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Carbohydrates

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DEFINITION

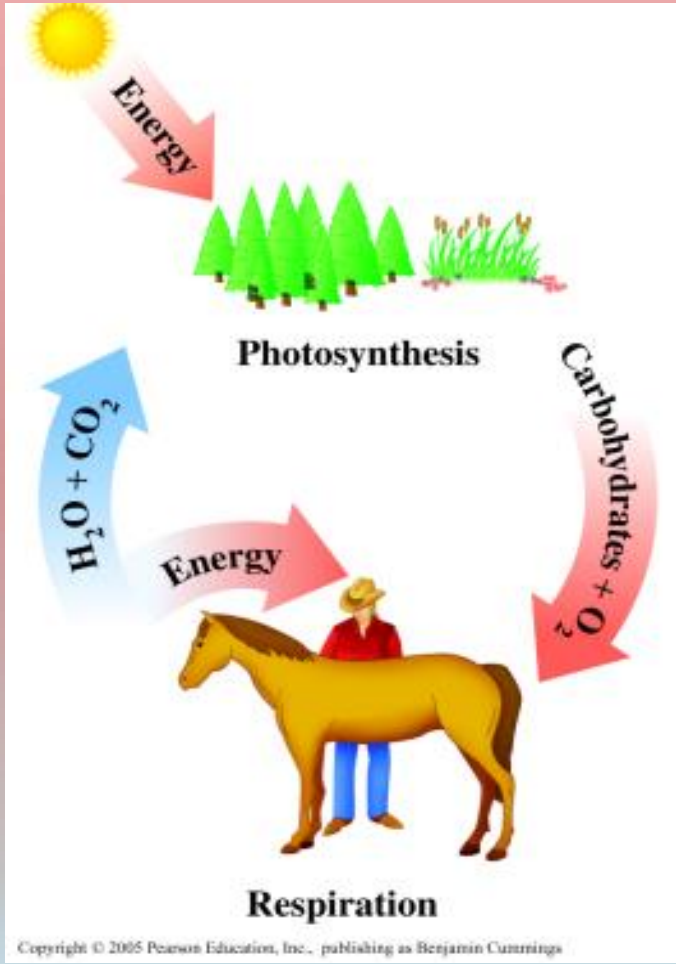
- Carbohydrates may be defined chemically as ***aldehyde*** or ***ketone*** derivatives of polyhydroxy (more than one hydroxy group) alcohols or as compounds that yield these derivatives on hydrolysis.

Carbohydrates are :

- A major source of energy from our diet.
- Composed of the elements C, H, and O.
- Also called saccharides, which means “sugars.”

Carbohydrates

- Such as glucose are synthesized in plants from CO_2, H_2O, and energy from the sun.
- Are oxidized in living cells (respiration) to produce CO_2, H_2O, and energy.



Functions of Carbohydrates

- Source of energy for living beings, e.g. ***glucose***
- Storage form of energy, e.g. ***glycogen*** in animal tissue and ***starch*** in plants.
- Serve as structural component, e.g. ***glycosaminoglycans*** in humans, ***cellulose*** in plants and ***chitin*** in insects.
- Non-digestable carbohydrates like cellulose, serve as dietary fibers Constituent of nucleic acids RNA and DNA, e.g. ***ribose*** and ***deoxyribose*** sugar.
- Play a role in lubrication, cellular intercommunication and immunity
- Carbohydrates are also involved in detoxification.

Classification of Carbohydrates

- Carbohydrates are classified into three groups:
  1. Monosaccharides
  2. Oligosaccharides
  3. Polysaccharides
- The suffix ose indicates that a molecule is a carbohydrate.e.g maltose, glucose, lactose, fructose ,ribose

Monosaccharides (Greek: Mono = one)

- Monosaccharides are also called ***simple sugars.*** The term
- Sugar is applied to carbohydrates that are soluble in water and sweet to taste
- They consist of a single unit
- Polyhydroxy aldehyde or ketone unit, and thus cannot be hydrolyzed into a simpler form.

Monosaccharides

- Monosaccharides may be subdivided into two groups as follows:

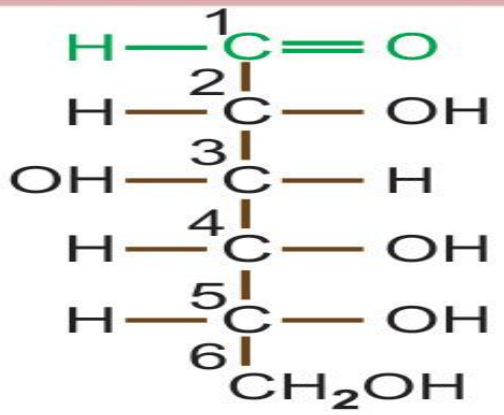
1. Depending upon the number of carbon atoms they possess, e.g.
   - Trioses 3 carbon Glyceraldehyde
   - Tetroses 4 carbon Erythrose
   - Pentoses 5 carbon Ribose, Xylose
   - Hexoses 6 carbon Glucose, Galactose, fructose
   - Heptoses. 7 carbon Glucoheptos
2. Depending upon the functional aldehyde (CHO) or ketone (C=O) group present:
   - Aldoses CHO Glucose, Galactose
   - Ketoses. C=O Fructose

Oligosaccharides (Greek: oligo = few)

- Oligosaccharides consist of a short chain of monosaccharide units (2 to 10 units), joined together by a characteristic bond called ***glycosidic bond*** which, on hydrolysis, gives two to ten molecules of simple sugar (monosaccharide) units.

