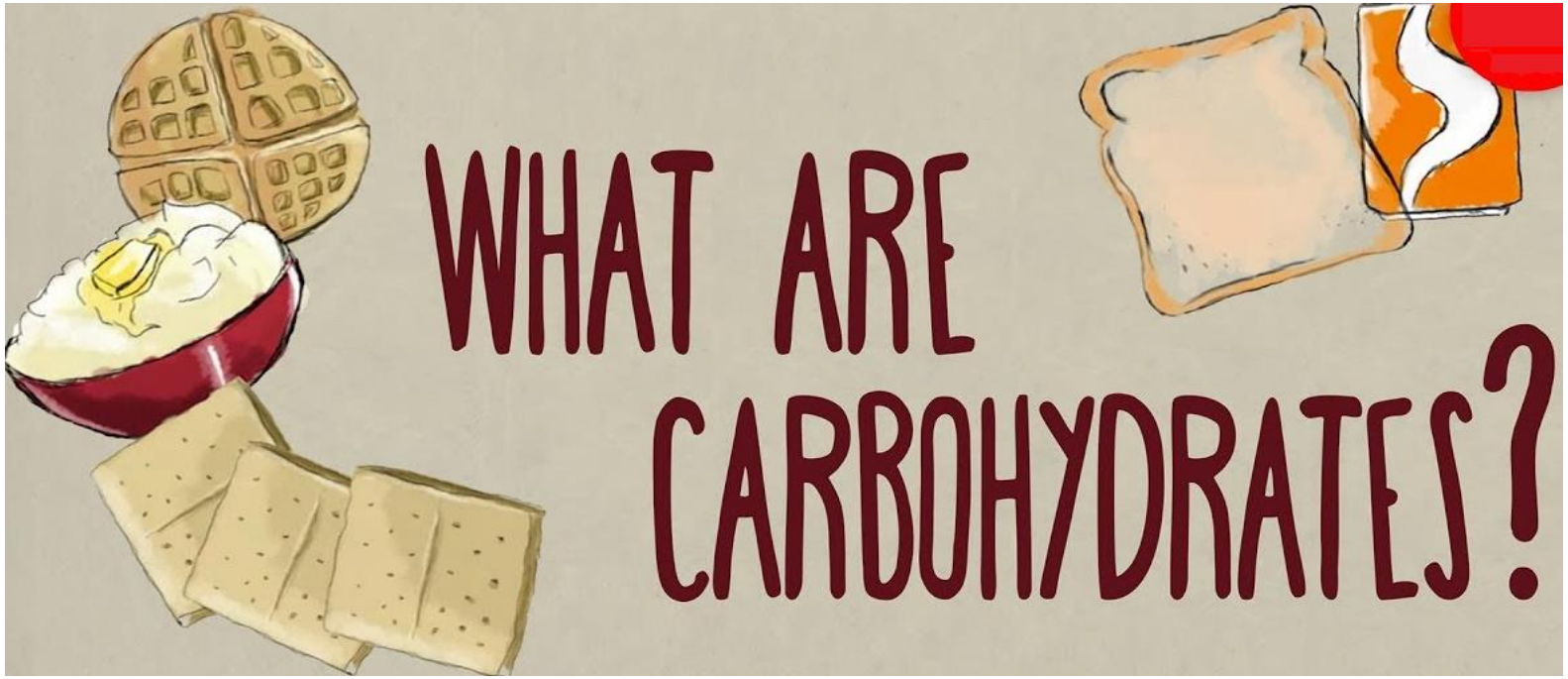
Tishk International University

TISHK INTERNATIONAL UNIVERSITY
FACULTY OF APPLIED SCIENCE
Physiotherapy Department

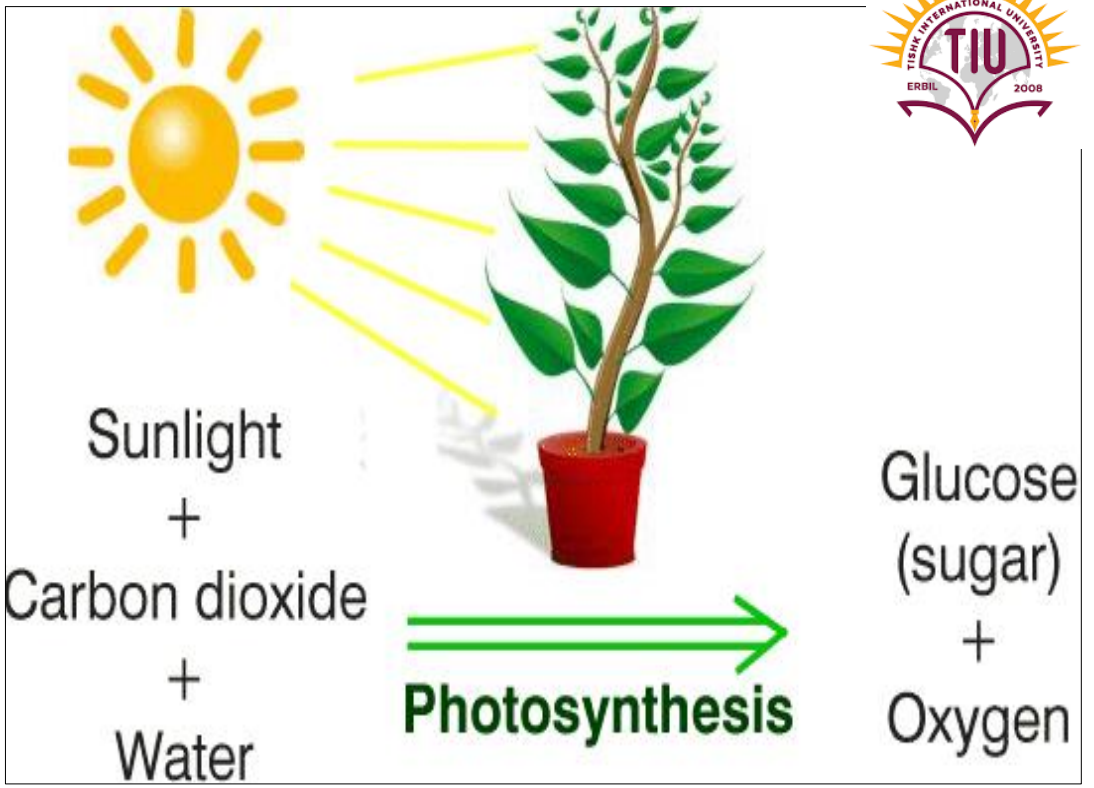


Autumn Semester 2023-2024
Course Name : **Biochemistry (Theory)**
Stage : 2 Lecture 2&3: Carbohydrates
Lecture: Dr. Soma Majedi / Ph.D. in Organic Chemistry

EXERCISE BIOCHEMISTRY

Carbohydrates

- ✓ Carbohydrates are primarily produced by plants and form a very large group of naturally occurring organic compounds.
- ➢ Examples: Cane sugar, Glucose, Starch



- ✓ Most of them have a general formula: $\mathbf{C_x(H_2O)_y}$ and were considered as **hydrates of carbon**. (Old definition)
- ✓ The molecular formula of glucose ($C_6H_{12}O_6$) fits into this general formula, $C_6(H_2O)_6$.
- ❖ **Sacharride: another word for sugar.**

Functions of Carbohydrates

- Dietary **Source** of **energy** (4 C/g) for all organisms. Example:

glucose (C.H.O) $\xrightarrow{\text{metabolism}}$ $CO_2 + H_2O +$ **Energy ATP**

- Prevents the breakdown of proteins for energy.
- They supply energy and serve as **Storage** form of **energy** (glycogen).
- Participate in the **Structure** of the cell membrane. **Structural** material of plants (**Cellulose**) or exoskeleton of insects (**Chitin**) and bacteria.
- Participate in the **structure** of **DNA** & **RNA**.

Functions of Carbohydrates (Continue)

- Carbohydrates are **Precursors** for many organic compounds (fats, amino acids).

- Carbohydrates are utilized as raw materials for several **Industries**. For e.g., **paper**, **plastics**, **drugs** (e.g., **Streptomycin**), etc.

- Help with **fat metabolism**. If the body has enough energy for its immediate needs, it stores extra energy as fat.

Classification of Carbohydrate

There are **two** major types of carbs or sugars (based on the **number** of **sugar molecules**):

- ✓ **Simple**
- ✓ **Complex**

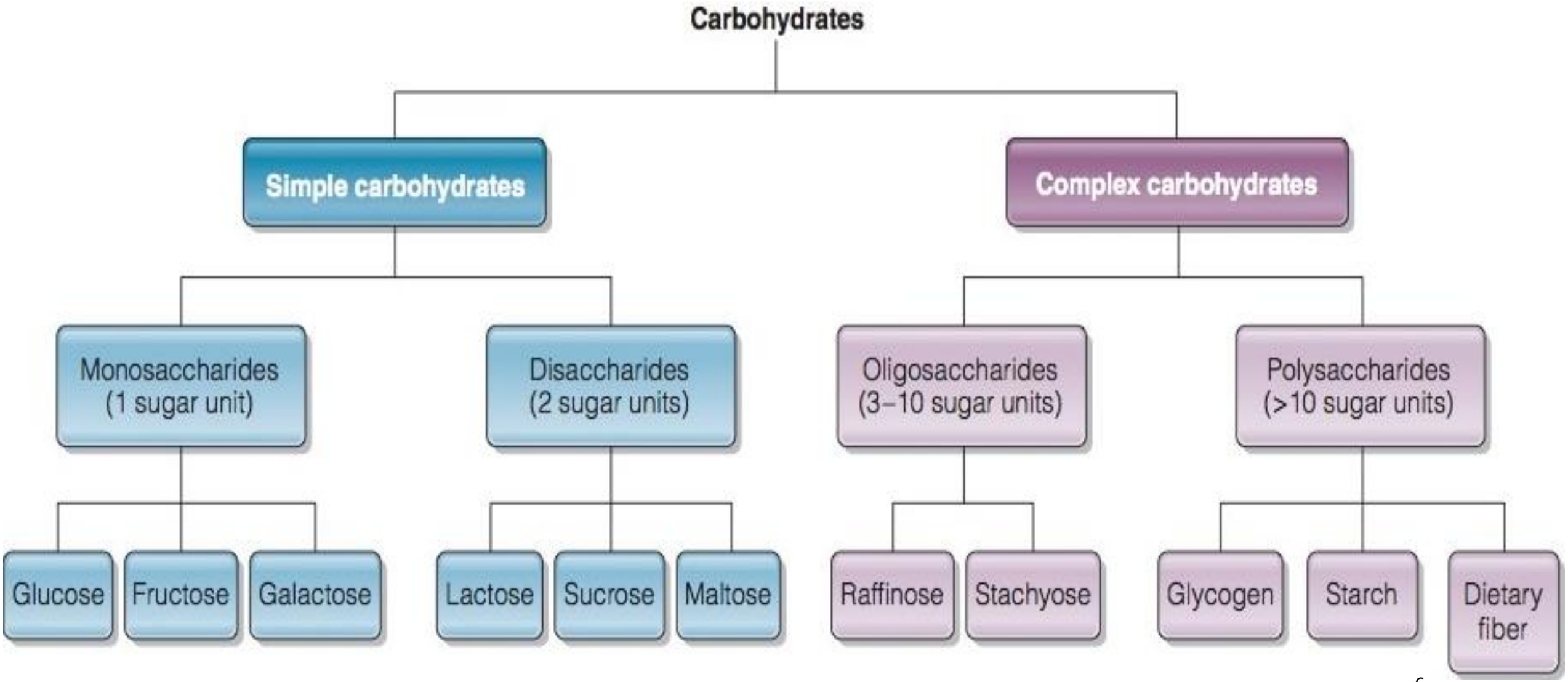
Simple carbs: Contain **one** or **two** sugar molecules:

- Monosaccharide
- Disaccharide

Complex carbs: Have **three** or **more** sugar molecules:

- ❖ Oligosaccharide (3-10)
- ❖ Polysaccharide

Classification of Carbohydrate



SIMPLE CARBOHYDRATES

COMPLEX CARBOHYDRATES

Classes of Monosaccharides

- **Monosaccharides** can be indicated by names composed of a stem denoting the **number of Carbon atoms** and the suffix **-ose**.

  - For example, **triose**, **tetrose**, **pentose**, and **hexose** signify monosaccharides with, respectively, **three**, **four**, **five**, and **six** carbon atoms.

- **Monosaccharides are also classified as aldoses** or **ketoses**.

