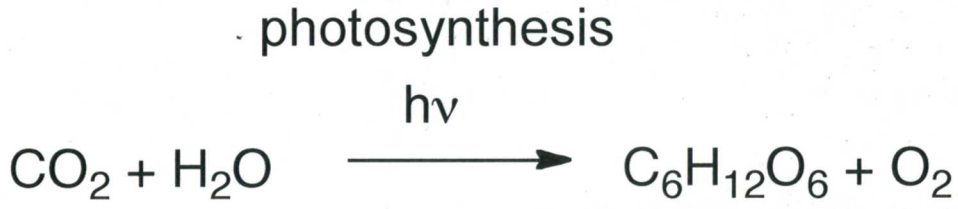
Carbohydrates (also known as sugars or saccahrides)

carbon + water : approximate formula $C_nH_{2n}O_n$

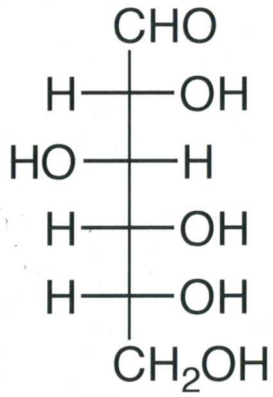
$4x10^{11}$ metric tons of carbon dioxide are converted to glucose annually by plants

glucose (in bound form) is the most abundant organic compound

0.02% of the sun's energy incident on this planet used for:



Carbohydrates occur in every living organism



Glucose (also called dextrose)

Carbohydrates - classification

carbon + water : approximate formula $C_nH_{2n}O_n$

triose : 3 carbons

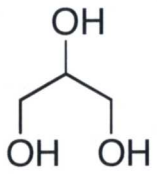
tetrose : 4 carbons

pentose : 5 carbons

hexose : 6 carbons

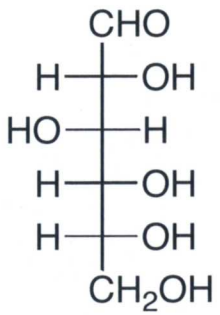
aldose : aldehyde

ketose : ketone

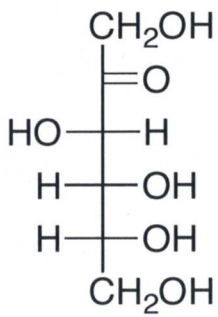


Glycerol

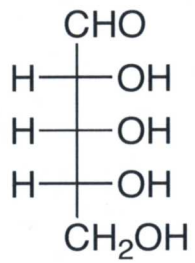
(a triose)



Glucose
(an aldohexose)



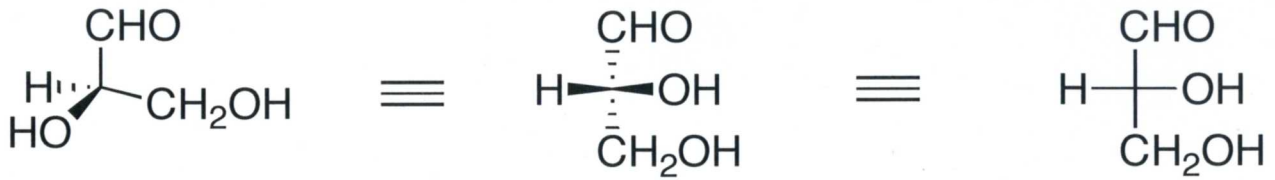
Fructose
(a ketohexose)



Ribose
(an aldopentose)