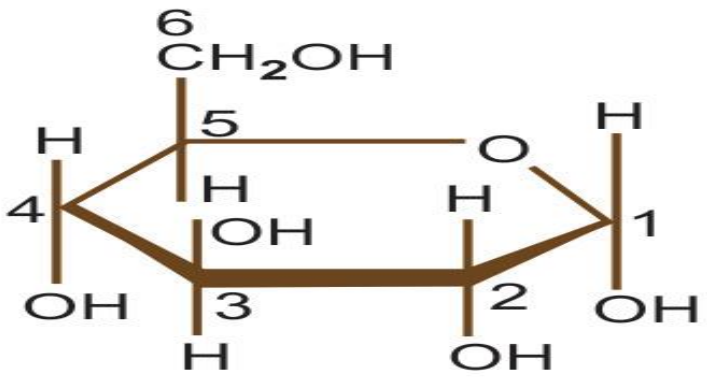
GLUCOSE

- Physiologically and biomedically, glucose is the most important monosaccharide
- It is called blood sugar
- $C_6H_{12}O_6$
- It is monosaccharide
- It is source of energy
- It is produced by hydrolysis of glycogen

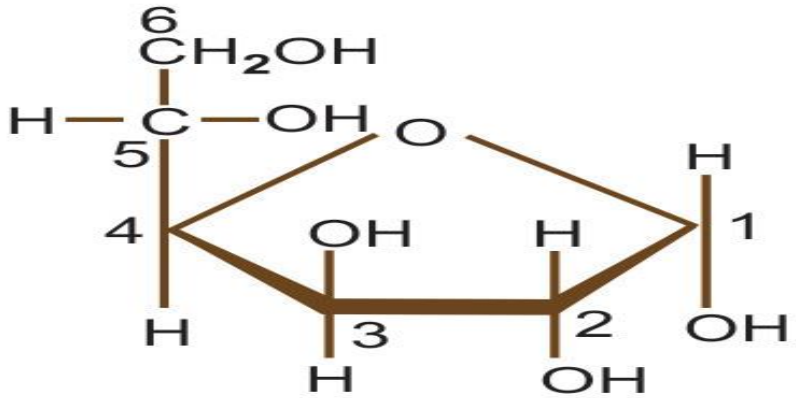


D-Glucose

Straight chain structure of D-glucose (Fisher projection formula)



α-D-Glucopyranose



α-D-Glucofuranose

Ring structure or Haworth projection formula of glucose

- ***isomerism***

  Glucose and fructose are isomers of each other having the same chemical (molecular) formula C6H12O6, but they differ in structural formula There is a ***keto*** group in position two of fructose and an ***aldehyde*** group in position one of This type of isomerism is known as ***ketose-aldose isomerism .***

Asymmetric carbon

- Asymmetric carbon: carbon atom which attached to four(4)different groups .

