



# Disaccharides & Polysaccharides

## Lecture 2

**Lecture** : Biochemistry

**Stage** : 1st Stage, Second Semester

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**Department**: Chemistry and Biochemistry

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# Learning Objective

By the end of this lecture, students will be able to:

- ✓ **Classify carbohydrates** and understand glycosidic bonds ( $\alpha$  and  $\beta$ ).
- ✓ **Differentiate** between reducing and non-reducing sugars.
- ✓ **Describe** the structures and roles of key disaccharides (maltose, lactose, sucrose).
- ✓ **Compare** major polysaccharides (starch, glycogen, cellulose, and heparin).
- ✓ **Understand glycoproteins**, their linkages (O-linked & N-linked), and their biological functions.

# Course Textbook & Resources

- The primary textbook for this lecture is available for download. You can access the required chapter through the link below:
- <https://classroom.google.com/c/ODMwNjg0MjYyNTk0>
- **Book Details:**
- **Textbook:** *Lehninger Principles of Biochemistry*
- **Required Reading:** Chapter 7 (Carbohydrates and Glycobiology)

# Disaccharides

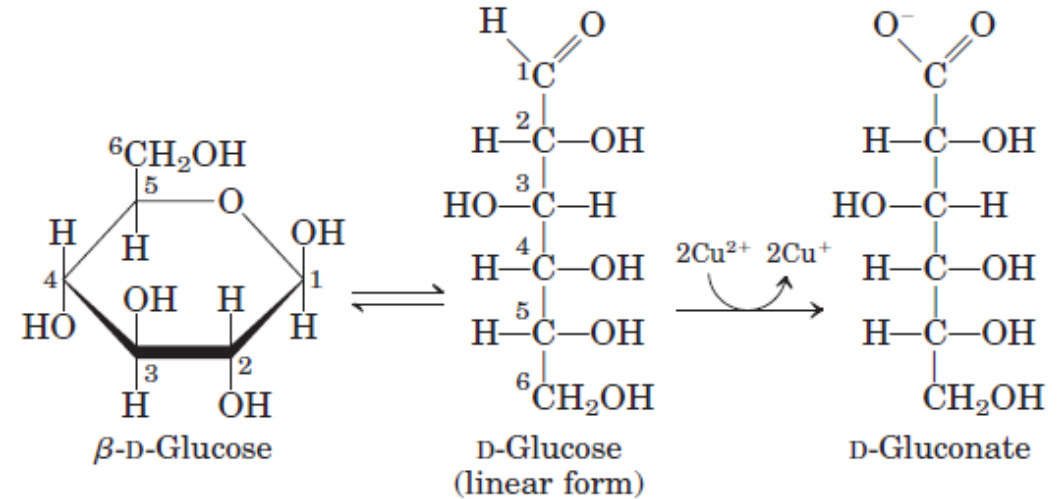
- Among the oligosaccharides disaccharides are the most common.
- As is evident from the name, a disaccharide consists of two monosaccharide units (similar or dissimilar) held together by a glycosidic bond.
- They are crystalline, water-soluble and sweet to taste.

## □ The disaccharides are of two types:

- a. **Reducing disaccharides** with free aldehyde or keto group e.g. maltose, lactose.
- b. **Non-reducing disaccharides** with no free aldehyde or keto group e.g. sucrose.

# Sugars as Reducing Agents: Fehling's Reaction

- **Mechanism:** Oxidation of the anomeric carbon of glucose (and other sugars).
- **Equilibrium:** The ring (hemiacetal) form cannot be oxidized directly. However, it is in equilibrium with the open-chain form, which undergoes oxidation.



## □ Fehling's Reaction:

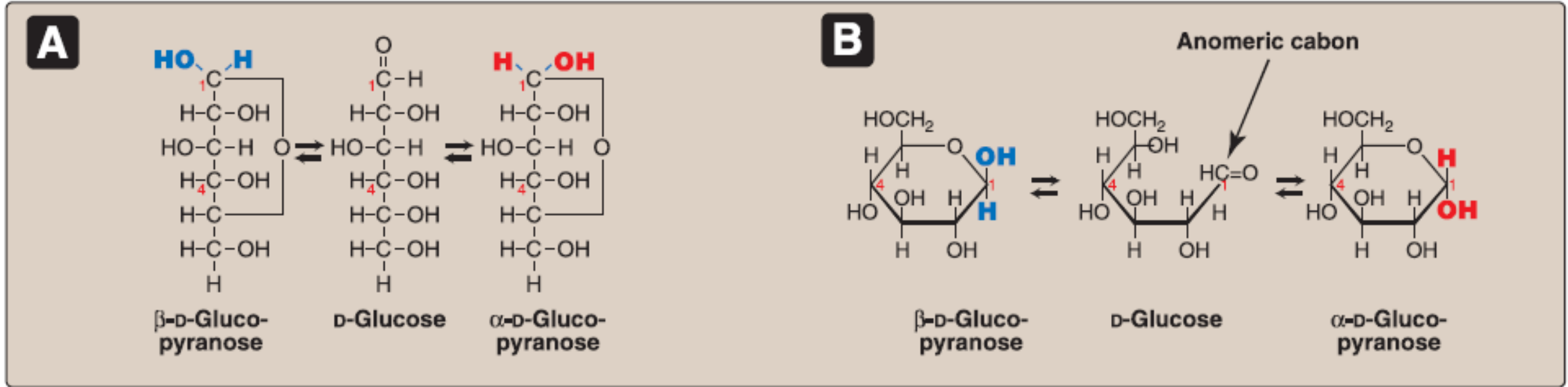
- Cupric ion ( $\text{Cu}^{2+}$ ) is reduced under alkaline conditions to Cuprous ion ( $\text{Cu}^{+}$ ).
- This forms a **red cuprous oxide precipitate**.
- D-Glucose is oxidized to D-Gluconate .