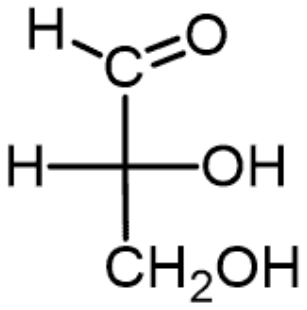
  - Those monosaccharides that contain an **aldehyde functional group** are called **aldoses**; those containing a **ketone functional group** on the second carbon atom are **ketoses**.

Number of carbons

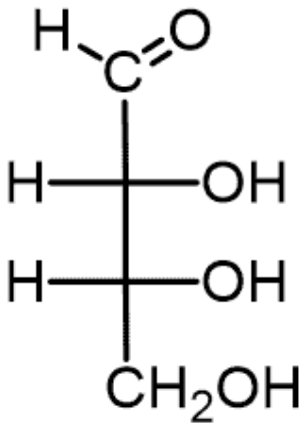
Three carbons: triose
Four carbons: tetrose
Five carbons: pentose
Six carbons: hexose
Seven carbons: heptose etc.

- **Combining** these **classification systems** gives general names that indicate both the **type** of **carbonyl** group and the **number** of **carbon** atoms in a molecule.
- Thus, monosaccharides are described as **aldotetroses**, **aldopentoses**, **ketopentoses**, **ketoheptoses**, and so forth.

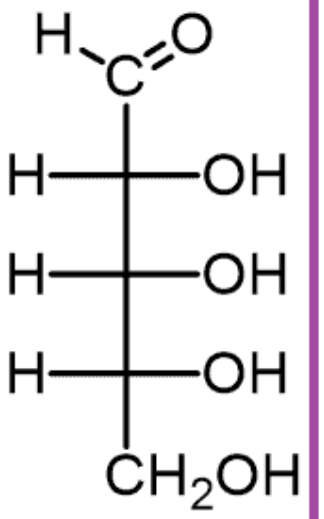
triose



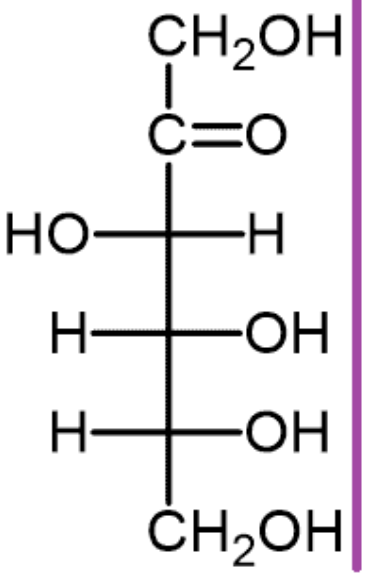
tetrose



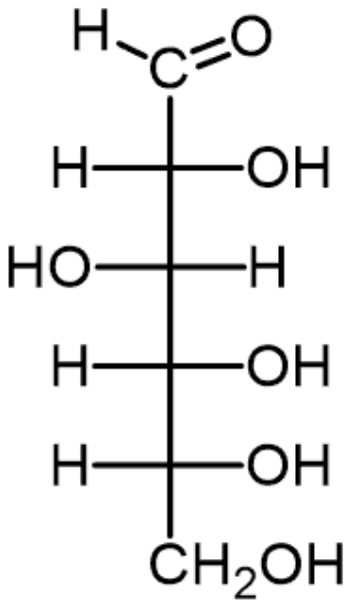
pentose

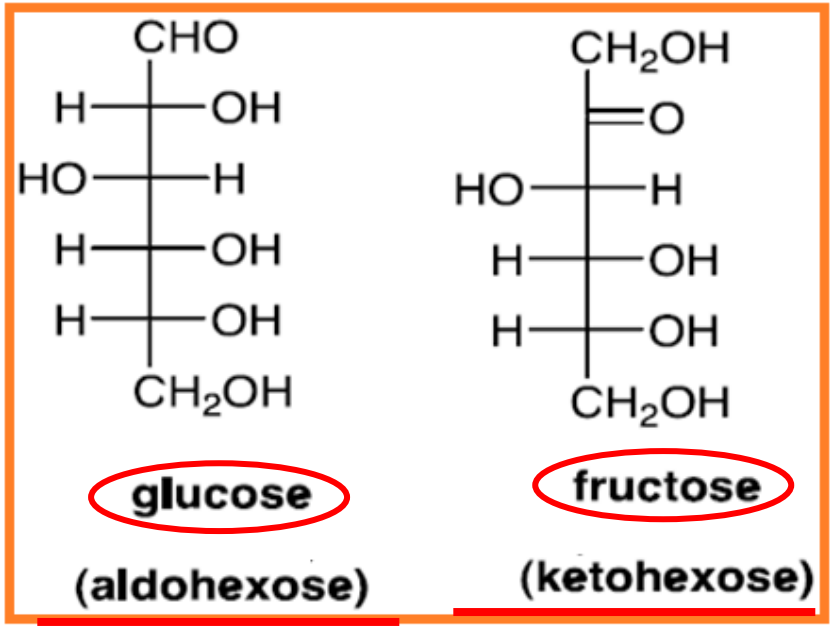


hexose



hexose





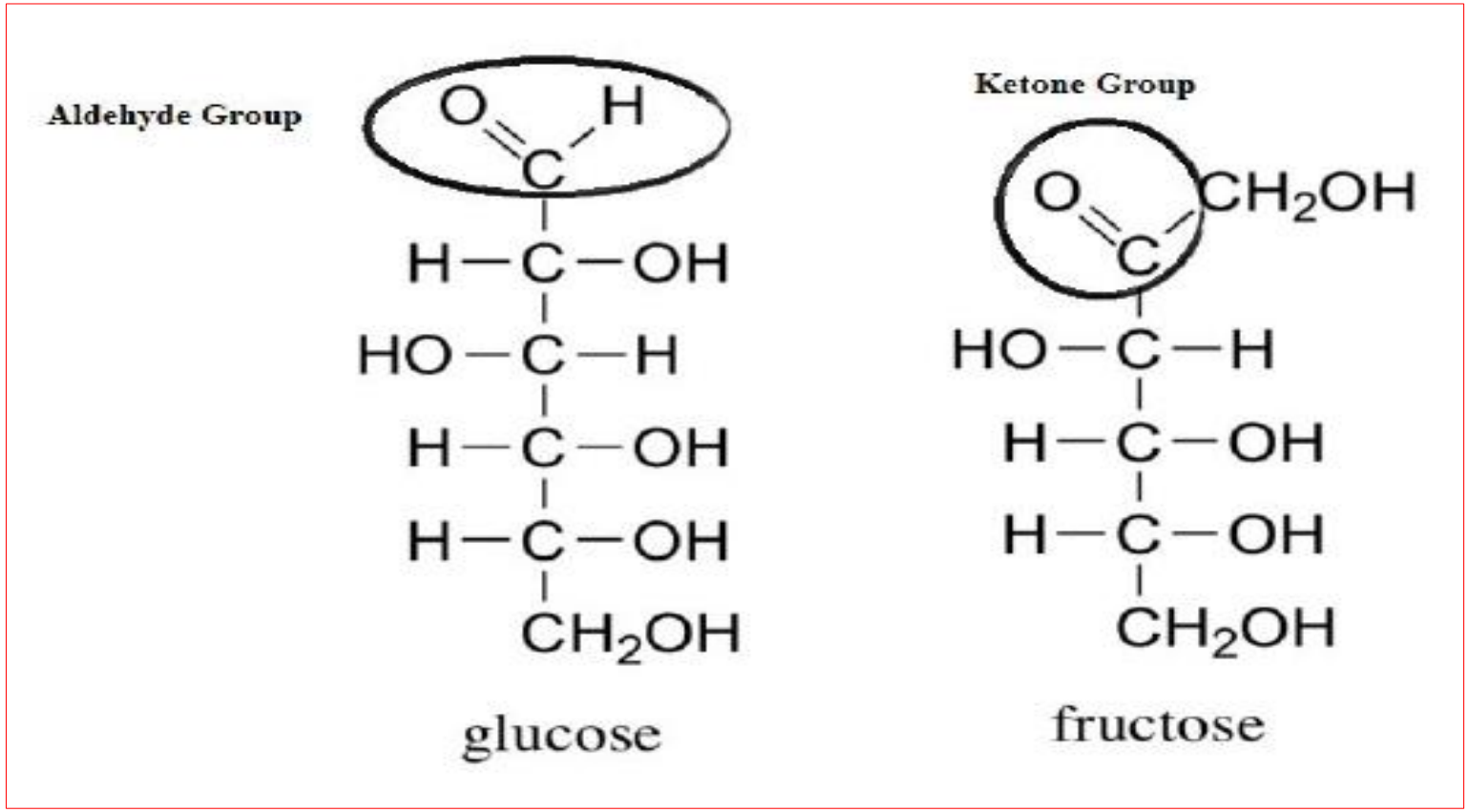
Types of carbohydrates depended on acidic hydrolysis

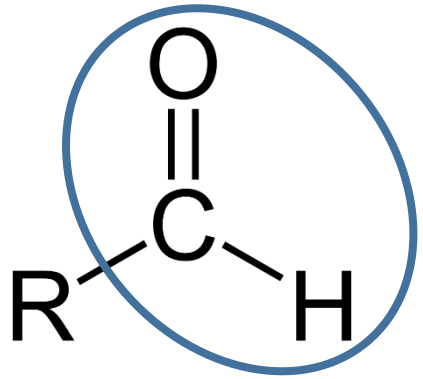
- Simple $C_n(H_2O)_m$
  - Monosaccharides
    - Aldose
      - n = 3 it is called triose
      - n = 4 it is called tetrose
      - **n = 5 it is called pentose**
      - **n = 6 it is called hexose**
      - n = 7 it is called heptose
      - n = 8 it is called octose
    - Ketose
      - n = 3 it is called triose
      - n = 4 it is called tetrose
      - **n = 5 it is called pentose**
      - **n = 6 it is called hexose**
      - n = 7 it is called heptose
      - n = 8 it is called octose
- Compound
  - Disaccharides (2 Monosaccharides)
  - Oligosaccharides (3-9 Monosaccharides)
  - Polysaccharides (>9 Monosaccharides)
    - **Hetero**polysaccharides Combined with some structures which called Aglycon
    - **Homo**polysaccharides Only containing monosaccharides

Sugar alcohols (Polyols)

Carbohydrates are polyhydroxy **aldehydes** and **ketones**.

Aldehydes (–CHO) and Ketones (=CO) constitute the major groups in Carbohydrates.