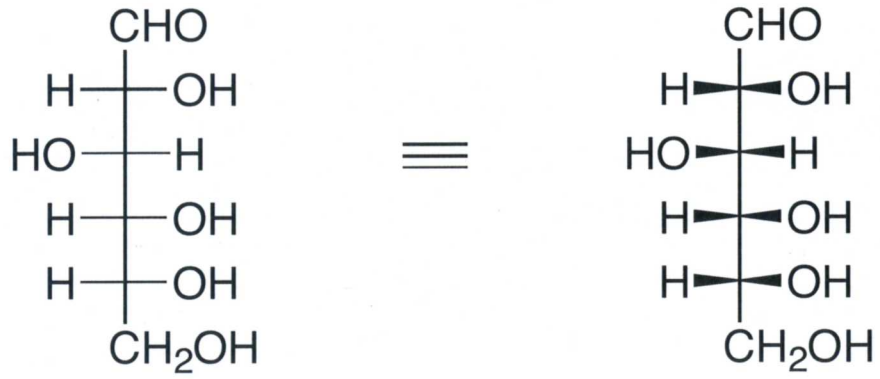
Carbohydrates - Configuration & Fischer Projections

Fischer projection is represented by two crossed lines:
horizontal lines represents bonds coming out toward you



(R)-glyceraldehyde

Fischer projection of
(R)-glyceraldehyde

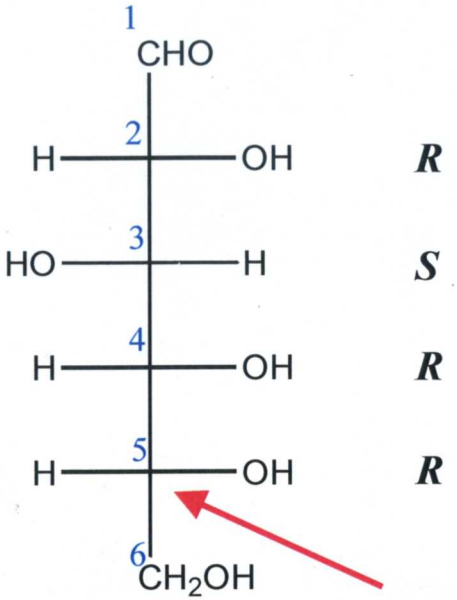


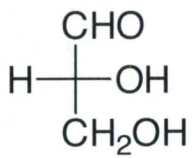
Fischer projection of
Glucose

Carbohydrates - D & L Sugars

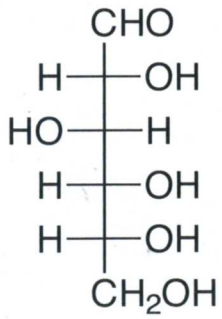
D-sugar is defined as one that has R configuration at the highest numbered stereogenic center

L-sugar is defined as one that has S configuration at the highest numbered stereogenic center