**Quickly**  
understand

**Fehling's test**



# Recall about forming the cyclic carbohydrates



# Naming of Disaccharides

## Part 1: The First Sugar (The Sender / Left Side)

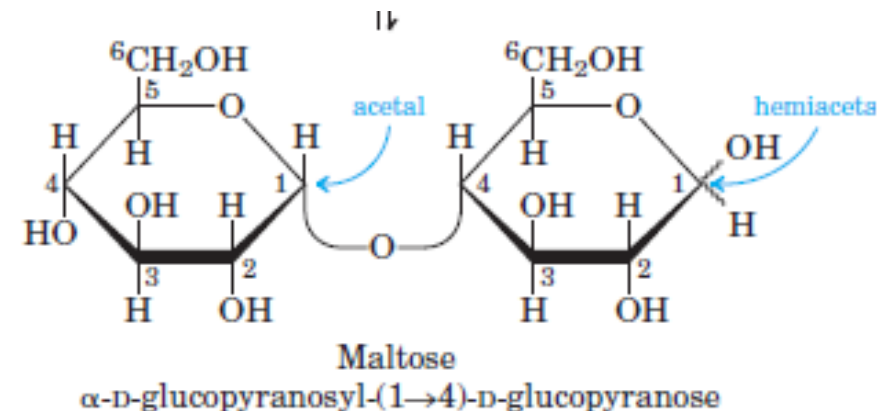
This is the sugar that uses its **anomeric carbon** to start the bond. To identify it, we need 3 details:

**1.The Position:** Is the bond pointing down ( $\alpha$ , alpha) or up ( $\beta$ , beta)?

**2.The Name & Ring Shape:** Identify the sugar (like glucose) and specify its ring size: insert "pyrano" for a **6-sided ring** or "furano" for a **5-sided ring**.

**3.The Connection Tag:** Because this sugar is linking to another, we drop the standard ending and replace it by **syl**.

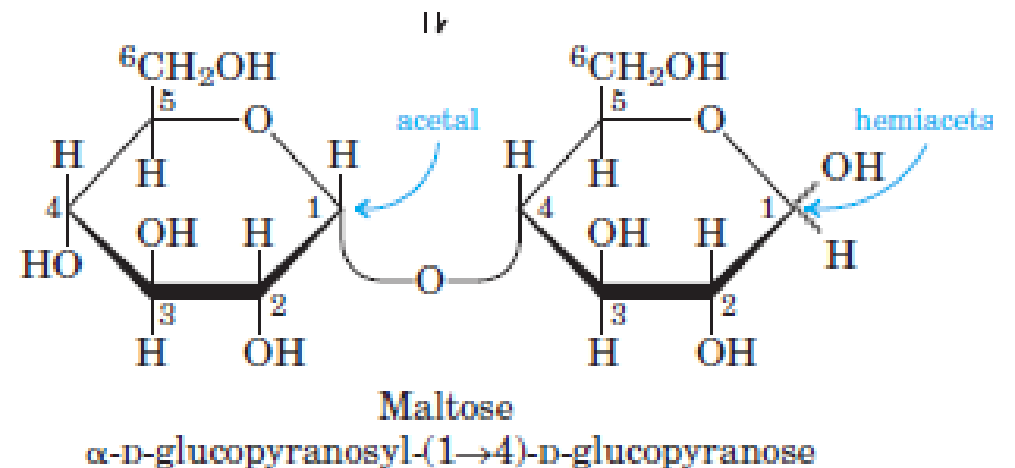
• **Maltose** : The first sugar is an alpha **glucose** with a 6-sided ring right arrow so it becomes  **$\alpha$ -D-gluco**pyranosyl****.



# Naming of Disaccharides

## Part 2: The Bridge (The Connection)

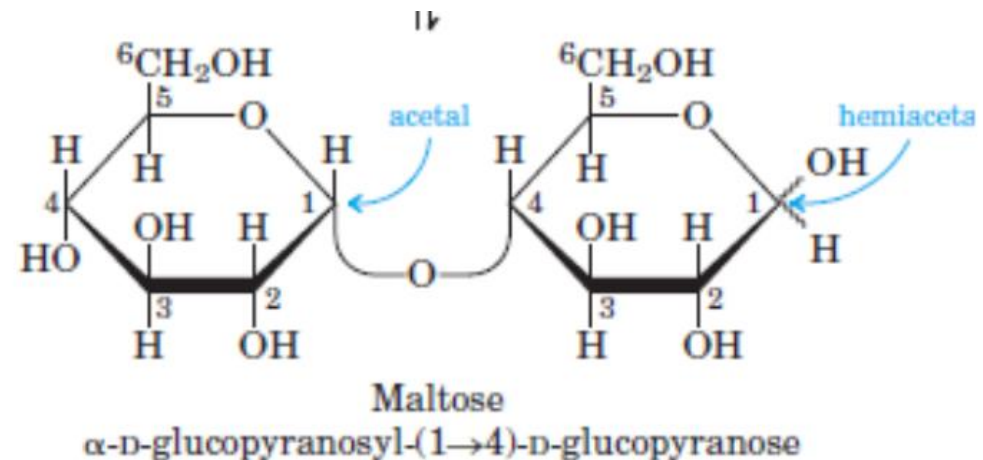
- Here, we explain exactly where the bridge starts and where it ends.
- We open a set of parentheses (), write in the carbon numbers involved inside, then draw an arrow between them.
- *In Maltose*: Carbon 1 of the first sugar connects to Carbon 4 of the second sugar right arrow so we write (1 ---> 4).



# Naming of Disaccharides

## Part 3: The Second Sugar (The Receiver / Right Side)

- This sugar is just sitting there receiving the bond.
- Naming it is easy: use its normal name, add the ring shape, and finish with the standard sugar ending "-**ose**".
- **In Maltose:** The second sugar is a glucose with a 6-sided ring, so it remains D-glucopyran**ose**.

