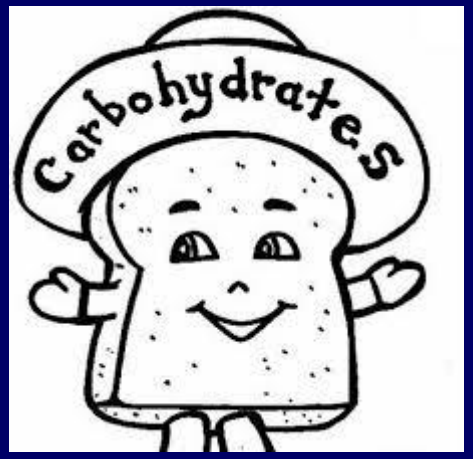


Carbohydrates

7th lect. Of medical chemistry
Dr. Salih Mahdi Salman

Introduction

Also called Saccharides

The most abundant biological molecules

Compounds of the generic formula $(C \cdot H_2O)n$ $(n \geq 3)$

Can also contain other atoms (N, S)

The Functions of Carbohydrates in the Body

There are five primary functions of carbohydrates in the human body.

1. **Energy Production :** the primary role of carbohydrates is to supply energy to all cells in the body.
2. **Energy Storage:** If the body already has enough energy to support its functions, the excess glucose is stored as glycogen (the majority of which is stored in the muscle and liver)
3. **Building Macromolecules:** Although most absorbed glucose is used to make energy, some glucose is converted to ribose and deoxyribose, which are essential building blocks of important macromolecules, such as RNA, DNA, and ATP.
4. **Sparing Protein:** In a situation where there is not enough glucose to meet the body's needs, glucose is synthesized from amino acids. The presence of adequate glucose basically spares the breakdown of proteins from being used to make glucose needed by the body.
5. **Lipid Metabolism:** As blood-glucose levels rise, the use of lipids as an energy source is inhibited. Thus, glucose additionally has a "fat-sparing" effect. This is because an increase in blood glucose stimulates release of the hormone insulin, which tells cells to use glucose (instead of lipids) to make energy.

Monosaccharides

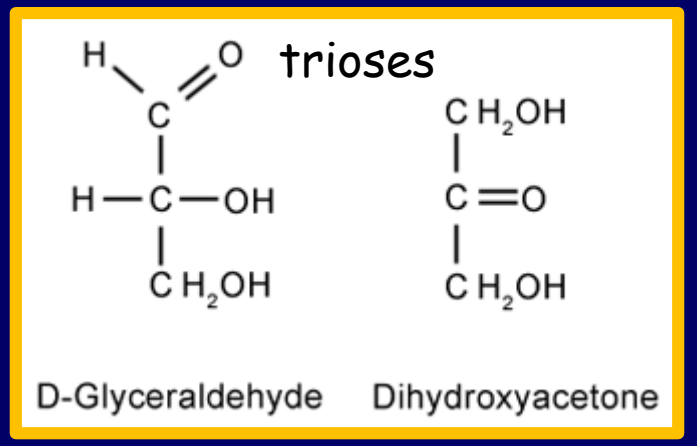
- Derived from CO_2 and H_2O by photosynthesis

$$6\,CO_2 + 6\,H_2O \xrightarrow{h\nu} C_6H_{12}O_6 + 6\,O_2$$

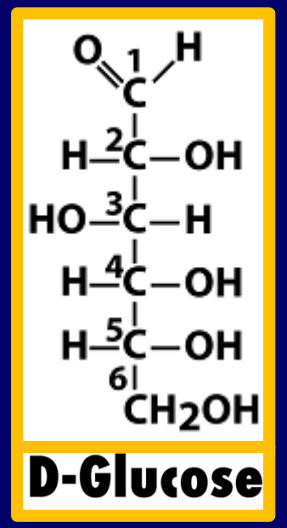
- They are classified according to:

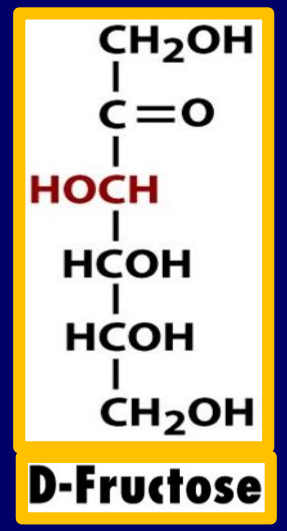
1. Their carbonyl group: *aldehydes* or *ketones*

2. The number of C (trioses, tetroses, pentoses,…)



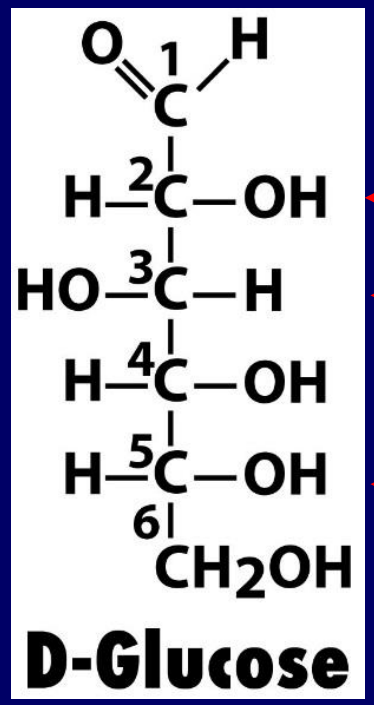
aldoses *ketoses*





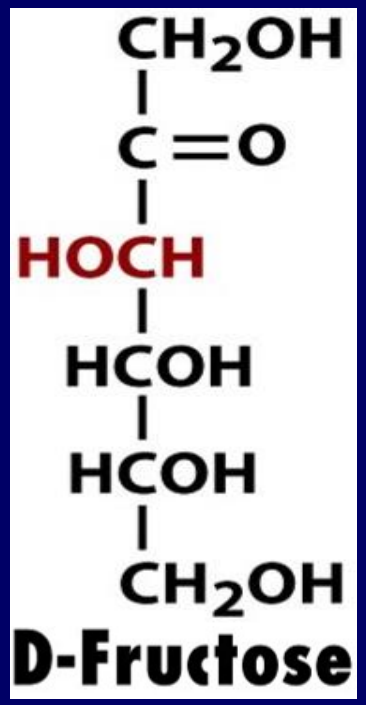
Hexoses

Stereoisomers



Chiral Centers

2^4=16 steroisomers



Chiral Centers

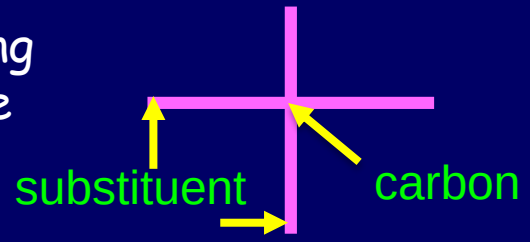
2^3=8 steroisomers

Asymmetric Centers or Chiral Centers: a carbon atom with four different constituents

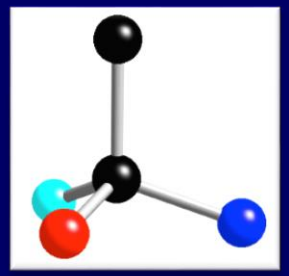
Fischer Projections

Tetrahedral carbon represented by two crossed lines:

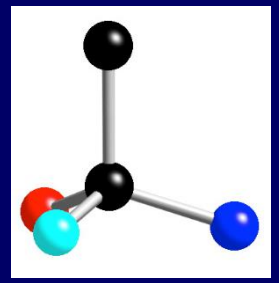
horizontal line is coming out of the plane of the page (toward you)



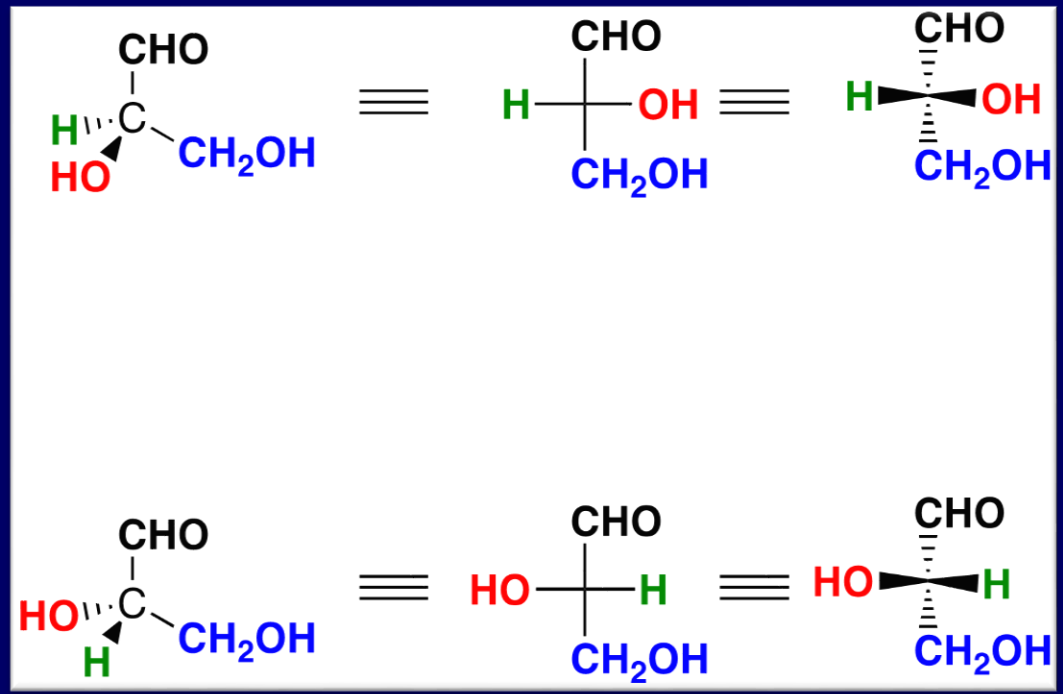
vertical line is going back behind the plane of the paper (away from you)

