

CARBOHYDRATES

pektin



cellulose



Polysaccharides



fructose



starch



sucrose

CARBOHYDRATES

- Carbohydrates are one of the main classes of nutrients.
- They occur in foods such as sugars and starches.
- Sugars are produced in plants from CO₂ and H₂O



Photosynthesis/ Respiration

- **Function of carbohydrates:** Storage material for carbon and energy.
- **Carbohydrates** are polyhydroxy aldehydes or ketones and their derivatives.

C₆ (H₂O)₆ monosaccharide

C₁₂ (H₂O)₁₁disaccharide

C₁₈ (H₂O)₁₆trisaccharide

(C₆H₁₀O₅)_n.....polysaccharide

CLASSIFICATION OF CARBOHYDRATES

CARBOHYDRATES

Monosaccharides (a single polyhydroxy aldehyde or keton unit-3 to 7 C atoms) ●

Pentoses-ribose, arabinose, xylose (5 C atoms)

Hexoses (6 C atoms)

Aldohexoses-glucose, galactose

Ketohexoses-fructose

Oligosaccharides (polymers of 2 to about 10 monosaccharide residues)

Disaccharides

Sucrose, maltose, lactose

Trisaccharides

Raffinose, gentianose, melezitose



Polysaccharides (polymers of more than 10 monosaccharide residues)

Homo-(One kind of monosaccharide unit)

Pentosans-xylan, araban

Hexosans-starch, glycogen, cellulose, inulin

Hetero-(two or more kinds of monosaccharide units)

Pectins, gums, mucilages,...

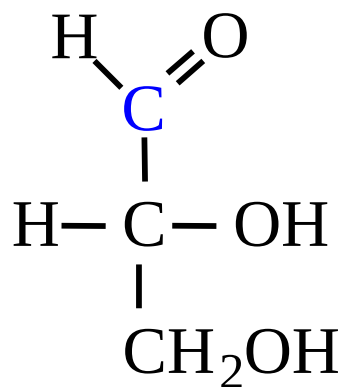
Nitrogen-containing - Chitin

MONOSACCHARIDES

Monosaccharides

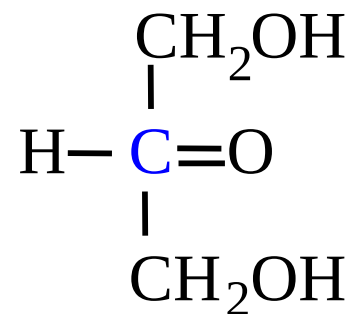
- water-soluble
- white
- crystalline solids
- have a sweet taste

Aldoses, the carbonyl group at the first C atom (C-1)



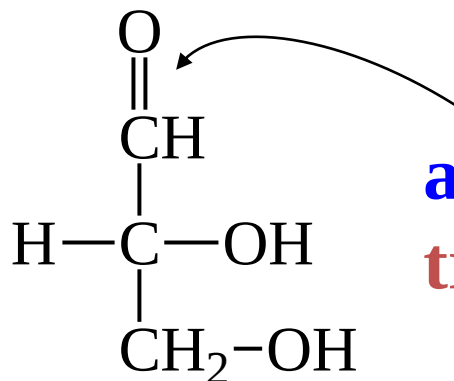
D-glyceraldehyde

Ketoses, the carbonyl group at the subsequent C atom (C-2)



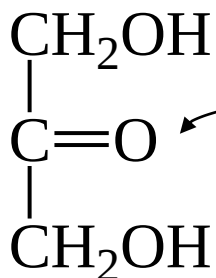
Dihydroxyacetone
no asymmetric C

MONOSACCHARIDES



aldose
triose = **aldotriose**

Glyceraldehyde
(chiral)



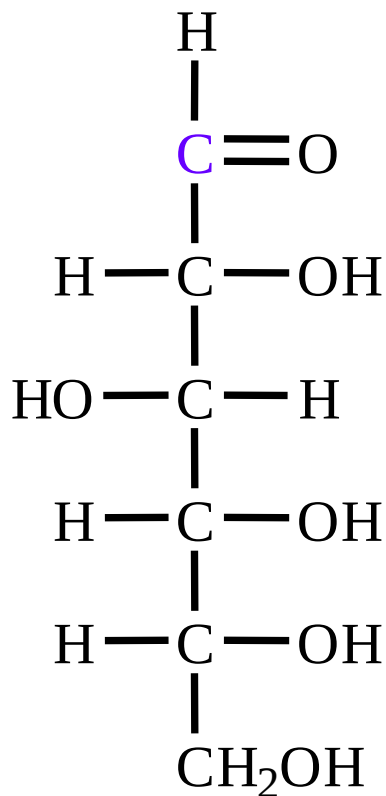
ketose
triose = **ketotriose**

dihydroxyacetone
(achiral)

MONOSACCHARIDES

Aldoses, the carbonyl group at the first C atom (C-1)

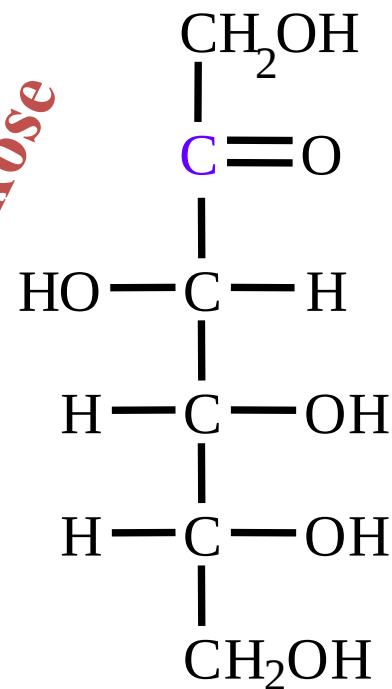
aldose // *aldohexose*
hexose



D-glucose

Ketoses, the carbonyl group at the subsequent C atom (C-2)

ketose // *ketohexose*
hexose



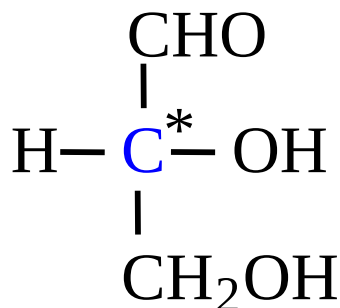
D-fructose

MONOSACCHARIDES

Enantiomers by configuration

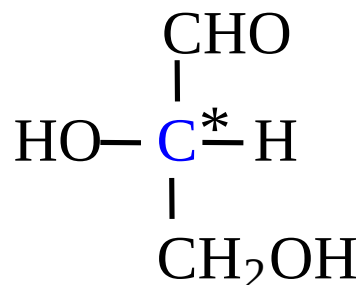
The position of the –OH group at the **highest numbered asymmetric carbon atom** determines D or L character. It is the **farthest from the carbonyl group**.

D-sugars are sweet, L-sugars not sweet



D-glyceraldehyde

(*Hydroxy group* at the highest numbered asymmetric carbon atom is written to the *right*)

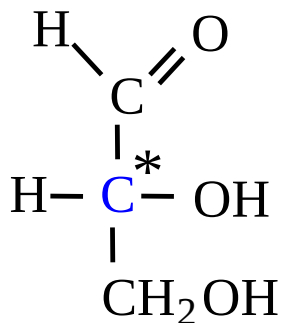


L-glyceraldehyde

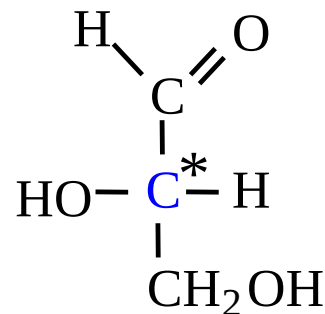
(*Hydroxy group* at the highest numbered asymmetric carbon atom is written to the *left*)

MONOSACCHARIDES

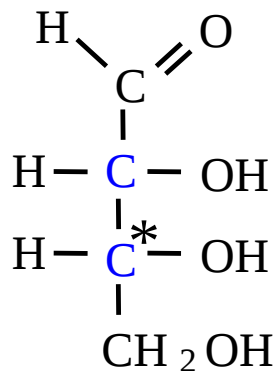
Enantiomers by configuration



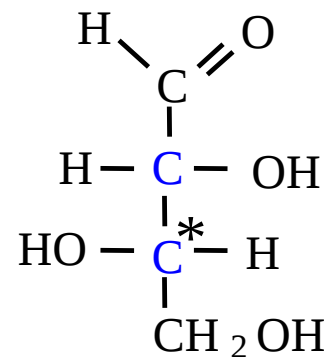
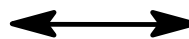
D-Glyceraldehyde



L-Glyceraldehyde



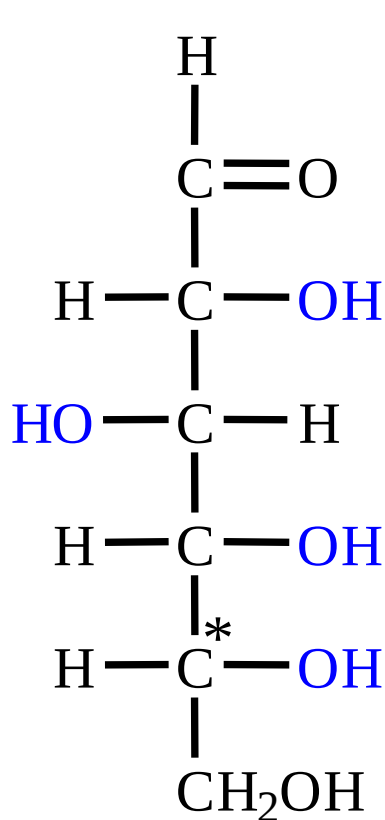
D-Erythrose



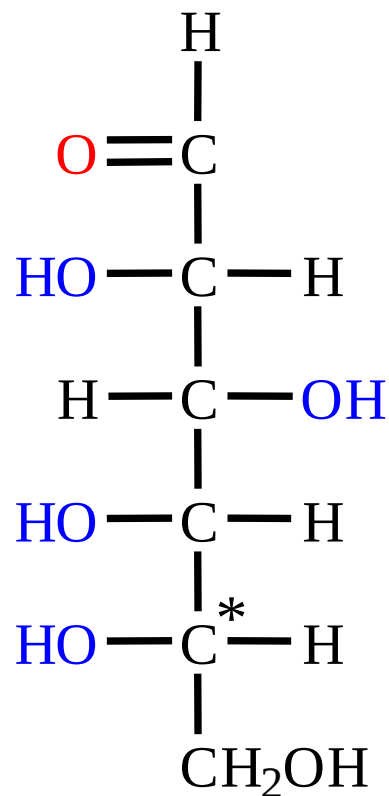
L-Threose

MONOSACCHARIDES

Enantiomers by configuration



D-glucose



L-glucose

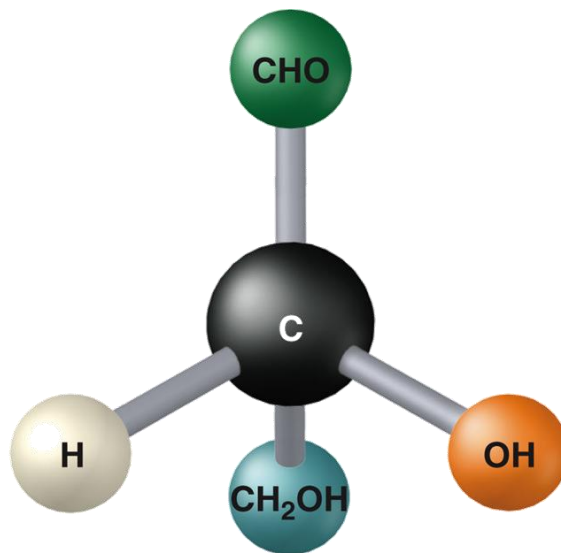
MONOSACCHARIDES

Optical activity

Optical activity is the ability of a body to turn the plane of vibration of polarised light.

