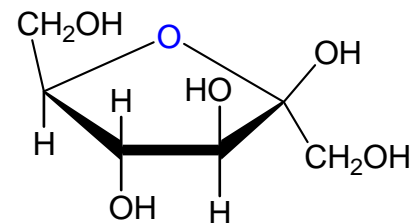
furan

furanose hemiacetals exists as anomers



α -D-fructose

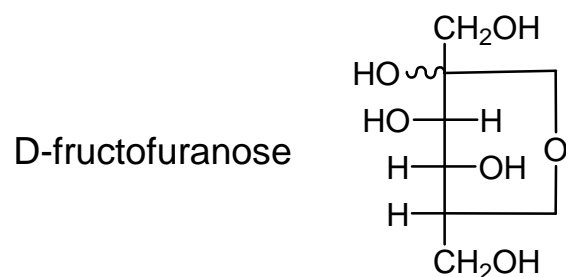
α -D-fructofuranose



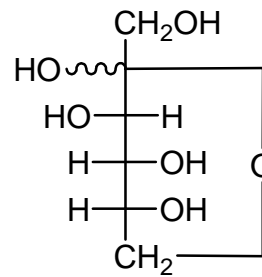
β -D-fructose

β -D-fructofuranose

Fructose also exists in the pyranose form- cyclization of OH group at C-5.



D-fructofuranose

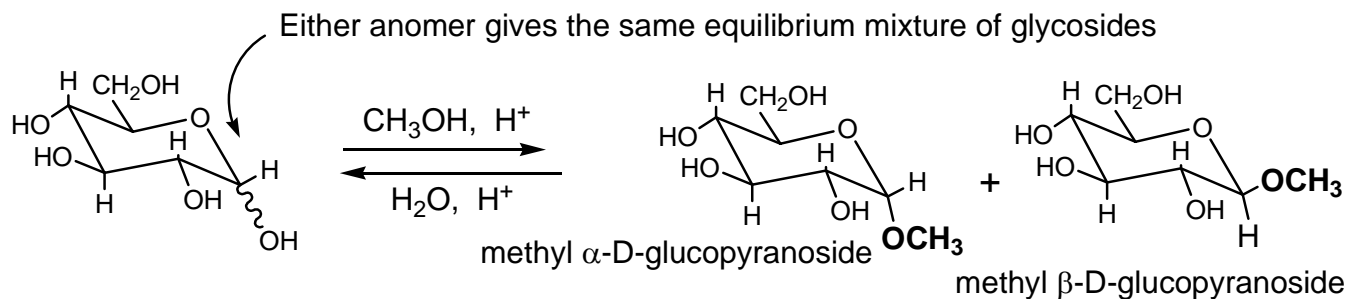


D-fructopyranose

Glycosides- cyclic acetals

Treatment of monosaccharide with alcohol gives cyclic acetal.

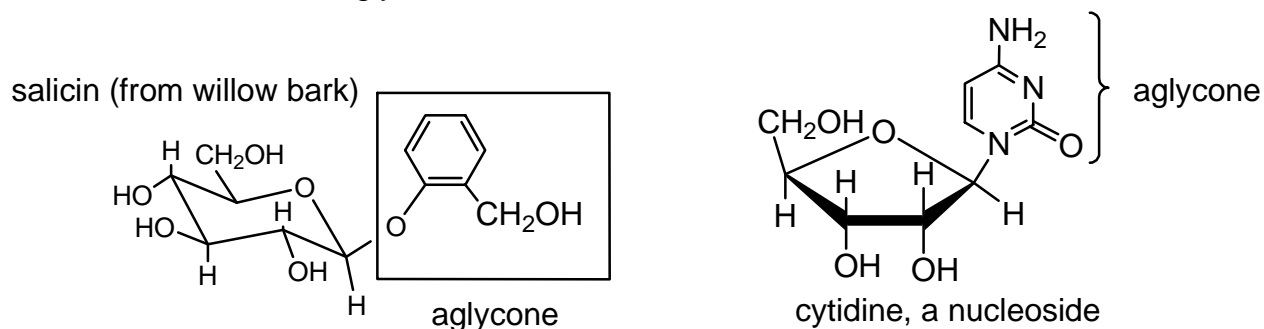
Monosaccharides exist mostly in hemiacetal form; conversion to acetal occurs easily:



“ose” suffix- hemiacetal (may be open-chain aldehyde or ketone)

“oside” suffix- acetal

An aglycone is the group bonded to the anomeric carbon atom of a glycoside; in the example above, methanol is the aglycone.



Mutarotation is not possible since acetals are not in equilibrium with open-chain form. Glycosides are stable in base like any acetal but easily hydrolyze in acid.

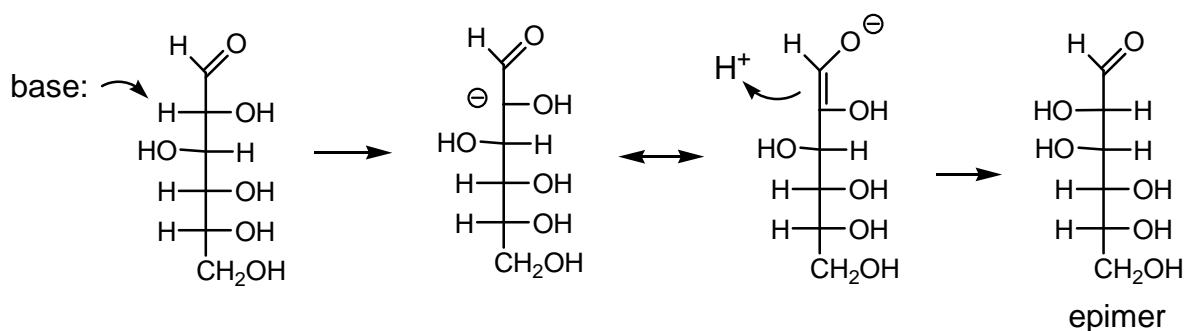
Reactions of monosaccharides

1. Epimerization and isomerization in base- mostly useless
2. Reduction of aldehydes and ketones- alditols
3. Oxidation-aldonic acids and aldaric acids
4. Formation of ethers and esters
5. Reactions with phenylhydrazine- osazones
6. Chain-shortening- Ruff degradation
7. Chain-lengthening- Kiliani-Fischer synthesis

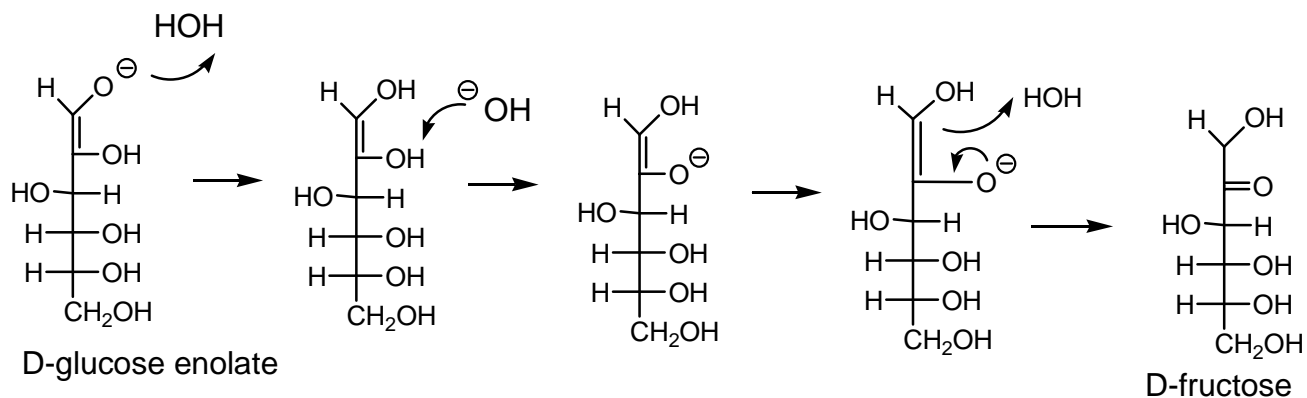
1. Reactions with base- epimerization and isomerization

Base removes the alpha proton.