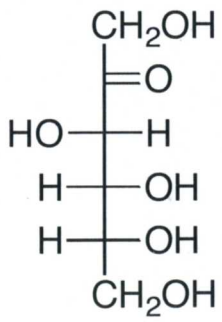




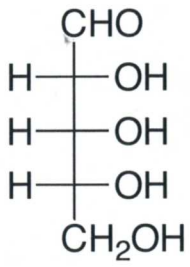
D-Glyceraldehyde



D-Glucose



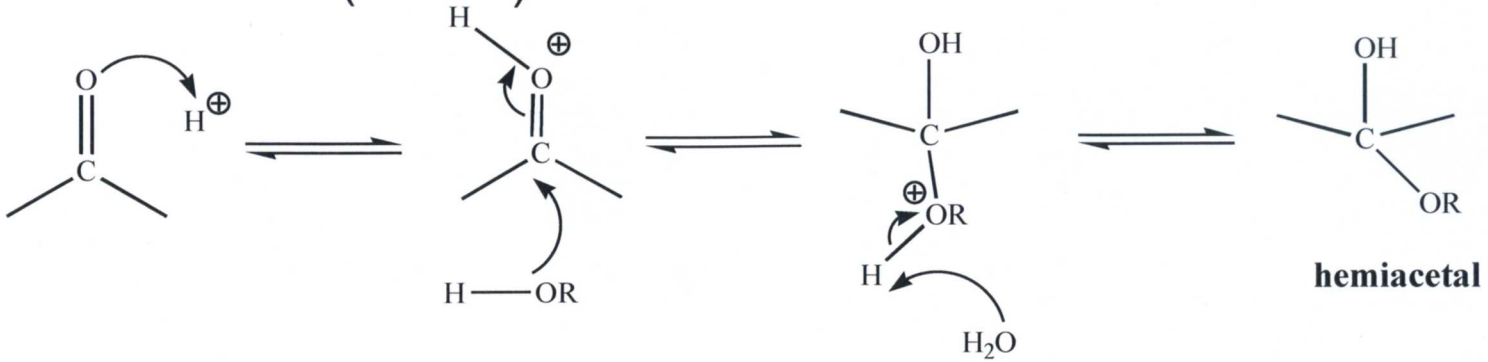
D-Fructose



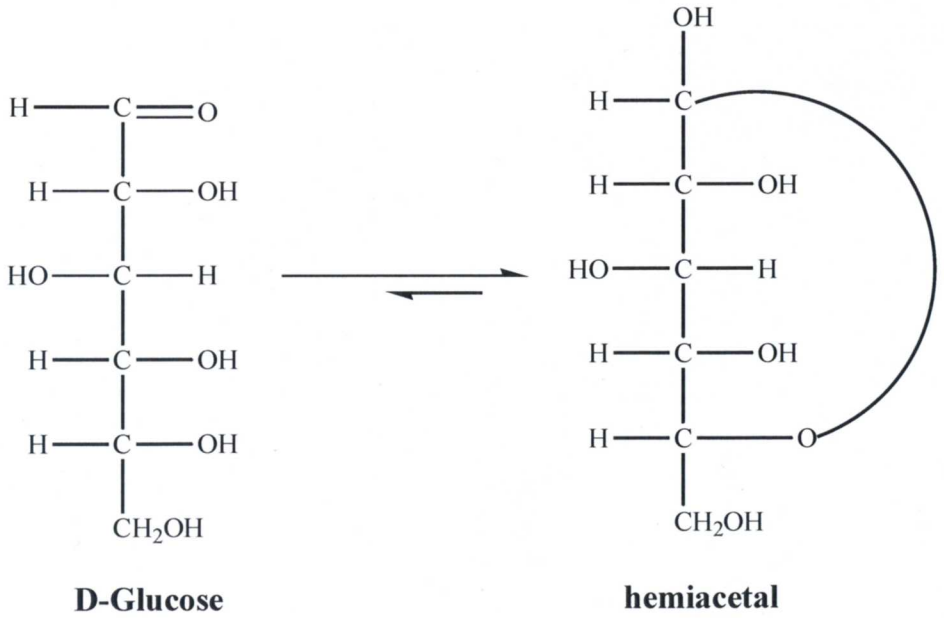
D-Ribose

Carbohydrates - Hemiacetal Formation

mechanism (review):