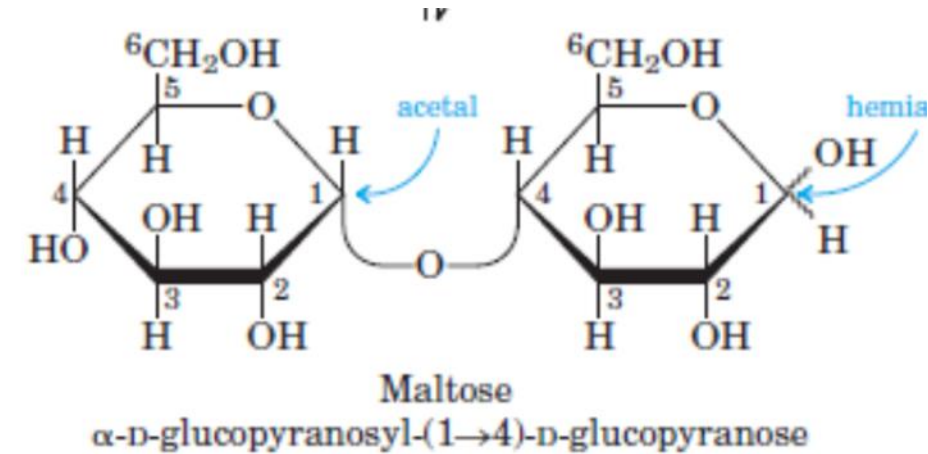


# Naming of Disaccharides

## The Final Result (Putting It All Together)

(First Sugar) + (The Bridge) + (Second Sugar)

$\alpha$ -D-glucopyranosyl-(1  $\longrightarrow$  4)-D-glucopyranose



## The "Shortcut" Version (For the Efficient Biochemist!) 💡

3-letter abbreviations for the sugars are used (Glc for **glucose**, Gal for **galactose**, Fru for **fructose**), and they smash the configuration and the bridge together in the middle.

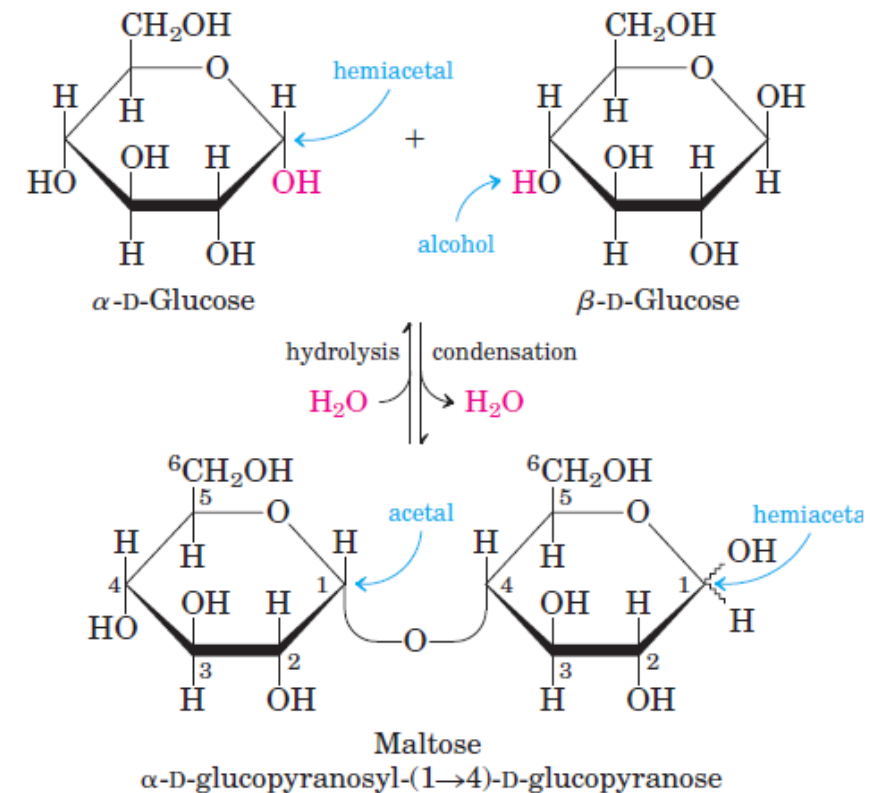
• **Maltose** : Glc( $\alpha$  1  $\longrightarrow$  4)Glc

# Abbreviations for the sugars

Abequose	Abe
Arabinose	Ara
Fructose	Fru
Fucose	Fuc
Galactose	Gal
Glucose	Glc
Mannose	Man
Rhamnose	Rha
Ribose	Rib
Xylose	Xyl