This is a reversible step and epimerization will occur:



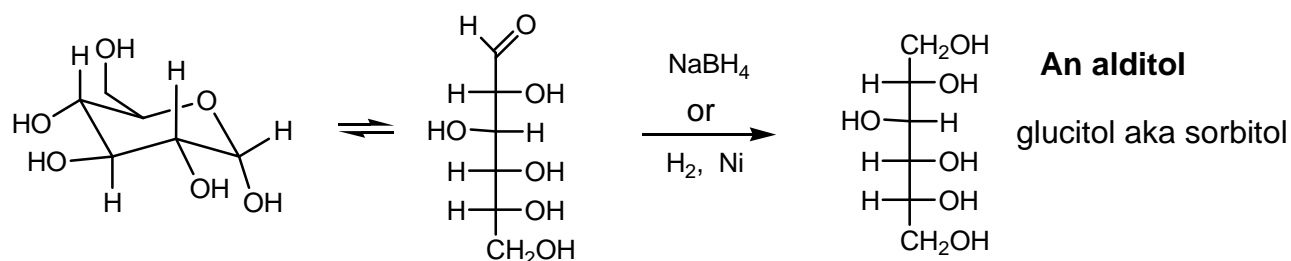
Deprotonation forms the enolate which may also undergo a rearrangement:



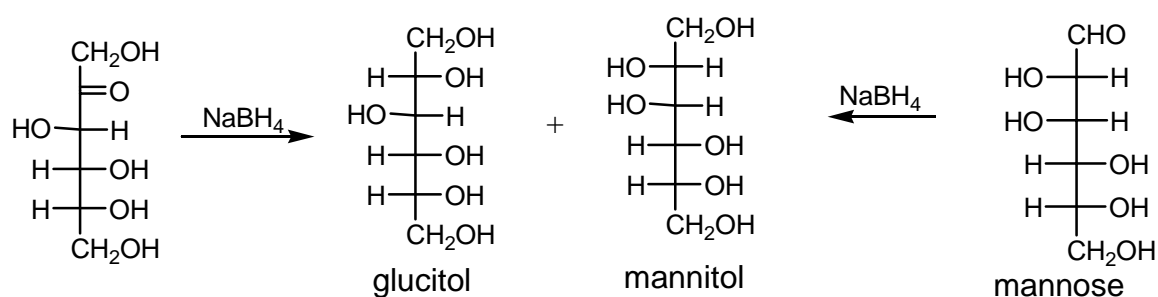
This is called the enediol rearrangement.

2. Reduction of aldehydes and ketones- alditols

Reduction of an aldose:

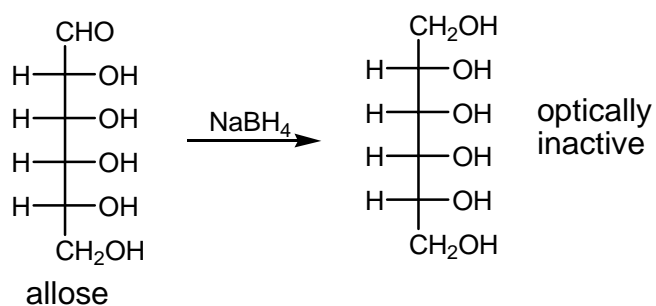


Reduction of a ketose gives epimers at C-2:



Notice that mannose and fructose provide mannitol.

