Carbohydrates

General characteristics

- The term came from the hydrate (H_2O) of carbon (C)
- It has the general formula $(CH_2O)_n$
- The most abundant compounds found in nature
  ↗ primary (fed state)
- Used as source of energy and energy storage
- Can be converted into fats and proteins
  lipogensis   pyruvate → Alanine
- Important in the formation of genes, vitamins and drugs
- Participate in biological transport

Intravenous infusion of fructose elevate the rate of lipogenesis caused by the enhanced production of acetyl CoA.

Acetyl CoA ↑
lipogenesis =

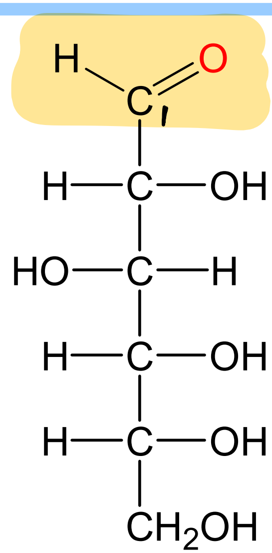
Classification of carbohydrates

- **Monosaccharides:**
  - Trioses, tetroses, pentoses and hexoses (3, 4, 5, 6)
  - Examples: glucose, galactose, mannose, fructose
    - glucose: Aldose, OH to right
    - mannose: C_2 epimer of glucose
- **Disaccharides:** 2 monosaccharides covalently linked (e.g. Sucrose, maltose, lactose)
  - maltose: α (1-4) glucose
  - lactose: β (1-4) glucose-galactose
  - Sucrose: glucose - fructose α (1-2)
- **Oligosaccharides:** (3-10)
  - Tri, tetra, penta up to 9 or 10 units covalently linked (3, 4, 5)
- **Polysaccharides or glycans**
  - Simple polysaccharides (starch, glycogen, amylopectin)
    - amylopectin: noncrystal form of starch
  - Complex carbohydrates (nucleic acid, glycoproteins, glycolipids, ...etc)

Monosaccharides

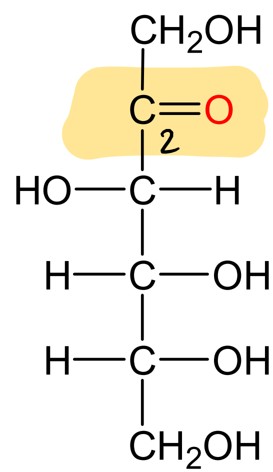
➢ Either aldose or ketose

Aldose C_1



D-glucose

Ketose C_2

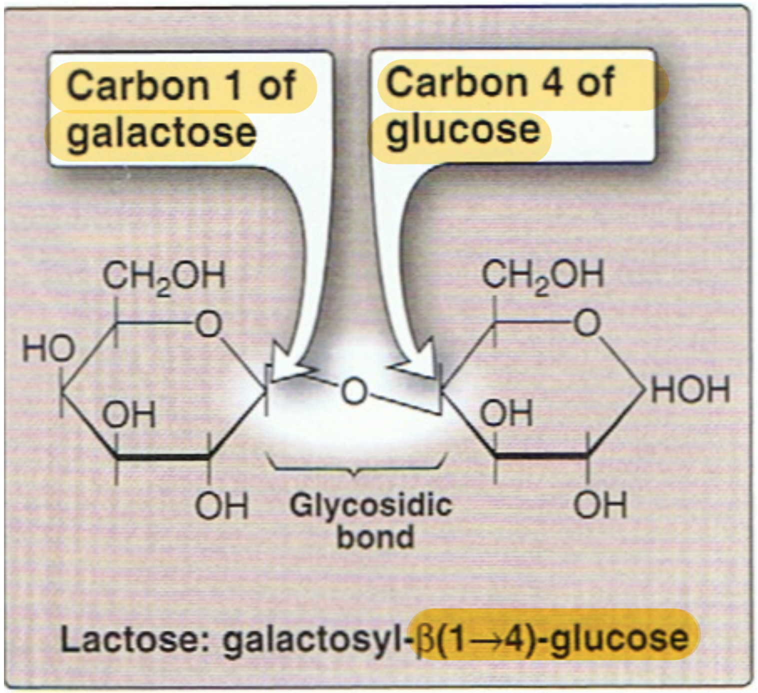


D-fructose

Glycosidic bond

For di — maltose, sucrose, lactose

- For di- and polysaccharides
- Can form O- or N-glycosidic bond



maltose α

Disaccharides

α

- **Maltose**: is a disaccharide with an α(1 → 4) glycosidic link between C1 - C4 OH of 2 glucoses.