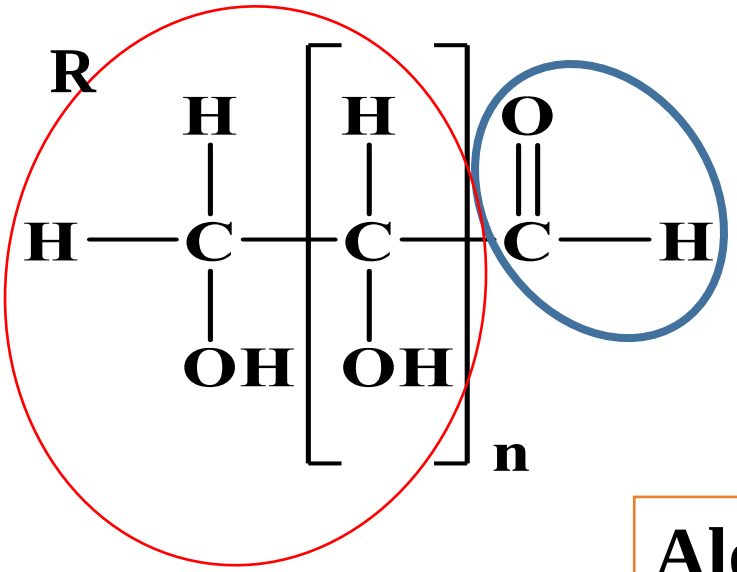




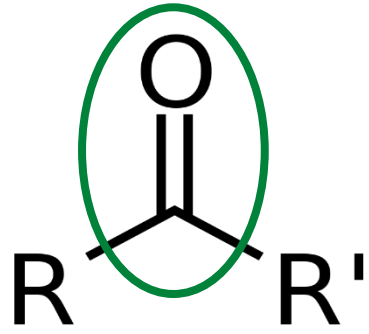
functional groups of Aldehyde

Aldehyde

R = Hydrocarbons or Carbohydrate



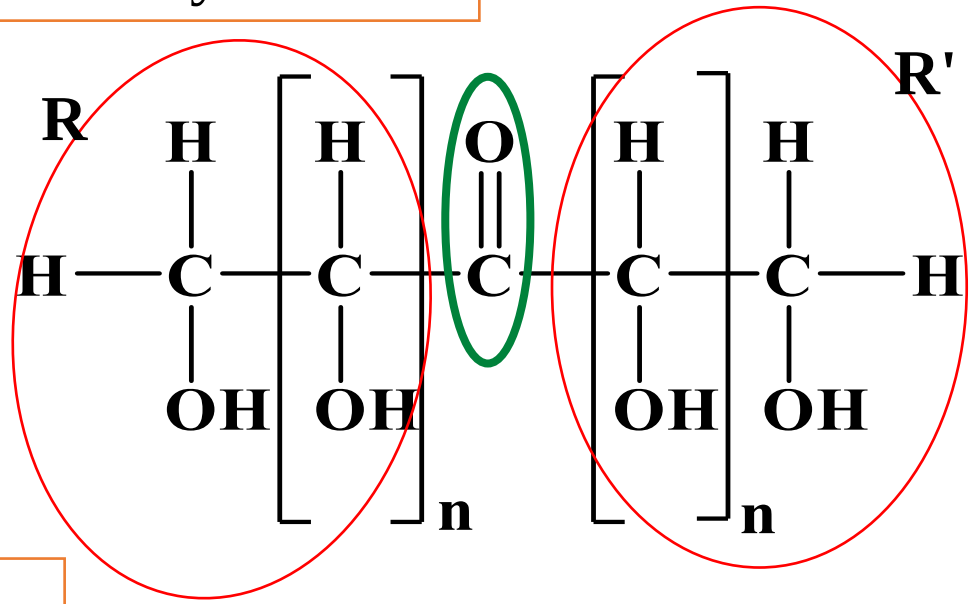
Aldose



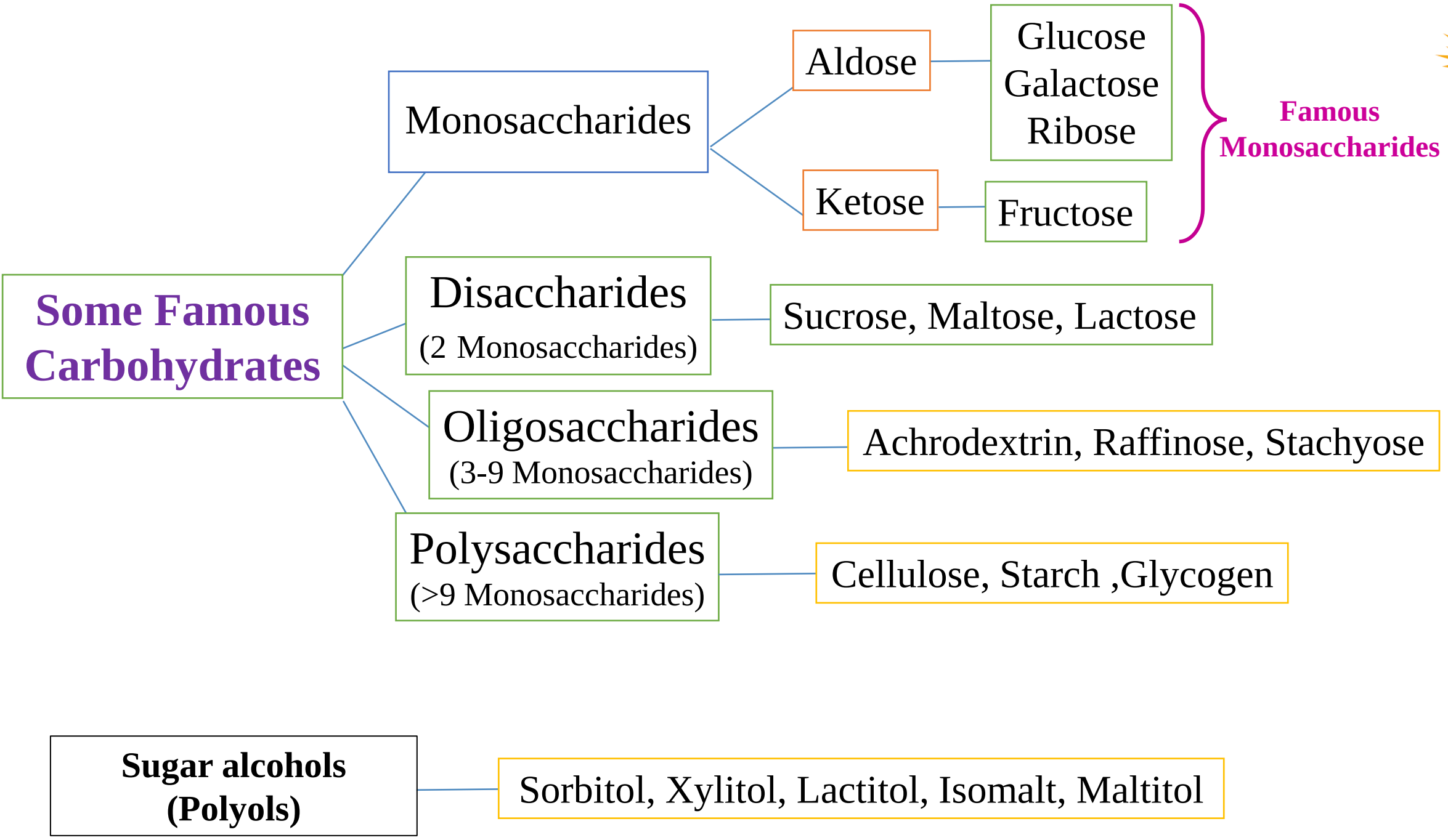
functional groups of Ketone

Ketone

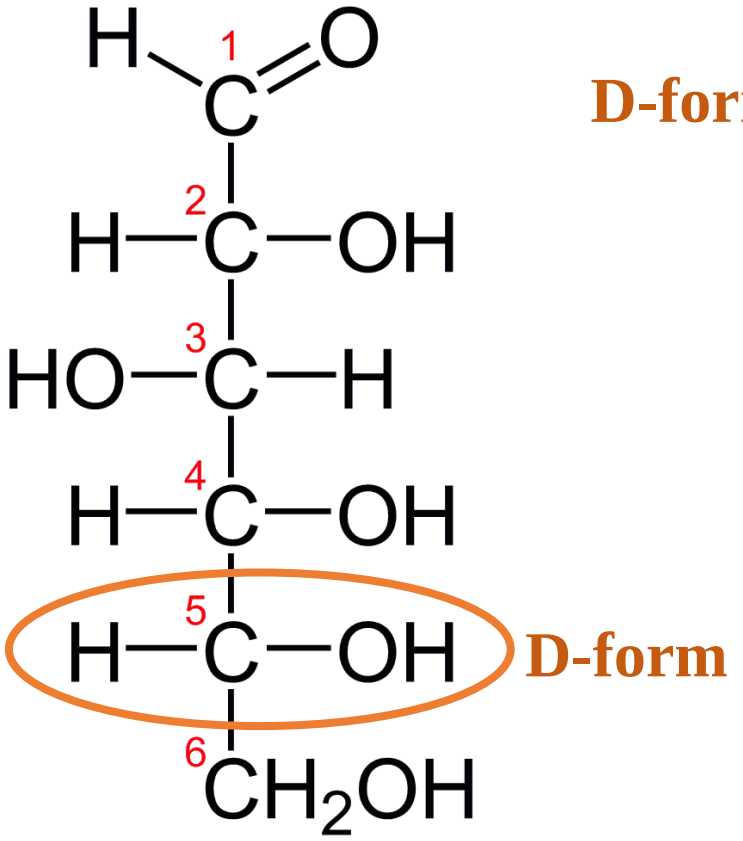
R,R' = Hydrocarbons or Carbohydrate



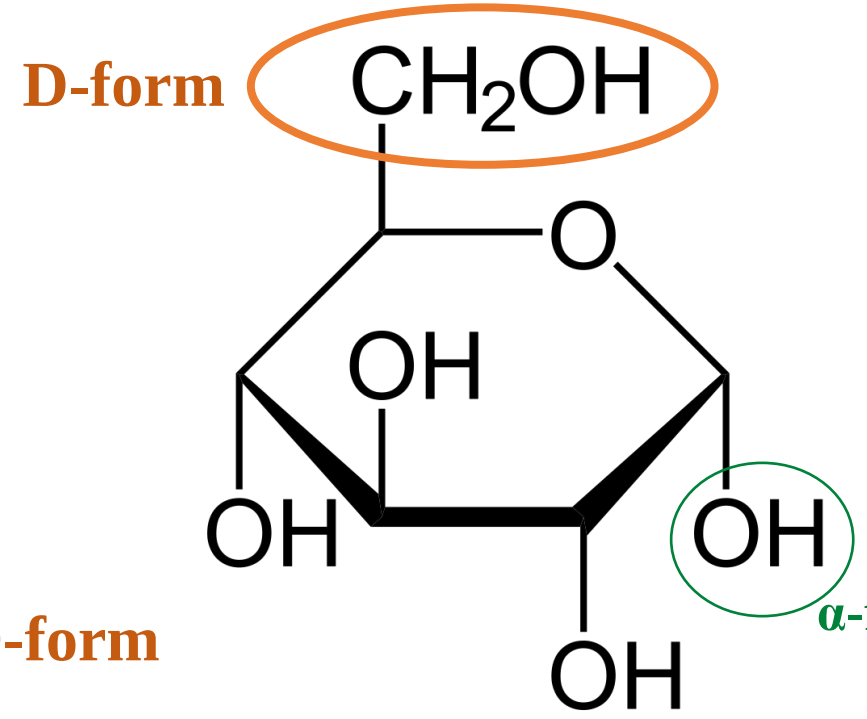
Ketose


Some Famous Carbohydrates
Monosaccharides
Aldose
Glucose
Galactose
Ribose
Ketose
Fructose
Famous Monosaccharides
Disaccharides
(2 Monosaccharides)
Sucrose, Maltose, Lactose
Oligosaccharides
(3-9 Monosaccharides)
Achrodextrin, Raffinose, Stachyose
Polysaccharides
(>9 Monosaccharides)
Cellulose, Starch ,Glycogen
Sugar alcohols (Polyols)
Sorbitol, Xylitol, Lactitol, Isomalt, Maltitol

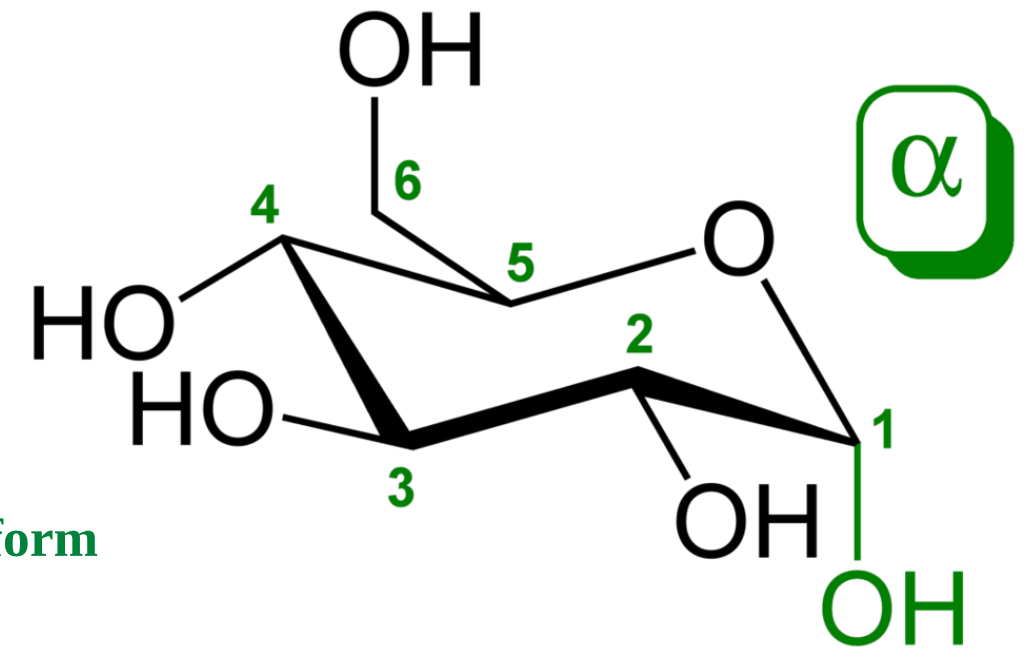
Conversion Forms of Carbohydrates: Fischer form, Haworth form, Chair form