In general, carbohydrates are optically active.

A carbon compound is **chiral** if it has at least one carbon atom bonded *to four different atoms or groups*



D-glyceraldehyde

MONOSACCHARIDES

Optical activity

The direction of rotation of a body to the right or to the left is indicated by the prefix (+) or (-).

The direction of rotation is independent of whether the sugar belongs structurally (by configuration) to D- or L-series.

For instance; D-fructose rotates to the left
D(-)-fructose

L-ascorbic acid rotates to the right
L(+)-ascorbic acid

If equal amount of D- and L- bodies are present in a crystalline mixture or a solution this mixture is called a **racemic mixture**.

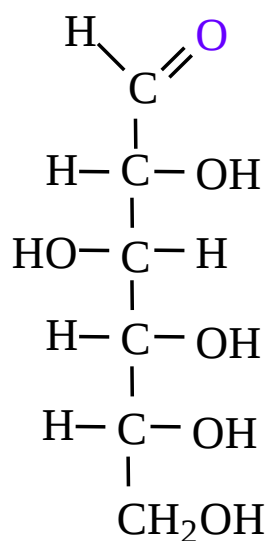
MONOSACCHARIDES

Structure representations

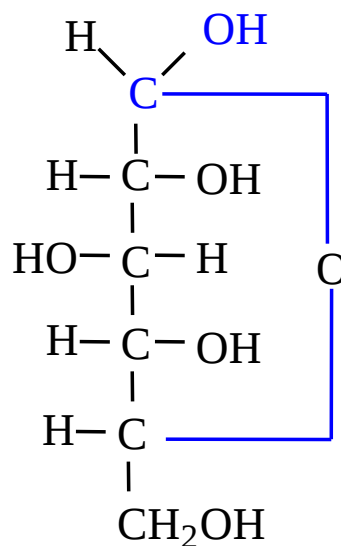
If (OH) group on the anomeric C and ring are on the same side; it is α

If (OH) group on the anomeric C and ring are on opposite side; it is β

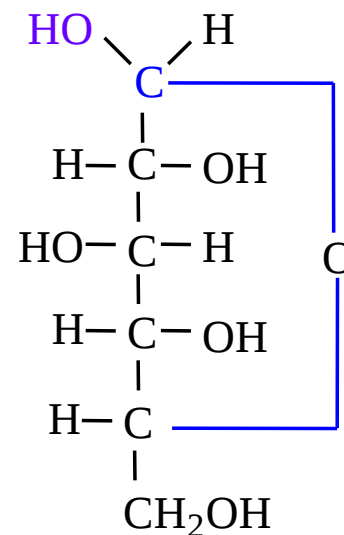
Anomeric Carbon: The carbon atom which is involved in hemiacetal or acetal formation.



Open carbonyl form
(Free aldehyde form)



or

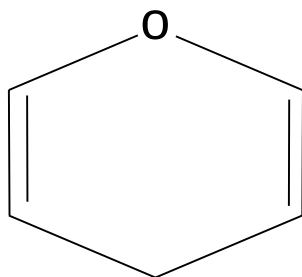


Cyclic hemiacetal formula
(Fischer projection form)

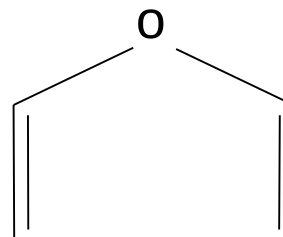
MONOSACCHARIDES

Structure representations

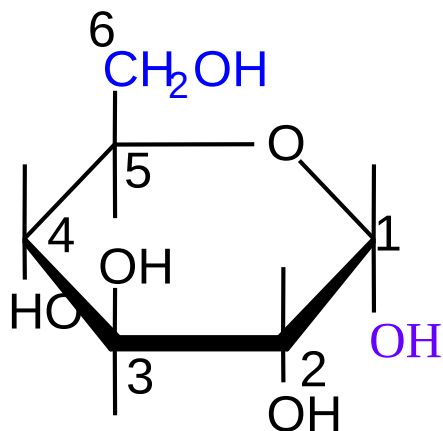
Six and five member rings



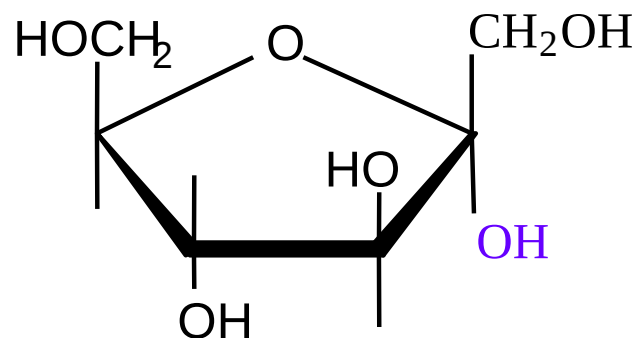
Pyran



Furan



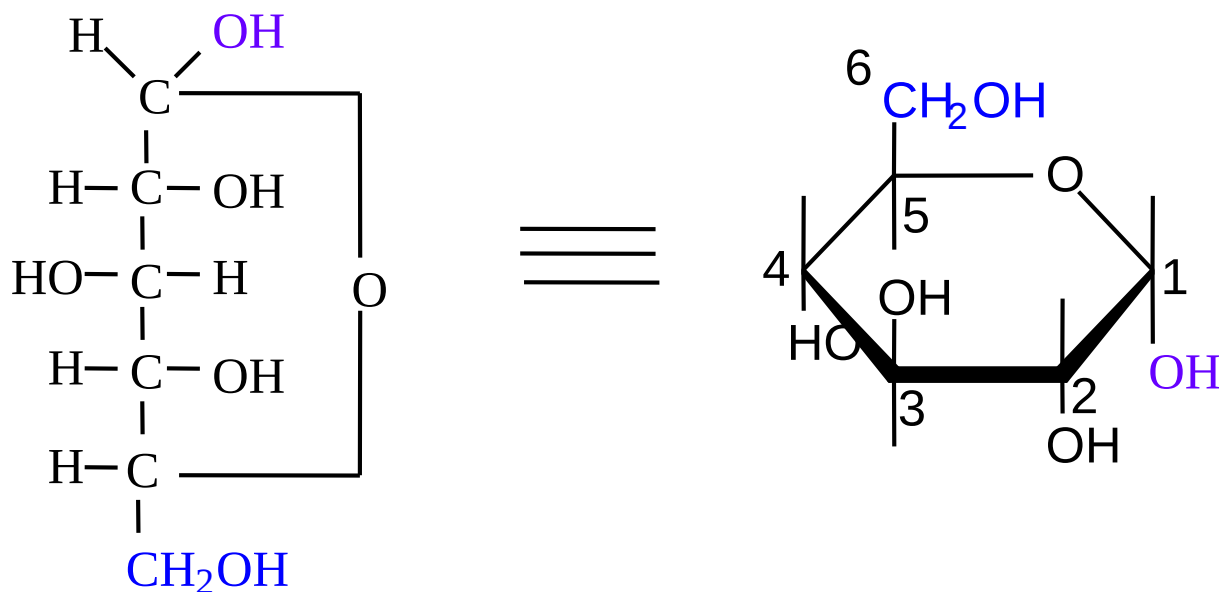
α - D – Gluco**pyranose**



α - D - Fructo**furanose**

MONOSACCHARIDES

Structure representations



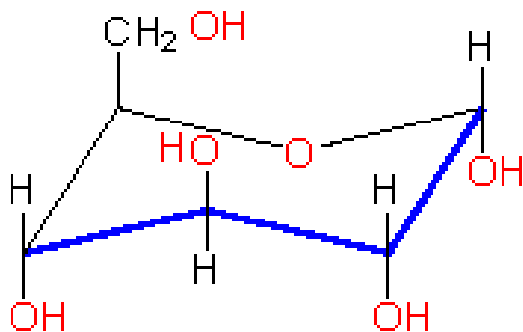
Fischer projection form

Haworth ring form

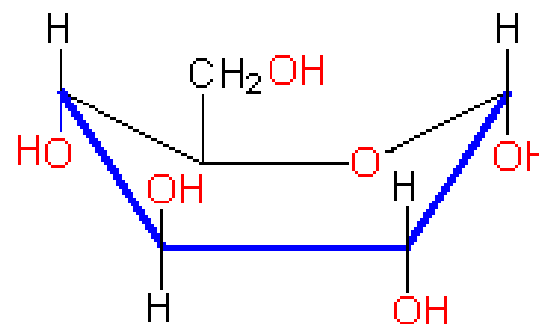
MONOSACCHARIDES

Structure representations

α - D – Glucopyranose



Chair form

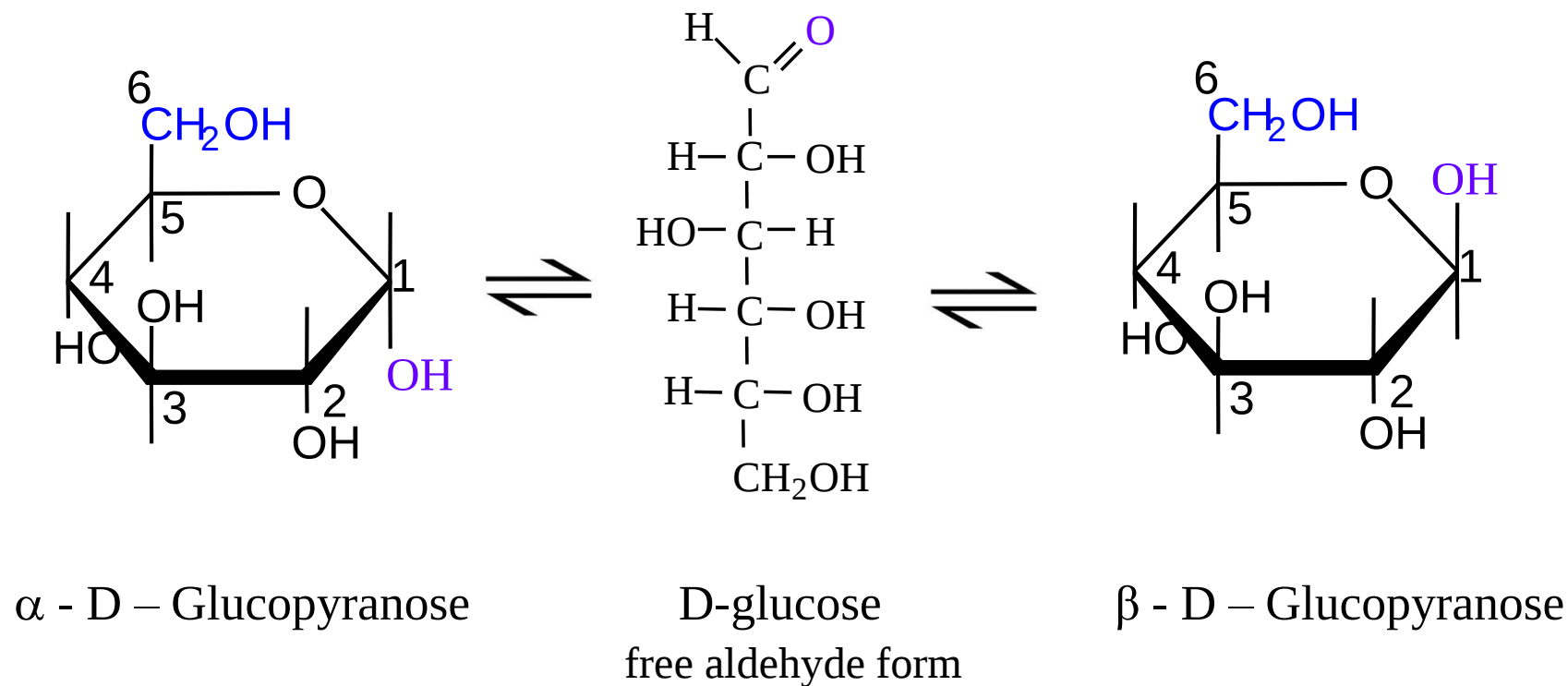


Boat form

Conformational form

MONOSACCHARIDES

Anomers: The two isomeric forms of the particular monosaccharide are known as anomers and designated α and β