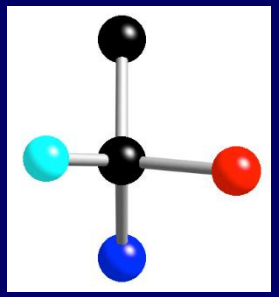


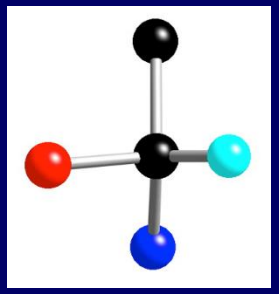
(*R*)-(+)-glyceraldehyde



(*S*)-(-)-glyceraldehyde







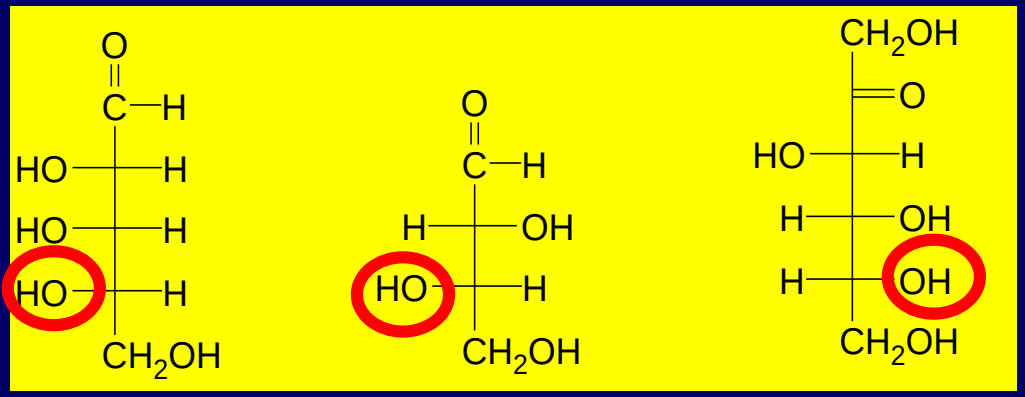
D, L Notation

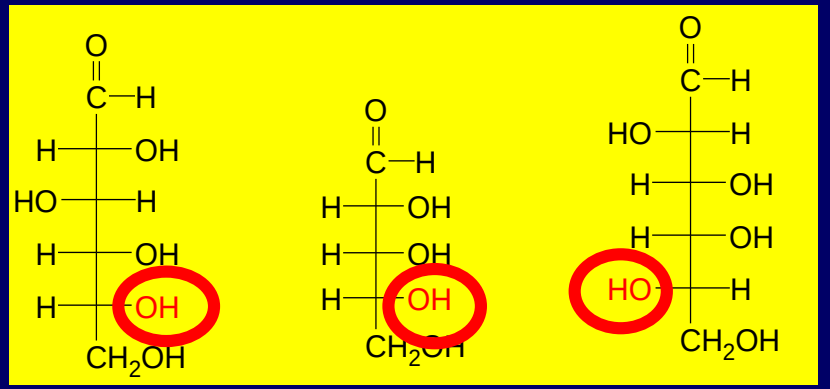
D-carbohydrates have the -OH group of the highest numbered chiral carbon pointing to the right in the Fischer projection as in R-(+)-glyceraldhyde

D-glyceraldehyde
R-(+)-glyceraldhyde
(+)-rotation = dextrorotatory
= d

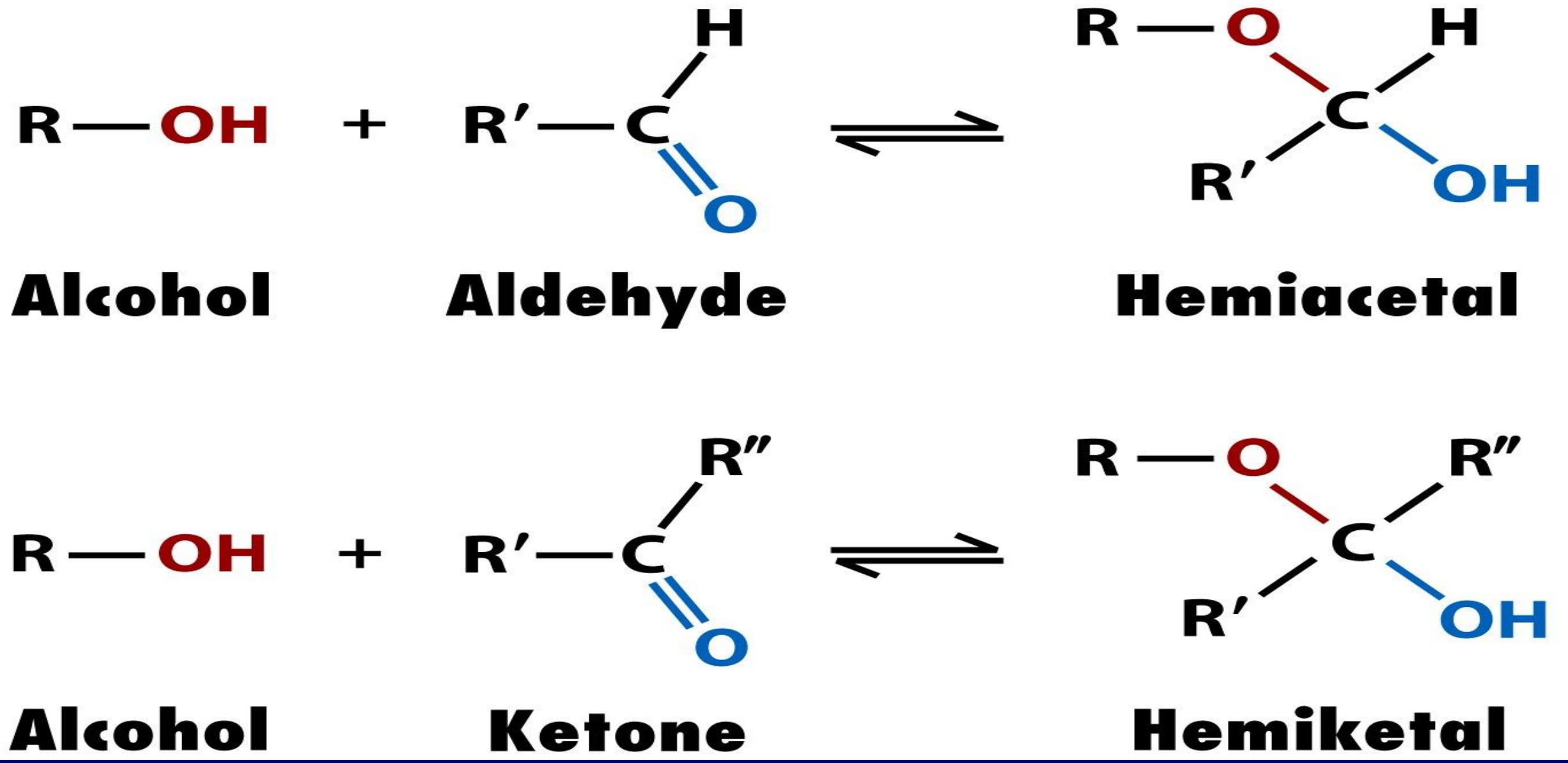
L-glyceraldehyde
S-(-)-glyceraldhyde
(-)-rotation = levorotatory
= l

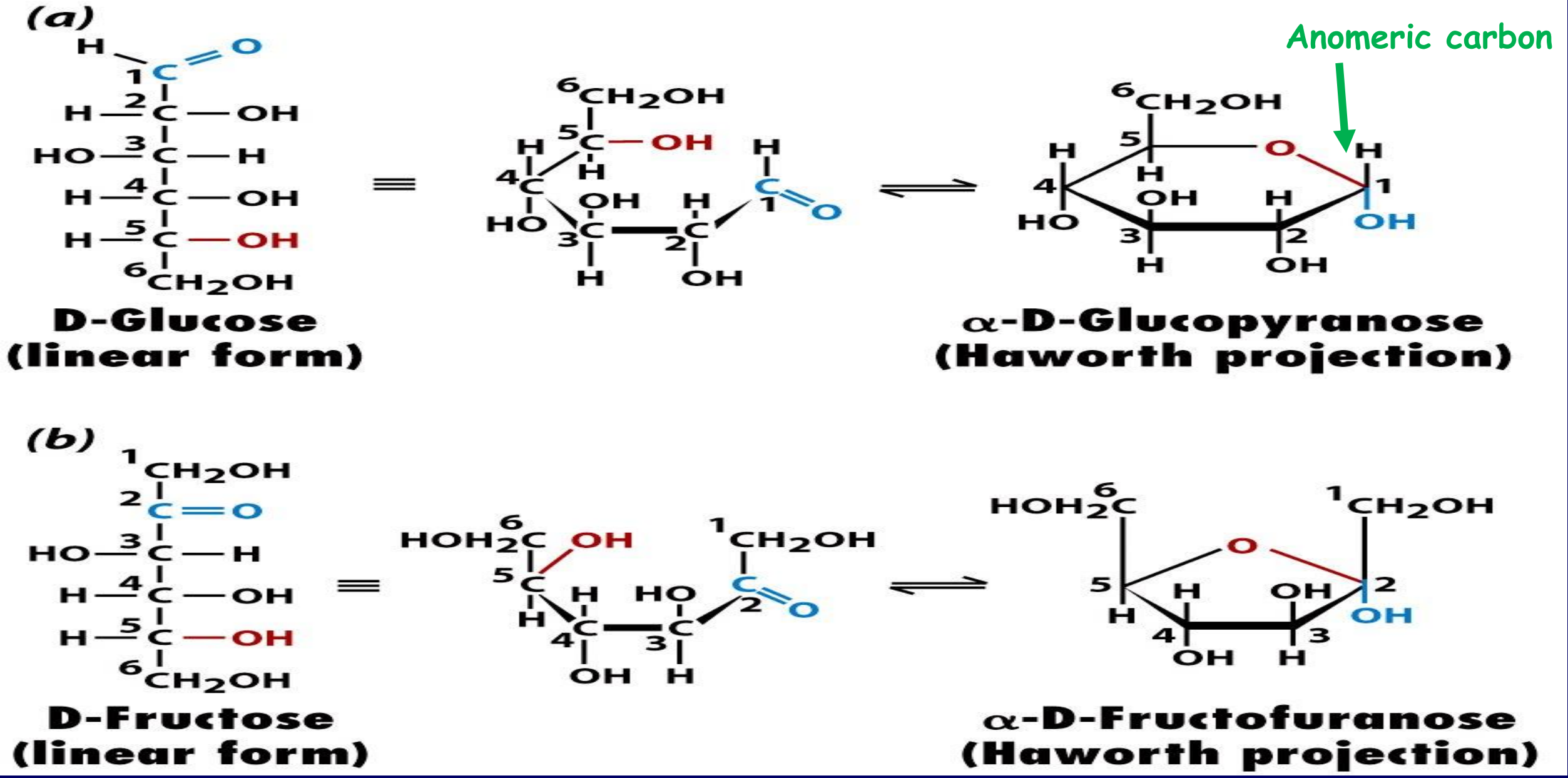
For carbohydrates, the convention is to arrange the Fischer projection with the carbonyl group at the top for aldoses and closest to the top for ketoses. The carbons are numbered from top to bottom.