D-glucose
(open-chain form)

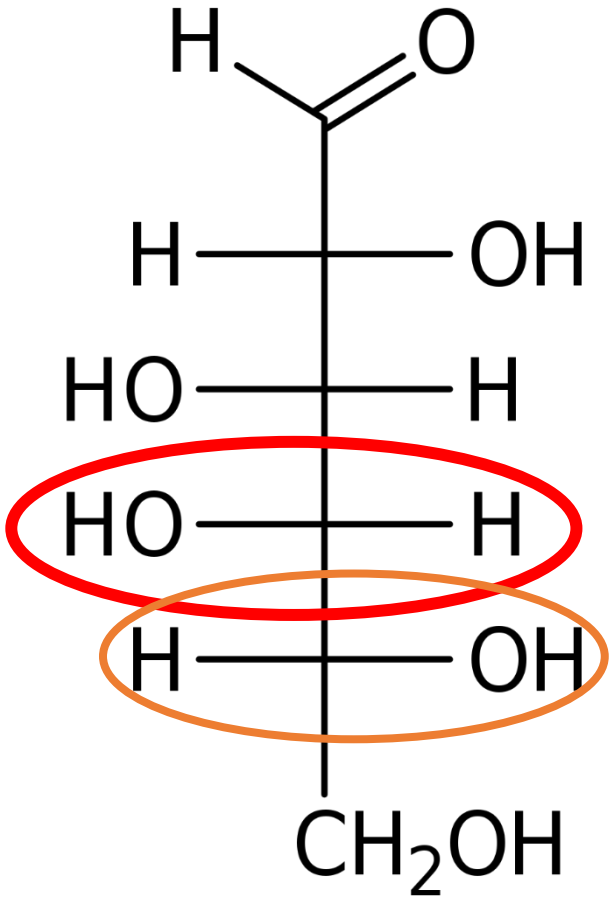


Haworth projection
of
α-D-glucopyranose



α-D-glucopyranose
(Chair Form)

Conversion Forms of Carbohydrates: Fischer form, Haworth form

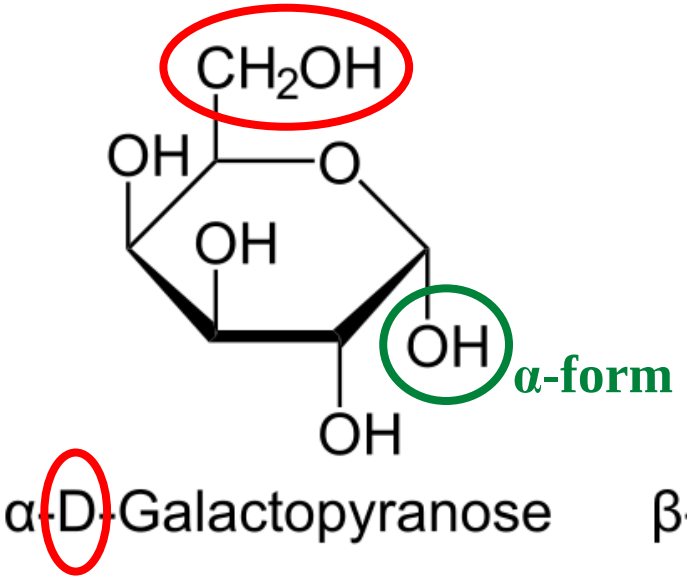


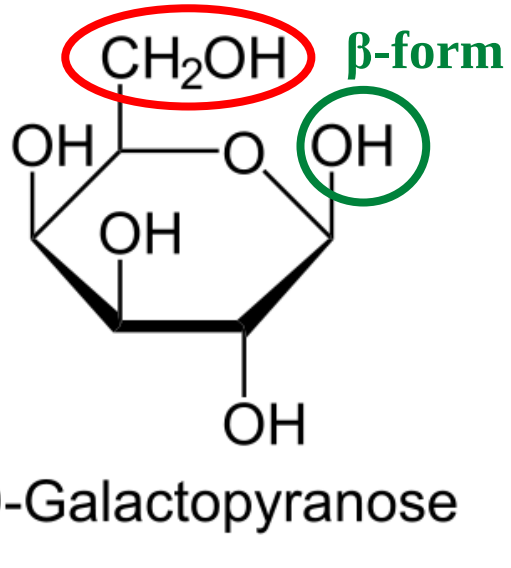
Glucose's Isomer

D-form

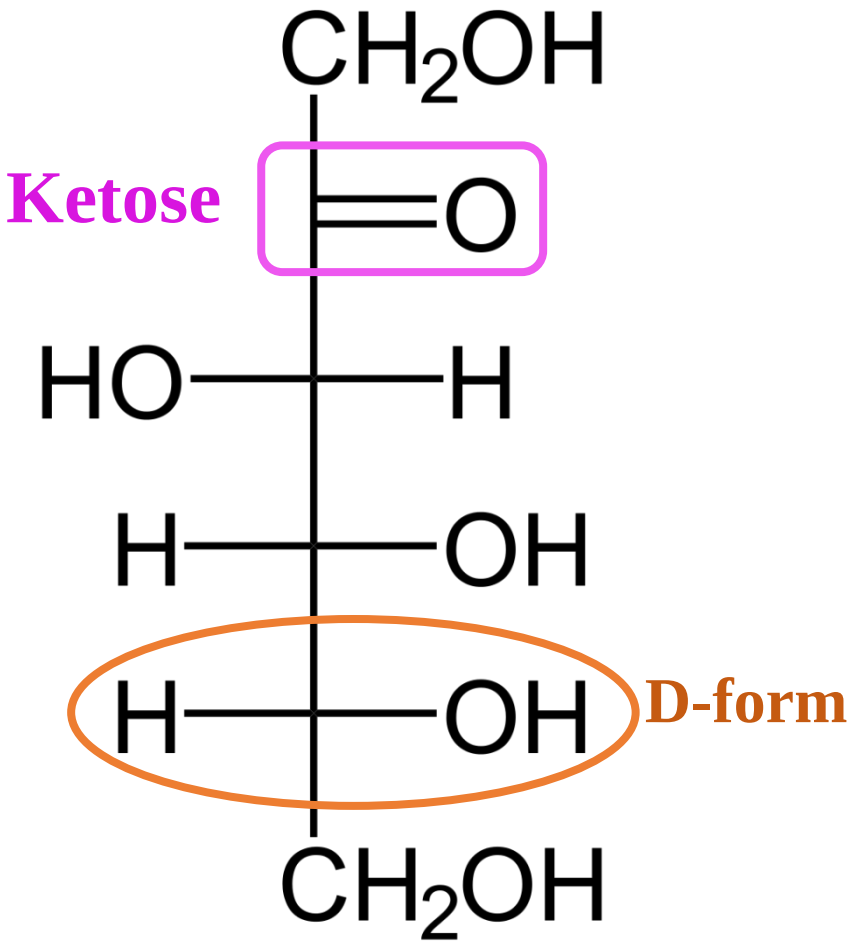
D-Galactose (Glucose's Isomer)

(open-chain form)

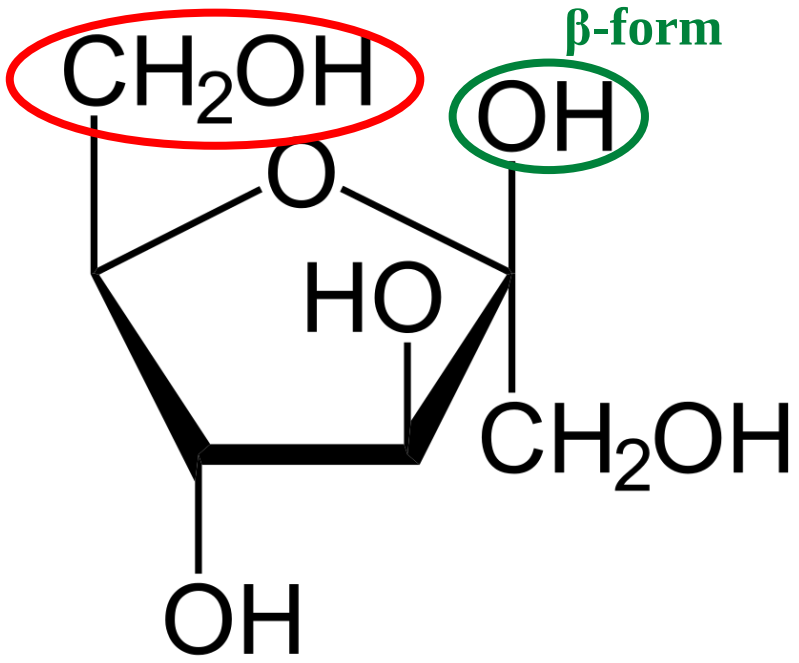




Conversion Forms of Carbohydrates: Fischer form, Haworth form

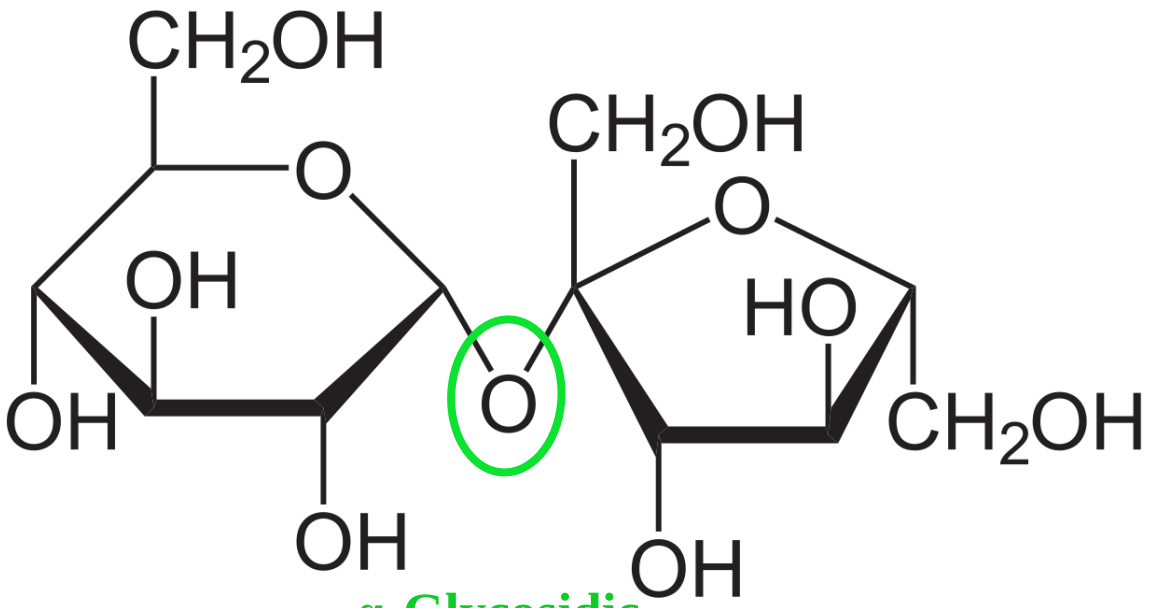


D-Fructose
(open-chain form)