MONOSACCHARIDES

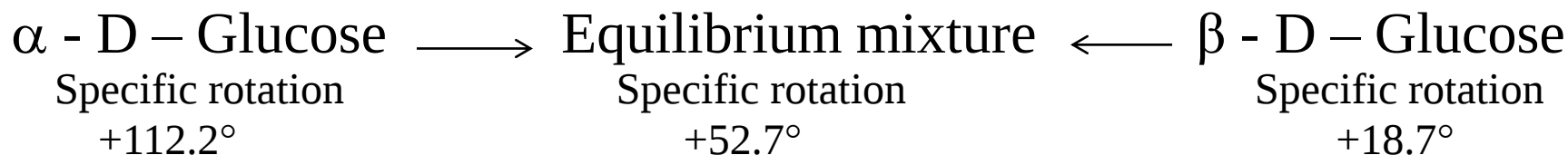
Mutarotation: When an aqueous solution of a monosaccharide is allowed to stand, the specific rotation of the solution changes with time (representing interconversion of α and β forms of D-glucose into an equilibrium mixture) until it reaches a constant value. This process is called **mutarotation**.

α and β anomers of a particular monosaccharide will differ in optical rotation.

Specific rotation of α - D – Glucose: $+112.2^\circ$

Specific rotation of β - D – Glucose: $+18.7^\circ$

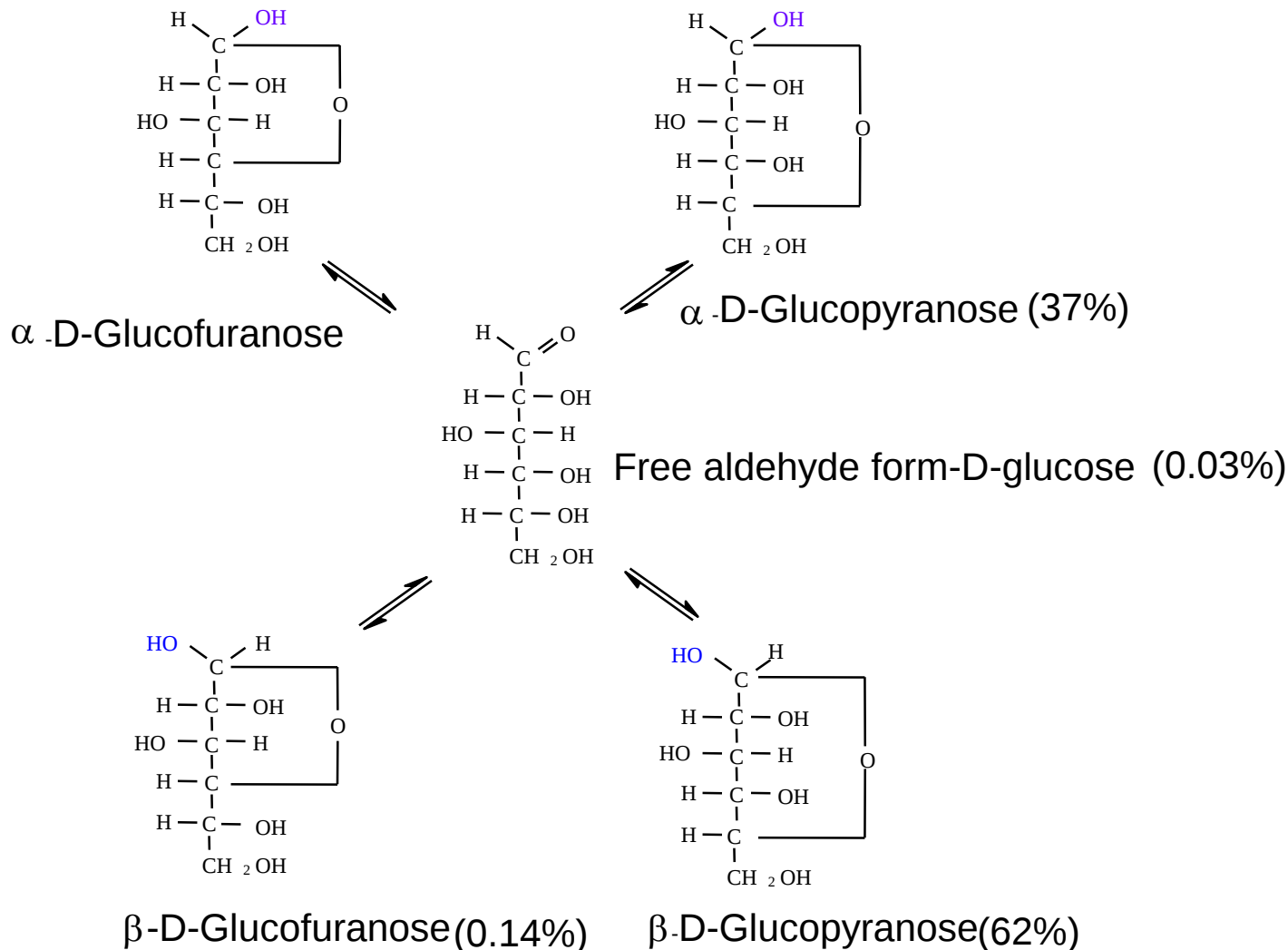
A solution of D-glucose (at equilibrium) will attain a specific rotation value of $+52.7^\circ$



MONOSACCHARIDES

Mutarotation

At equilibrium molar fractions of isomers are:



MONOSACCHARIDES

Mutarotation

In the crystalline state only one of the two forms (α or β) is found at only one time.



α and β -D glucose have different physical properties;

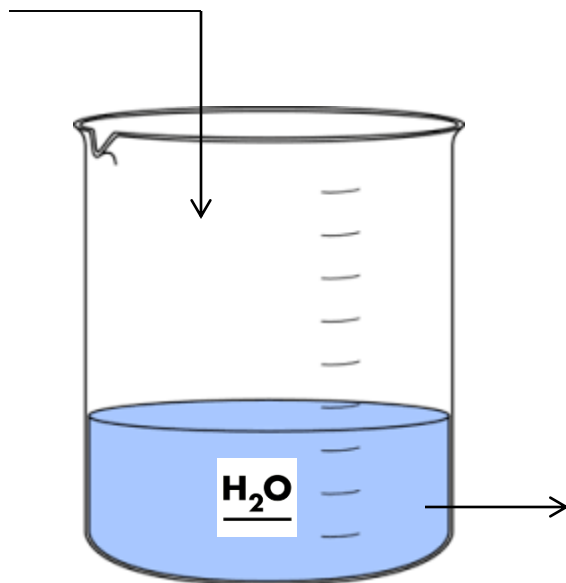
Physical property	α - D – Glucose	β - D – Glucose
Specific rotation	+112.2°	+18.7°
Solubility in water (g/100 mL)	82.5	17.8
Melting points (°C)	146	150
The effect of glucose oxidase	10%	<1%

MONOSACCHARIDES

Mutarotation

Since the linear and cyclic forms of glucose inter-convert with each other, α -D-glucose can turn into β -D-glucose and vice versa. If you take a sample of pure α -D-glucose and put it into water, you'll end up with a sample that is part α and part β -D-glucose.

Crystalline pure α -D-glucose



mixture of
 α and β -D-glucose

MONOSACCHARIDES

Hexoses

A hexose is a monosaccharide with six carbons



- soluble in water
- reduce Fehling's solution
- exhibits optical activity and mutarotation

Aldohexoses

- D-Glucose
- D-Mannose
- D-Galactose

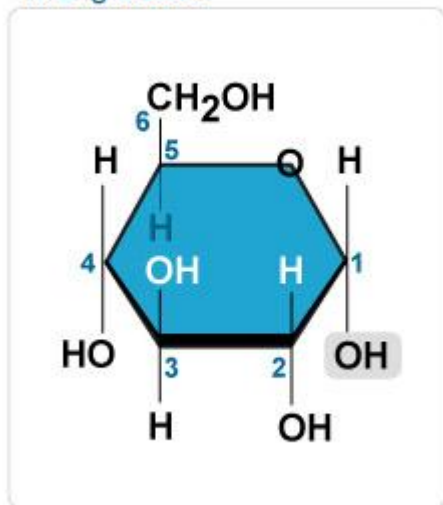
Ketohexoses

- D-Fructose
- D-Tagatose

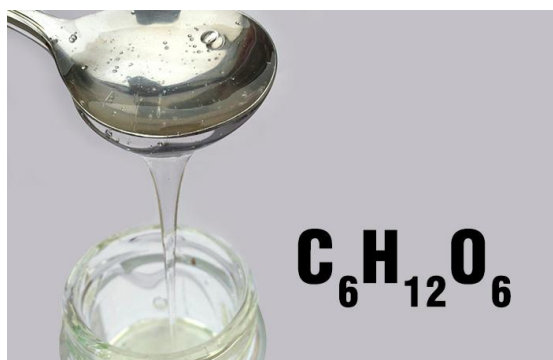
MONOSACCHARIDES

D-glucose

α -D-glucose



The usual crystalline D-glucose is α -D-glucose monohydrate (m.p. 80 to 86 °C)



Because it is dextrorotatory it is called DEXTROSE.

Commercially produced by acid or enzymatic hydrolytic cleavage of potato starch, maize starch, ..,

MONOSACCHARIDES

D-glucose

It is found in fruits, honey and corn syrup



Honey: about 17% water, almost the rest is sugars. (fructose 38%, glucose 31%, maltose 7%, sucrose 1.3%, other sugars 1.5%)

Apples: over 10% sugar, (57% fructose, 23% glucose and 20% sucrose). Very high fructose.