glucose + glucose
C1 C4

- **Cellobiose**: is the otherwise equivalent **b** anomer (O on C1 points up) linked by b(1→ 4) glycosidic linkage

non reducing sugar

- **Sucrose**, common table sugar, has a glycosidic bond linking the anomeric hydroxyls of glucose & fructose. the linkage is a(1□2)

- **Lactose**, milk sugar, is composed of galactose & glucose, with b(1□4) linkage from the anomeric OH of galactose.

maltose α (1-4)
sucrose α (1-2)

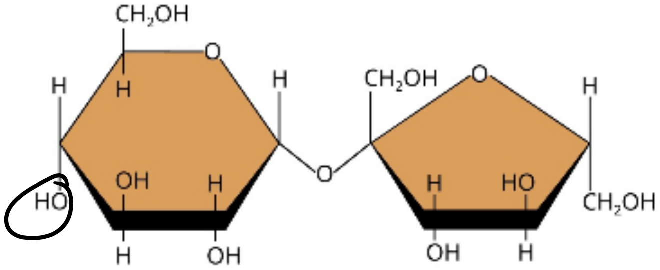
cellobiose
lactose } β (1,4)

Disaccharide	Monosaccharide Components	Linkage Type	Common Source
Maltose α	Glucose + Glucose C_1 C_4	$\alpha(1 \rightarrow 4)$ OH down	Malt sugar / Starch breakdown
Cellobiose β	Glucose + Glucose C_1 C_4	$\beta(1 \rightarrow 4)$ OH up	Cellulose breakdown
Sucrose	Glucose + Fructose C_1 C_2	$\alpha(1 \rightarrow 2)$	Table sugar / Sugar cane
Lactose	Galactose + Glucose C_1 C_4	$\beta(1 \rightarrow 4)$	Milk sugar

DISACCHARIDES

α(1-2)

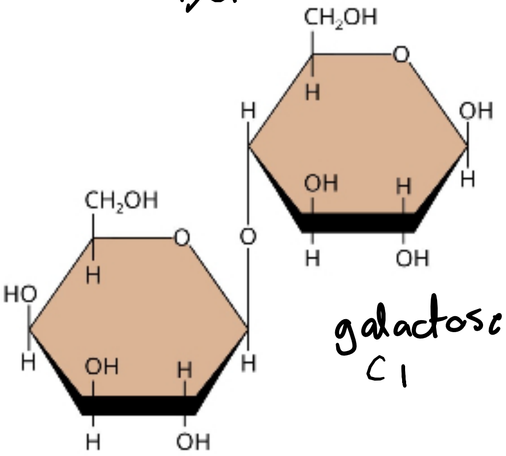
Sucrose



α glucose   fructose

Lactose

β(1-4)

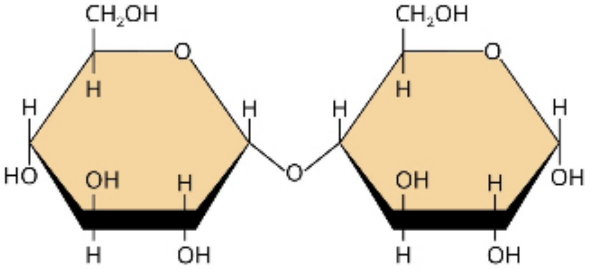


galactose C1

β glucose C4

α(1-4)