Haworth projection
of
β-D-Fructofuranose

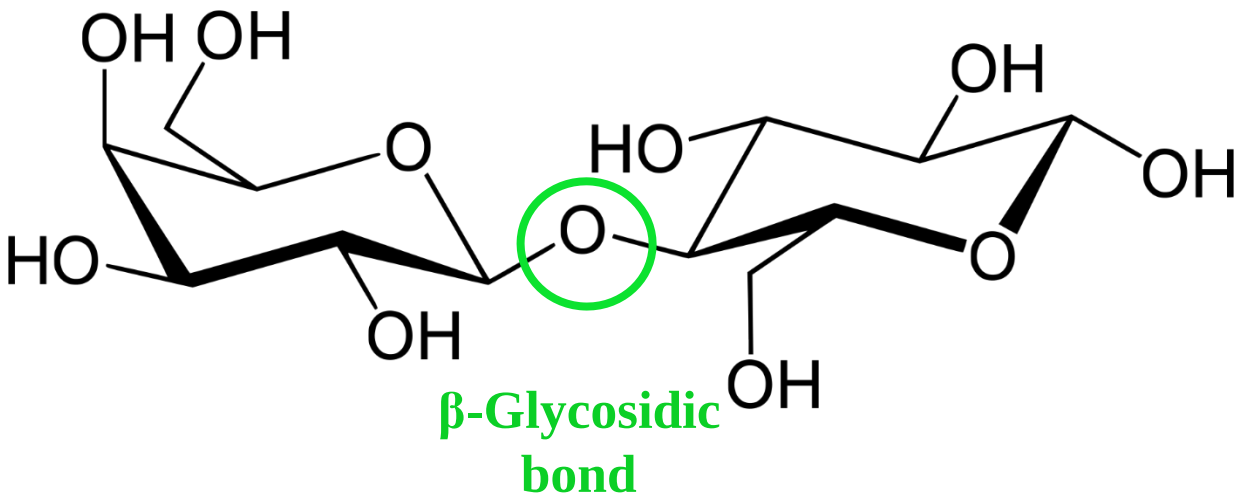
Famous Disaccharide



Sucrose

Disaccharide composed of two monosaccharides:

glucose and fructose

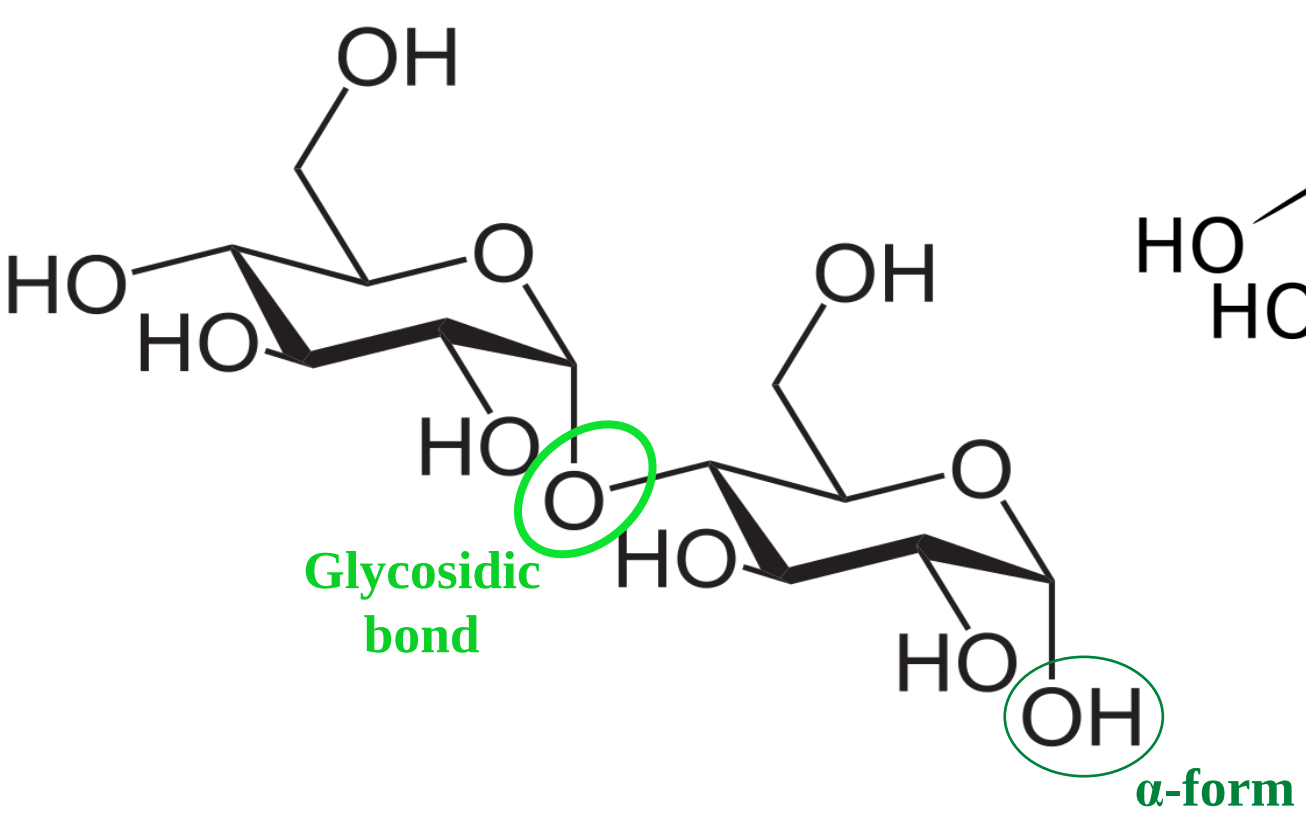


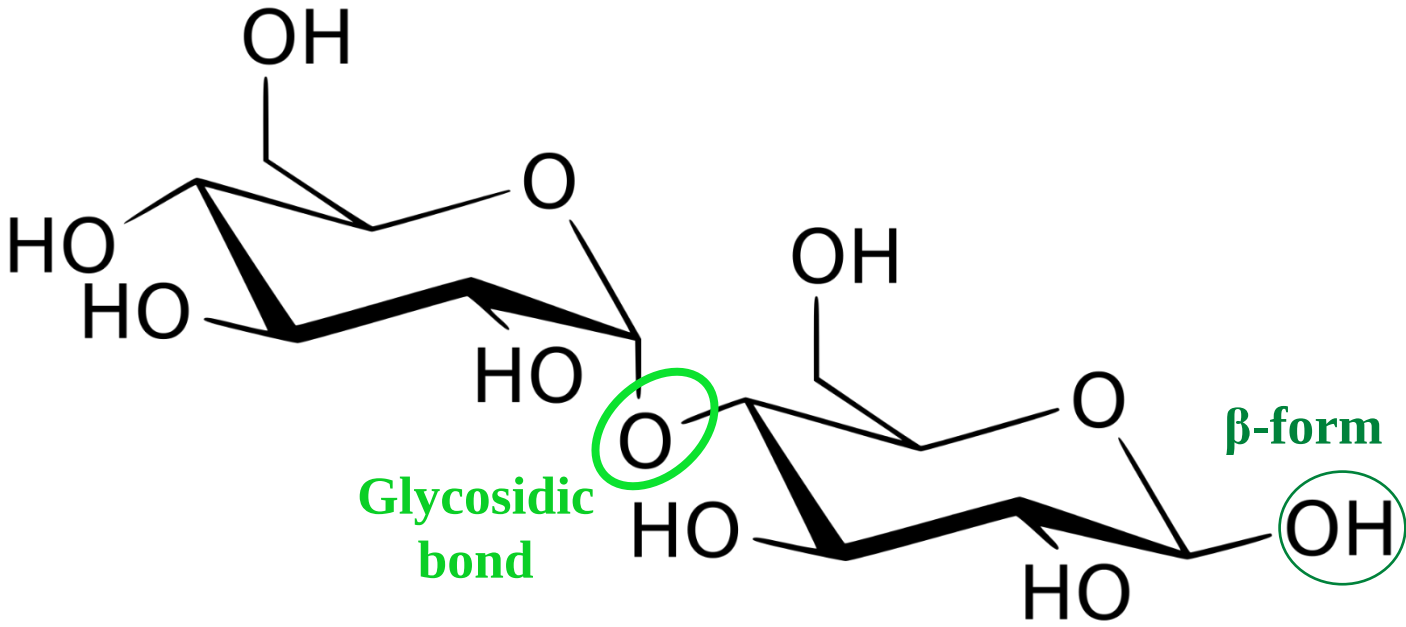
Lactose

Disaccharide composed of two monosaccharides:

galactose and glucose

Famous Disaccharide

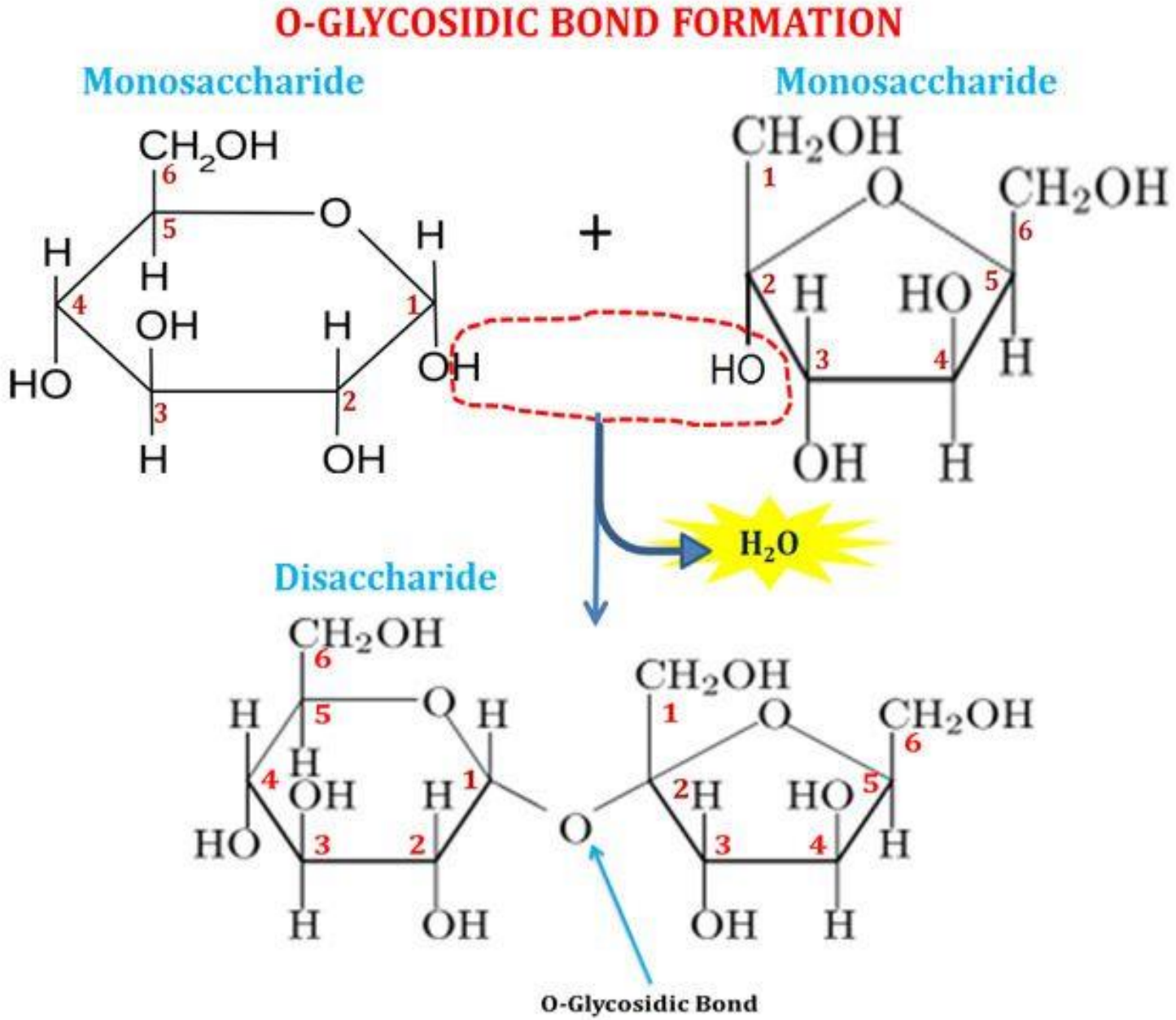




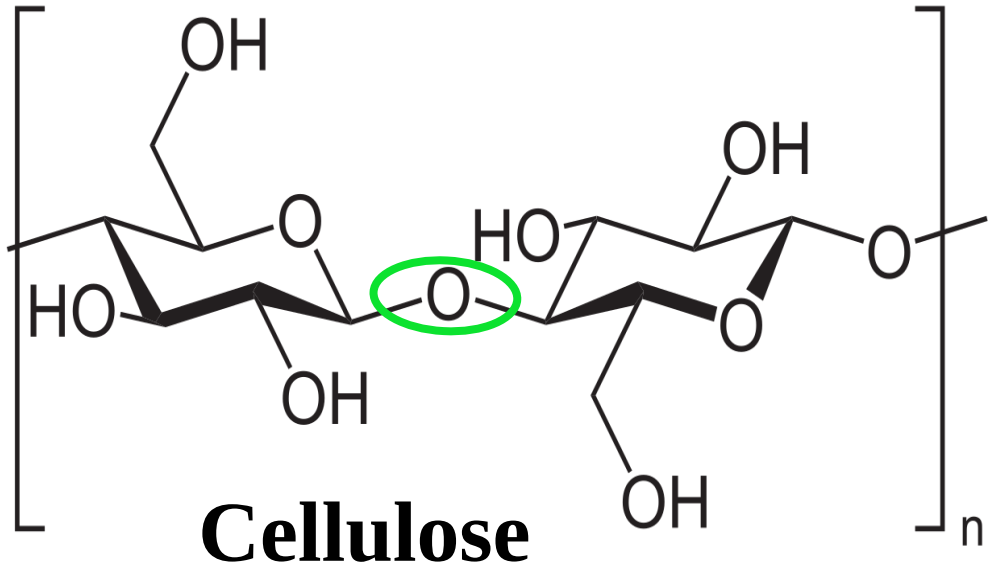
α-Maltose **β-Maltose**

A Disaccharide formed from two units of Glucose

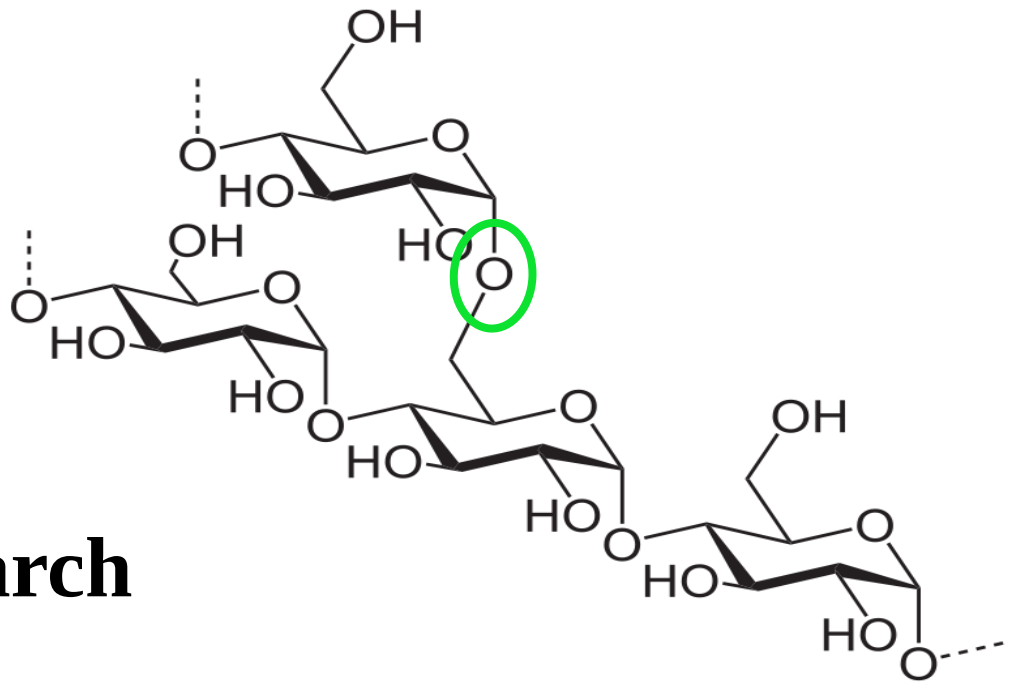
- In general, a **glycosidic bond** is the covalent bond between two monosaccharides to form a disaccharide.
- It is formed by a **condensation reaction** to a hydroxyl group of an organic compound which may or may not be another carbohydrate.
- A substance with a glycosidic bond is called a **glycoside**.