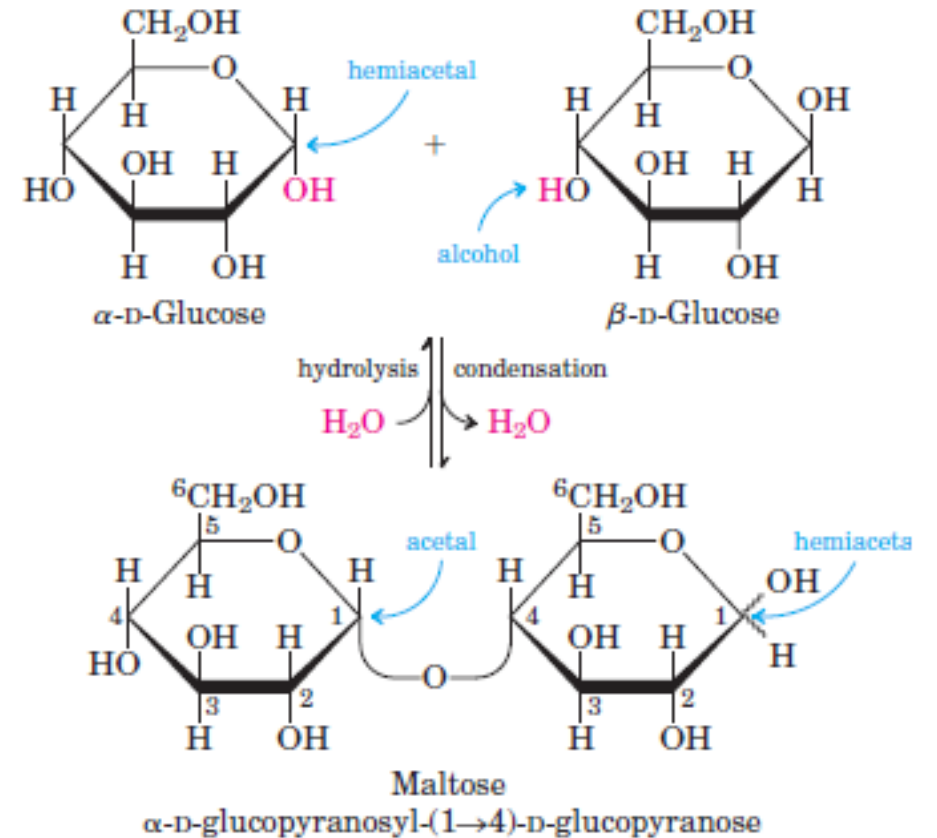
# Glycosidic Bond

- Disaccharides (such as maltose, lactose, and sucrose) contain of two monosaccharides joined by an **O-glycosidic bond**.
- This bond is formed when a hydroxyl group of one sugar reacts with the anomeric carbon of the other.
- This reaction is the formation of an acetal from a hemiacetal
- **Acid vs. Base:** Glycosidic bonds are readily hydrolyzed by acid but resist cleavage by base.
- **Yield:** Thus, disaccharides can be hydrolyzed to yield their free monosaccharide components by boiling with dilute acid.



# Maltose

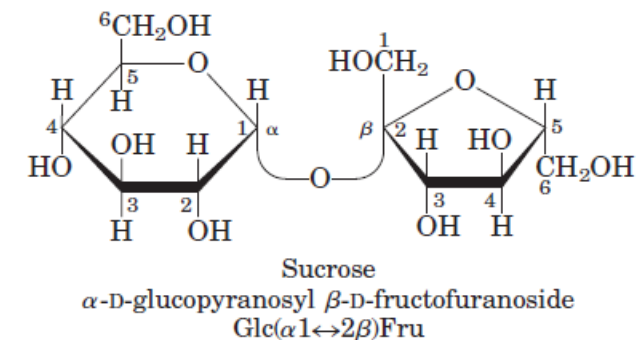
- Maltose is composed of two  $\alpha$ -D-glucose units held together by  $\alpha$  (1-4) glycosidic bond.
- The free aldehyde group present on C1 of second glucose the reducing reactions, besides the osazone formations.
- Maltose can be hydrolysed by dilute acid or the **enzyme maltase** to give two molecules of  $\alpha$ -D-glucose.



**FIGURE 7-11** Formation of maltose. A disaccharide is formed from two monosaccharides (here, two molecules of D-glucose) when an

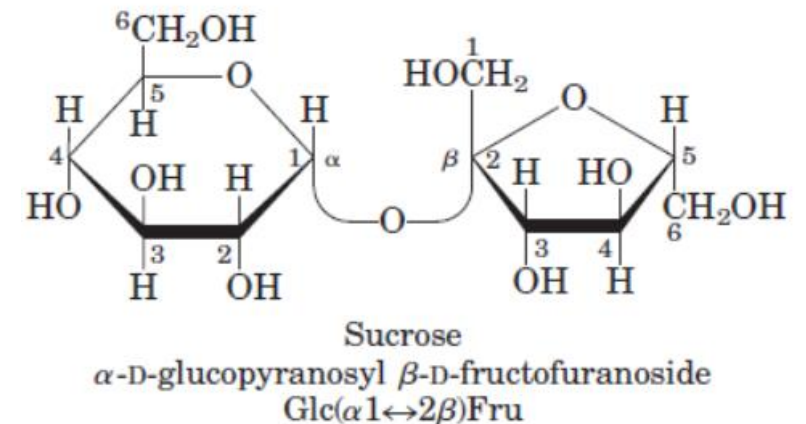
# Sucrose

- Sucrose is the sugar of table, mostly made by sugarcane .
- Sucrose is made up of  $\alpha$ -D-glucose and  $\beta$ -D-fructose.
- The two monosaccharides are held together by a glycosidic bond ( $\alpha$ 1 -  $\beta$ 2), between C1 of  $\alpha$ -glucose and C2 of  $\beta$ -fructose.
- The reducing groups of glucose and fructose are involved in glycosidic bond, hence sucrose is a non-reducing sugar, and it cannot form osazones.
- **What is the abbreviated name of sucrose ?**



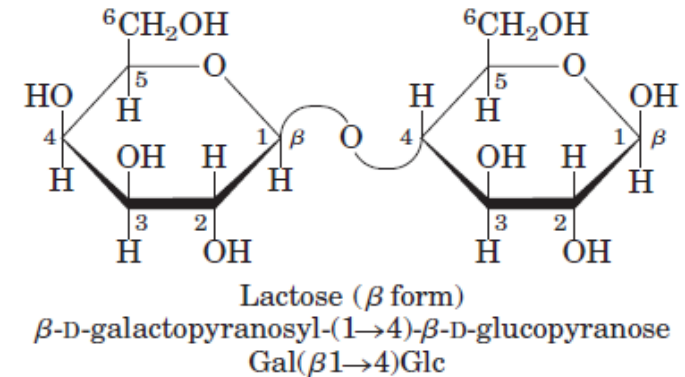
# Sucrose

- Sucrose is an important source of dietary carbohydrate.
- It is sweeter than most other common sugars (except fructose) glucose, lactose and maltose.
- Sucrose is used as a sweetening agent in food industry.
- The enzyme that converts sucrose into glucose and fructose is **invertase**, also known as **sucrase**.
- **Invertase/sucrase** catalyzes the **hydrolysis** of the glycosidic bond in sucrose.