Peaches: 8.4% sugar, (57% sucrose, 23% glucose and 18% fructose)

Pears: 9.8% sugar, (64% fructose, 28% glucose and 8% sucrose)

Grapes: 15% sugar, (53% fructose and 47% glucose)

MONOSACCHARIDES

D-glucose

It is found in small amounts (0.1%) in blood

It is a building block of

cane sugar	sucrose	glucose-fructose
milk sugar	lactose	glucose-galactose
malt sugar	maltose	glucose-glucose
	starch	glucose-glucose-glucose-glucose...
	glycogen	glucose-glucose-glucose-glucose...
	cellulose	glucose-glucose-glucose-glucose...

MONOSACCHARIDES

D-fructose

Fructose is the most important **ketose sugar**

Fructose is more commonly found together with glucose and sucrose in honey and fruit juices



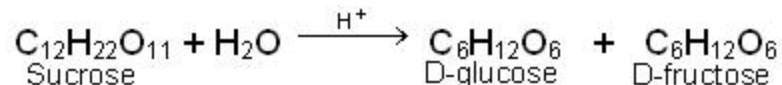
- Fructose is sometimes called as levulose, because of its levorotatory property of rotating plane polarized light to the left.
- Show mutarotation
- When D-fructose is reduced, equal amounts of the two sugar alcohols, D-sorbitol (2.6 calories/g - 60% sweetness of sucrose) and D-mannitol (1.6 calories/g - 50% sweetness of sucrose), are formed.

MONOSACCHARIDES

D-fructose

It is frequently derived from sugar cane, sugar beets, and corn.

Invert sugar: a mixture of equal parts of fructose and glucose, results from the hydrolysis of sucrose. This process is called **inversion**, because **invert sugar** rotates polarised light in the opposite direction (left) to the original sucrose.



Sugar type	Specific rotation
Glucose	+52.7
Fructose	-92.0
Sucrose	+66.5
Invert sugar	-19.8
Invert sugar (when fully hydrolysed)	-39.3

MONOSACCHARIDES

D-fructose

High-fructose corn syrup (HFCS), which is widely used as a sweetener in beverages and foods, is a mixture of glucose and fructose.

The primary reason that fructose is used commercially in foods and beverages is because of its low cost and its high relative sweetness. It is the sweetest of all naturally occurring carbohydrates being 1.73 times as sweet as sucrose.

Component	HFCS-42	HFCS-55	Corn syrup	Fructose	Sucrose	Invert sugar	Honey
	%	%	%	%	%	%	%
Fructose	42	55	0	100	50	45	49
Glucose	53	42	100	100	50	45	43
Others	5	3	100	0	0	10	5
Moisture	29	23	20	5	5	25	18

MONOSACCHARIDES

D-fructose

Free fructose is absorbed directly by the intestine. When fructose is consumed in the form of sucrose, it is digested (broken down) and then absorbed as free fructose.

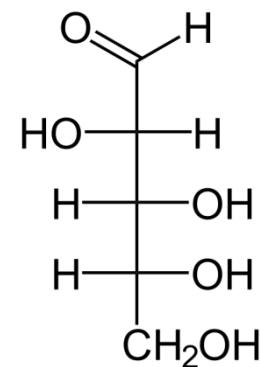
Uric acid is generated via fructose. Uric acid is normally an anti-oxidant but without sufficient amounts of ascorbic acid (vitamin C) present in the plasma, it functions as a pro-oxidant. Because many soft drinks and foods that are sweetened with high fructose corn syrup do not contain vitamin C, the resulting uric acid can lead to a number of harmful effects, including gout, chronic inflammation, hypertension, increased adiposity, fatty liver disease and obesity

MONOSACCHARIDES

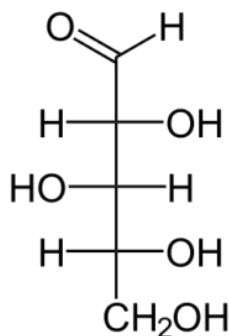
Pentoses

Pentoses are five-carbon sugars seldom found in the free state in nature.

In plants they occur in polymeric forms and are collectively known as pentosans. Thus, xylose and arabinose are the constituents of pentosans present in plant fibres and vegetable gums, respectively. Pentose sugars (D-xylose and D-Arabinose) are primarily obtained from woody biomass and various crop residues.



D-Arabinose



D-Xylose

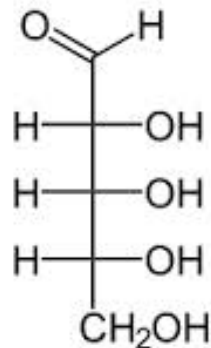
xylose
is mostly converted to
xylitol (sweetener)



MONOSACCHARIDES

Pentoses

As the sugar moieties in nucleic acids and riboflavin, ribose and deoxyribose are indispensable constituents of the life process. D-ribose has the following chemical structure

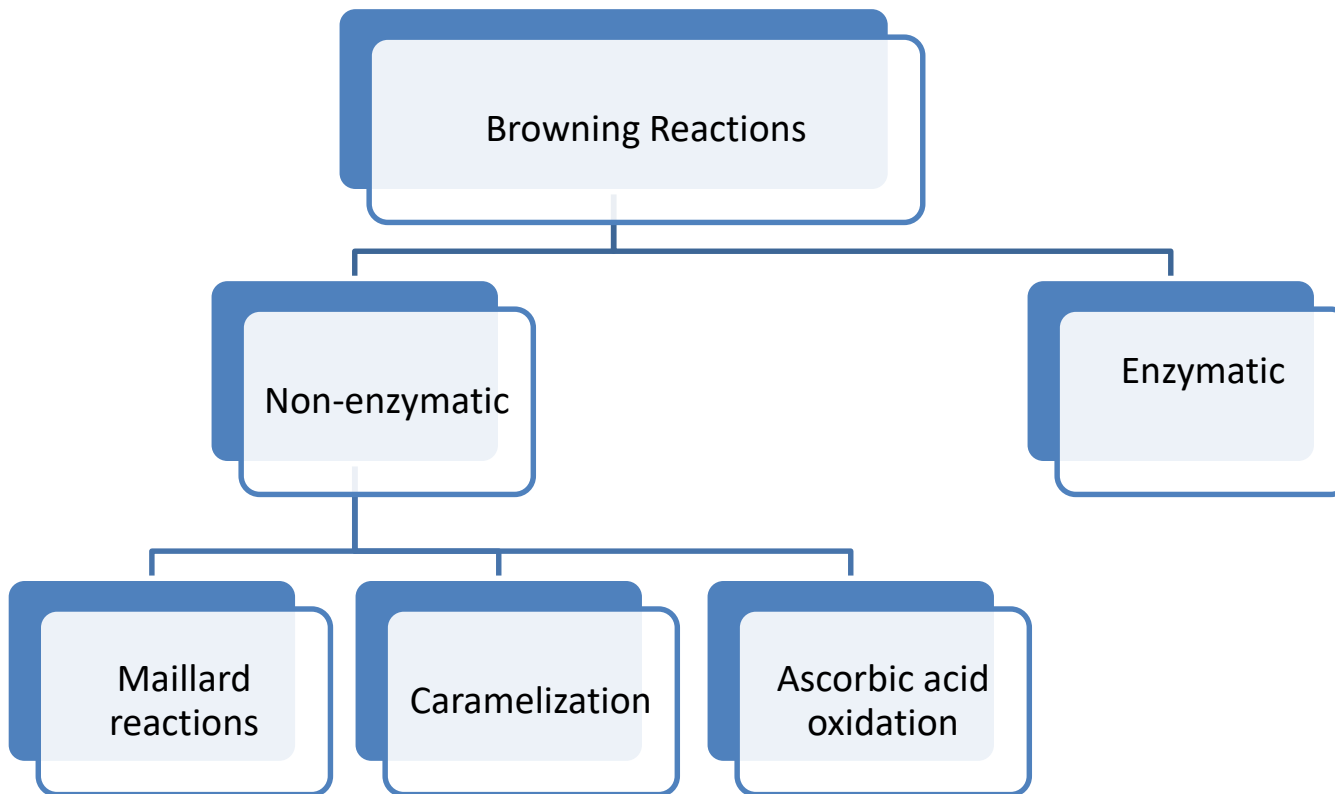


D-Ribose

MONOSACCHARIDES

Browning reactions

Browning is a common color change seen in food during preparation, processing or storage.



MONOSACCHARIDES

Enzymatic browning

Fruits such as apples, apricots or vegetables such as potato quickly turn brown when their tissues exposed to oxygen.

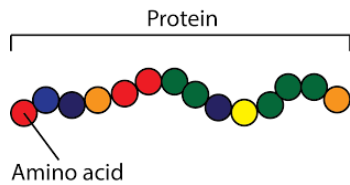
It is related with an enzyme called phenolase or polyphenoloxidase.



MONOSACCHARIDES

Maillard reactions

Maillard reaction is a reaction between reducing sugars and N-containing compounds (amino group) in the presence of heat.



Amino acids



Reducing sugars



Heat



Flavor & color

MONOSACCHARIDES

Maillard reactions

The reaction starts by reaction of the reducing group (glycosidic hydroxyl group) of sugars with amines, amino acids, peptides, proteins and so on to form glycosylamines in the presence of heat.

- Produces flavor
- Produces color
- Produces antioxidant products
- Produces toxic products
- Destroys nutrients



MAILLARD
.....REACTIONS

Dr. FG & Dr. DKY



MONOSACCHARIDES

Caramelization

When sugars are heated in the absence of nitrogeneous compounds above their melting points they darken to a brown coloration under alkaline or acidic conditions.



+



Any sugar

heat

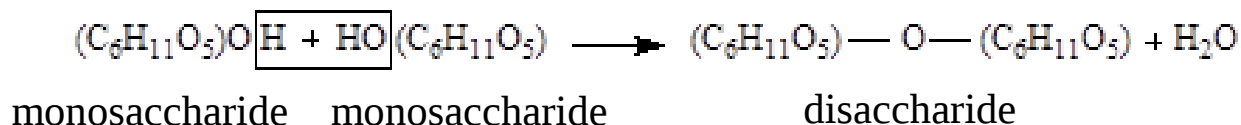
Flavor & color

If this reaction is not carefully controlled it could lead to the production of unpleasant, burnt and bitter products. If the reactions are carried out under controlled conditions, pleasant qualities of caramel are obtained.

DISACCHARIDES

In forming a disaccharide, the anomeric carbon of one sugar molecule can interact with one of several hydroxyl groups in the other sugar molecule.

Disaccharides are formed by the union of two monosaccharide molecules, with loss of water:



It is not possible to prepare disaccharides from monosaccharides in the laboratory by this process. Nature, however, accomplishes it without difficulty.

DISACCHARIDES

Disaccharides are easily split into their component monosaccharides by enzymes or by boiling with dilute acids. Many disaccharides are known but the most important, and the only ones of interest in food science, are sucrose, maltose, and lactose.

Some Important Disaccharides			
Name	Monosaccharide constituents	Glycosidic linkage	Source
Maltose	Glucose and glucose	α (1 $\rightarrow$ 4)	Hydrolysis of starch
Lactose	Galactose and glucose	β (1 $\rightarrow$ 4)	Mammalian milk
Sucrose	Glucose and fructose	α -1 $\rightarrow$ β -2	Sugar cane and sugar beet

DISACCHARIDES

Sucrose (Cane sugar or beet sugar)

Ordinary (table) sugar, whether obtained from sugar-cane or sugar-beet, is substantially pure sucrose.