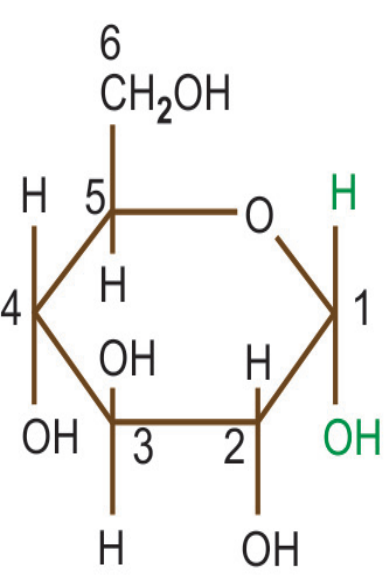
α-D-Glucose
+112°

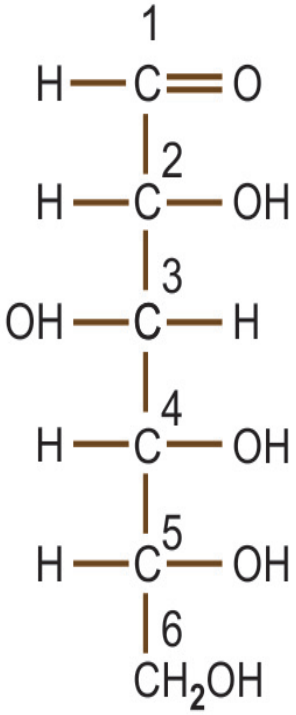
⇌

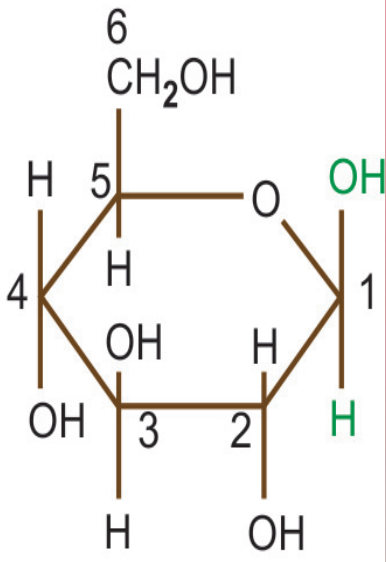
Equilibrium mixture of
α- and β-D-Glucose
+52.7°

⇌

β-D-Glucose
+18.7°







α-D-Glucose
(36%)

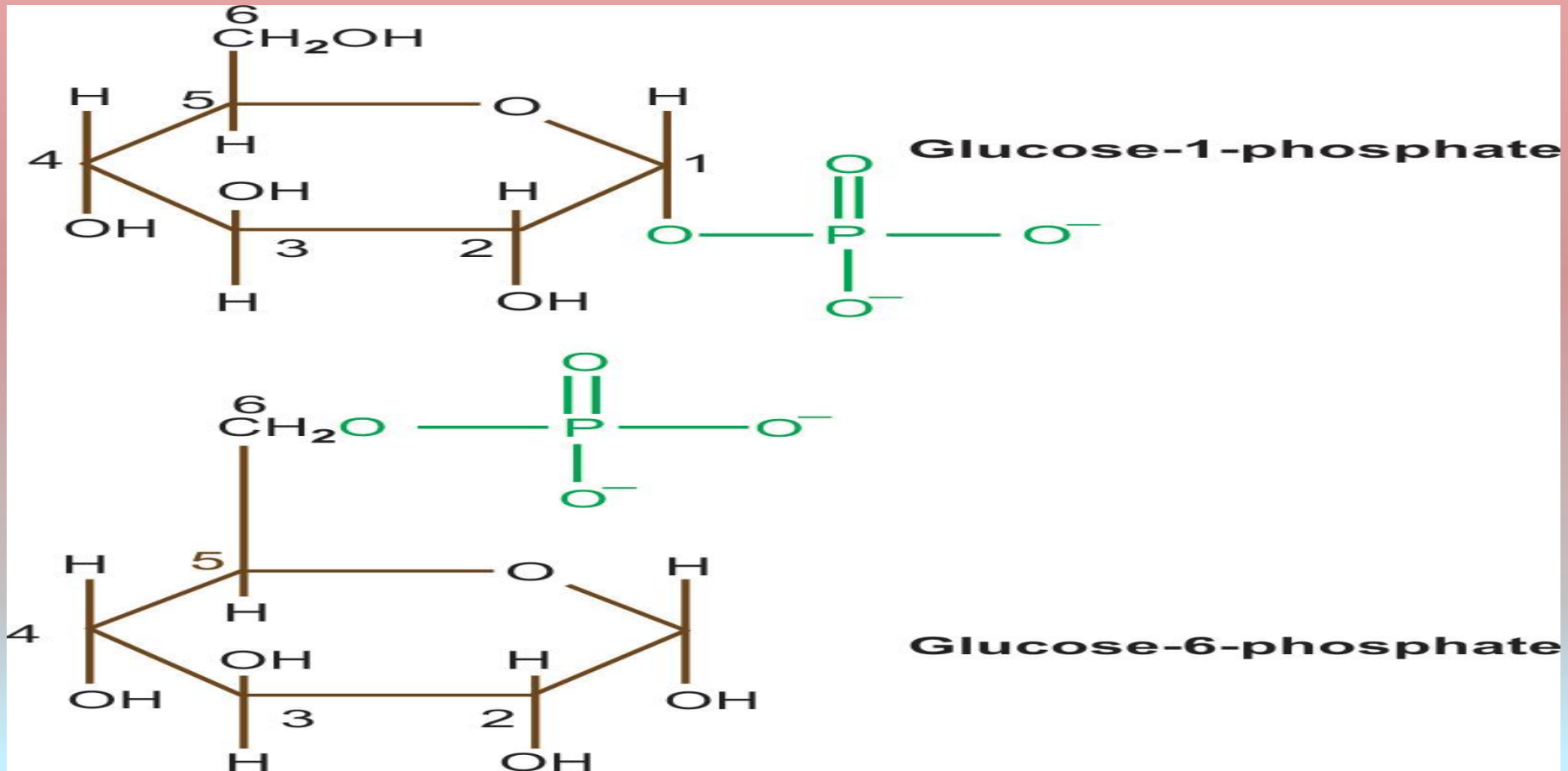
D-Glucose
(1%)

β-D-Glucose
(63%)