Reduction may disclose latent remaining symmetry- reduction of allose gives an optically inactive alditol:

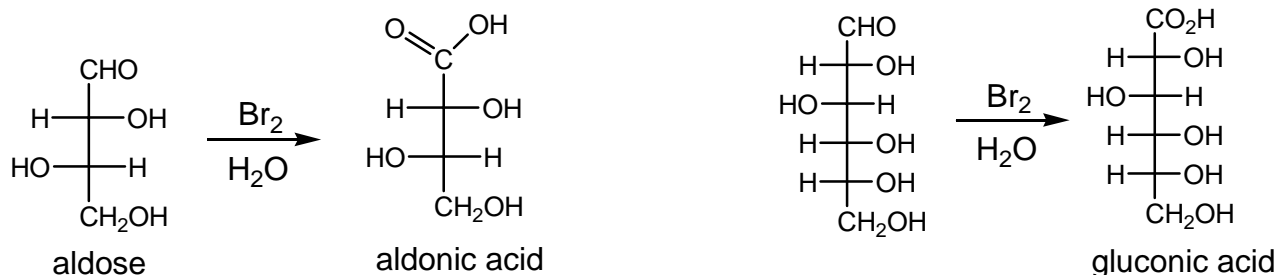


3. Oxidation-aldonic acids and aldaric acids

Two sites of oxidation:

Aldehyde
terminal CH₂OH group

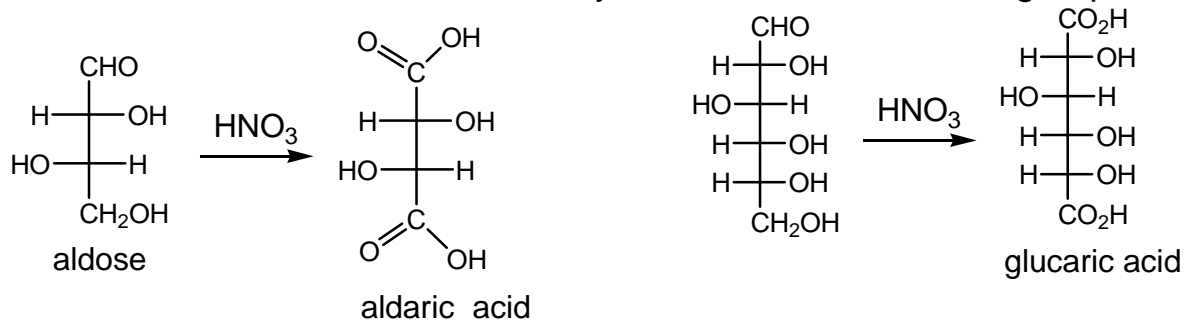
- Bromine water oxidizes aldoses:



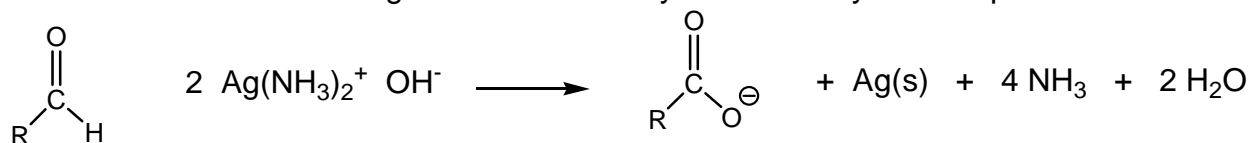
Bromine water

- ✓ does not oxidize ketoses
- ✓ does not oxidize other CH₂OH groups
- ✓ does not cause epimerization or rearrangement of carbonyl group.

- Nitric acid oxidizes both aldehyde and terminal CH₂OH group.