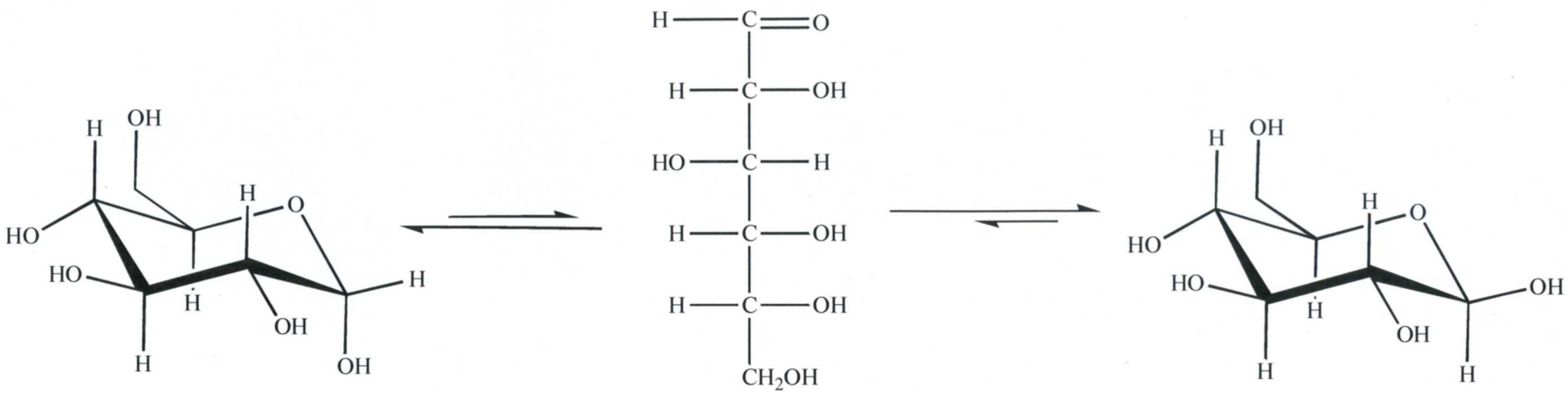


In nature, formation of 5- and 6-member rings is favored, a molecule will form such a ring when it can



D-Glucose **hemiacetal**

Carbohydrates - Hemiacetal Formation



α-D-Glucopyranose **D-Glucose** **β-D-Glucopyranose**

6-membered rings exist in energy minimum chair forms

6-membered sugar rings are called pyranoses

5-membered sugar rings are called furanoses

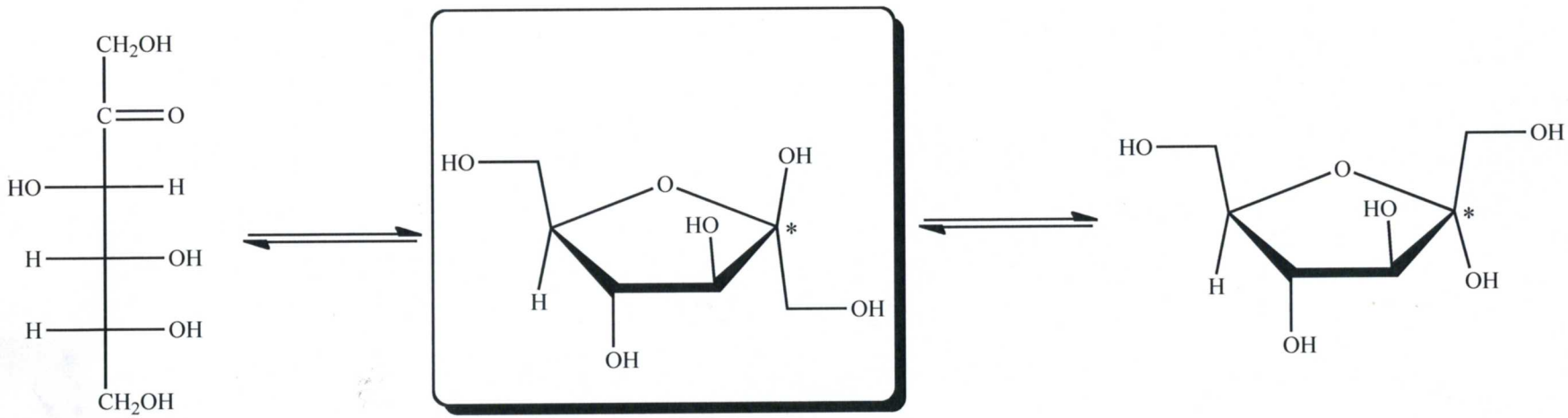
The intramolecular cyclization reaction creates a new stereogenic carbon with either R or S configuration, with OH group in either equatorial or axial position

term ***α*** used if OH at C1 is opposite side to CH_2OH group of C6
term ***β*** used if OH at C1 is sames side to CH_2OH group of C6