GLYCOSIDE FORMATION

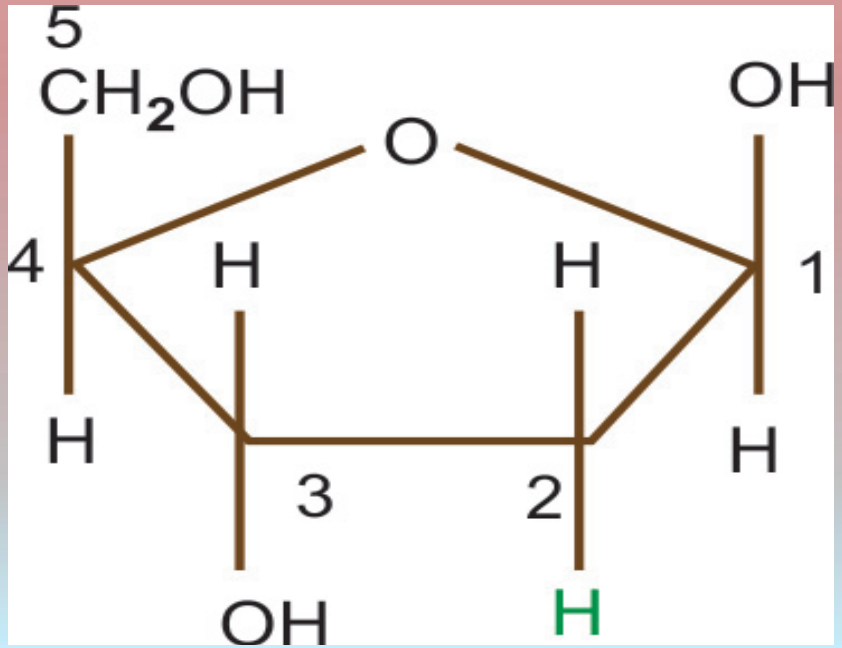
- Glycosides are formed when the hydroxyl group of anomeric carbon of a monosaccharide reacts with **OH** or **NH** group of second compound that may or may not be a carbohydrate. The bond so formed is known as **glycosidic** or **glycosyl bond.**
- The mono saccharides are joined by glycosidic bonds to form **disaccharides, ligosaccharides** and polysaccharides.

Phosphoric acid ester of glucose



Deoxy Sugars

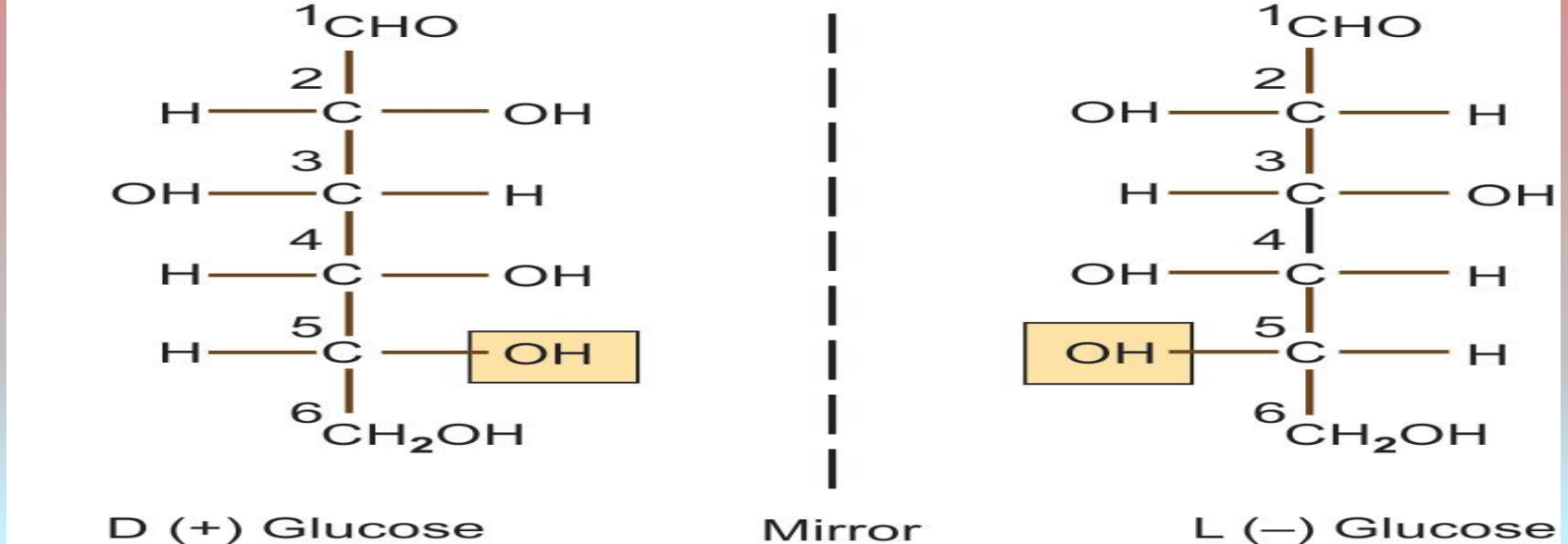
- Deoxy sugars possess a hydrogen atom in place of one of their hydroxy groups e.g. 2-deoxyribose .
- Found in DNA



D and L isomerism

- D and L isomerism depends on the orientation of the H and OH groups around the asymmetric carbon atom adjacent to the terminal primary alcohol carbon, e.g. carbon atom number 5 in glucose determines whether the sugar belongs to D or L isomer.
- When OH group on this carbon atom is on the right, it belongs to **D-series,** when it is on the left, it is the member of the **L-series.** The structures of D and Lglucose based on the reference monosaccharide, D and L glyceraldehyde, a three carbon sugar .