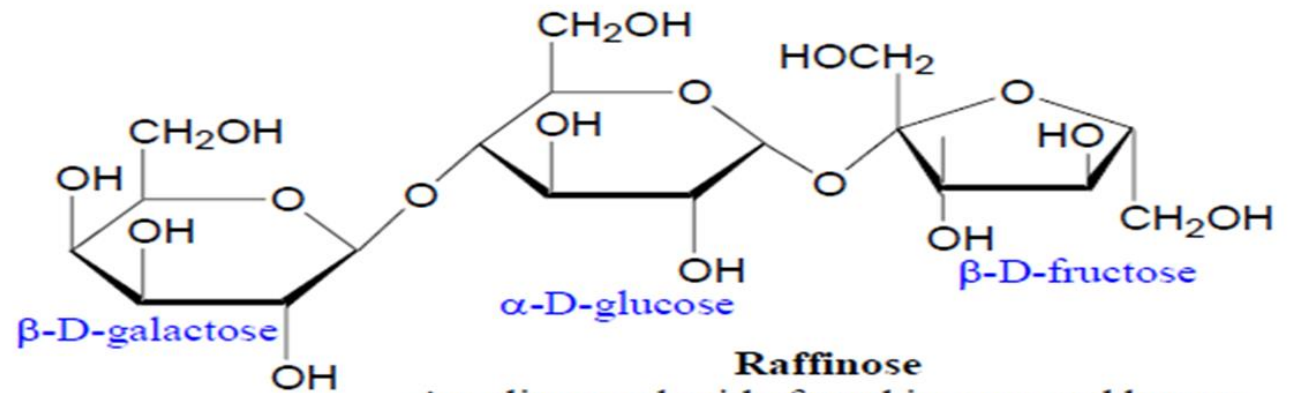
# Lactose

- Lactose is more commonly known as milk sugar since it is the disaccharide found in milk.
- Lactose is composed of  **$\beta$ -D-galactose** and  **$\beta$ -D-glucose** held together by  $\beta$  (1 - 4) glycosidic bond.
- The anomeric carbon of C1 glucose is free, and thus lactose is a reducing disaccharide.
- Lactose of milk is the most important carbohydrate in the nutrition of young mammals.
- Its abbreviated name is Gal( **$\beta$**  1  $\longrightarrow$  4)Glc.
- The enzyme responsible for the hydrolysis of lactose to glucose and galactose is **Lactase** (also known as  **$\beta$ -galactosidase**).



# What are Oligosaccharides?

- **Definition:** Carbohydrates composed of a small number of monosaccharide units.
- Typically contain between **3 to 10 monosaccharide units** linked by glycosidic bonds.
- Often found attached to proteins (glycoproteins) or lipids (glycolipids) on cell surfaces.



**Raffinose**  
An oligosaccharide found in peas and beans; largely undigested until reaching the intestinal flora in the large intestine, releasing hydrogen, carbon dioxide, and methane)

# Polysaccharides

Polysaccharides are large molecules made of many repeating sugar units (monosaccharides).

- These units are connected by Glycosidic bond.
- They have two main functions: building parts of cells and **Energy storage**.
- Polysaccharides can be: Linear (straight chains) or Branched (chains with side branches).
- Branching happens because bonds can form at different OH (hydroxyl) groups in the sugar molecule.
- **Main storage polysaccharides:**
  - Starch → found in plants
  - Glycogen → found in animals

# Polysaccharides

- **Polysaccharides are of two types:**

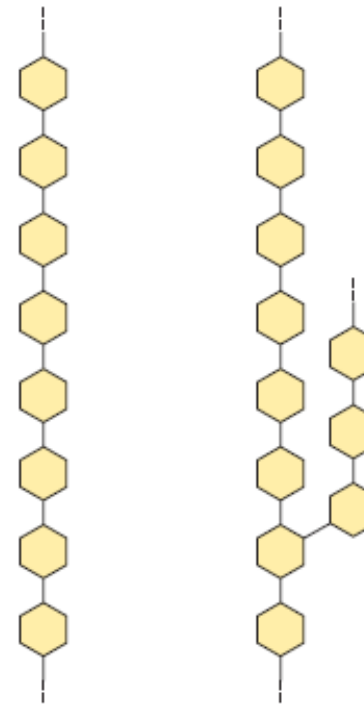
1. **Homopolysaccharides** which on hydrolysis yield only a single type of monosaccharide.

They are named based on the nature of the monosaccharide unit. Thus, glucans are polymers of glucose, while fructosans are polymers of fructose.

2. **Heteropolysaccharides:** on hydrolysis yield a mixture of a few monosaccharides or their derivative

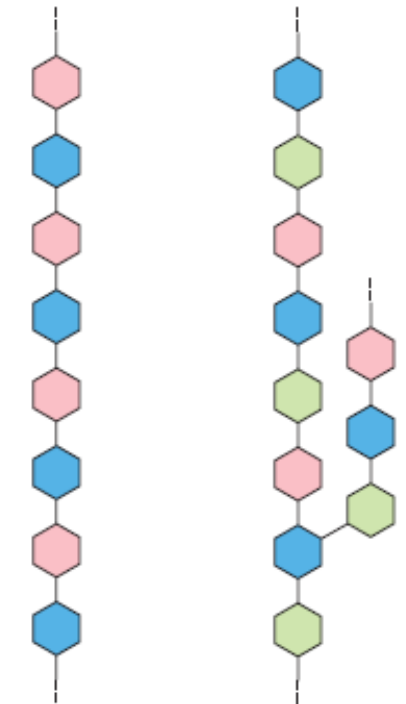
## Homopolysaccharides

Unbranched    Branched



## Heteropolysaccharides

Two monomer types, unbranched    Multiple monomer types, branched



**FIGURE 7-13** Homo- and heteropolysaccharides. Polysaccharides may be composed of one, two, or several different monosaccharides, in straight or branched chains of varying length.