Carbohydrates - Hemiacetal Formation

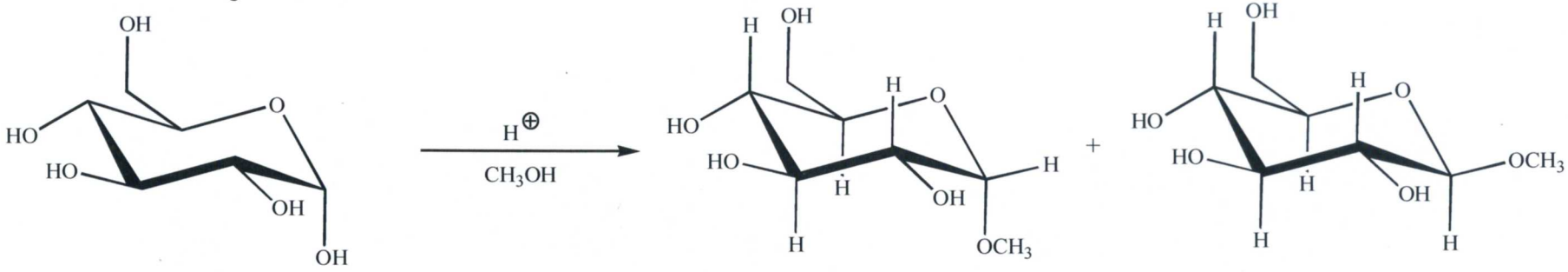
The two stereoisomers are interconverting structural isomers called **anomers**. Differ only in stereochemistry at C1 position: known as the **anomeric carbon**

Formation of 5-member ring is possible for D-Glucose, but it exists predominantly as 6-membered ring.
Fructose, on the other hand, exists predominantly as 5-member ring (furanose)



D-Fructose **β-D-Fructofuranose** **α-D-Fructofuranose**

Carbohydrates - Acetal Formation



α-D-Glucopyranose

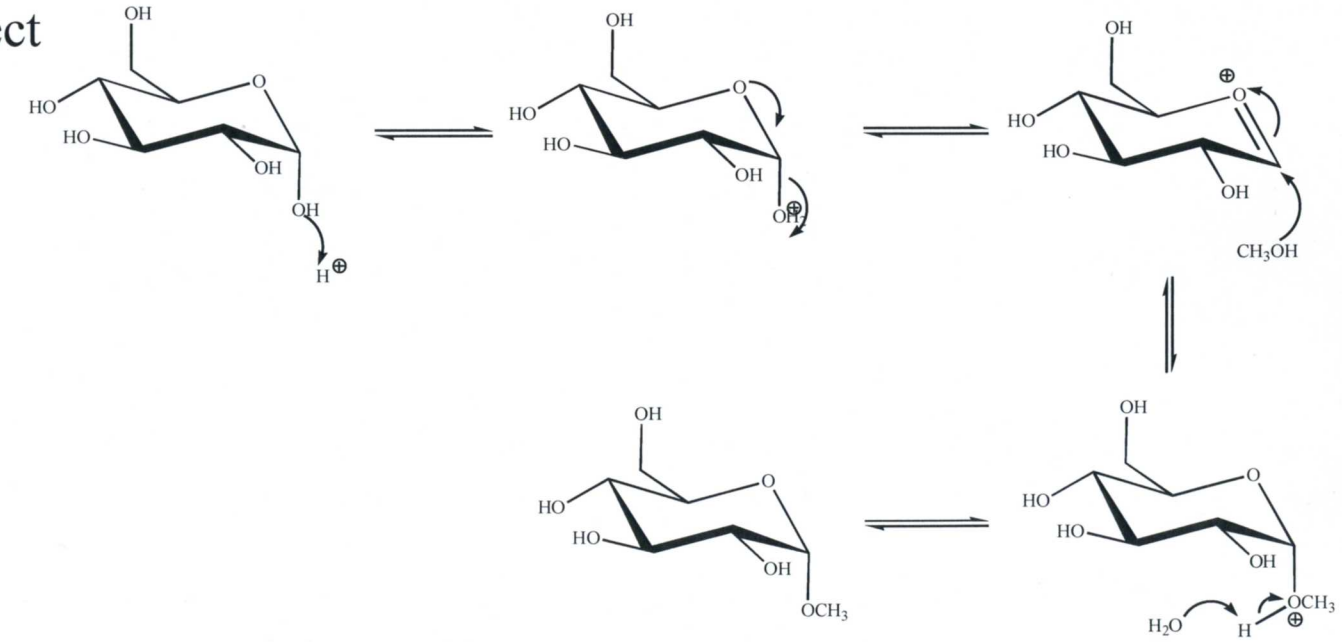
α-D-Glucopyranoside (favored)