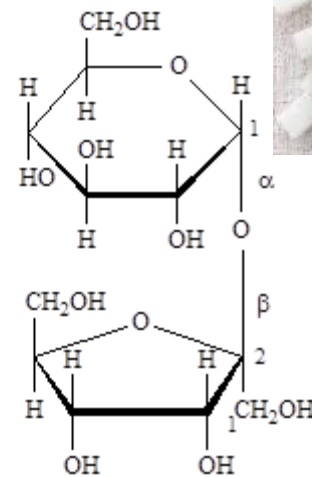
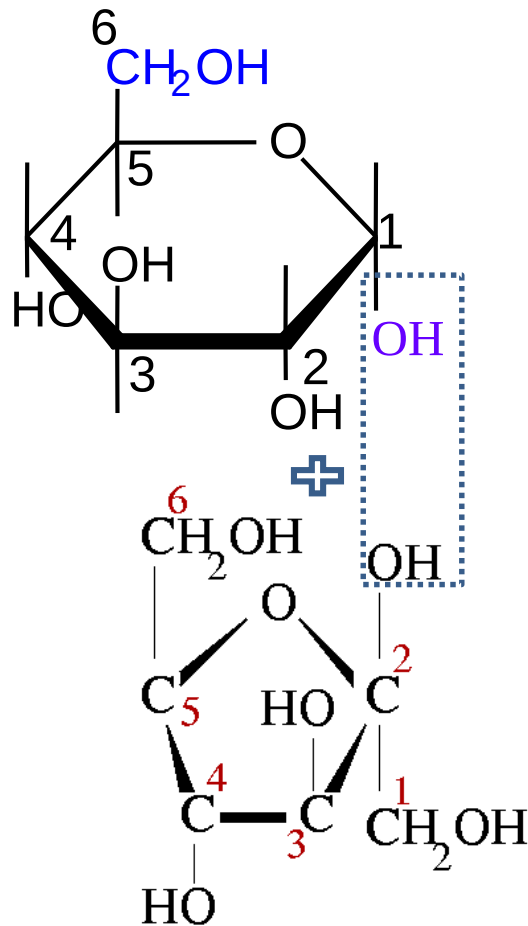
On hydrolysis with dilute acids, or the enzyme sucrase, sucrose gives equal quantities of glucose and fructose, so the sucrose molecule must contain one glucose unit combined with one fructose unit.

The fructose unit in sucrose does not have a six-membered ring but a five membered ring. Sucrose is distinguished from the other three disaccharides (Lactose, maltose, cellobiose) in that its glycosidic bond links the anomeric carbon atoms of two monosaccharide residues.

DISACCHARIDES

Sucrose

Configurations of both the glucopyranose and fructofuranose residues in sucrose are fixed, and neither residue is free to equilibrate between α and β anomers. So it is a **nonreducing** sugar.



Sucrose

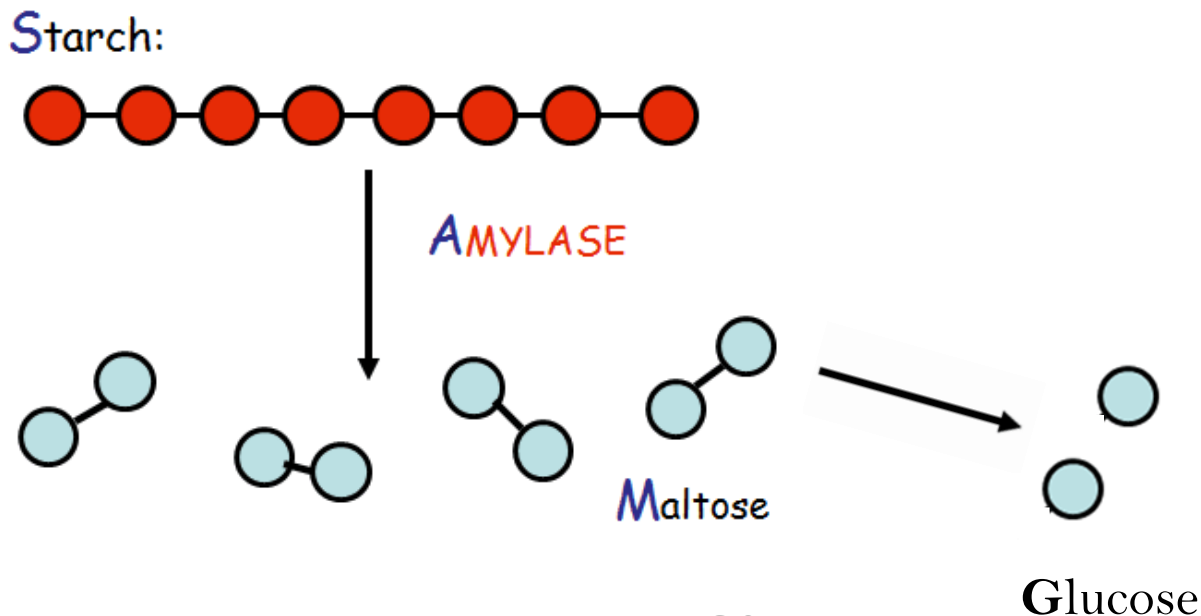
α -D-Glucopyranosyl-(1-2)- β -D-fructofuranoside



DISACCHARIDES

Maltose (malt sugar)

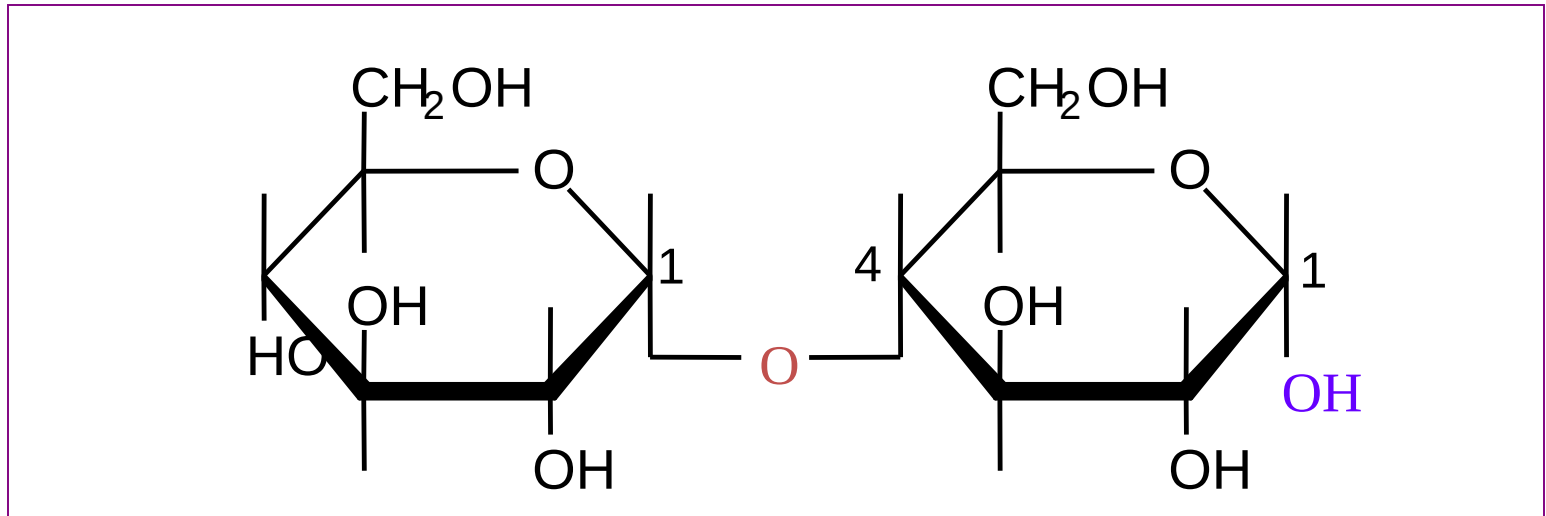
Maltose derived its name from the fact that it occurred in the extracts from sprouted barley or other cereals (**malt** liquors). Maltose is a disaccharide released during the hydrolysis of starch by enzyme amylase. Maltose is composed of two D-glucose residues joined by an α -glycosidic bond. The enzyme maltase splits maltose into two glucose units.



DISACCHARIDES

Maltose

The glycosidic bond links C-1 of one residue (on the left) to the oxygen atom attached to C-4 of the second residue (on the right). Maltose is therefore α -D-glucopyranosyl-(1-4)-D-glucose. It is important to note that the glucose residue on the left, whose anomeric carbon is involved in the glycosidic bond, is fixed in the α configuration, whereas the glucose residue on the right (**the reducing end**) freely equilibrates among the α , β , and open chain structures.



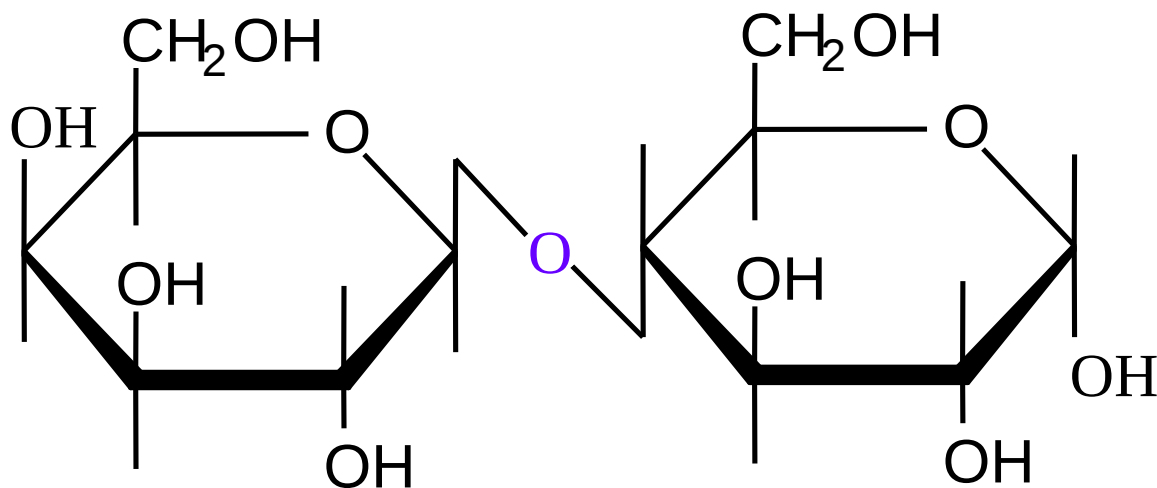
DISACCHARIDES

Lactose (milk sugar)

Lactose (β -D-galactopyranosyl-(1-4)-D-glucose), a major carbohydrate in milk, is a disaccharide synthesized only in lactating mammary glands.

It occurs in the milk of all animals:

cow's milk contains about 4-5% and human milk 6-8%.