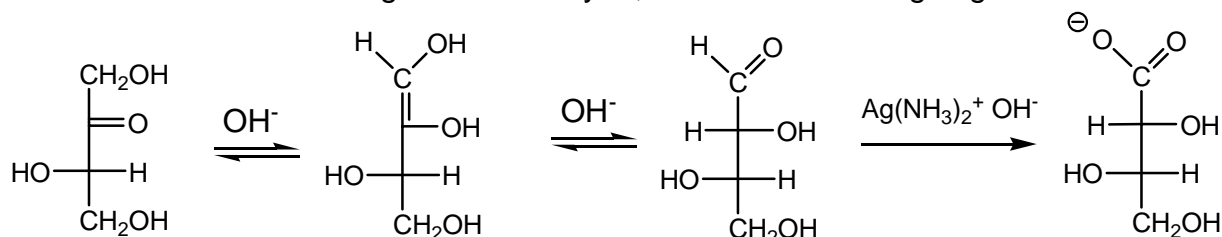
Tollen's Test- Tollen's reagent oxidizes aldehyde to carboxylate and produces metallic silver.



Due to the basic conditions cause epimerization and enediol rearrangements.

Sugars that reduce Tollen's reagent are called **reducing sugars**.

Since a ketose will rearrange to an aldehyde, it is also a reducing sugar.

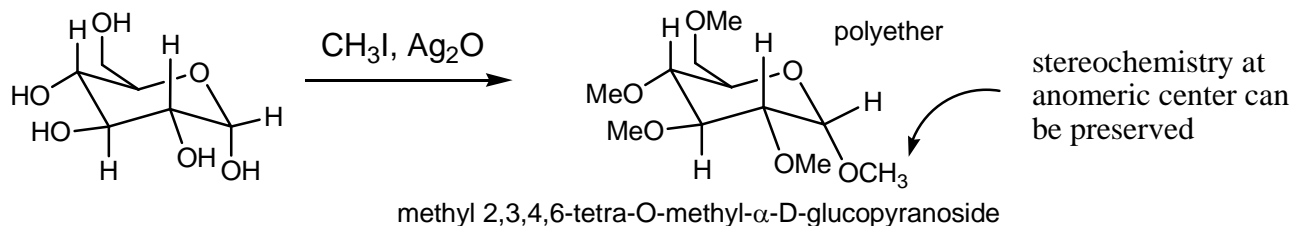


Glycosides are acetals and are **non-reducing sugars**. Acetals are not in equilibrium with open-chain carbonyl.

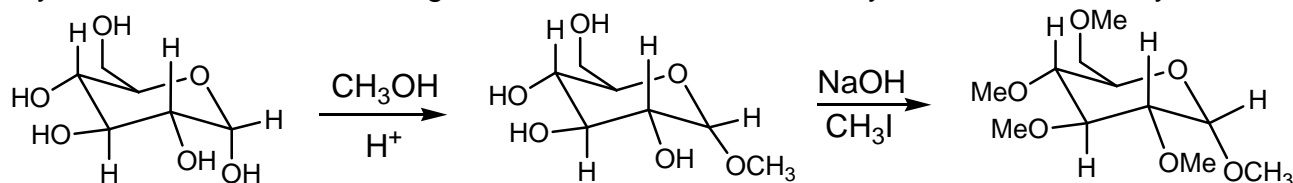
4. Formation of ethers and esters

Hydroxy groups can be alkylated using CH_3I and silver oxide.

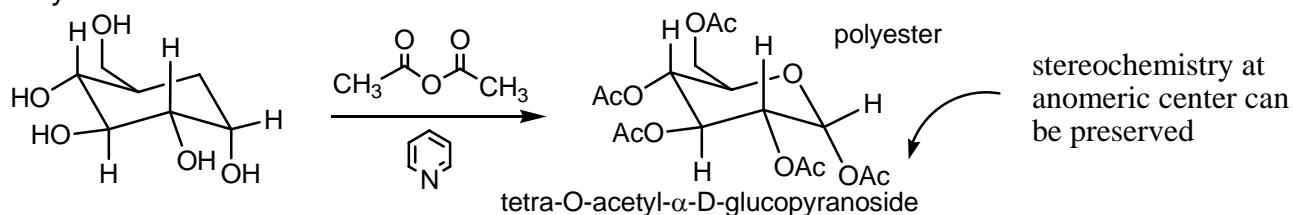
Silver oxide polarizes the C-Iodine bond and makes a strong electrophile:



Glycoside can be formed using methanol and acid followed by Williamson ether synthesis:



Polyesters can be formed also:



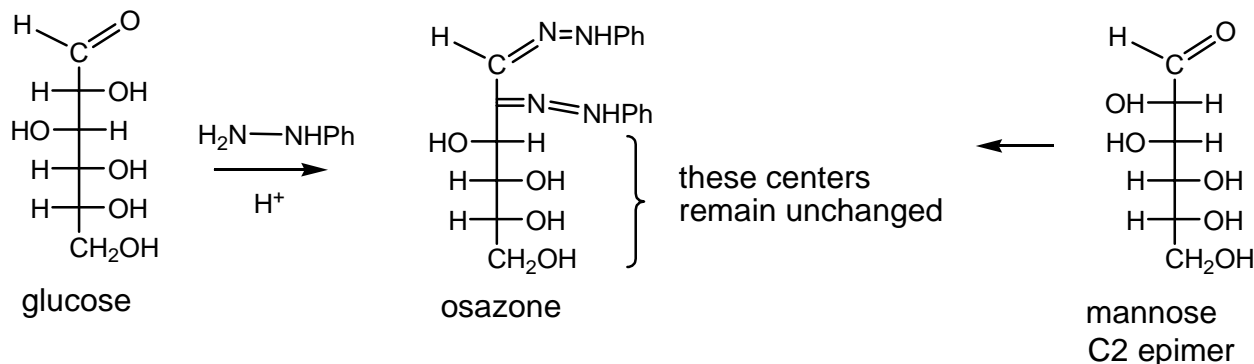
Polyether and polyester derivatives are easier to crystallize from water.

5. Reactions with phenylhydrazine- osazones

Sugars condense with two molecules of phenylhydrazine to give osazones.

These are nice solids with sharp melting points.

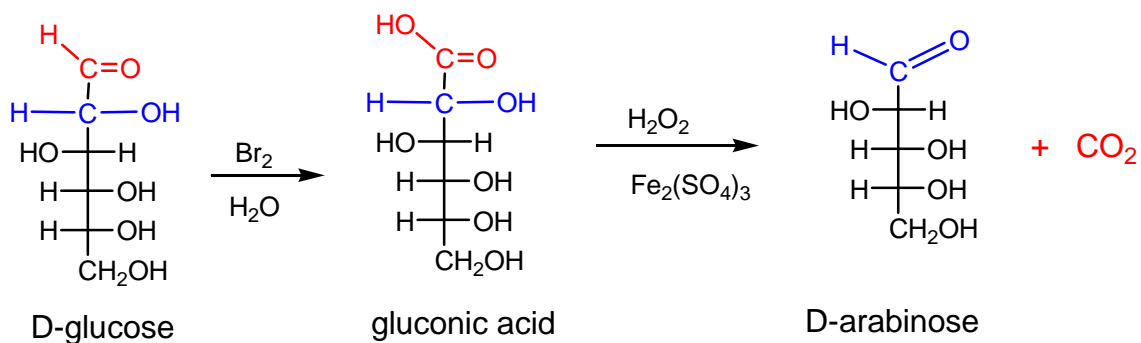
Both C1 and C2 are converted to hydrazones:



Both aldoses and ketoses form osazones and the C2 stereochemistry is lost.

C2 epimers give the same osazone (see glucose and mannose above).

6. Chain-shortening- Ruff degradation



7. Chain-lengthening- Kiliani-Fischer synthesis