- **D and L isomerism**



- **Anomerism**

- α **and** β **Anomerism**
- The predominant form of glucose and fructose in a solution are not an open chain. Rather, the open chain form of these sugar in solution cyclize into rings. An additional asymmetric center is created when glucose cyclizes. Carbon-1 of glucose in the open chain form, becomes an asymmetric carbon in the ring form and two ring structures can be formed.

- These are:

  α-D-glucose

  β-D-glucose.
- The designation α means that the hydroxyl group attached to C-1 is below the plane of the ring, β means that it is above the plane of the ring. The C-1 carbon is called the ***anomeric carbon atom*** and so, α and β forms are anomers.

DISACCHARIDES

- Disaccharides consist of two monosaccharide units.
- They are crystalline, water soluble and sweet to taste. they are divided to:

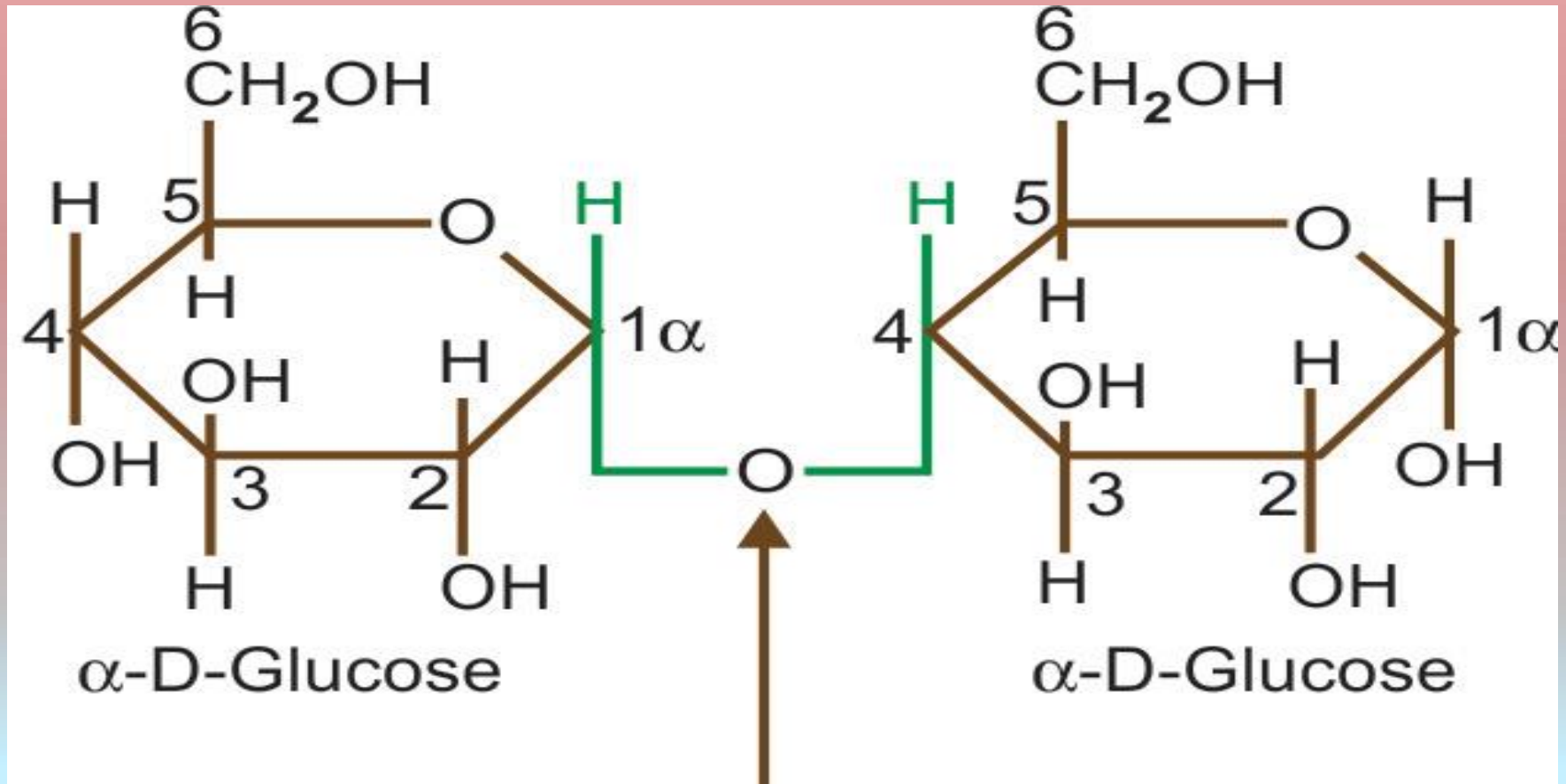
  1.Reducing disaccharides with free carbonyl group, e.g. maltose, lactose