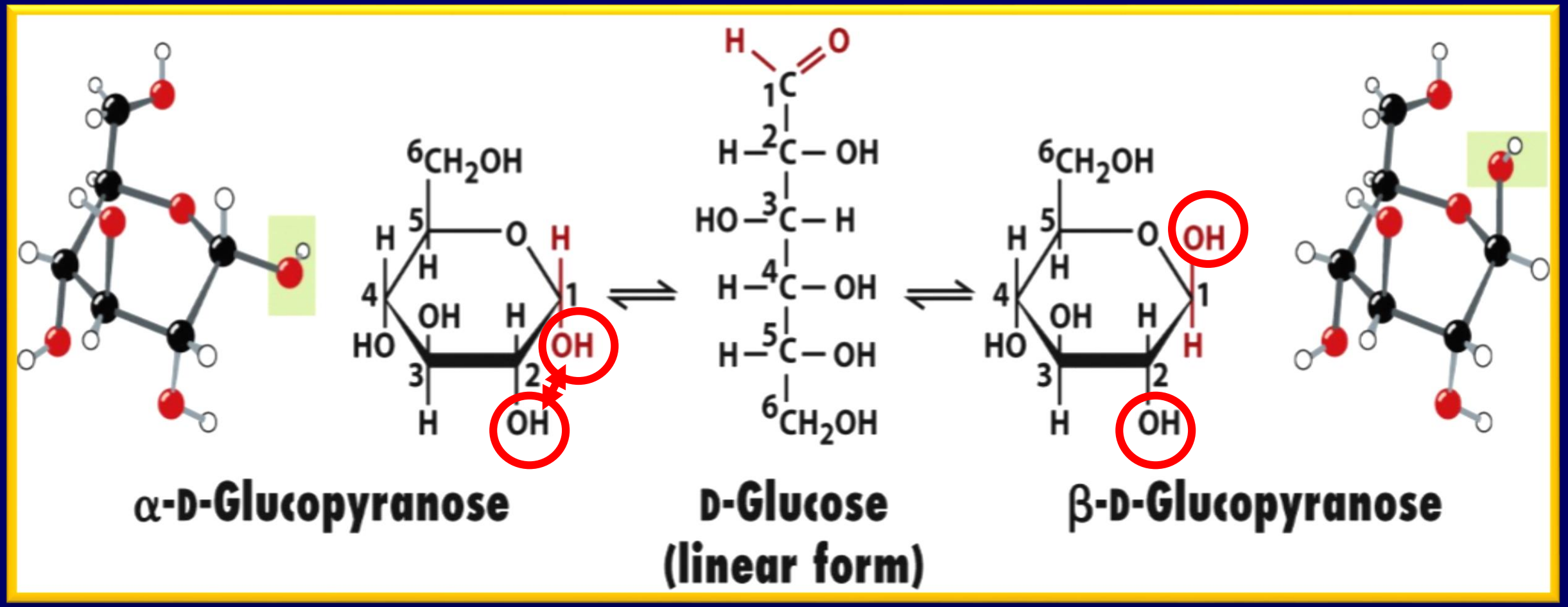


Cyclization of monosaccharaides



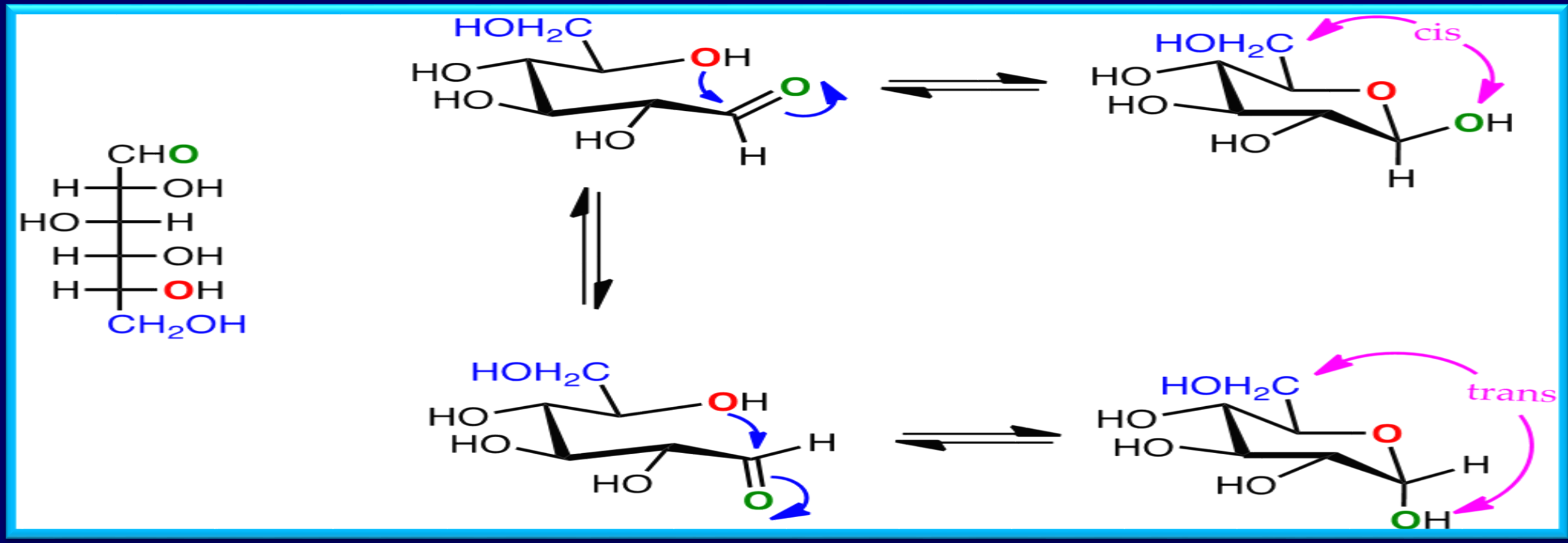

(a)
D-Glucose
(linear form)
Anomeric carbon
α-D-Glucopyranose
(Haworth projection)
(b)
D-Fructose
(linear form)
α-D-Fructofuranose
(Haworth projection)

- ✓ The two anomers freely interconvert in aqueous solution
- ✓ At equilibrium: D-glucose is a mixture of the β anomer (63.6%) and the *a* anomer (36.4%)



Mutarotation

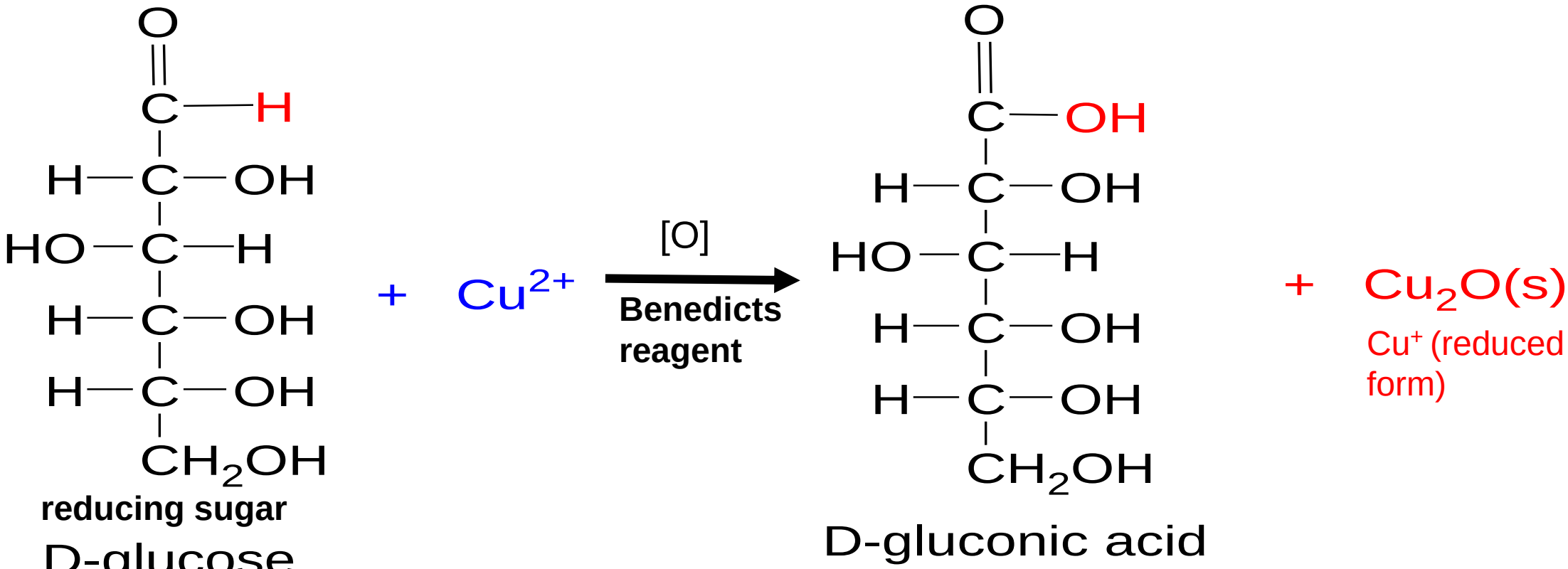
The α- and β-anomers are in equilibrium, and interconvert through the open form. The pure anomers can be isolated by crystallization. When the pure anomers are dissolved in water they undergo mutarotation, the process by which they return to an equilibrium mixture of the anomer.