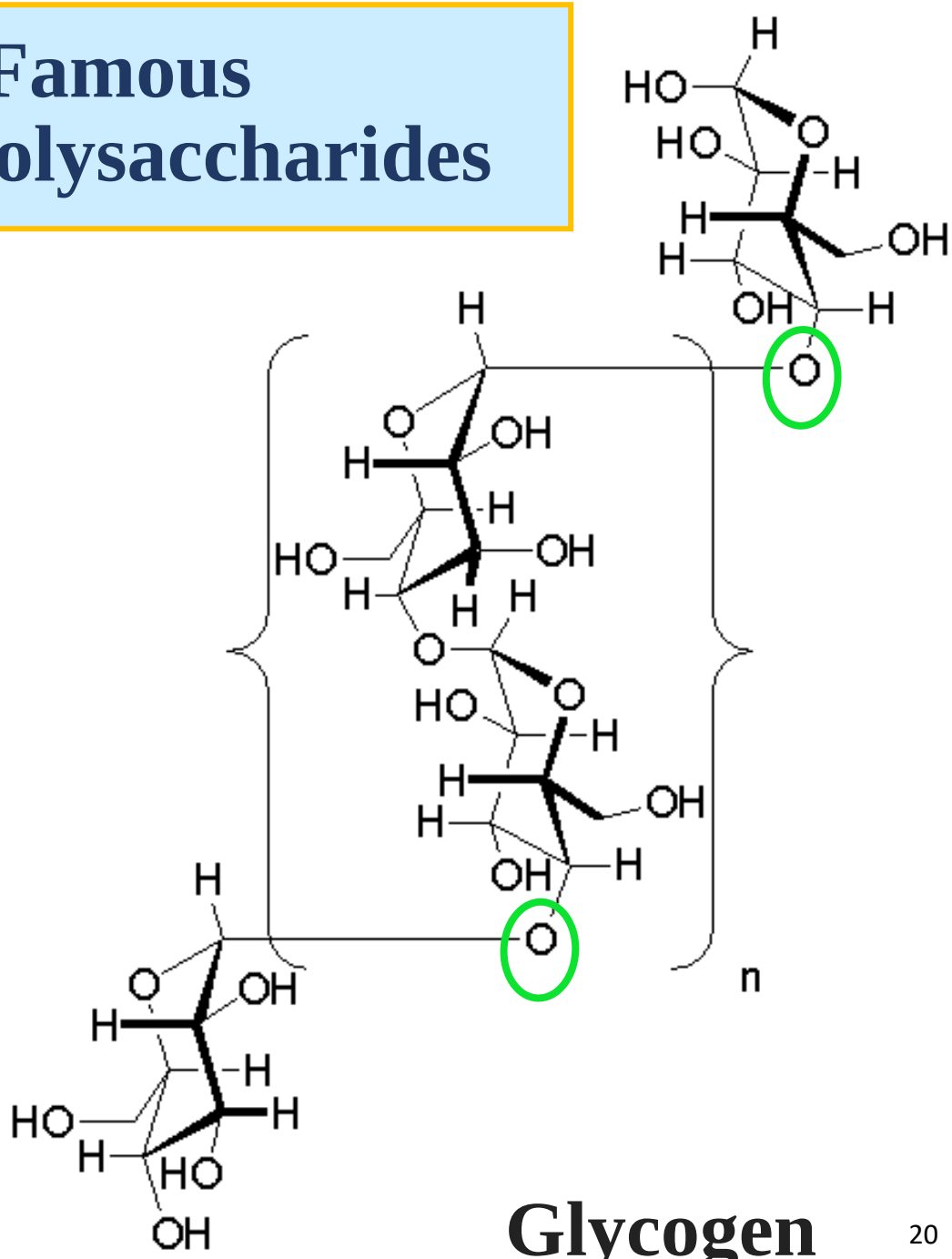
Famous Homopolysaccharides



Cellulose



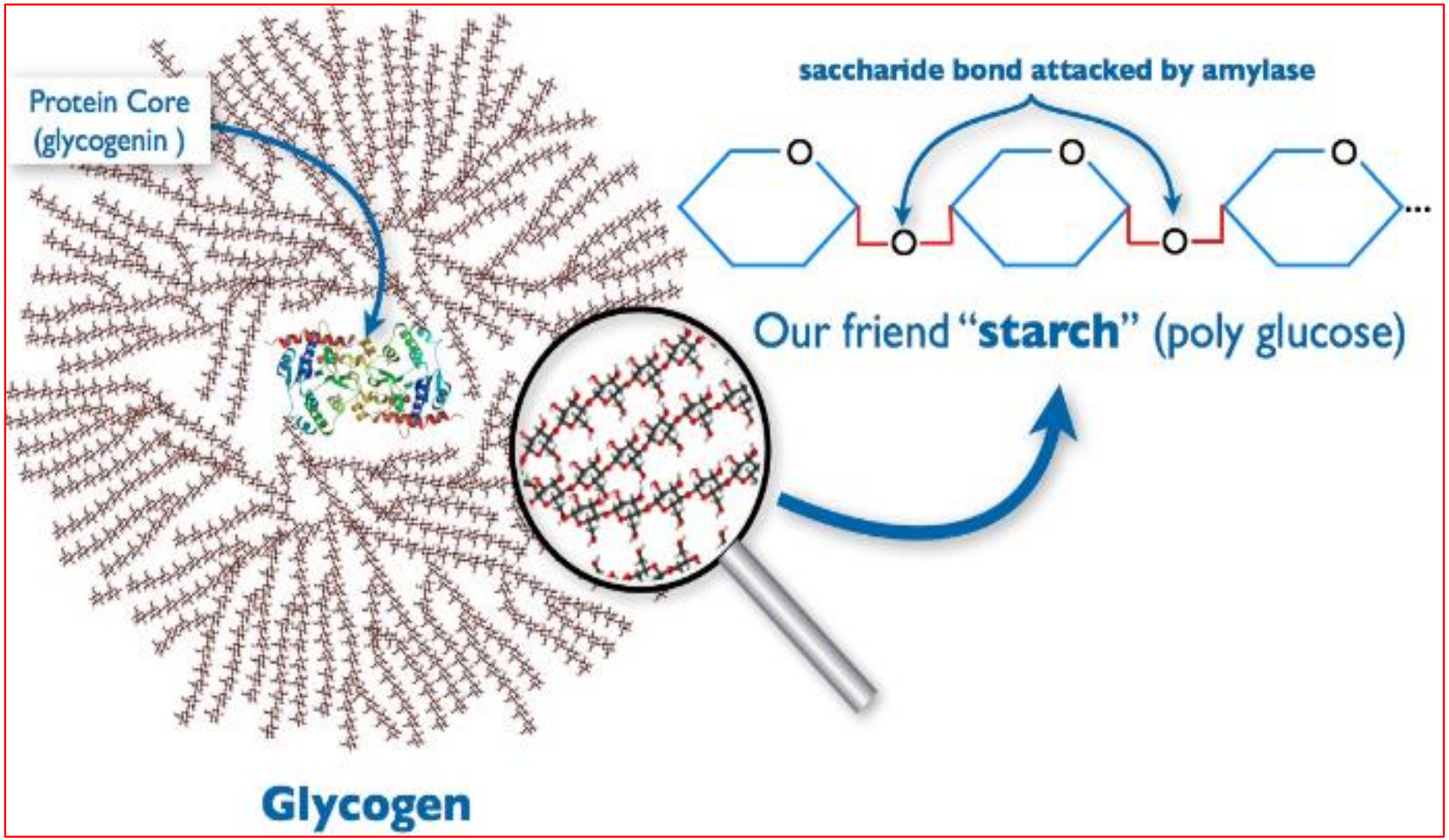
Starch



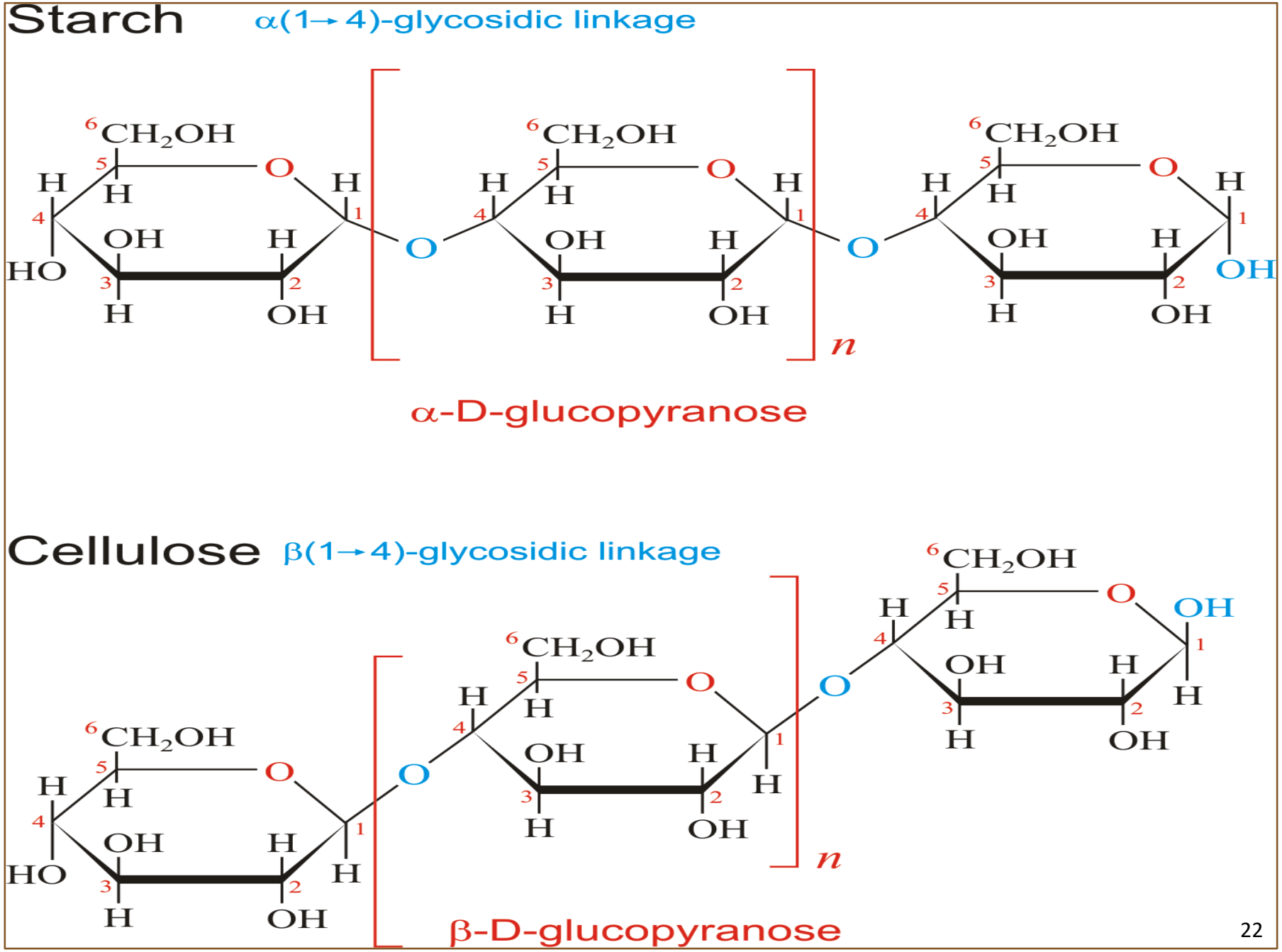
Glycogen

- **Glycogen** is a **multibranched polysaccharide** of **glucose** that serves as a form of **energy storage** in animals, fungi, and bacteria.

- The polysaccharide structure represents the **main storage form** of **glucose** in the body.

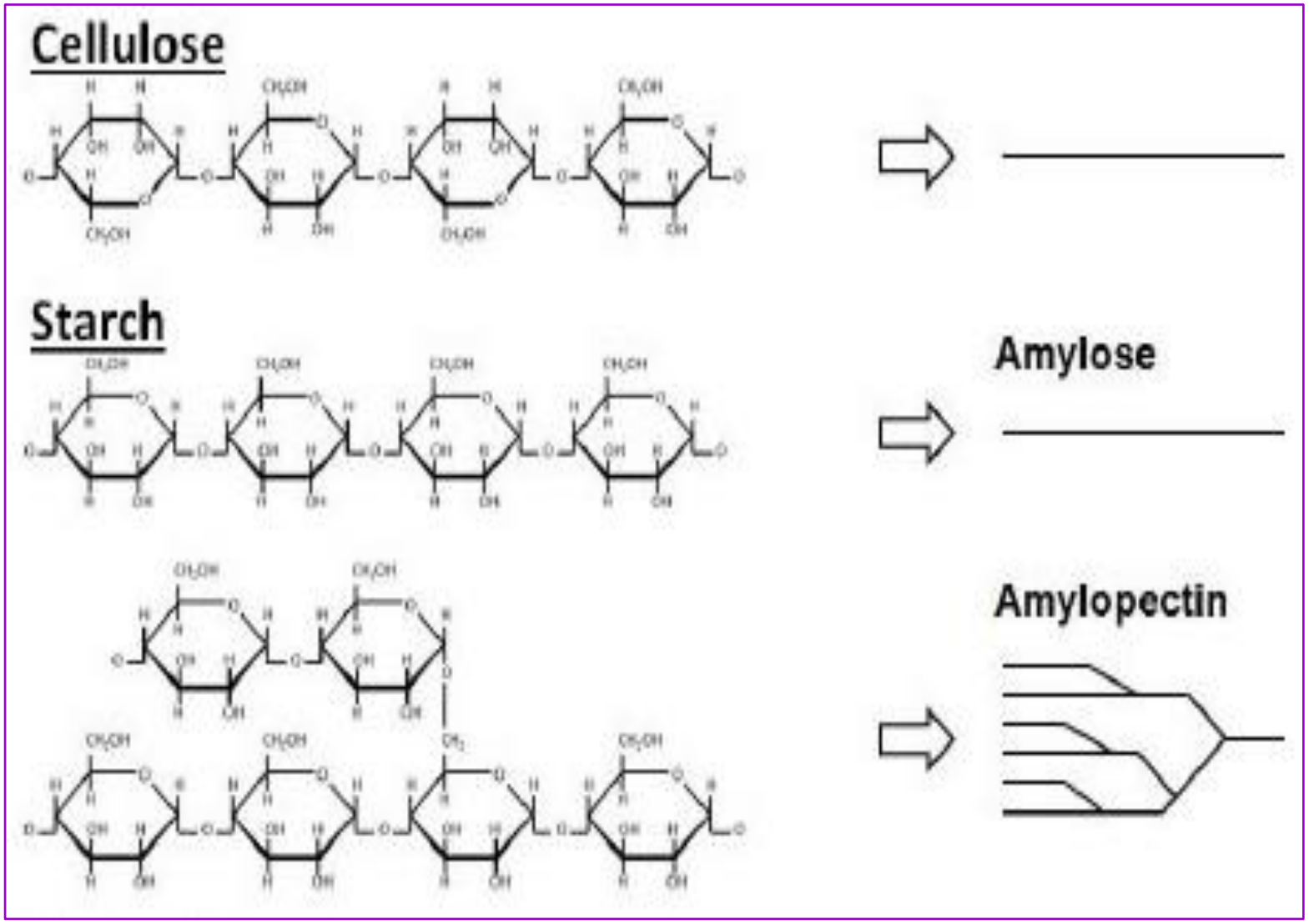


- ✓ **Starch** is formed from **alpha glucose**.
- ✓ **Cellulose** is made of **beta glucose**.



❖ **Starch** can be straight or branched and is used as **energy storage** for plants.

❖ **Cellulose** is the main substance in the **walls of plant cells**, helping plants to remain stiff and upright.



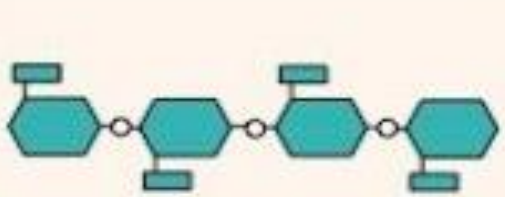
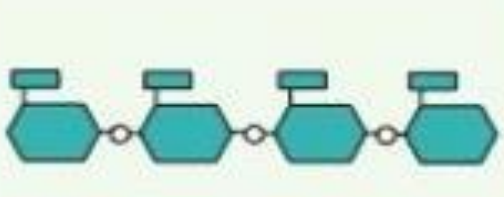
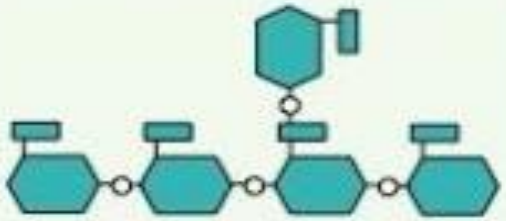
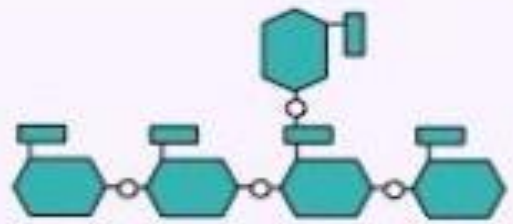
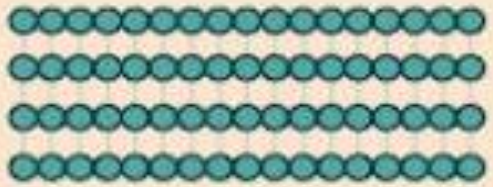
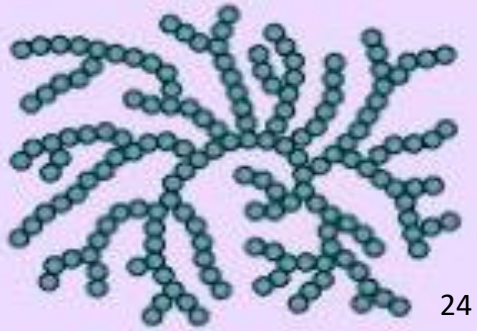
❖ **Humans cannot digest cellulose**, but it is important in the diet as **fibre**.

❖ **Amylose**, is an unbranched (linear) polysaccharide

❖ **Amylopectin**, is a branched polysaccharide.

❖ **Both the forms of Starch are polymers of α-D-glucose.**

❖ **Natural Starch** contains **10-20% Amylose** and **80-90% Amylopectin**.

	Cellulose	Starch		Glycogen
		Amylose	Amylopectin	
Source	Plant	Plant	Plant	Animal
Subunit	β-glucose	α-glucose	α-glucose	α-glucose
Bonds	1-4	1-4	1-4 *and* 1-6	1-4 *and* 1-6
Branches	No	No	Yes (~per 20 subunits)	Yes (~per 10 subunits)
Diagram				
Shape				

Classification of Carbohydrates (based on their **reducing nature)**

1. Reducing Sugars
2. Non-reducing sugars

1. **Reducing Sugars:** Sugars in which their **functional groups** are **free**, are called reducing sugars (All monosaccharaides & most disaccharides).

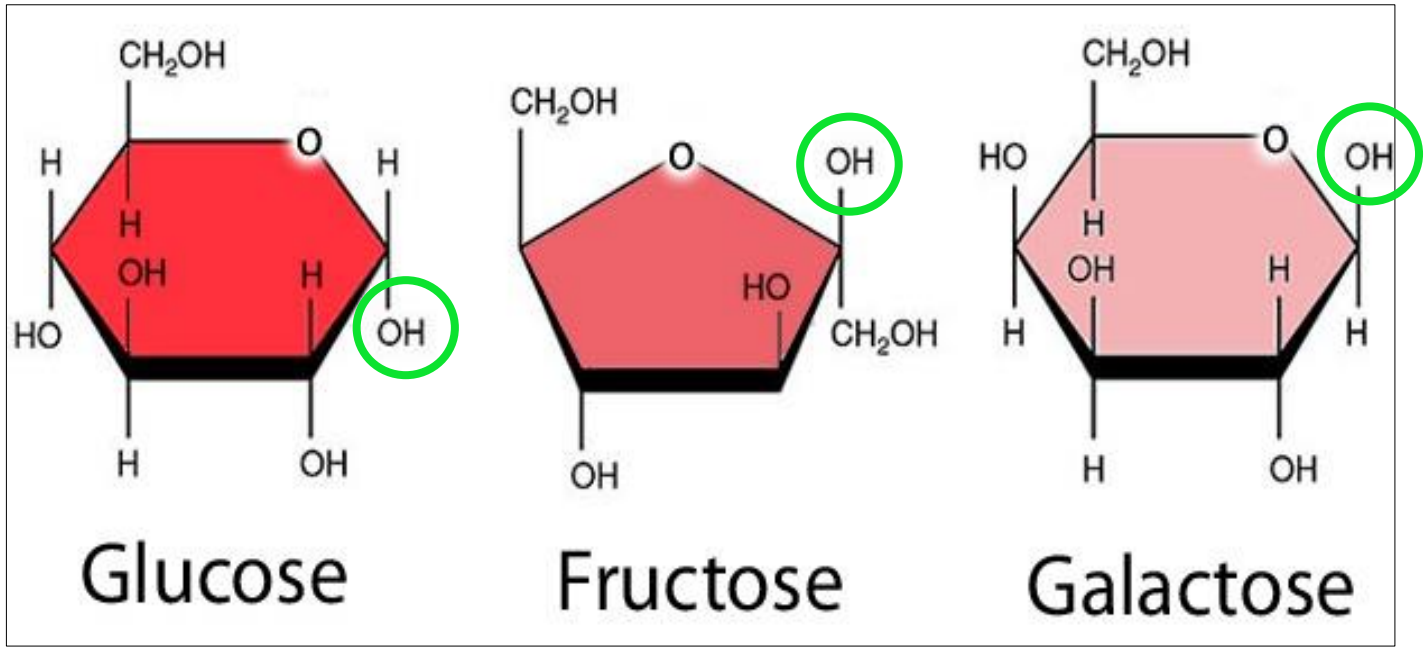
- ✓ **All Monosaccharides** (aldose & ketose) are **reducing sugars** that have free Aldehyde or Ketone group. **(Glucose, Fructose, Maltose, Lactose etc.)**
- ✓ All those carbohydrates which reduce Fehling's solution and Tollens' reagent are referred to as reducing sugars.