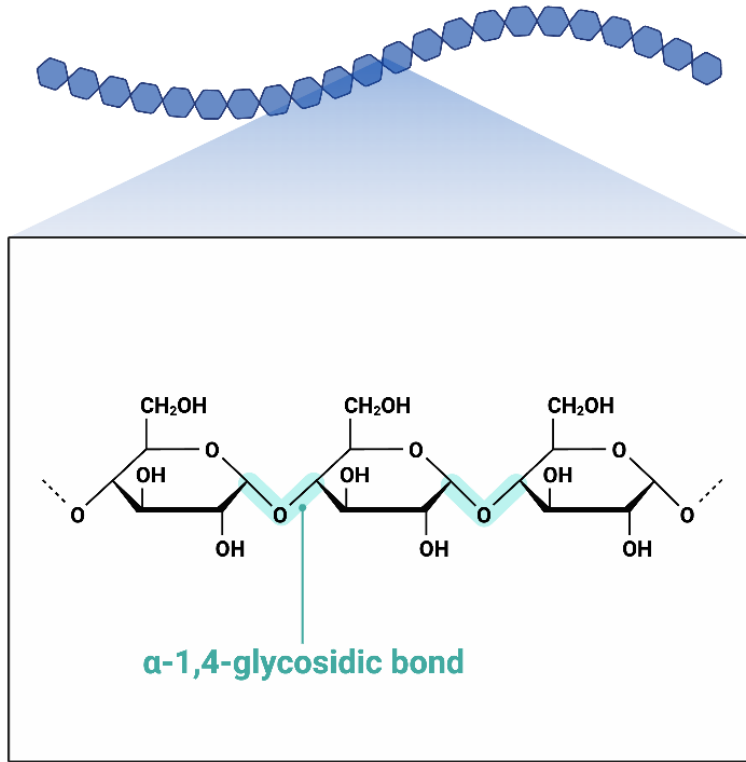
## *Starch*

- **Starch** is a polymer consisting of D-glucose units.
- Starches (and other glucose polymers) are usually insoluble in water because of the high molecular weight, but they can form thick colloidal suspensions with water.
- There are two forms of starch: **amylose** and **amylopectin**.

# Types of Starch

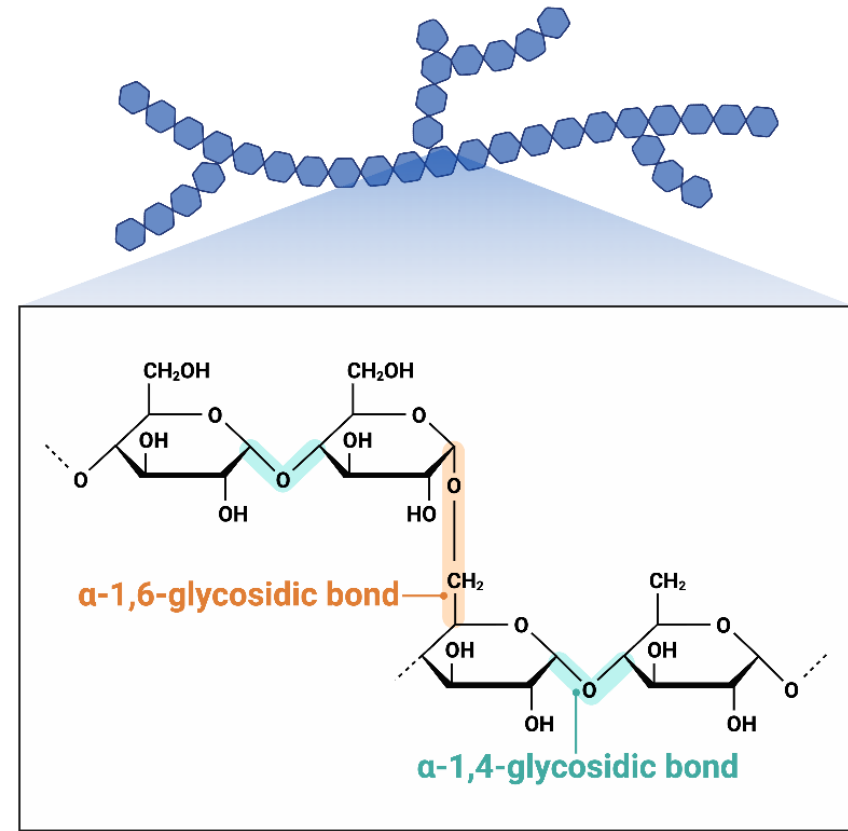
## Structure of Amylose vs. Amylopectin

Amylose



Amylose is composed of glucose molecules connected by  $\alpha$ -1,4-glycosidic bonds.

Amylopectin



Straight-chain portions of amylopectin are connected by  $\alpha$ -1,4-glycosidic bonds, whereas the branches are connected by  $\alpha$ -1,6-glycosidic bonds.

# Type of Starch

## ❖ 1. Amylose

- **Structure:** Contains of long, **unbranched** chains of D-glucose.
- **Linkages:** glucose are connected by  **$\alpha(1\rightarrow4)$**  glycosidic linkages.

**Molecular Weight:** from a few thousand to more than a million.

## ❖ 2. Amylopectin

**Structure:** Highly **branched** chains.

**Linkages:** The glucose in the main chains are joined by  **$\alpha(1\rightarrow4)$**  glycosidic linkages (just like amylose).