β-D-Glucopyranoside (minor)

Treatment with dilute acid & alcohol converts only the OH at the anomeric position into an acetal called a glycoside

The *α* anomer with the methoxy group in axial position is favored due to the anomeric effect

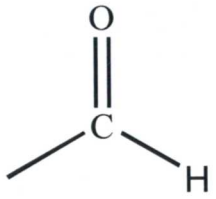
mechanism



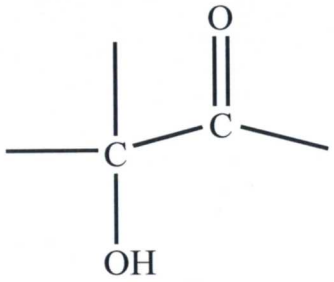
Reducing or non-reducing sugars

Silver nitrate in aqueous ammonia is allowed to react with sugar.
If a silver mirror is observed, then the sugar is reducing

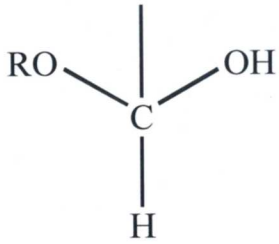
Structural motifs for reducing sugars: (others, e.g. acetal are non-reducing)



aldehyde

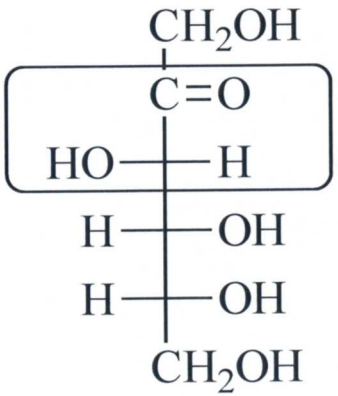


α-hydroxyketone



hemiacetal

Example:



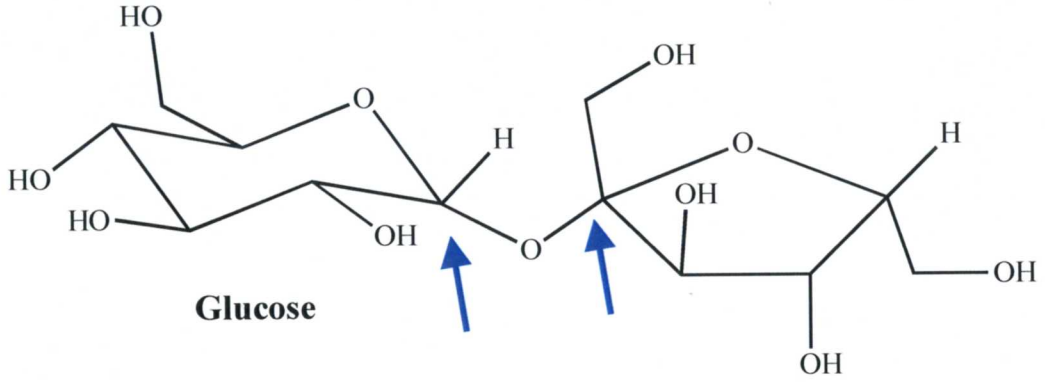
D-Fructose

D-fructose is sweetest of sugars and is a reducing sugar

sweetness index 180

Reducing or non-reducing sugars - Example

the disaccharide below is sucrose (Table Sugar)