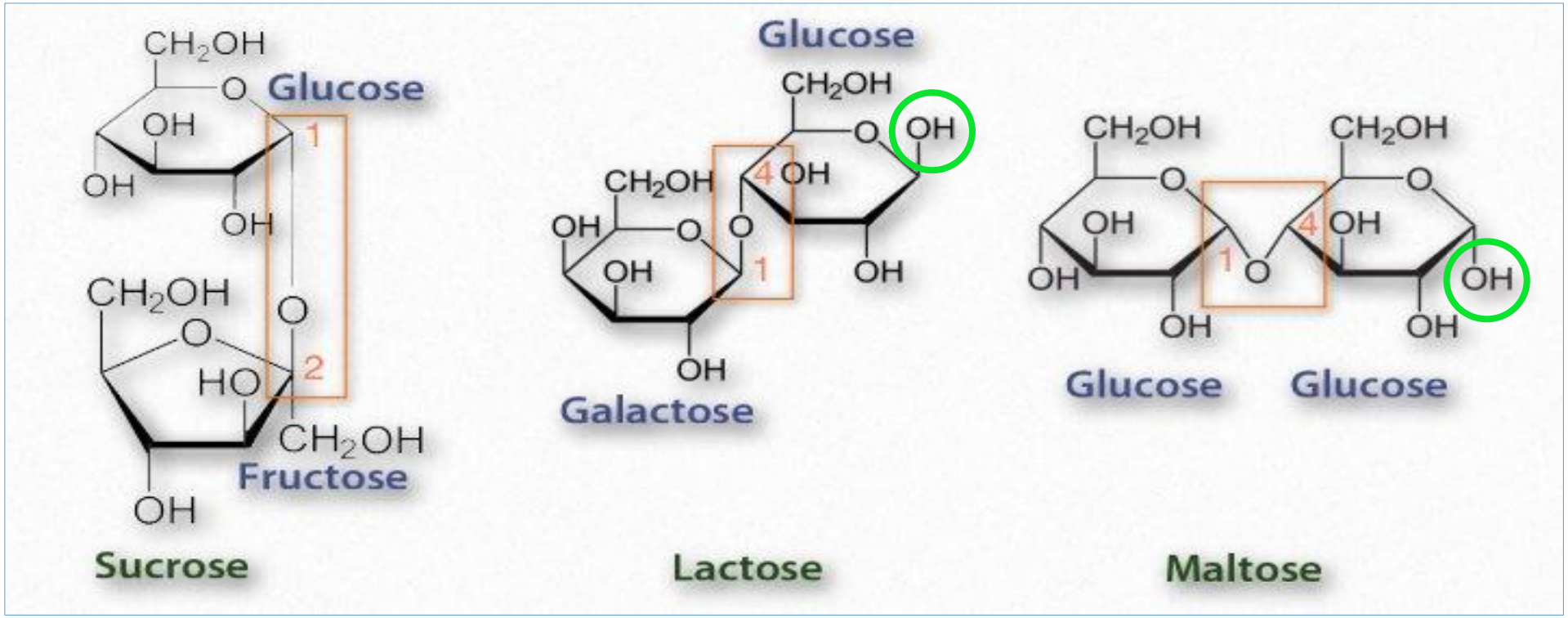
Classification of Carbohydrates (based on their **reducing nature)**

2. Non-reducing sugars (Such as **all Polysaccharides** & **Sucrose)**

- Do not have **free Aldehyde** or **Ketone** group.
- Do not reduce **Fehling's solution** and **Tollens' reagent**

❖ In **Disaccharides**, if the reducing groups of monosaccharides i.e., aldehydic or ketonic groups are bonded, these are non-reducing sugars
Example: **Sucrose**


Glucose
Fructose
Galactose


Glucose
Fructose
Sucrose
Glucose
Galactose
Lactose
Glucose
Glucose
Maltose

Properties of Monosaccharides

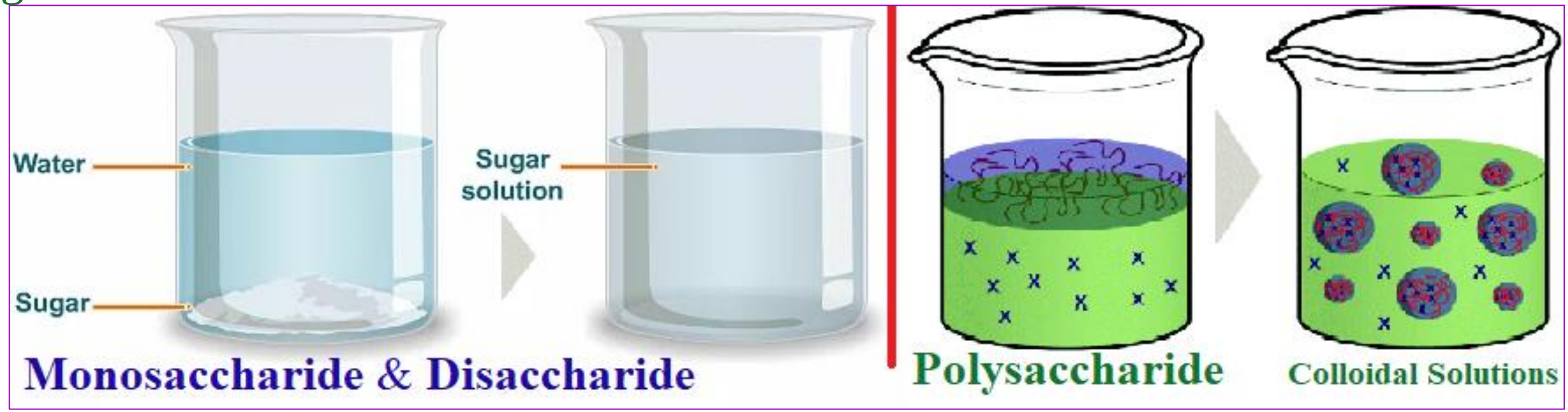
➢ Physical Properties

- Colorless - Crystalline compounds - Readily soluble in water - Sweetish

- Solubility of sugars

Monosaccharide & **Disaccharide** are soluble in water because water is a **polar** substance (Hydrogen bond between water & sugars).

Polysaccharide is insoluble in water, because, it has high molecular weight, which give colloidal solutions in water.



Monosaccharide and disaccharide dissolved in water

Starch do not dissolved easily in water

How are carbohydrates digested?

Carbohydrates take a journey starting with the intake at the **mouth** and ending with elimination from **colon**.

1. Mouth

The Saliva secreted from salivary glands releases an enzyme called **Amylase**, which **catalyze** the **hydrolysis** of **α-1-4 glycosidic bonds** in polysaccharides to simpler sugars

2. Stomach

The carbohydrates travel through **esophagus** to **stomach**. Stomach makes acid to kill bacteria in the chyme.

3. Small Intestine & Pancreas & Liver

The chyme then goes into the **first part of the small intestine** (**duodenum**).
This causes the pancreas to release **pancreatic amylase**. This enzyme breaks down the chyme **into Dextrin, Lactase, Sucrase, and Maltose.**

- The enzymes break down the sugars even further into **monosaccharides** or **single sugars**.
- **Single sugars** are the ones that are finally **absorbed** into the **small intestine**.
- Once **Single sugars** absorbed, they're **processed more** by the **liver** and **stored** as **Glycogen**.
- Other glucose is moved through the body by the bloodstream.
- The **hormone insulin** is released from the **pancreas** and allows the glucose to be used as **energy**.

4. Colon

Anything that's left over after these digestive processes goes to the **colon**.
It's then broken down by **intestinal bacteria**.
Fiber is contained in many carbohydrates and cannot be digested by the body.
Fiber reaches the colon and is then eliminated with stools.

The role of carbohydrates in physical and movement diseases

1. Muscle growth with carbohydrates

In sports, we must say that you need carbohydrates to build muscle. **Protein alone is not enough!** Gaining muscle mass requires more calories, muscle training also requires macronutrients including carbohydrates. **On the other hand, endurance under intense training requires glycogen.**

2. Peripheral diabetic neuropathy

It is the **most common type of neuropathy** in which the peripheral nerves of the brain and spinal cord are damaged. **Diabetic peripheral neuropathy** typically affects the nerves of the **feet** and **hands** and can include motor neuropathy, sensory neuropathy, or both. Nerve damage that mainly affects the legs and sometimes the hands and arms is called peripheral neuropathy.

3. Autonomic neuropathy

In this type, the **nerves controlling internal organs** are **damaged**. In addition, autonomic neuropathy causes problems with **heart rate**, **blood pressure**, **digestive system**, **bladder**, **genitals**, **sweat glands**, **eyes**.

4. focal neuropathy

In this type of disease, single nerves are usually damaged in the nerves of the **hands**, **head**, **legs** and **feet**.

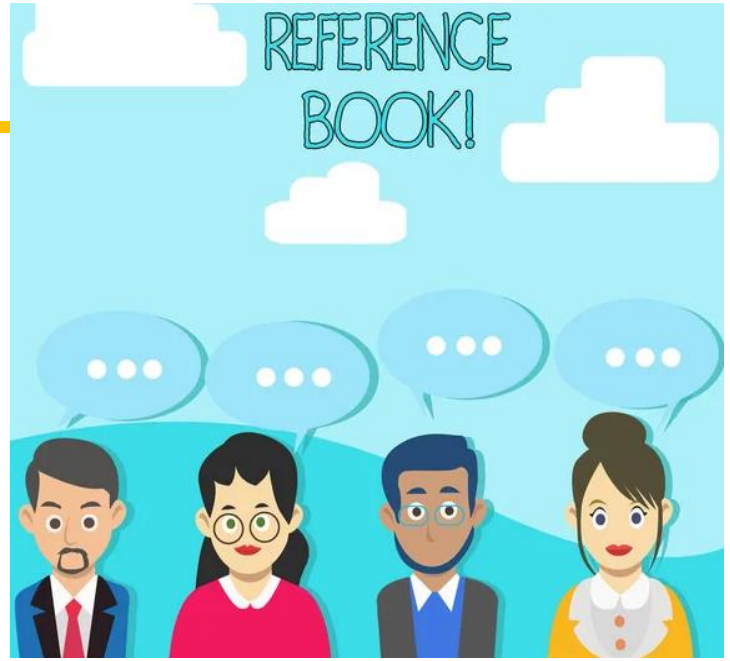
5. Proximal neuropathy

It is a rare type of nerve damage that causes weakness of the nerves in the **pelvis**, **thigh** and **buttocks**. This type of diabetic neuropathy usually involves one side of the body and rarely spreads to the other side. Proximal neuropathy often causes **severe pain** and possible **weight loss**.

6. High carbohydrate diets are associated with an increased risk of PD.

Group discussion

1. Define and give examples of the following terms: (**polysaccharide, aldose, ketose, glycoside bond, glycoprotein).**
2. How does glycogen differ from cellulose?
3. Which of the following, if any, are D-glucose epimers: (**D-mannose, D-galactose or D-ribose)**
4. Dehydration of glucose with fructose
5. Dehydration of two glucose unit
6. Dehydration of glucose and galactose
7. How you explain if somebody have lactose intolerance?
8. Why in maltose and lactos is hemiacetal but sucrose is hemiketal?
9. Reducing sugar vs non reducing sugar and give ex.
10. Can we add further sugar into all disaccharides, why?
11. Difference between amylose, glycogen an amylopectin?
12. Difference between glycogen and starch.



- **Carbohydrates: The Essential Molecules of Life**, 2nd Edition, by Robert V. Stick, Spencer Williams

- **Carbohydrate Chemistry: Proven Synthetic Methods**, Volume 5 1st Edition, by Paul Kosma, Tanja M. Wrodnigg, Arnold Stütz.