Maltose



α glucose   α glucose

glycogen in liver

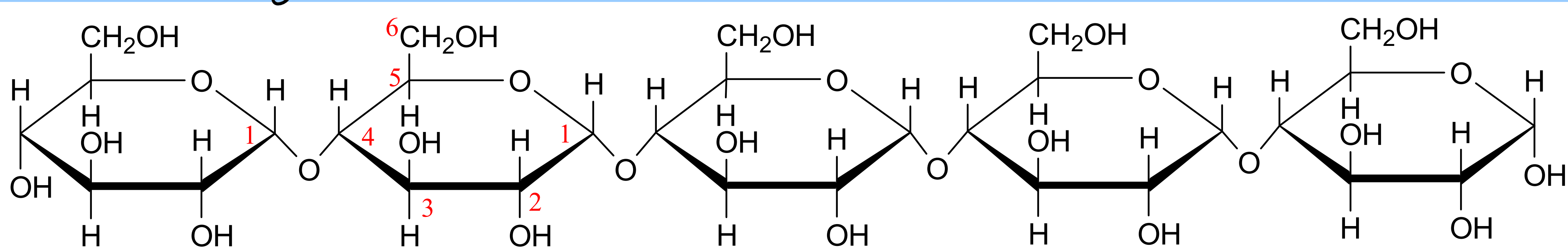
amylose in plants

Polysaccharides

non crystal Form of starch

- **Plants** store glucose as **amylose** or **amylopectin**, glucose polymers collectively called starch.
- Glucose storage in **polymeric** form **minimizes osmotic effects**.
- **Amylose** is a glucose polymer with **a(1□4)** linkages.
- The end of the polysaccharide with an anomeric C1 not involved in a glycosidic bond is called the **reducing end**.

Amylose α



amylose

Key Biological Concepts

- **Osmotic Efficiency:** By storing glucose as a single large polymer (polysaccharide) rather than thousands of individual glucose molecules, the plant **minimizes osmotic pressure**. If stored as free glucose, the high concentration would cause the cell to take in too much water via osmosis, potentially leading to cell rupture.
- **The Reducing End:** Every polysaccharide chain has a specific polarity. The **reducing end** is the terminal sugar that possesses a free anomeric carbon (C1) not currently tied up in a glycosidic bond. This end is chemically reactive and capable of acting as a reducing agent.
- **The Non-Reducing End:** Conversely, the other ends of the polymer (where C4 is free) are "non-reducing." Enzymes that break down starch for energy typically start working from these non-reducing ends.

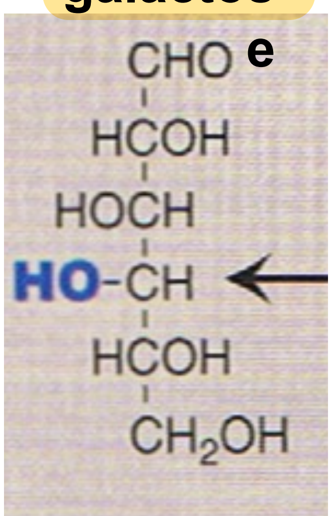
Sugar isomers

➢ Compounds with the same chemical formula are called isomers.

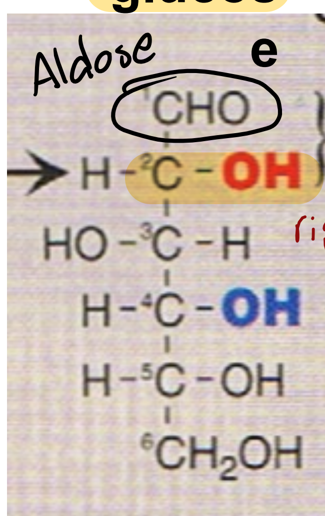
➢ **Epimers** If two monosaccharide isomers differ in configuration around one specific carbon atom (with the exception of the carbonyl carbon), they are defined as epimers of each other.

➢ If a pair of sugars are mirror images of each other (enantiomers), the two members of the pair are designated as D- and L-sugars.