Sugar Derivatives

1. Aldonic acids

Oxidation of the aldehyde group of aldoses → Aldonic Acids



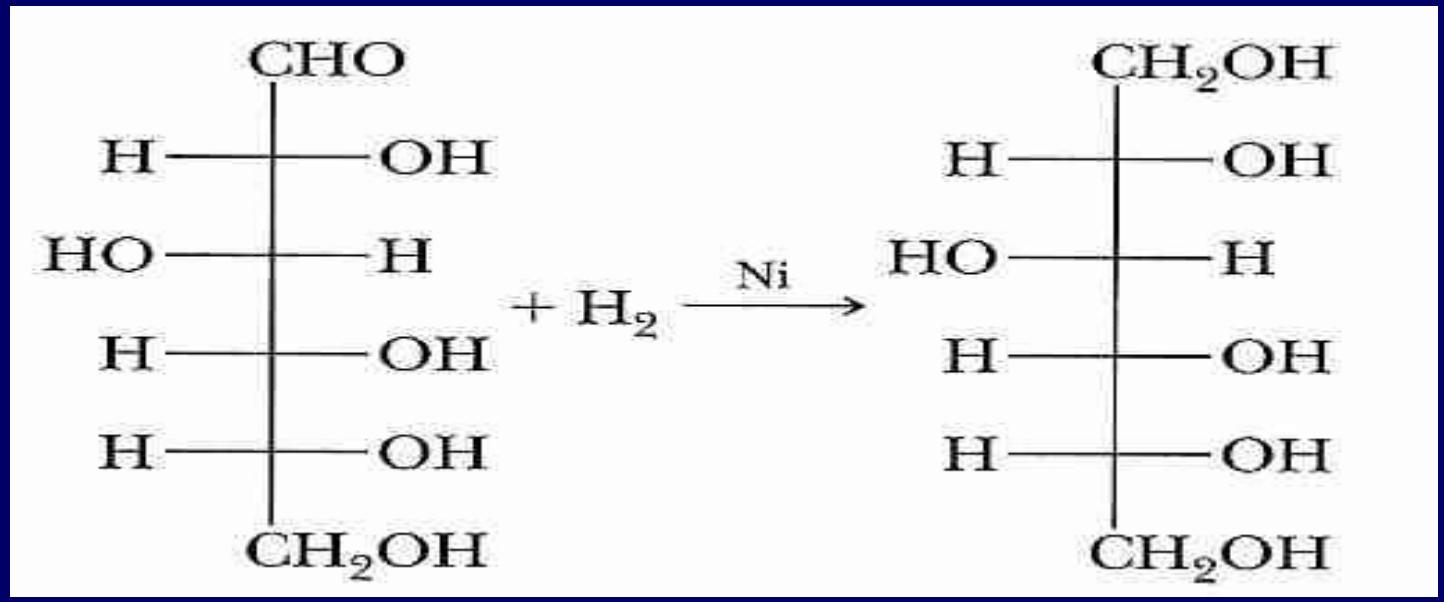
2. Alditols

The reduction of monosaccharides

Involves the carbonyl group.

Produces sugar alcohols called *alditols.*

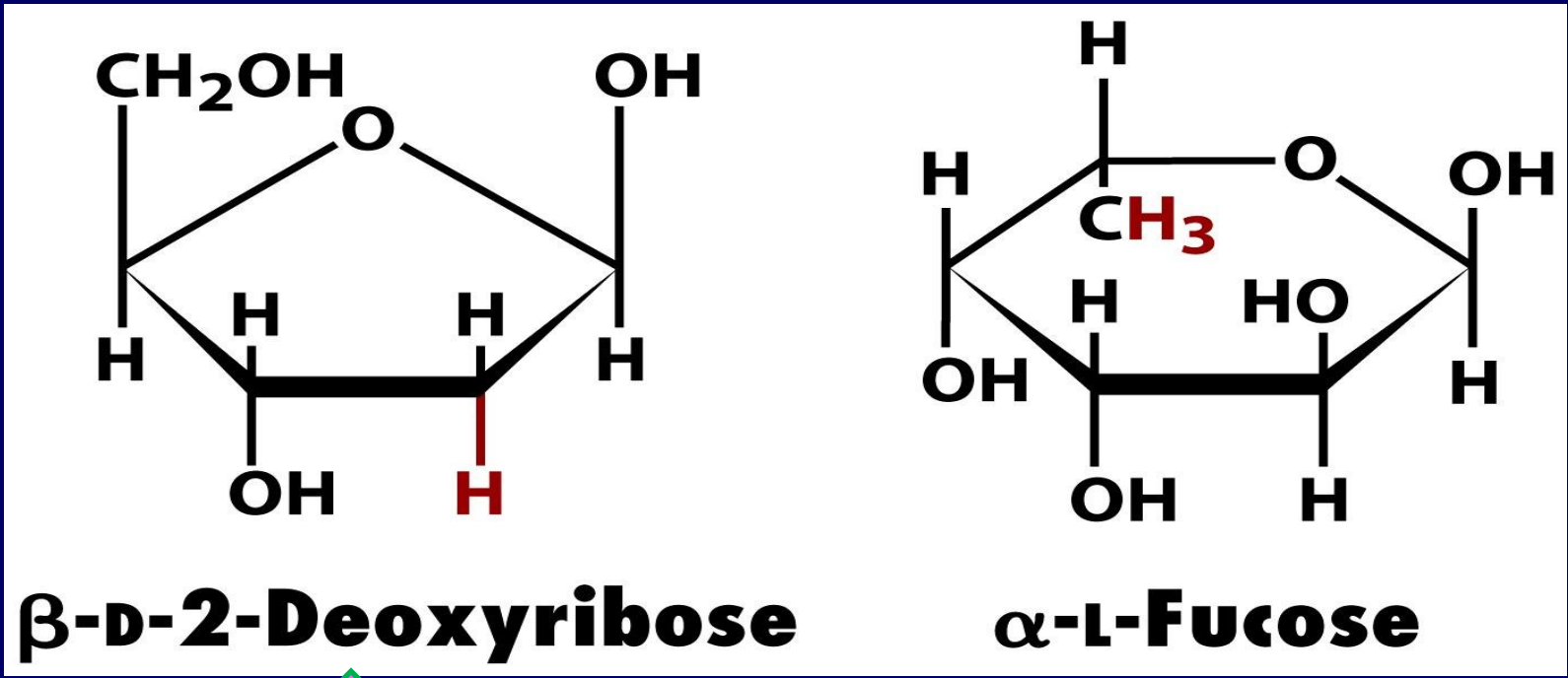
Such as D-glucose gives D-glucitol also called sorbitol.