DISACCHARIDES

Lactose

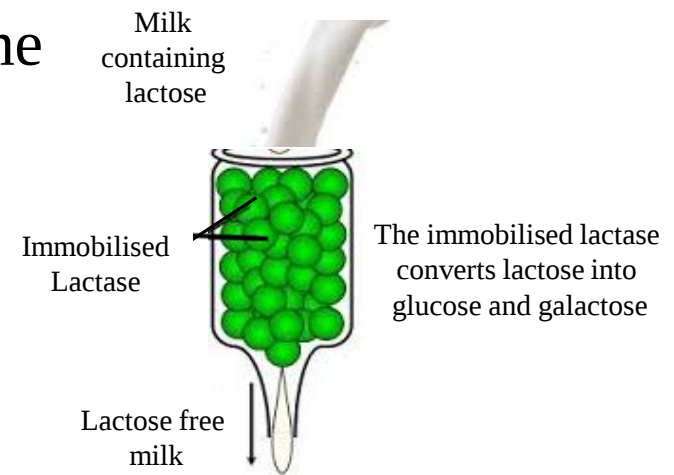
Lactose may be hydrolysed by dilute solutions of strong acids and the enzyme β -D-galactosidase (lactase).

Lactase

Enzyme required to hydrolyze lactose

Lactose intolerance

Lack or insufficient amount of the enzyme



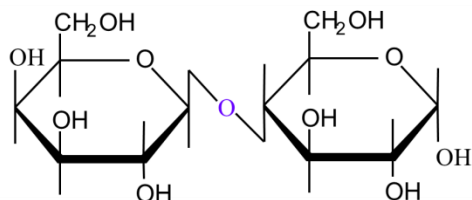
DISACCHARIDES

Lactose

It is a reducing sugar and is decomposed by alkali.

Lactose is relatively insoluble which is a problem in many dairy products, ice cream, sweetened condensed milk.

One of its most important functions is its utilization as a fermentation substrate. Lactic acid bacteria produce lactic acid from lactose, which is the beginning of many fermented dairy products.

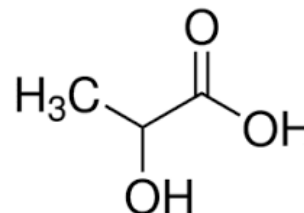


Lactose

Lactic acid bacteria



Fermentation



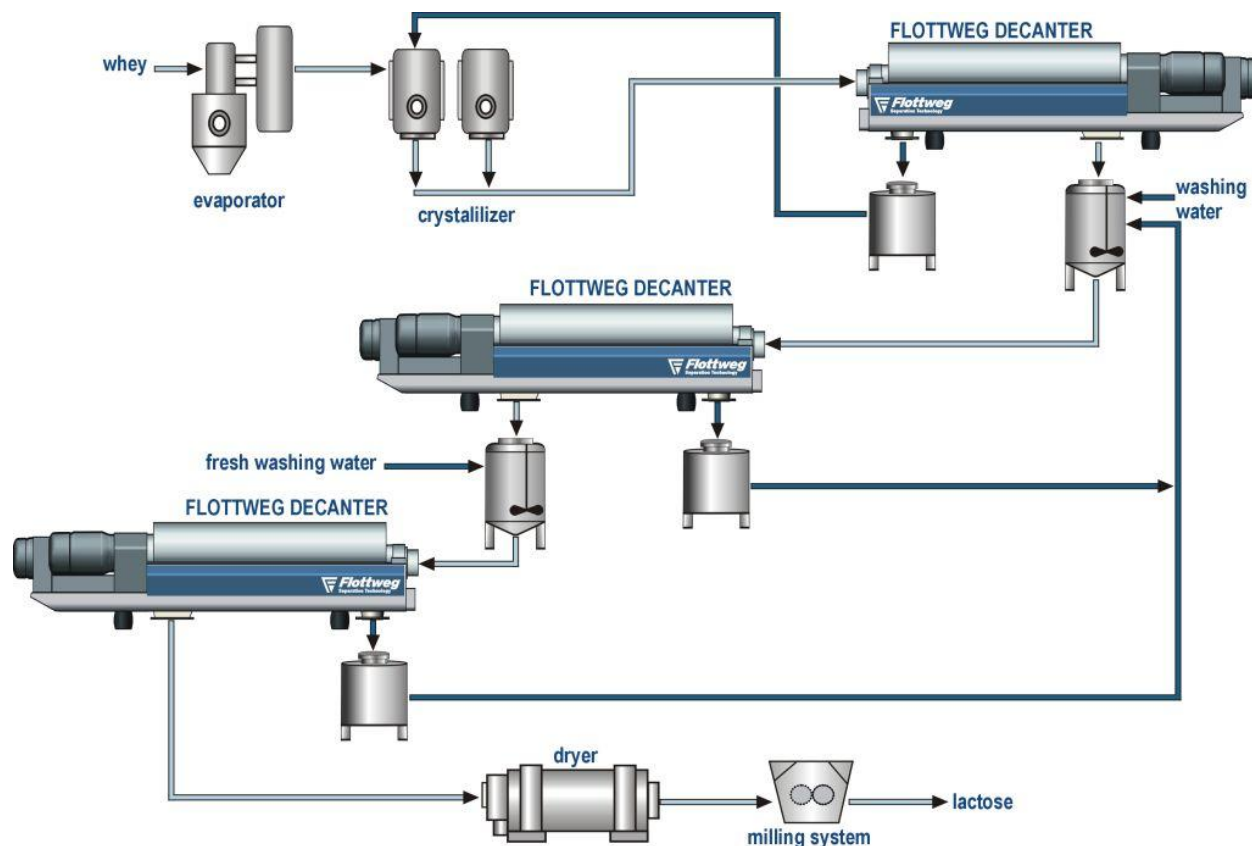
Lactic acid



DISACCHARIDES

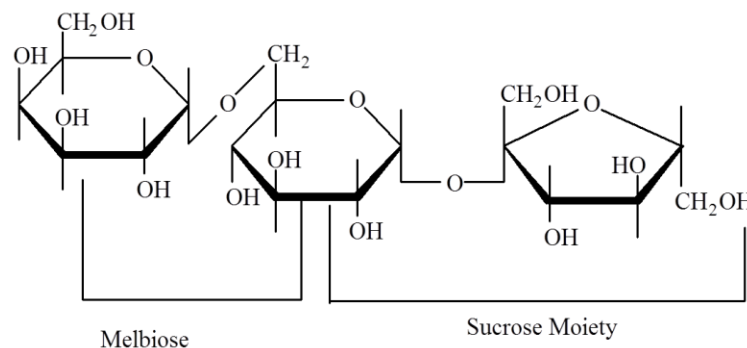
Lactose

Lactose is produced commercially from the whey left after the manufacture of cheese. It is prepared by allowing a supersaturated solution of lactose to crystallize at a temperature below 93.5°C.



TRISACCHARIDES

The trisaccharides contain three monosaccharide molecules, which may be the same or different from each other.



There are three important natural trisaccharides:

Some Important Trisaccharides		
Name	Monosaccharide constituents	Source
Raffinose	Galactose-glucose-fructose	beans, cabbage, brussels sprouts, broccoli
Gentianose	Glucose-glucose-fructose	gentian root
Melezitose	Glucose-fructose-glucose	produced by many plant sap eating insects

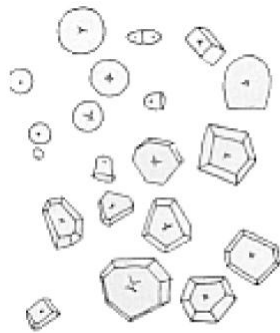
POLYSACCHARIDES

- They are high molecular carbohydrates
- They are long chains of polymeric carbohydrates
- Monosaccharides are linked together by glycosidic bonds
- Generally insoluble in water and tasteless
- General formula $(C_6H_{10}O_5)_n$

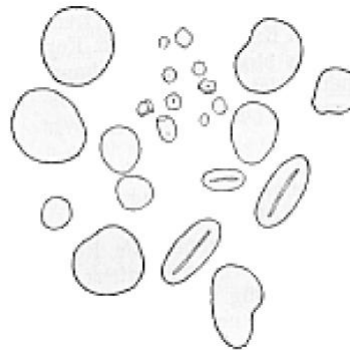
POLYSACCHARIDES

Starch

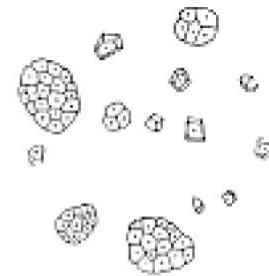
- The reserve carbohydrate of plants.
- Occurs as granules in the cell.
- Made of amylose and amylopectin.
- Size and shape of starch granules change from one source to another (potato, maize, rice, wheat, etc.)



Maize starch



Wheat starch



Rice starch

POLYSACCHARIDES

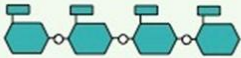
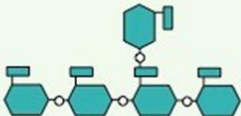
Starch

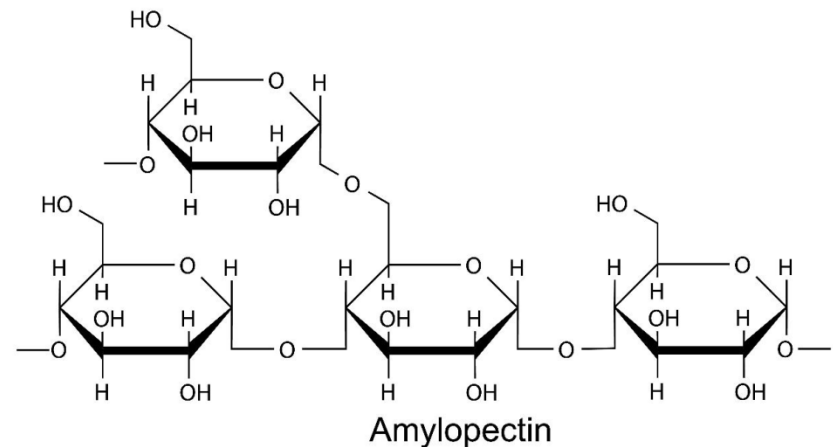
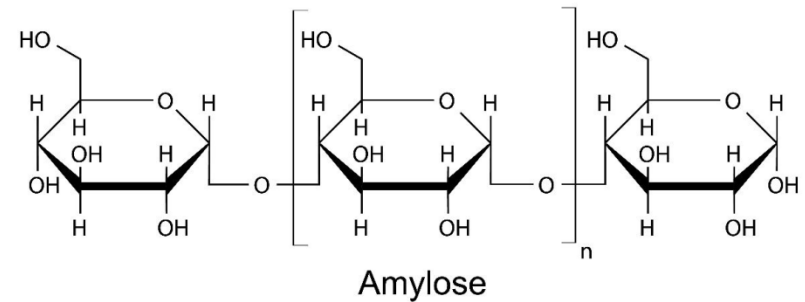
- Starch is used to control texture, moisture, consistency, and shelf stability of many products. It can be used to aid in processing, packaging, lubrication, or moisture equilibration.
- Starch serves as a multifunctional ingredient in the food industry. The most common sources of starch are maize, potato, wheat, and rice.
- Uncooked starchy foods are not easily digested because starch granules are contained within the cell walls of the plant, which the digestive juices cannot easily penetrate. Cooking softens the cell walls and allows water to enter the starch granules causing them to disintegrate and gelatinize.