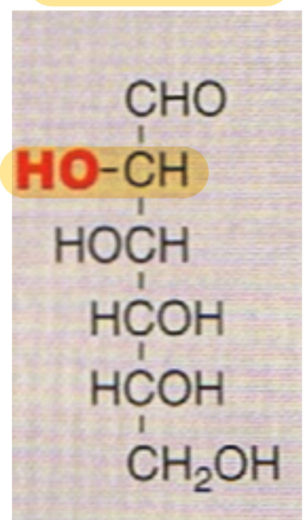
galactos



glucos

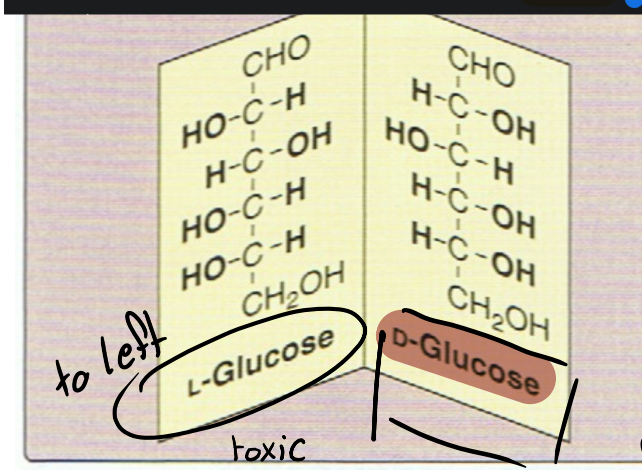


Mannose



- **Enantiomers (D- vs. L-Sugars):**

These are **mirror images** of each other. In biological systems, most naturally occurring sugars are **D-isomers** (the hydroxyl group on the asymmetric carbon farthest from the carbonyl group points to the right).



epimer **epimer**

Relationship	Carbon of Difference	Resulting Sugar
Glucose + Epimer at C2	C2	Mannose
Glucose + Epimer at C4	C4	Galactose

OH to right

No two letters

OH to left

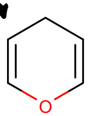
β is better bc its above the ring

α and β sugars

- When a sugar cyclizes, an anomeric carbon is created from the aldehyde group of an aldose or keto group of a ketose,

  - **Aldoses (like Glucose):** The C1 aldehyde reacts with the C5 hydroxyl (OH) group to form a **hemiacetal**.

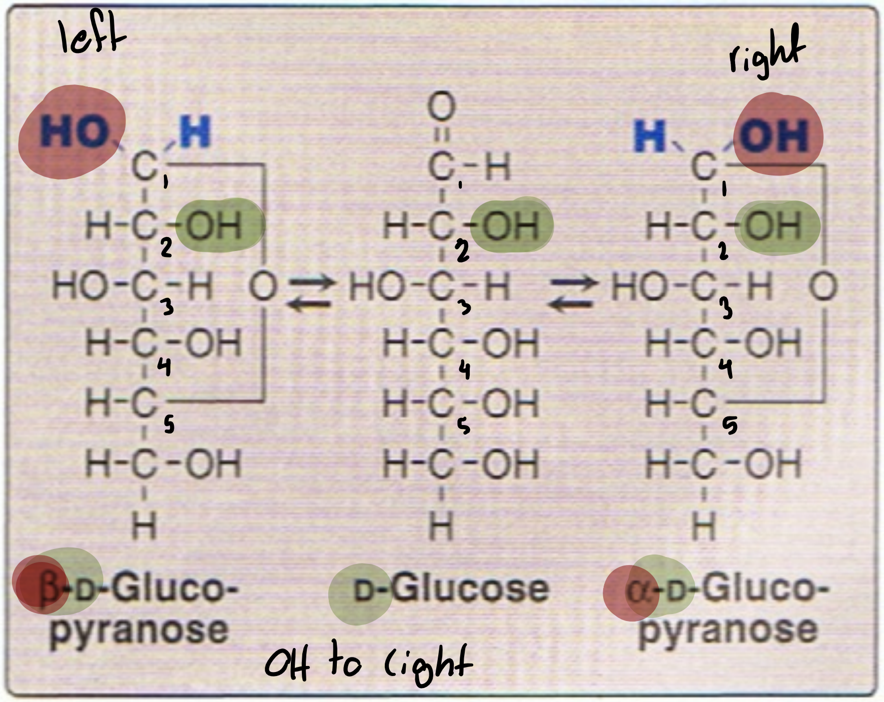
- Glucose forms an intra-molecular hemiacetal, as the C1 aldehyde & C5 OH react, to form a 6-member pyranose ring, named after pyran