**Branch Points:** Branching occurs every 24 to 30 residues, and the linkages at these specific branch points are  **$\alpha(1\rightarrow6)$** .

**Molecular Weight:** Very high, reaching up to 100 million.

# Quick Comparison Table

<b>Feature</b>	<b>Amylose</b>	<b>Amylopectin</b>
<b>Chain Structure</b>	Unbranched	Highly branched
<b>Main Linkages</b>	$\alpha(1\rightarrow4)$	$\alpha(1\rightarrow4)$
<b>Branch Linkages</b>	None	$\alpha(1\rightarrow6)$
<b>Molecular Weight</b>	Thousands to over a million	Up to 100 million

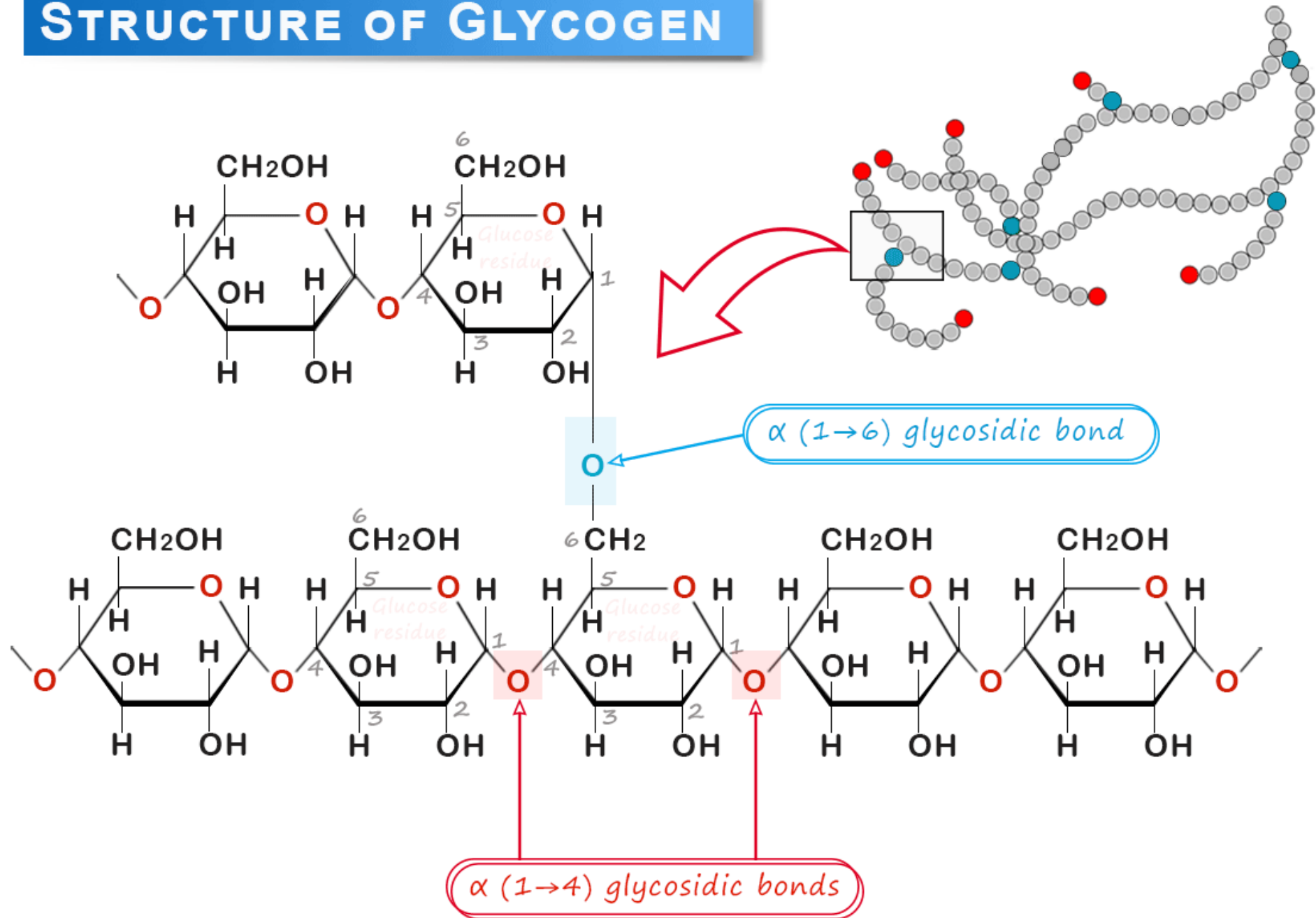
# Glycogen

- Glycogen is the storage form of carbohydrates in animals, so it is often called animal starch.
- It is mainly found in:
  - Liver (highest amount)
  - Muscle
  - Small amounts in brain and other tissues.
- Its structure is similar to Amylopectin, but it is more highly branched.
- Made of repeating **glucose** units
- Linked by:
  - **$\alpha(1 \rightarrow 4)$  bonds**  $\rightarrow$  form the main chain
  - **$\alpha(1 \rightarrow 6)$  bonds**  $\rightarrow$  form branches

# Glycogen

- A glycogen molecule has only *one* reducing end, but *multiple* nonreducing ends (one at the tip of every branch).
- **Targeted Breakdown:** When energy is needed, glucose units are removed one at a time specifically from the nonreducing ends.
- Because glycogen has many branches, enzymes can work on many points at the same time, so glucose is released **very quickly**.