  2. Non-reducing disaccharides with no free carbonyl group, e.g. sucrose.

Maltose

- Maltose contains two glucose residues, joined by glycosidic linkage between C-1 (the anomeric carbon) of one glucose residue and C-4 of the other, leaving one free anomeric carbon of the second glucose residue, which can act as a reducing agent.
- Thus, maltose is a ***reducing disaccharide***.

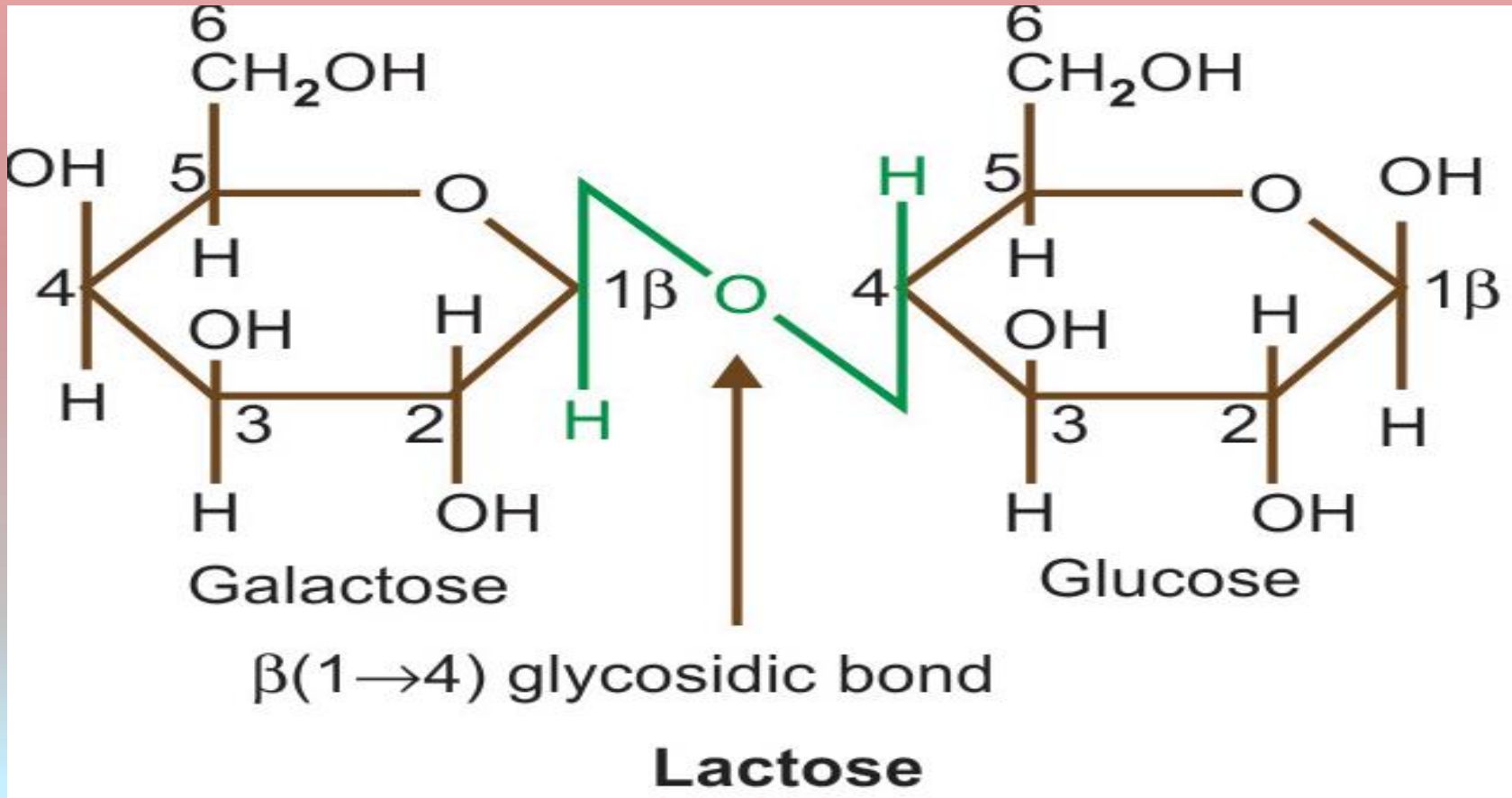
Maltose = Glucose + Glucose
it is reducing sugar