sweetness index 100

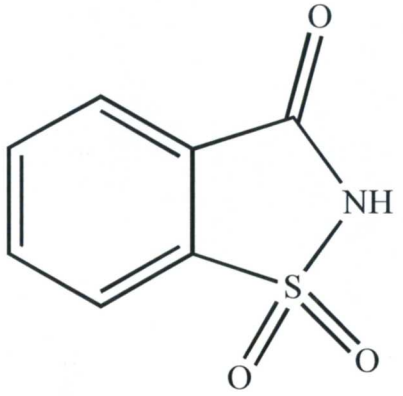
Is it a reducing or non-reducing sugar ? Non-reducing

Identify the anomeric carbons -see arrows

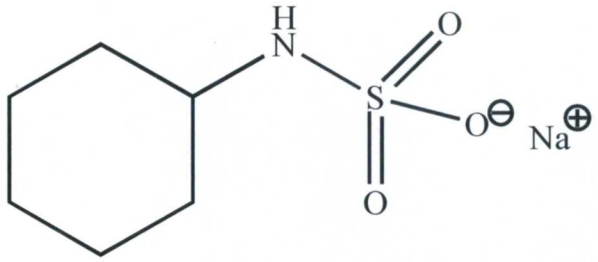
Are they acetals or hemiacetals? Acetals

α-D-glucopyranosyl-β-D-fructofuranoside

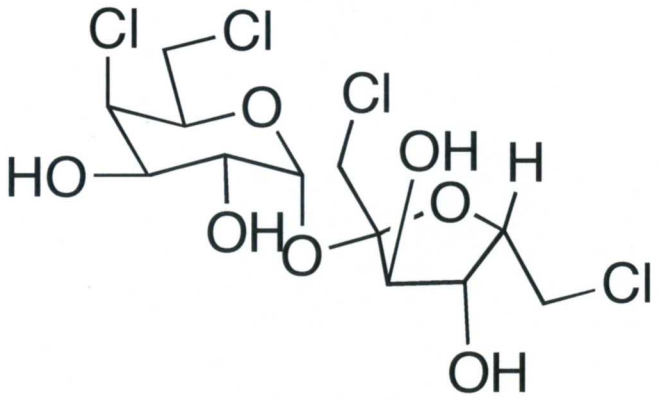
Artificial sweeteners - Examples



saccharin



sodium cyclamate

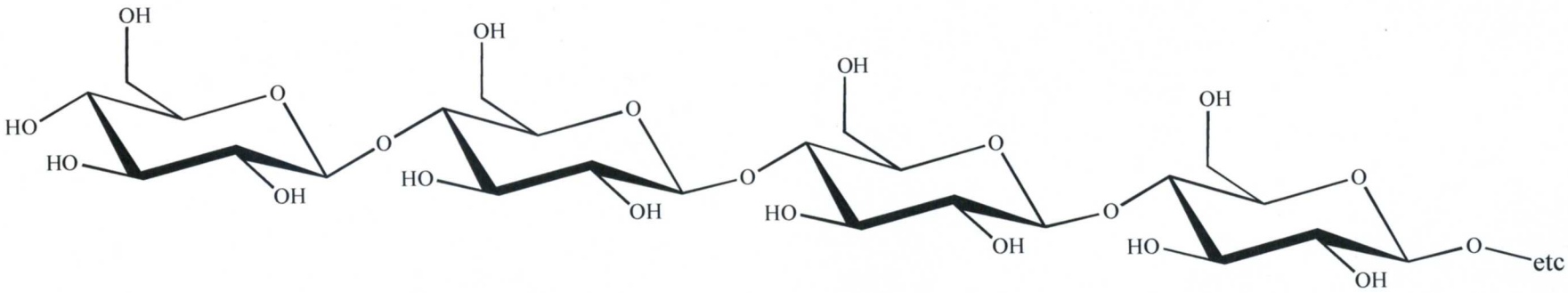


Splenda (sucralose)