D-glucose D-glucitol

3. Deoxy Sugars

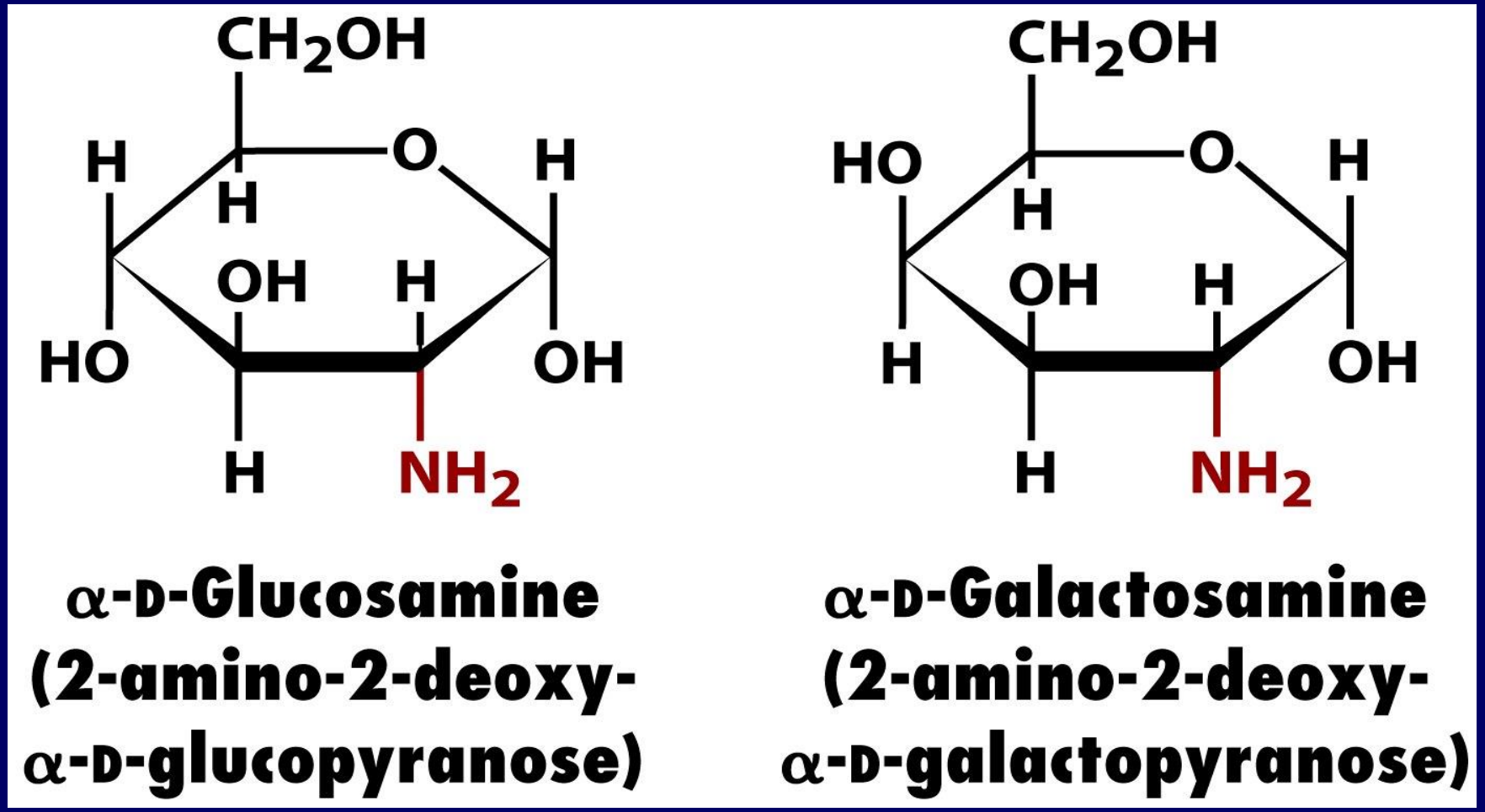
Carbohydrates that are missing hydroxyl group.



Part of DNA

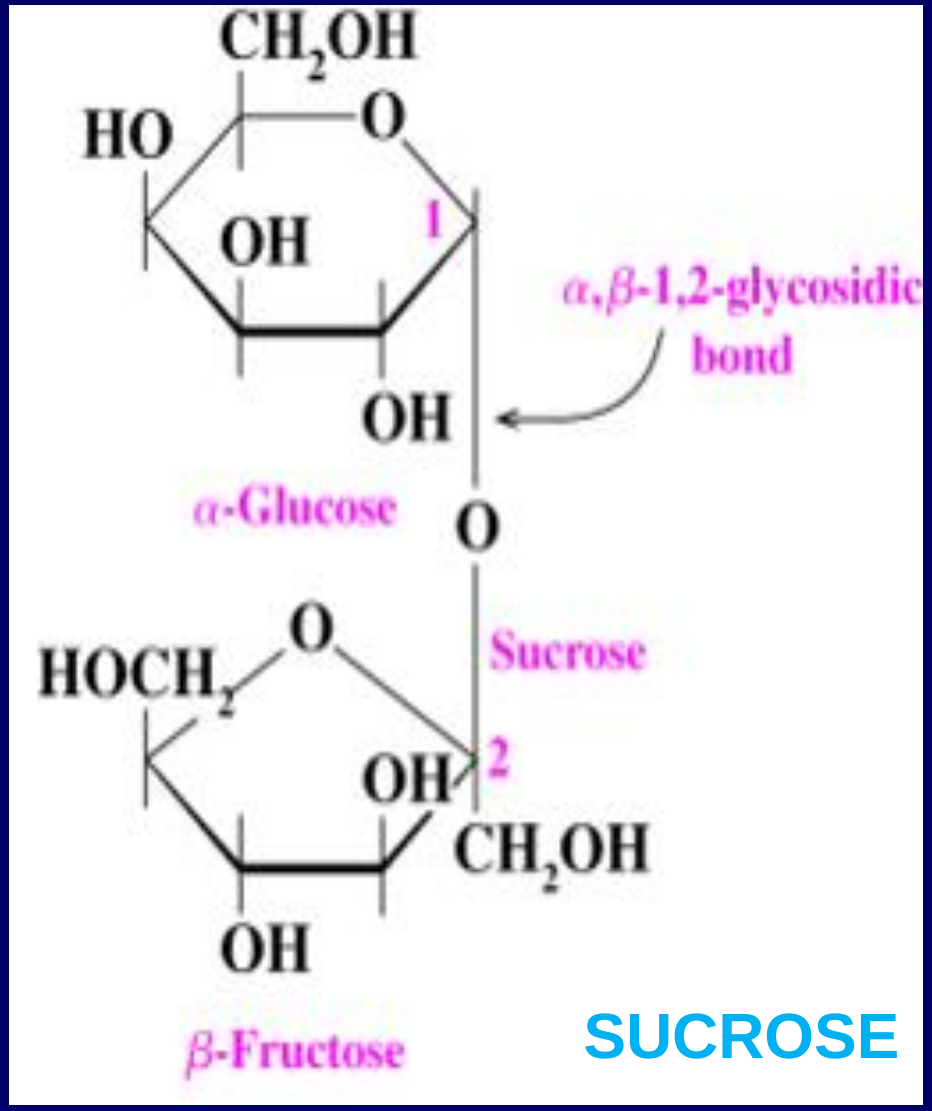
4. Amino Sugars

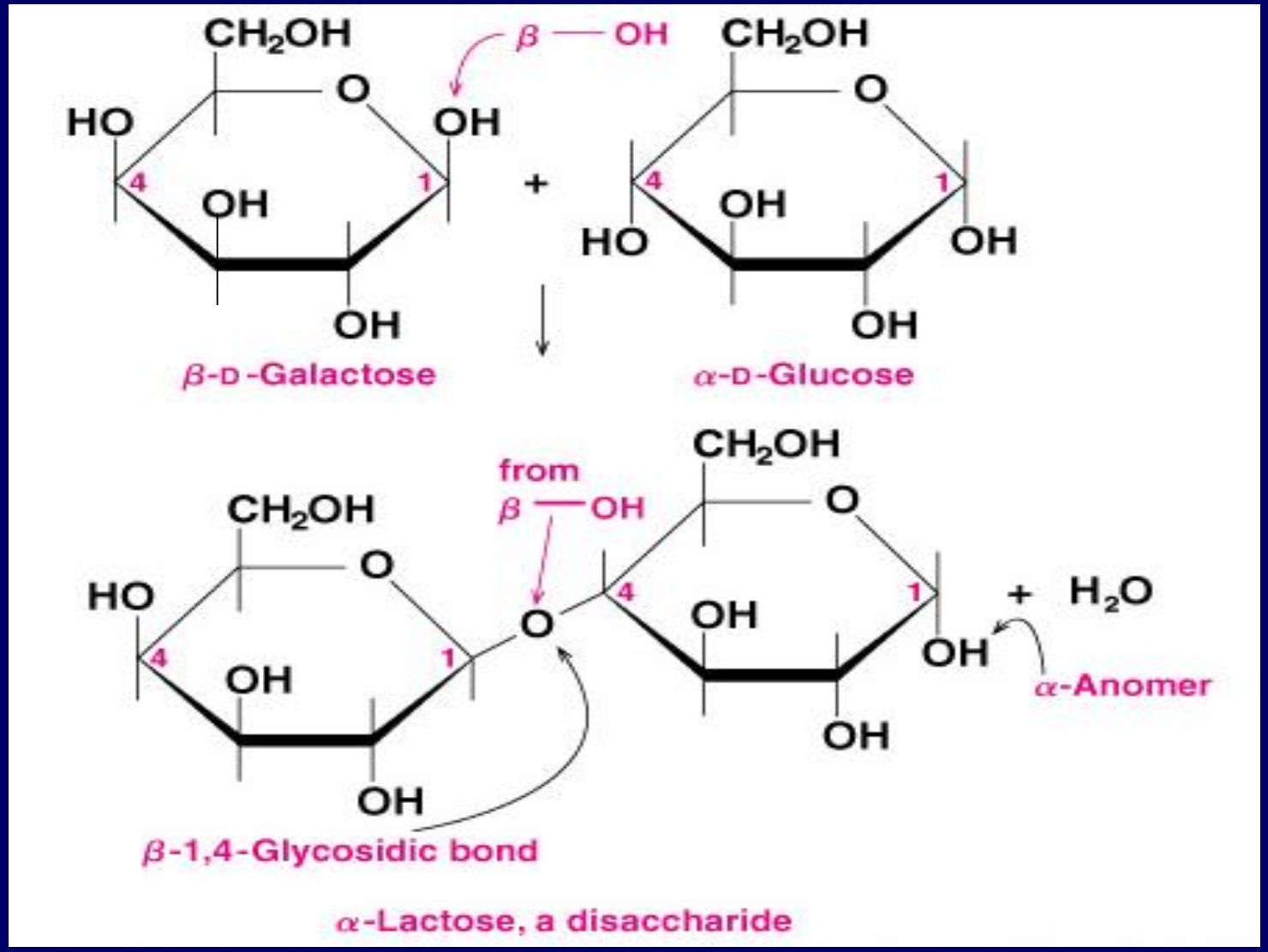
Carbohydrates in which a hydroxyl group is replaced with an -NH_2 or -NHAc group



Disaccharide

Consists of two monosaccharides.