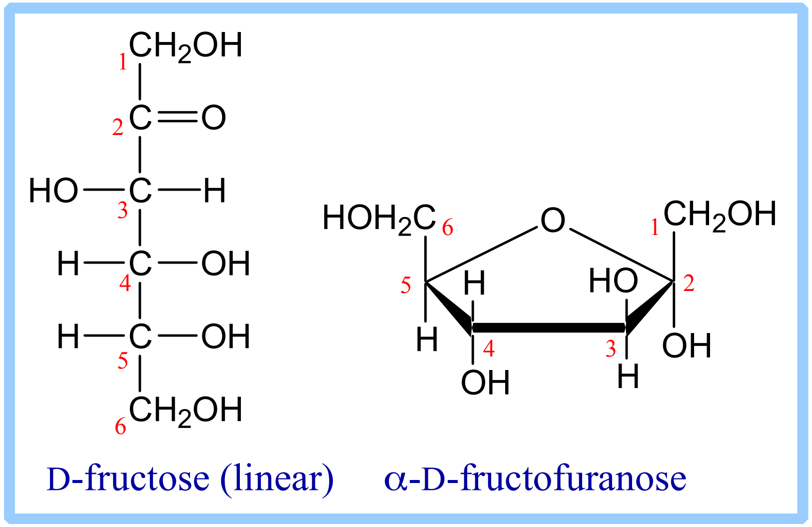


- This carbon can have two configuation, α or β. If the oxygen on the anomeric carbon is not attached to any other structure, that sugar is a reducing sugar

C1

- a (OH below the ring)
- b (OH above the ring).