Polysaccharides = polymers of sugars

Disaccharides = 2 sugars linked
Trisaccharides = 3 sugars linked
Tetrasaccharides = 4 sugars linked
Oligosaccarides - many sugars linked

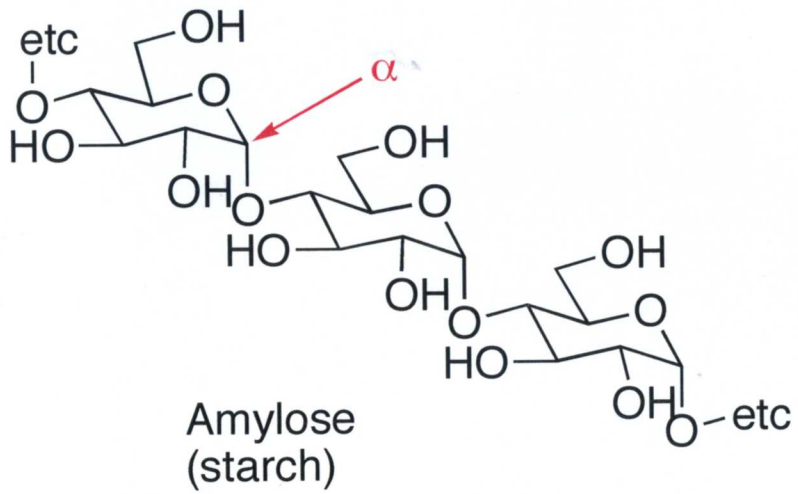
Example: Cellulose



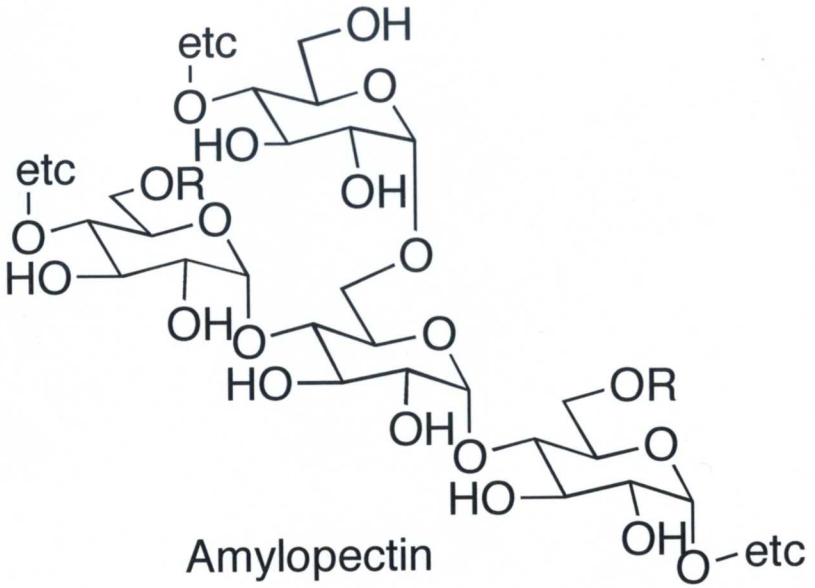
Cellulose is a polymer of simple repeating monosaccharide units (D-glucose).

most mammals cannot digest cellulose directly.
ruminants such as cows or goats have bacteria in their stomach to break it down.
bacteria have a cellulose hydrolysis enzyme called cellulase
humans cannot metabolize β linkages

Example: Amylose & Amylopectin (starch - 20% is amylose)



Amylose
(starch)



Amylopectin

Amylopectin is the other component in starch (~ 80%), which is similar to glycogen