POLYSACCHARIDES

Starch structure

- Starch was composed of strings of connected glucose units.
- It is composed of two substances called AMYLOSE and AMYLOPECTIN

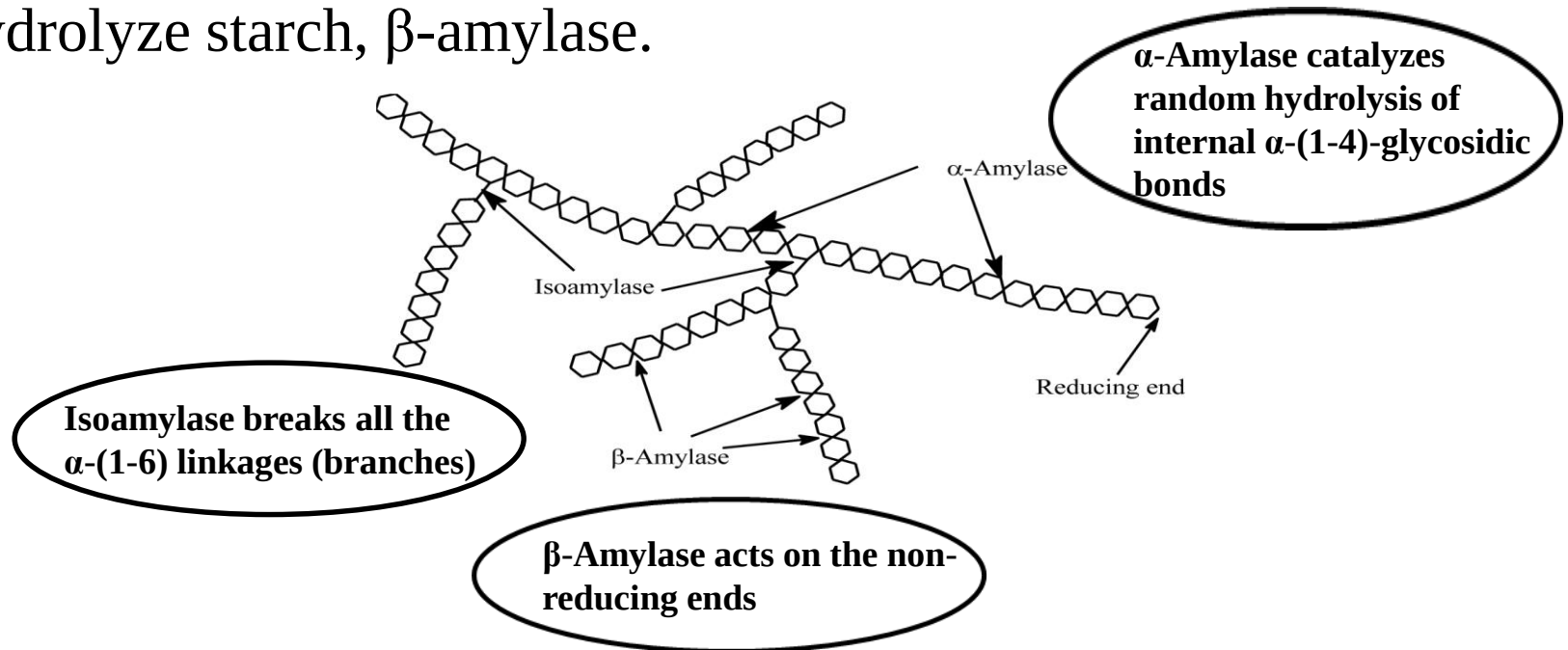
	Starch	
	Amylose	Amylopectin
Source	Plant	Plant
Subunit	α -glucose	α -glucose
Bonds	1-4	1-4 and 1-6
Branches	No	Yes (~per 20 subunits)
Diagram		
Shape		



POLYSACCHARIDES

Starch structure

Dietary starch is degraded in the gastrointestinal tract by the actions of a debranching enzyme α -amylase and an endoglycosidase that catalyzes the hydrolysis of the α -(1-4) glycosidic bonds of amylose and amylopectin. Some vascular plants contain another enzyme in their seeds and tubers to hydrolyze starch, β -amylase.



POLYSACCHARIDES

Modified starches

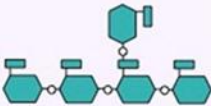
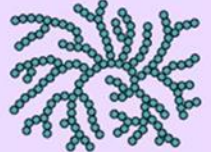
1. Pregelatinized Starch --- Precooked and roll dried starch to give product that readily disperses in cold water (improve solubility; used in candies, puddings, soup mixes, etc.).
2. Thin-boiling or Acid-modified Starch --- Suspended granular starch in a very dilute acid under somewhat below its gelatinization temperature (to get low and uniform viscosity which does not change with temperature).
3. Oxidized Starches --- Oxidation of starch with alkaline hypochloride to get -COOH at C_6 (improve printability in paper industry)

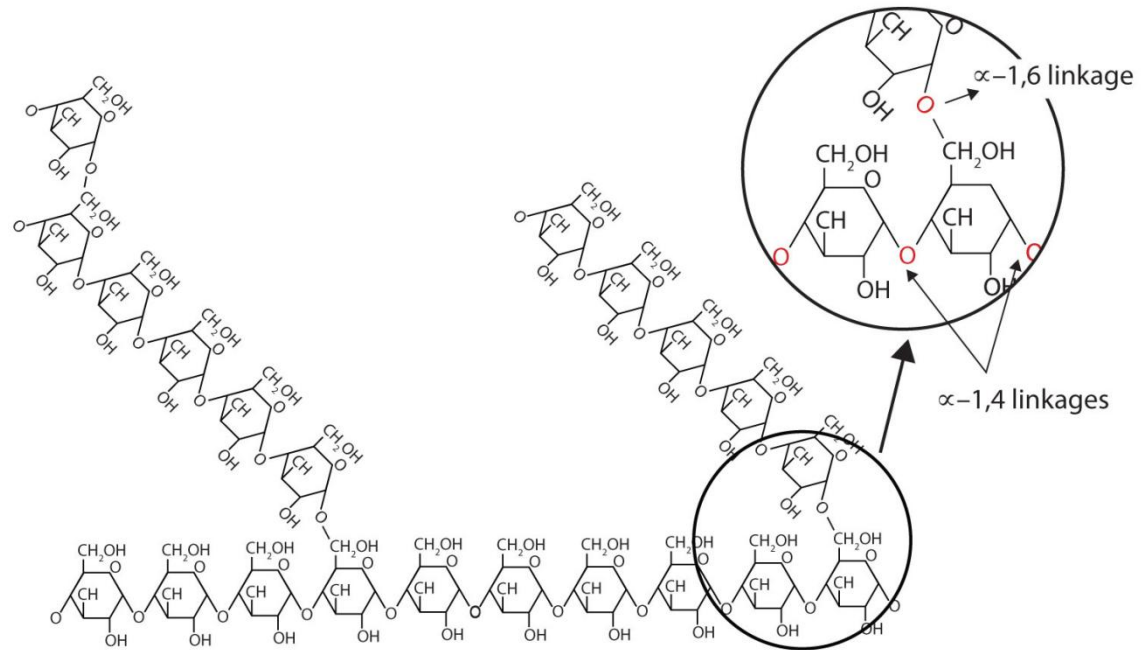
POLYSACCHARIDES

Glycogen

Glycogen is a multi-branched polymer of glucose that serves as energy storage in the animal organisms.

Glycogen has a structure similar to [amylopectin](#) (a component of starch), but is more extensively branched and more compact.

	Glycogen
Source	Animal
Subunit	α -glucose
Bonds	1-4 and 1-6
Branches	Yes (~per 10 subunits)
Diagram	
Shape	



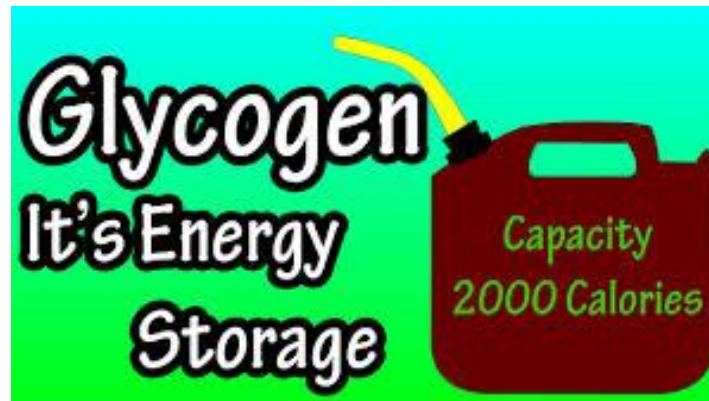
POLYSACCHARIDES

Glycogen

Glycogen serves as an energy reserve that can be quickly mobilized to meet a sudden need for glucose.

It is present in animals and man in the liver (5-6% of the liver weight) and in the muscles (1-2% of the muscle weight)

A cow has several kilograms of glycogen, however glycogen is not a normal constituent of the diet because it is converted into lactic acid after an animal has been killed.



POLYSACCHARIDES

Cellulose

- Cellulose is the chief structural carbohydrate of plants.



- Cellulose is totally insoluble in water

POLYSACCHARIDES

Cellulose

- Cellulose can not be digested by man
- Has no nutritional value, but serves as a useful purpose as a component of dietary fibre.
- Much cellulose is removed during the processing of food.

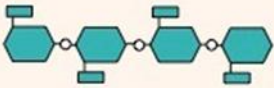
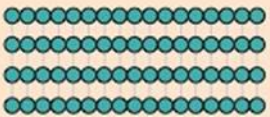


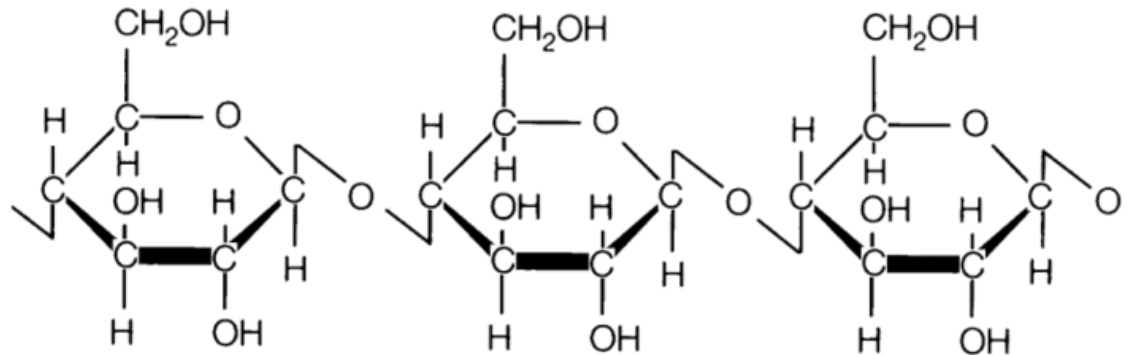
- Cellulose can be hydrolysed by heating it with HCl or H_2SO_4