# STRUCTURE OF GLYCOGEN



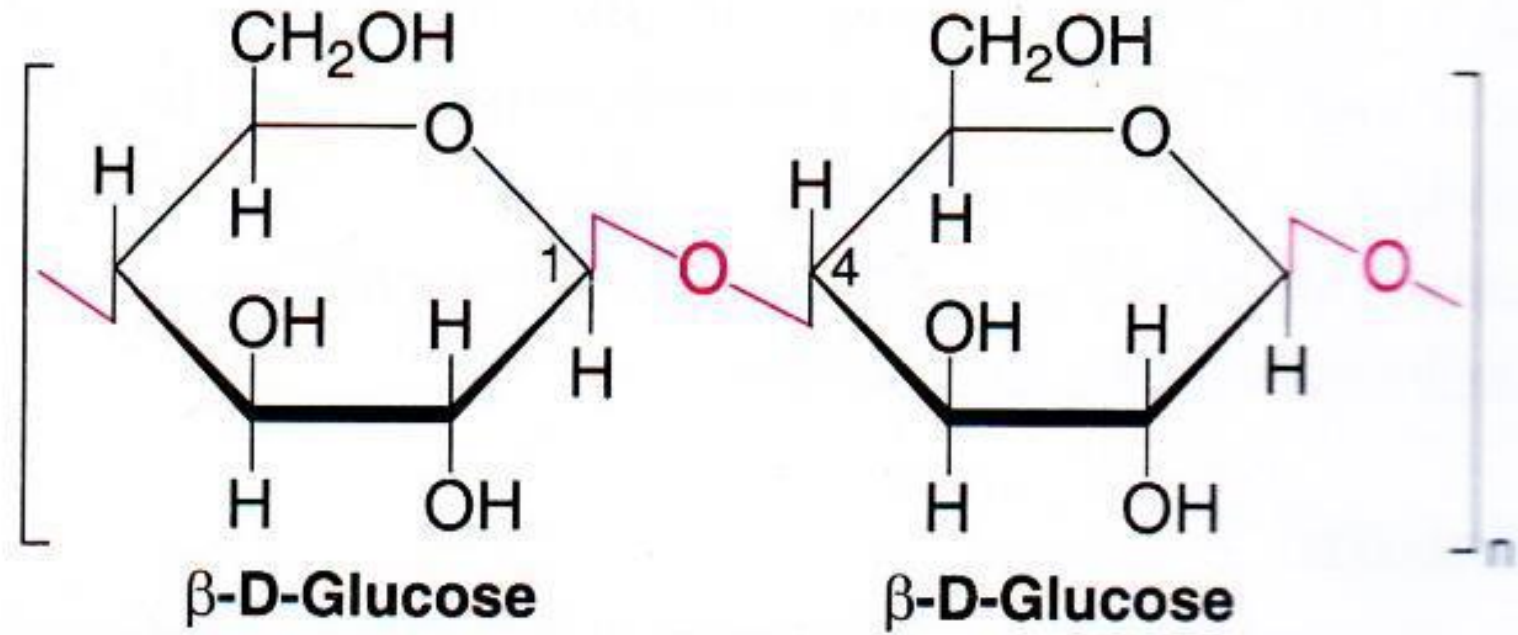
# Homework

- **Why Cells Store Glycogen Instead of Free Glucose?**

# Cellulose

- Cellulose occurs exclusively in plants and it is the most abundant organic substance in plant.
- It is a major basic of plant cell wall.
- Cellulose is totally absent in animal body.
- Cellulose is composed of  $\beta$ -D-glucose units linked by  $\beta$  (1 - 4) glycosidic bonds.
- Cellulose cannot be digested by mammals including human because of lack of the enzyme that cleaves  $\beta$ -glycosidic bonds ( $\alpha$  amylase breaks  $\alpha$  bonds only).
- Hydrolysis of cellulose yields a disaccharide cellobiose, followed by  $\beta$ -D-glucose.

# Cellulose



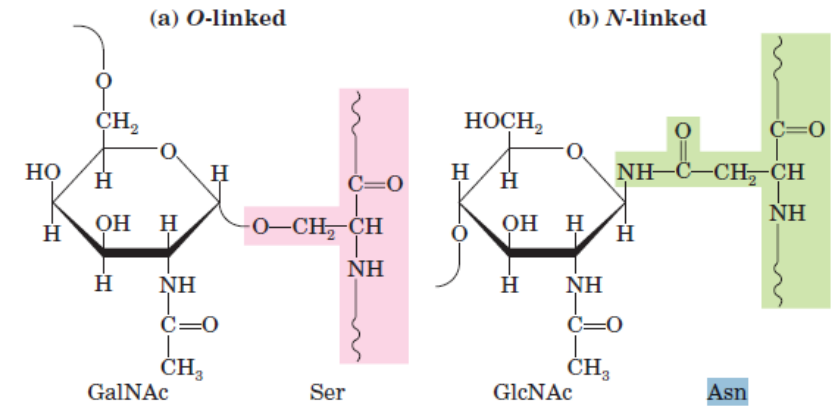
# Homework Question

- Explain how the human body deals with dietary Cellulose. Why is it not digested, and what is its physiological importance?

	Cellulose	Starch		Glycogen
		Amylose	Amylopectin	
Source	Plant	Plant	Plant	Animal
Subunit	$\beta$ -glucose	$\alpha$ -glucose	$\alpha$ -glucose	$\alpha$ -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				

# What are Glycoproteins?

- Proteins covalently bound to small sugar chains (oligosaccharides).
- Sugars can make up **1% to 70%** of the total mass.
- **How Sugars Attach:**
- **O-linked:** Sugar binds to the amino acid **Ser** (Serine) or Thr (Threonine).
- **N-linked:** Sugar binds to the amino acid **Asn** (Asparagine).
- **Solubility:** Makes the protein dissolve easily in water.
- **Protection:** Acts as a physical shield, stopping enzymes from destroying the protein.



A wooden easel stands on a light blue surface against a light green background. The easel holds a rectangular sign with a light beige background. The sign features the text "Thank you for your attention" written in a black, elegant cursive font. The text is arranged in three lines: "Thank you" on the top line, "for your" on the middle line, and "attention" on the bottom line. The easel is made of light-colored wood and has three legs. The sign is held in place by a small wooden peg at the top center.

Thank you  
for your  
attention