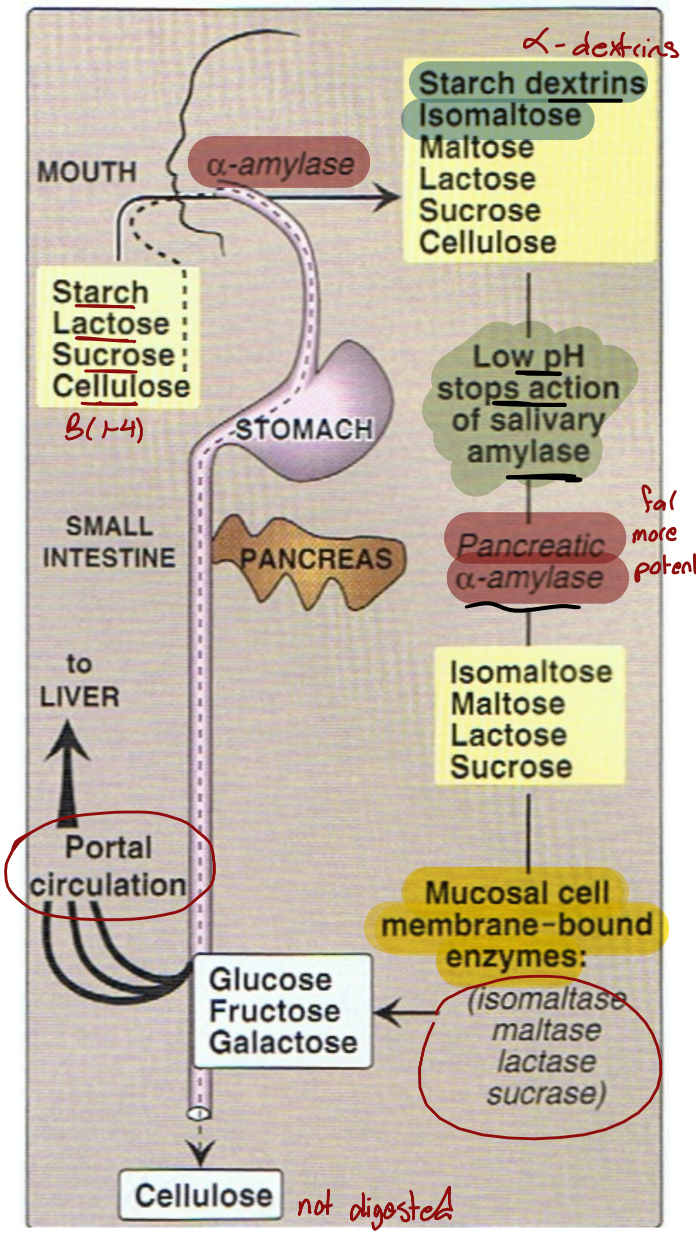




https://youtu.be/kukw5eVY9MM?si=lUUXVR203x4hRi1n

Digestion of carbohydrates

- Digestion of carbohydrates begins in the mouth by salivary α-amylase enzyme which breaks α-1,4 glycosidic bond
- The digestion stops in the stomach because the amylase is inactivated by the high acidity
- further digestion of carbohydrates by pancreatic enzymes occurs in the small intestine by pancreatic amylase more potent



Absorption of monosaccharides

- The duodenum and upper jejunum absorb the bulk of the sugars.

- Insulin is not required for the uptake of glucose by intestinal cells.

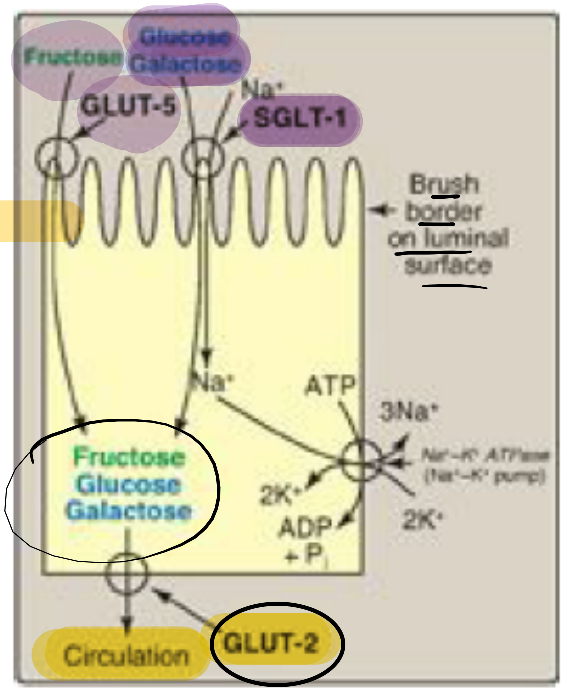
SGLT

- galactose and glucose are transported to the mucosal cells by an active, energy-requiring process that involves a specific transport protein and requires a concurrent uptake of sodium ions. - متزامن -

Na^+

- Fructose uptake requires a sodium-independent monosaccharide transporter (GLUT-5) for its absorption

Fructose = glut 5   glucose, galactose] SGLT for absorption



not insulin dependent

Abnormal degradation of disaccharides

في القالب

- Because predominantly monosaccharides are absorbed, any defect in a specific disaccharidase activity of the intestinal mucosa causes the passage of undigested carbohydrates into the large intestine.

they pull water

- As a consequence of the presence of this osmotically active material, water is drawn from the mucosa into the large intestine, causing osmotic diarrhea.

- This is reinforced by the bacterial fermentation of the remaining carbohydrate to two- and three-carbon compounds (which are also osmotically active) producing large volumes of CO_2 and H_2 gas, causing abdominal cramps, diarrhea, and flatulence,

انتفاخ بطن

1- abdominal cramps
2- diarrhea water
3- flatulence Co_2 / H_2 gas

Abnormal degradation of disaccharides

- Digestive enzyme deficiency
- Lactose intolerance: lactase deficiency
- Isomaltase-sucrase deficiency: defect in sucrose degradation (10% of eskimos)
- Measurement of hydrogen gas in the breath is a reliable test for determining the amount of ingested carbohydrate not absorbed by the body