Lactose (Milk sugar)

- It is present in milk. Lactose contains one unit of β-**galactose** and one unit of β-**glucose** that are linked by a β **(1 → 4) glycosidic linkage.**
- The anomeric carbon of the glucose unit is available for oxidation and thus lactose is a reducing disaccharide.
- Why lactose is a reducing sugar? answer

Lactose = Galactose + Glucose
it is reducing sugar

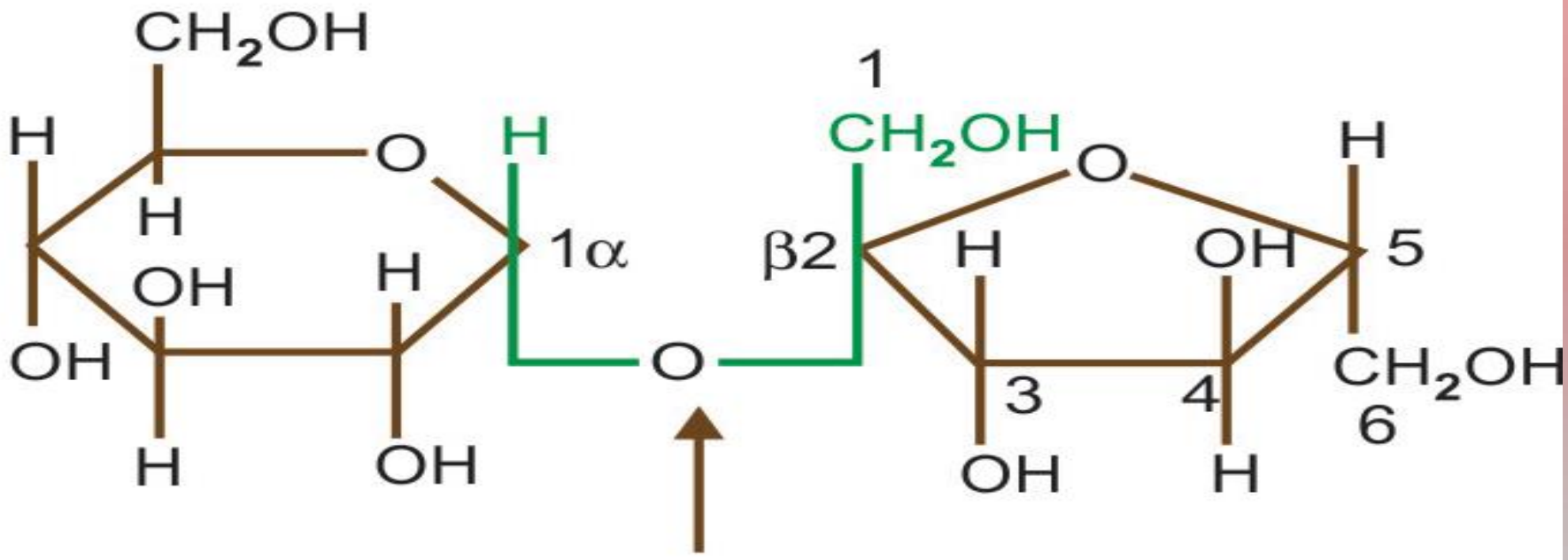


Lactose

Sucrose (Common Table Sugar)

- Sucrose is **a <u>disaccharide</u>** of **<u>glucose</u>** <u>and **fructose**.</u> it is formed by plant but not by human beings.
- Sucrose is the commonly used **table sugar.**
- In contrast to maltose and lactose, sucrose is **<u>non reducing</u>** sugar (why?) becaue sucrose contains no free anomeric carbon atom the anomeric carbon of both glucose and fructose are involved in the formation glycosidic bond.

Sucrose= Glucose + Fructose



Sucrose

Polysaccharides

- Carbohydrates composed of ten or more units of monosaccharide.
- Polysaccharides are colloidal in size. In polysaccharides, monosaccharide units are joined together by glycosidic linkages. Another term for polysaccharides is a ***"glycans"***.

Polysaccharides

- Polysaccharides are subclassified in two groups

1. **Homopolysaccharides** (Homoglycans): When a polysaccharide is made up of several units of one and the same type of monosaccharide unit only, it is called homopolysaccharide.e.g.starch,glycogen

2. **Heteropolysaccharides** (Heteroglycans): They contain two or more different types of monosaccharide units or their derivatives.

Starch

- It is the storage form of glucose in plants, e.g. in potato, in grains and seeds
- Starch is composed of two constituents.