Polysaccharides

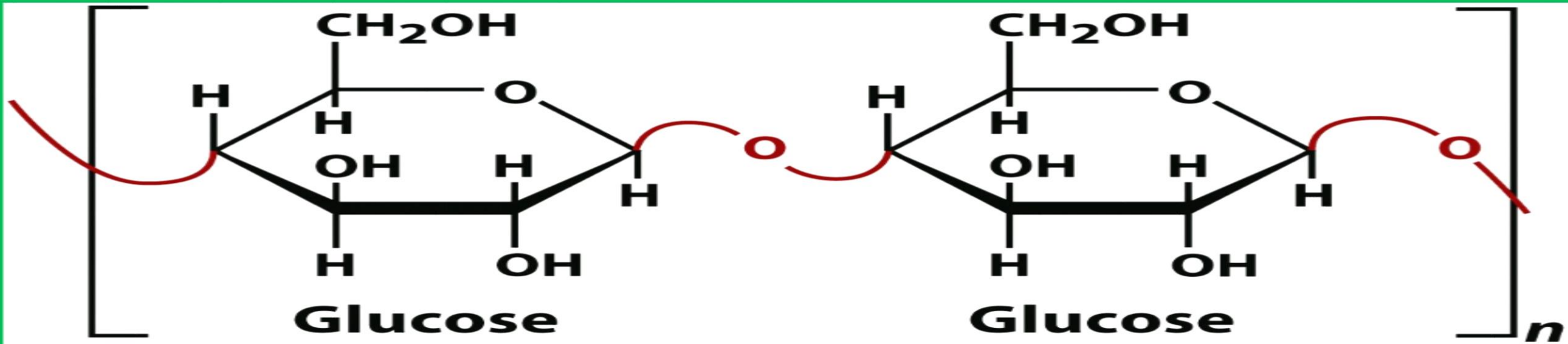
- Also known as *glycans*: monosaccharides linked together by *glycosidic bonds*
- Homopolysaccharides (composed of a single type of sugar monomer cellulose) and heteropolysaccharides (contain two or more different monosaccharide units heparin).
- Form both branched and linear polymers
- Two classes: Structural Polysaccharides and Storage Polysaccharides

Structural Polysaccharides

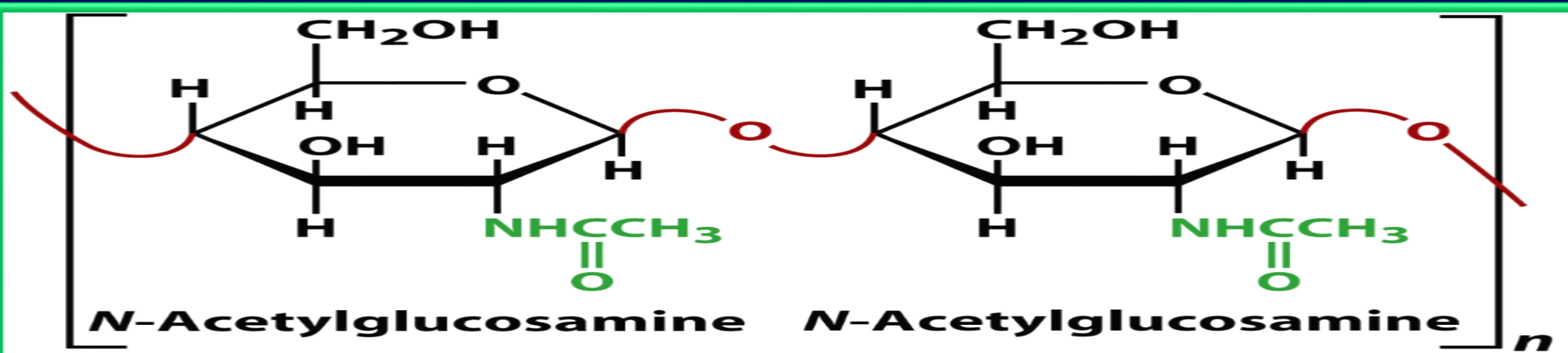
Composition similar to storage polysaccharides, but small structural differences greatly influence properties

Cellulose: Is the principal strength and support of trees and plants.

Chitin: exoskeletons of crustaceans, insects and spiders, and cell walls of fungi.



Cellulose Up to 15,000 D-glucose residues



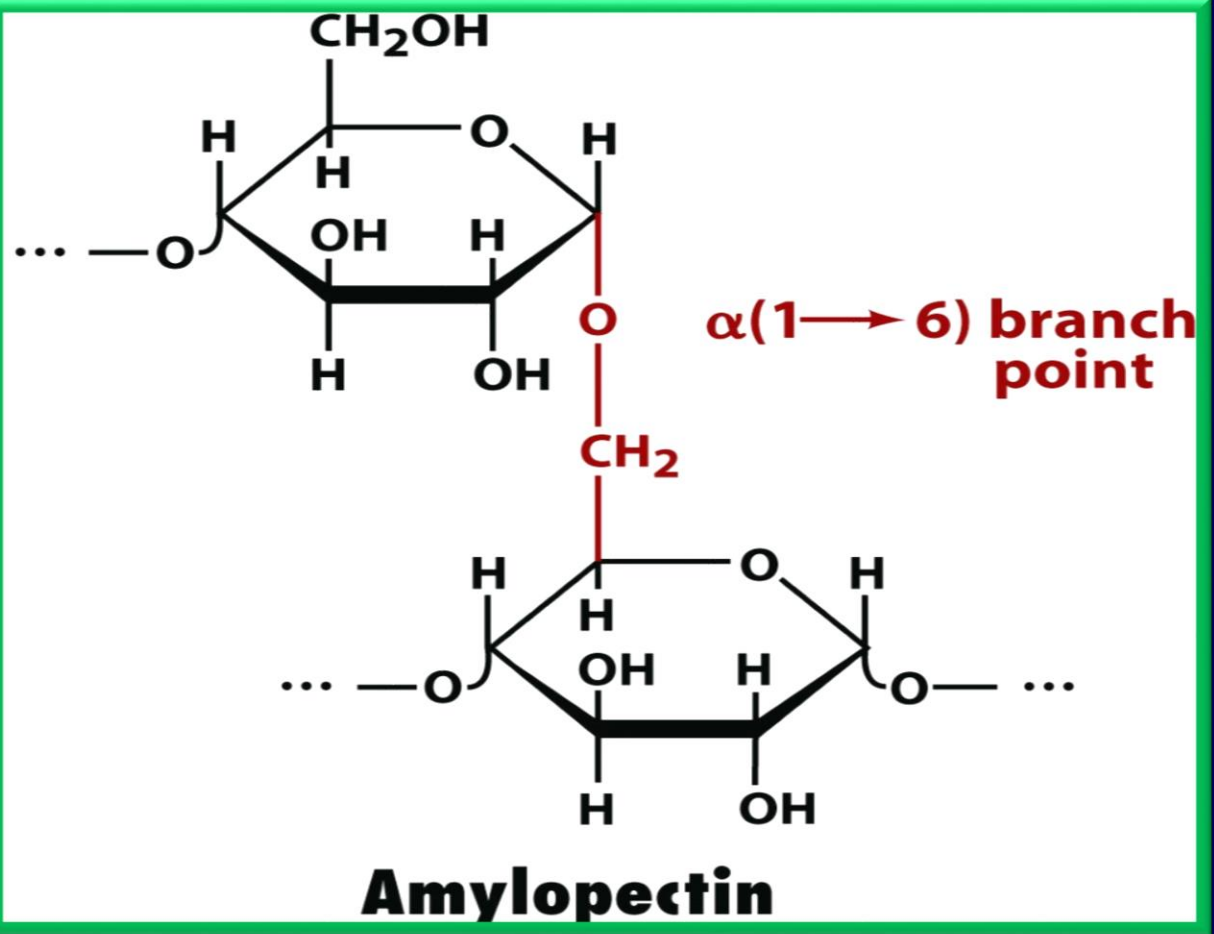
Chitin

Storage Polysaccharides

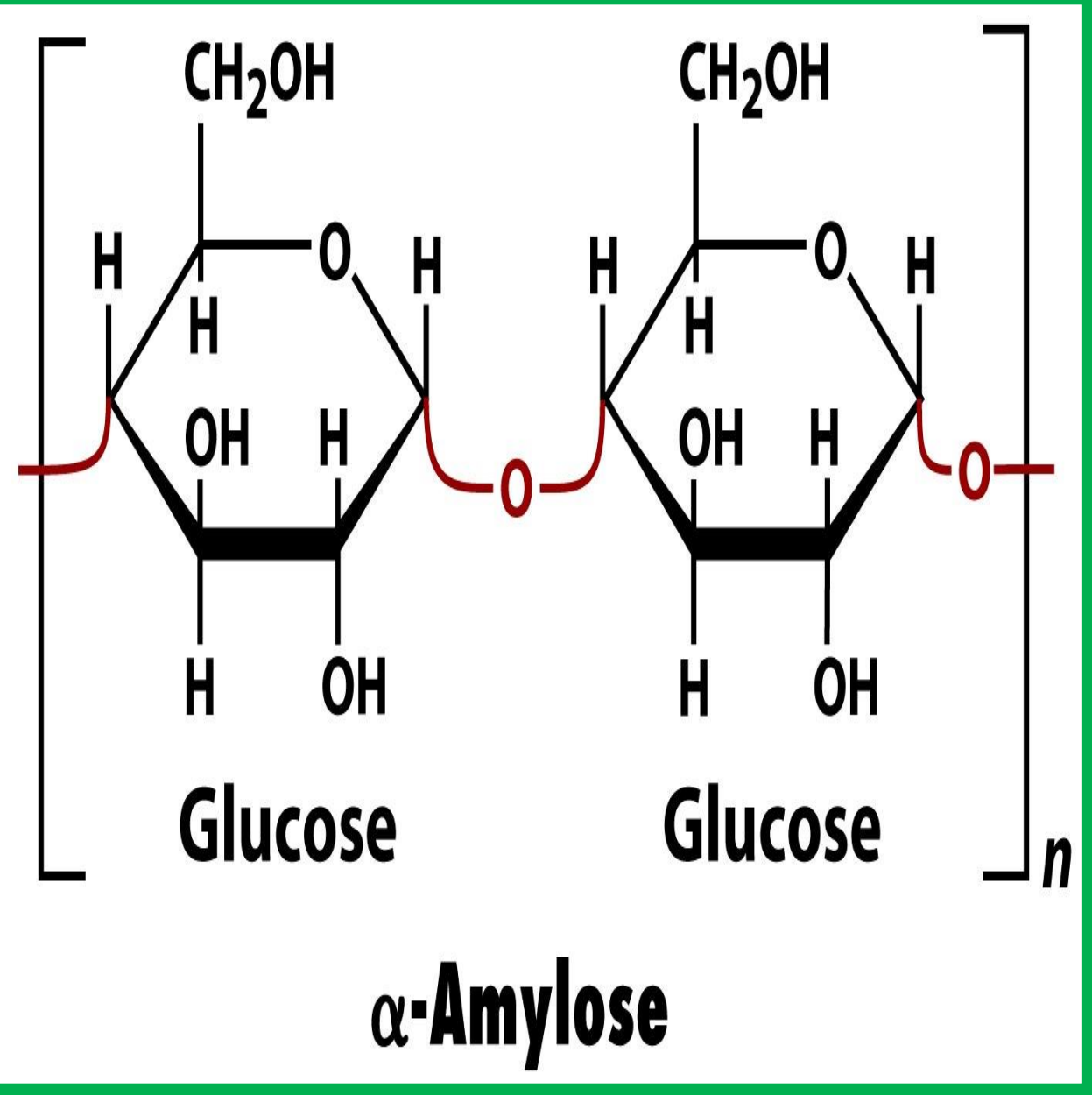
Starch: A mixture of glycans (principal energy source of plants) composed of α-**Amylose** and **Amylopectine**