POLYSACCHARIDES

Cellulose structure

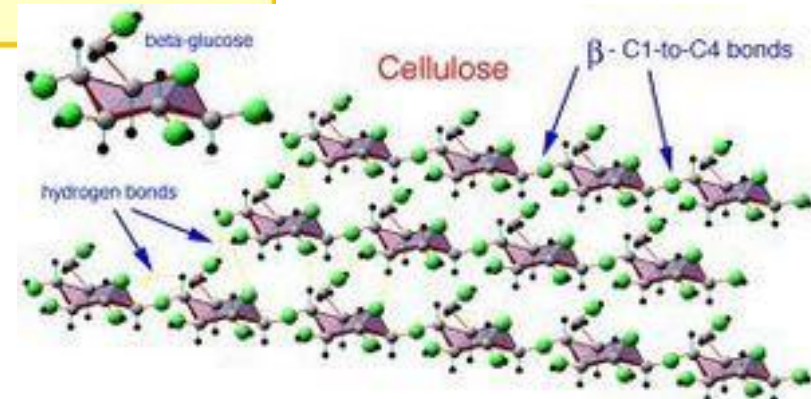
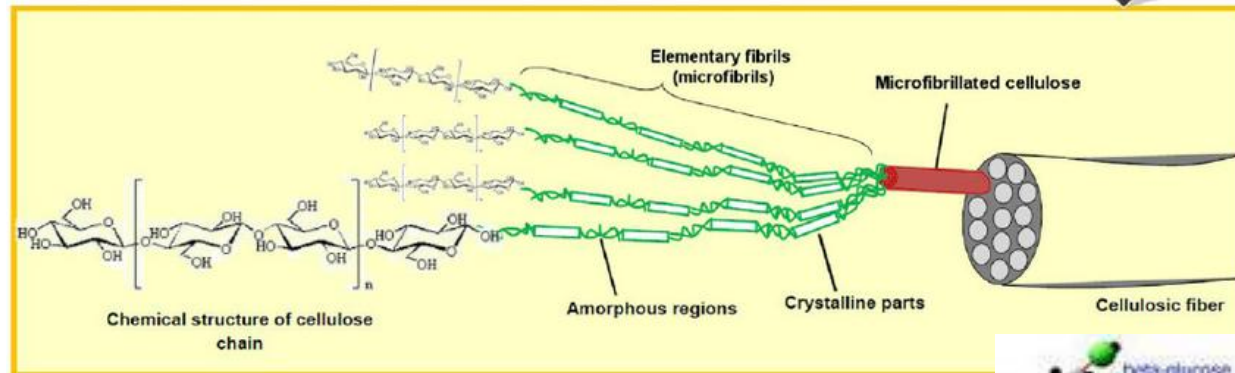
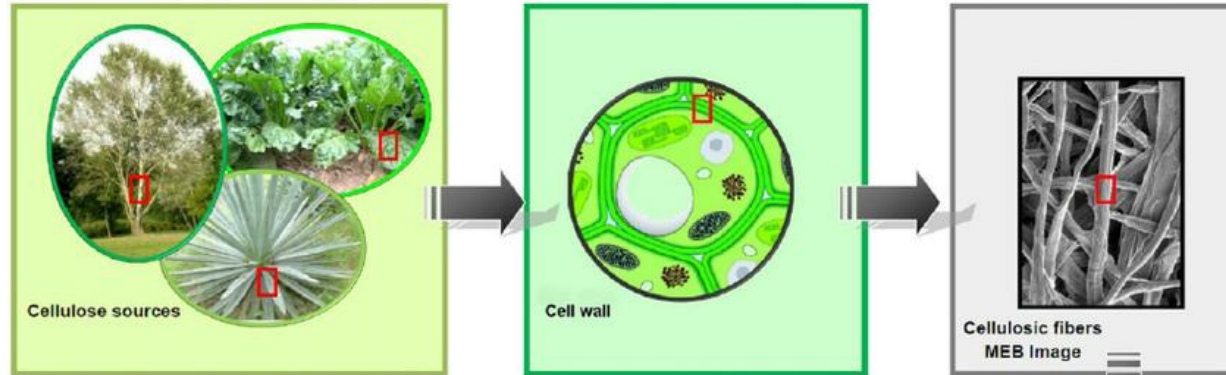
- Cellulose consists of β -D-glucose units connected at carbon atoms 1 and 4.

	Cellulose
Source	Plant
Subunit	β -glucose
Bonds	1-4
Branches	No
Diagram	
Shape	



POLYSACCHARIDES

Cellulose structure



POLYSACCHARIDES

Pectin

- Pectin is a heterosaccharide derived from the cell wall of plants.
- Pectin sources mostly are apples and citrus fruits (grapefruits, oranges, lemons).



POLYSACCHARIDES

Pectin

Group I High pectin	Group II Low pectin	Group III Very low or no pectin
Apples, sour	Apples, ripe	Apricots
Blackberries, sour	Blackberries, ripe	Blueberries
Citrus skins (oranges, tangerines, grapefruit, lemons, limes, etc. - the pectin is high in the skin but low in the fruit)	Cherries, sour	Cherries, sweet
Crabapples	Chokecherries	Figs
Cranberries	Elderberries	Grapefruit
Currants	Grape Juice, bottled (Eastern Concord)	Grapes (Western Concord)
Gooseberries	Grapes (California, and all other than Concord)	Guavas
Grapes (Eastern Concord)	Loquats	Nectarines
Lemons	Oranges	Peaches
Loganberries		Pears
Plums (not Italian)		Plums (Italian)
Quinces		Pomegranates
Raspberries		Raspberries
		Strawberries

POLYSACCHARIDES

Pectin

- Pectin is utilized ;
- ✓ in the jams and jellies because of its gelling ability
- ✓ in dairy industry because of its stabilizing and thickening abilities,
- ✓ in many drug delivery system as a gelling agent, binding agent, emulsifier, thickener, and film coater.

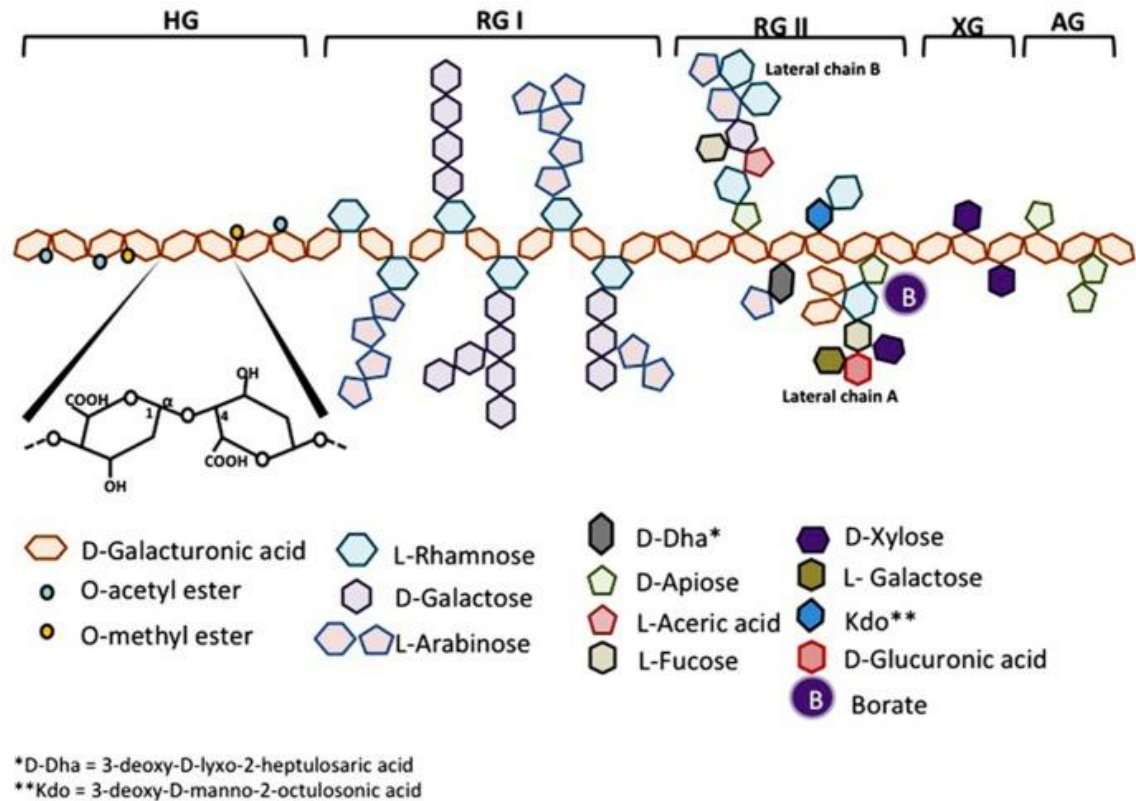


POLYSACCHARIDES

Pectin structure

- Pectin is a heterosaccharide derived from the cell wall of plants.

The characteristic structure of pectin is a linear chain of α -(1-4)linked D-galacturonic acid that forms the pectin-backbone, a homogalacturonan.



POLYSACCHARIDES

Gums

This large group of polysaccharides and their derivatives is characterized by their ability to give highly viscous solutions at low concentrations.

Some common gums are;

Name of gum	Alternative name	Source
Gum Acacia	Gum Arabic	Tree Sap
Agar		Seaweed
Carrageenan		Seaweed
Carboxymethylcellulose	Cellulose Gum	Cotton or Wood
Locust Bean Gum	Carob Gum	Seed
Guar Gum		Seed
Xanthan Gum		Fermentation (Glucose by <i>Xanthomonas Campestris</i>)



POLYSACCHARIDES

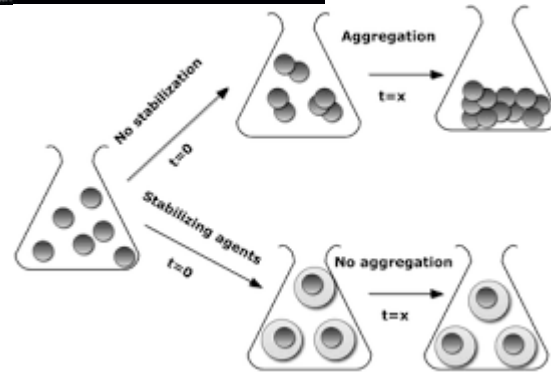
Gums

Gums are used as

- Gelling



- Stabilizing



- Suspending agents



Settled Particles Suspended Particles

Gum	Solubility	Water Interaction
Gum Arabic	Cold water	Slightly thickens
Guar	Cold water	Thickens
Xanthan gum	Cold water	Gels
Alginate	Cold water	Varies
Kappa carrageenan	Heat to ~180°F	Gels
Cellulose gum (CMC)	Cold water	Thickens
HPMC/MC	Heat to ~40-70°C	Gels with heat
Locust bean gum	Heat to 180°F	Thickens
Pectin	Heat to boiling	Gels
Agar	Heat to boiling	Gels

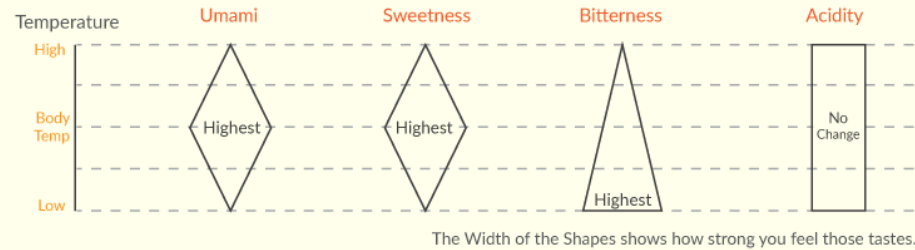
SWEETENERS

Sweetness

Relative sweetness is affected with

- Temperature

Change in Sense of Taste with Temperature



- Concentration



- Additives (Carbondioxide in carbonated beverages, etc.)

SWEETENERS

Sweetness

It is possible to compare relative sweetness of different substances