  1- ***amylose*** and***.***

  2- ***amylopectin***
- *Amylose*
- Amylose is a linear polymer of D-glucose units joined by α-1 → 4 glycosidic linkages

Amylopectin

- Amylopectin is structurally identical to those of amylose (α-1→ 4 glycosidic linkages) but with side chains joining them by α-1→ 6 linkages
- Thus, amylopectin is a **branched** polymer having both α-(1 → 4) and α-(1 → 6) linkages

Glycogen (Animal Starch)

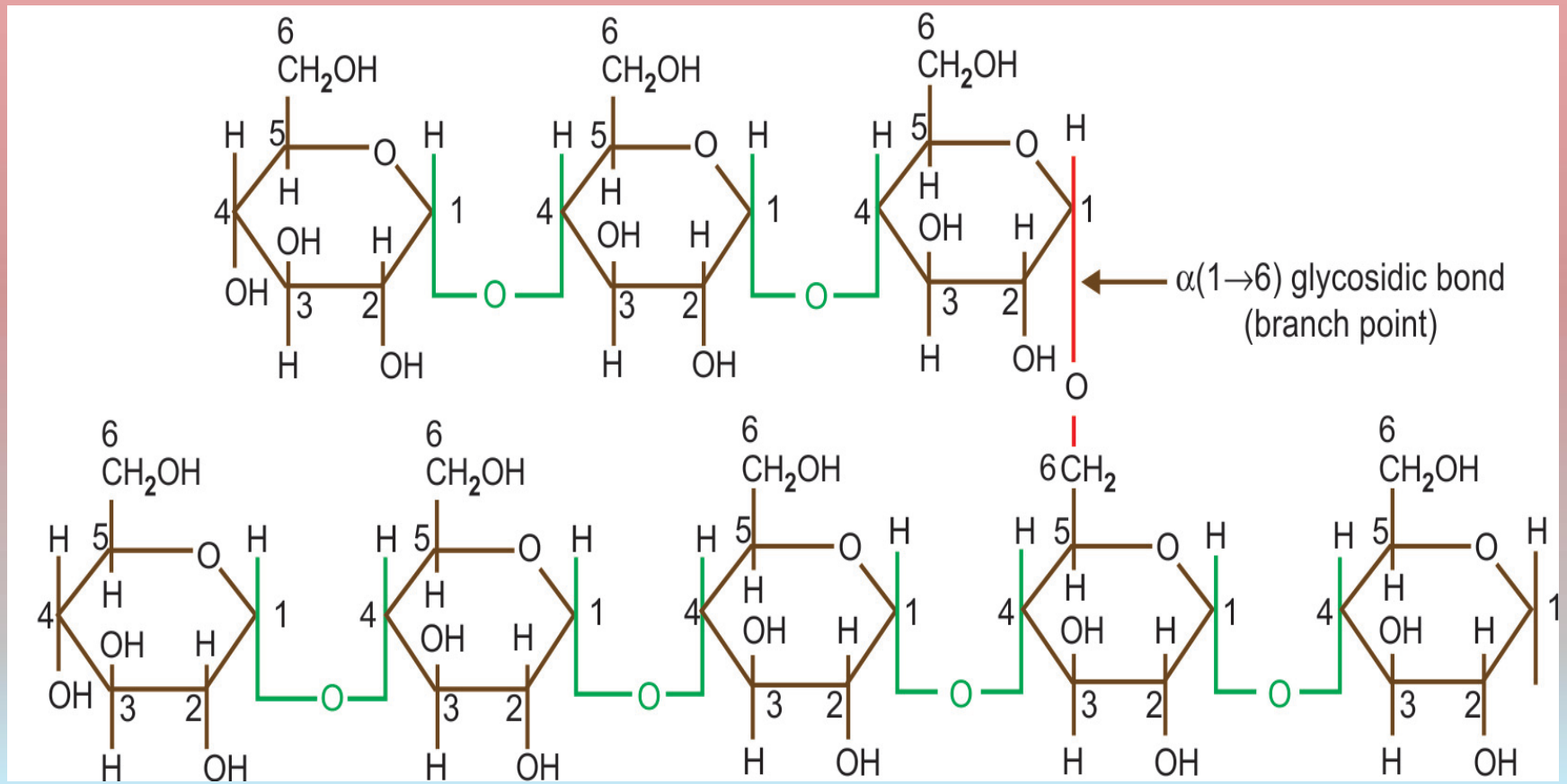
- Glycogen is the major storage form of carbohydrate (glucose) in animals, found mostly in liver and muscle.
- It is often called ***animal starch***.
- The structure of glycogen is similar to that of amylopectin, except that it is more highly branched,

Functions of glycogen

- The function of muscle glycogen is to act as a readily available source of glucose for energy within muscle itself.

- Liver glycogen is concerned with storage and maintenance of the blood glucose.

Structure of amylopectin



Cellulose

- Cellulose is the chief constituent of cell wall of plants.
- It is an ***unbranched polymer*** of glucose and consists of long straight chains which are linked by β-**(1→4) glycosidic linkages** and not α-(1→ 4) as in amylose

- Since humans lack an enzyme **cellulase** that can hydrolyze the β-(1→ 4) glycosidic linkages, ***cellulose cannot be digested and absorbed*** and has no food value unlike starch. However, the ruminants can utilize cellulose because they have in their digestive tractmicroorganisms whose enzymes hydrolyze cellulose

Structure of cellulose