Glycogen: Storage polysaccharide of animals (skeletal liver) structurally it resembles Amylopectin, but is more branched

It is degraded by **glycogen phosphorylase** (cleaves the α (1 - 4) bonds) and a **glycogen debranching enzyme** (cleaves the α (1 - 6) bonds).

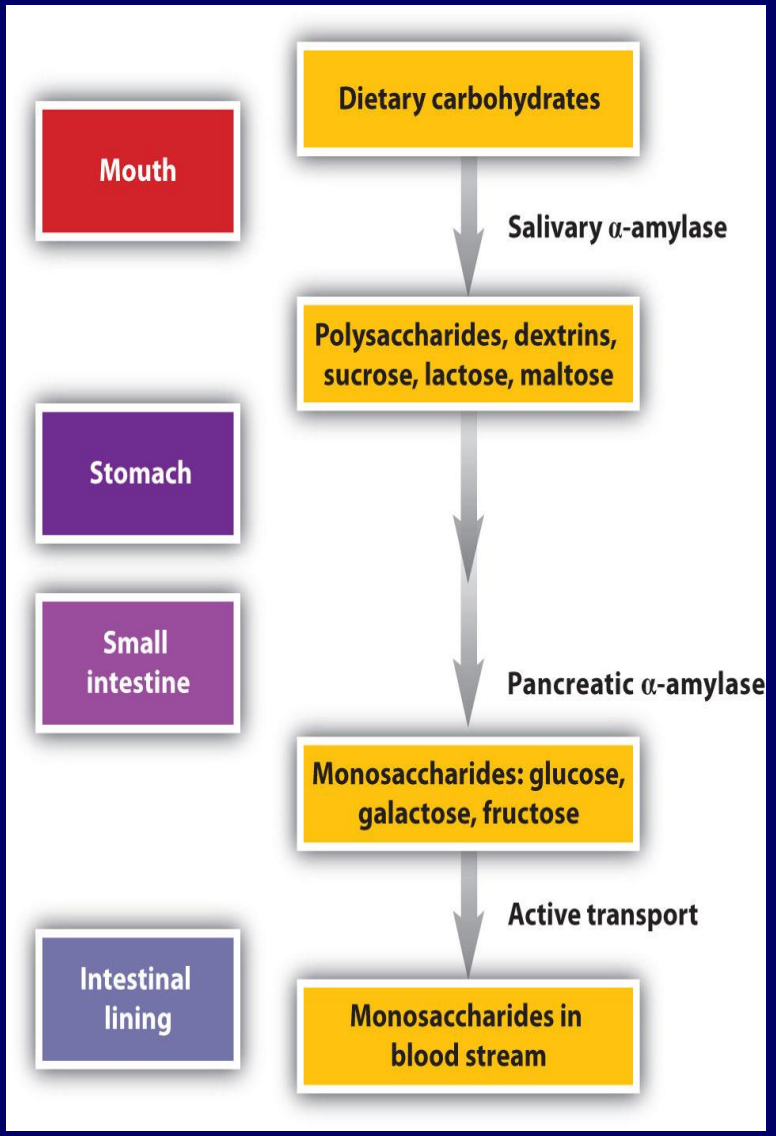


Up to 10^6 molecules of glucose residues mainly α (1 - 4),but has branched molecules via α (1 - 6) every 24-30 glucose residues.



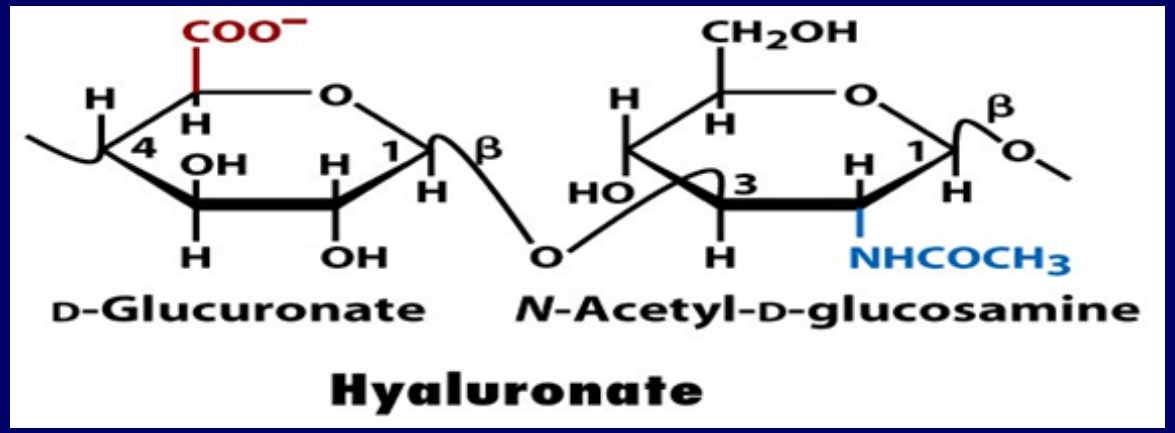
Digestion of Carbohydrates

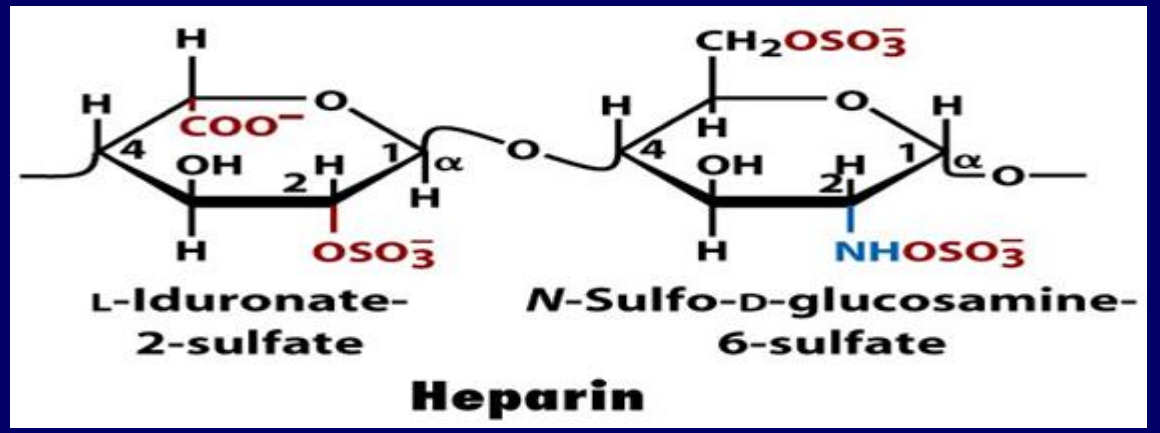
- Carbohydrate digestion begins in the mouth where salivary α-amylase attacks the α-glycosidic linkages in starch, the main carbohydrate ingested by humans.
- Cleavage of the glycosidic linkages produces a mixture of dextrins, maltose, and glucose.
- The α-amylase mixed into the food remains active as the food passes through the esophagus, but it is rapidly inactivated in the acidic environment of the stomach.
- The primary site of carbohydrate digestion is the small intestine.
- The secretion of α-amylase in the small intestine converts any remaining starch molecules, as well as the dextrins, to maltose.
- Maltose is then cleaved into two glucose molecules by maltase.
- Disaccharides such as sucrose and lactose are not digested until they reach the small intestine, where they are acted on by sucrase and lactase, respectively.
- The major products of the complete hydrolysis of disaccharides and polysaccharides are three monosaccharide units: glucose, fructose, and galactose. These are absorbed through the wall of the small intestine into the bloodstream.



Glycosaminoglycans

- Part of the connective tissue
- Unbranched polysaccharides: Alternating uronic acid and hexosamine residues
- Glycosaminoglycan is a repeating disaccharide consisting of two glucose derivatives, glucuronate (glucuronic acid) and *N*-acetylglucosamine.
- The glycosidic linkages are β (1-3) as in (**hyaluronate)** and β (1-4) as in (heparin).
- Glycosaminoglycans are highly polar and attract water. They are therefore useful to the body as a lubricant or as a shock absorber.





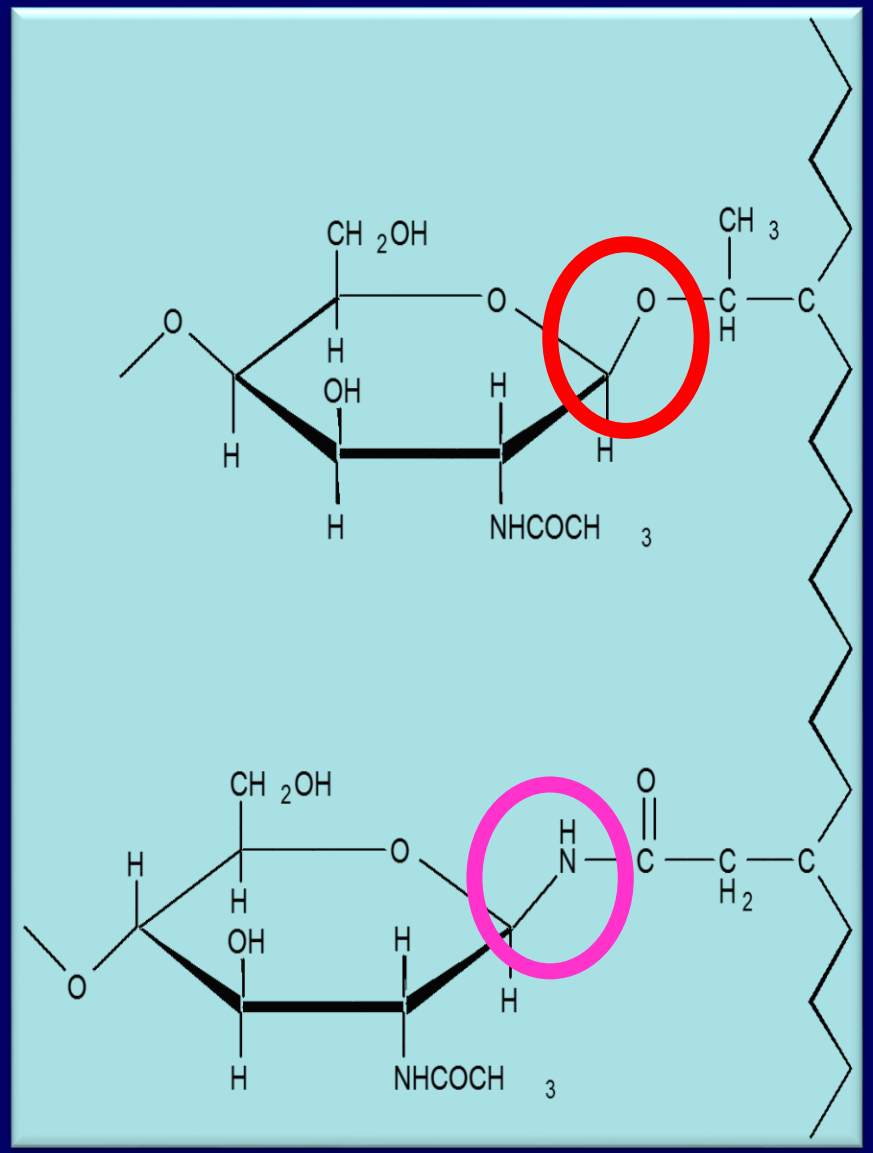
Proteoglycans

- Proteoglycans are glycosaminoglycans that are covalently linked to serine and threonine residues of specific core proteins

Linking sugars to proteins.

O-glycosidic bonds using hydroxyl groups of serine and threonine

N-glycosidic bonds using side chain amide nitrogen of asparagine residue



Proteoglycans and disease

- An inability to break down proteoglycans is characteristic of a group of genetic disorders, called mucopolysacchridoses.

- The inactivity of specific lysosomal enzymes that normally degrade glycosaminoglycans leads to the accumulation of proteoglycans within cells. This leads to a variety of disease symptoms, depending upon the type of proteoglycan that is not degraded

Carbohydrates and Blood Glucose

- Carbohydrates are not essential nutrients, because the carbon skeletons of amino acids can be converted into glucose .

- However, the absence of dietary carbohydrate leads to ketone body production ,and degradation of body protein whose constituent amino acids provide carbon skeletons for gluconeogenesis

- The RDA (Recommended Daily Allowance) for carbohydrate is set at 130 g/day for adults and children, based on the amount of glucose used by carbohydrate-dependent tissues, such as the brain and erythrocytes.

- Adults should consume 45–65 percent of their total calories from carbohydrates.

- It is recommended that added sugar represent no more than 25% of total energy because of concerns that sugar may displace nutrient-rich foods from the diet, potentially leading to deficiencies of certain micronutrients

Source of glucose in the body

There are two main mechanisms used by humans and many other animals to maintain blood glucose levels, avoiding hypoglycemia:-

1. Glycogenolysis

- 1/3rd of total glycogen is stored in liver and 2/3rd in muscle.
- When blood glucose falls liver cells break down glycogen into single molecules of glucose, which becomes available to supply energy to central nervous system and other organs .
- During exercise the muscle cell themselves use up the glycogen they store.

2. Gluconeogenesis

- Gluconeogenesis (GNG) is a metabolic pathway that results in the generation of glucose from non-carbohydrate carbon substrates such as pyruvate , lactate , glycerol and glucogenic amino acids.

- Glycogen stores only last for some hours , if a person does not replenish the depleted glycogen stores, body protein are broken down to make glucose by a process called “gluconeogenesis”

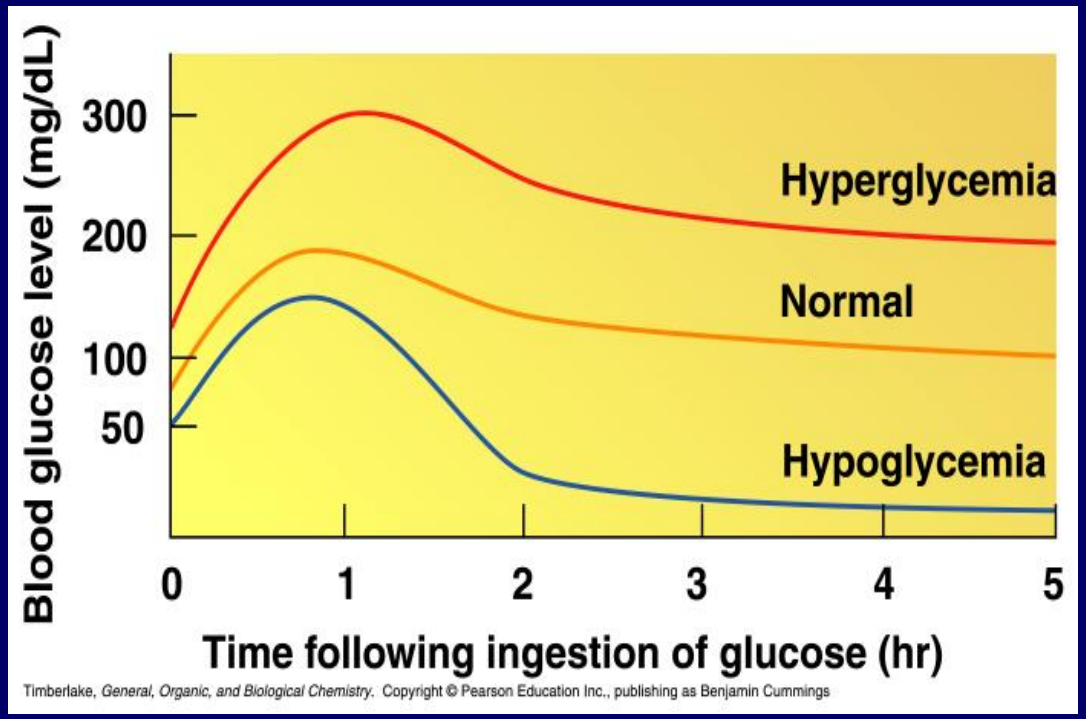
- Taking adequate amount of carbohydrate prevents the use of protein for energy, this role of carbohydrate is called protein sparing action.

- Inadequate supply of carbohydrates causes break down of body fat reserves. This not only supplies energy but also produces ketone bodies.

- Some ketone bodies are used by muscle and other tissues for energy, but when produced in excess they accumulate in blood and cause ketosis (disturbance of bodies normal acids-base balance)

Blood Glucose Level

Mg/dl = Milligrams per deciliter



Glucose has a normal blood level of 70-90 mg/dL. **(mg/dl x 0.0555= mmol/l)**

A glucose tolerance test measures blood glucose for several hours after ingesting glucose.

Glycemic index

Defined as the area under the blood glucose curves seen after ingestion of a meal with carbohydrate-rich food, compared with the area under the blood glucose curve observed after a meal consisting of the same amount of carbohydrate in the form of glucose or white bread.

Maintaining glucose homeostasis

- Blood glucose homeostasis is regulated mainly by two hormones:

(i) Insulin- secreted when blood glucose is high. Controls transport of glucose from blood to muscle and fat cells.

(ii) Glucagon- secreted when blood glucose is low. Helps in release of glucose from storage.

- Blood glucose remains high because insulin is inadequate (type 1 diabetes) or ineffective (type 2 diabetes).

- Type 2 diabetes is more common (cells fail to respond to insulin) and occurs as a consequence of obesity.

Hypoglycemia

Blood glucose level in very low.

Is rare in healthy people. Mostly seen as a consequence of poorly managed diabetes.

Symptoms are : weakness, rapid heart beat, hunger, sweating, anxiety, trembling


Thank you for your attention