Structure, types and function of carbohydrates

Carbohydrates

Carbohydrates are broadly defined as polyhydroxy aldehydes or ketones and their derivatives or as substances that yields one of these compounds

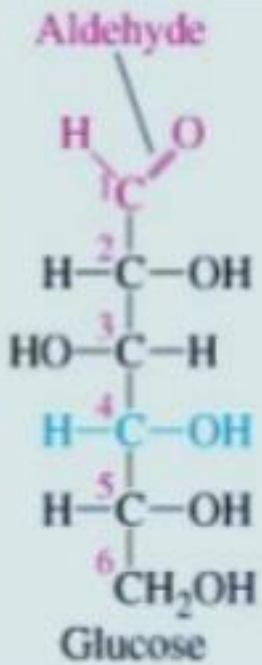
- Composed of carbon, hydrogen, and oxygen
- Functional groups present include hydroxyl groups
- -ose indicates sugar

Carbohydrates are the most abundant of all the organic compounds in nature.

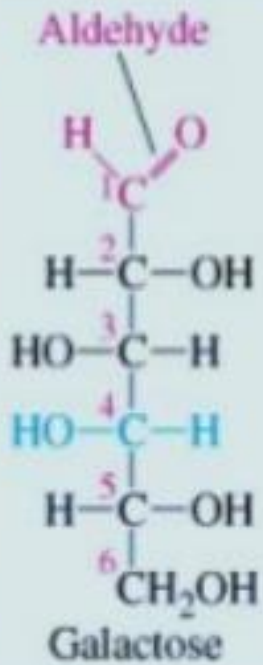
- In plants, energy from the Sun is used to convert carbon dioxide and water into the carbohydrate glucose.
- Many of the glucose molecules are made into long-chain polymers of starch that store energy.
- About 65% of the foods in our diet consist of carbohydrates.
- Each day we utilize carbohydrates in foods such as bread, pasta, potatoes, and rice.
- Other carbohydrates called disaccharides include sucrose (table sugar) and lactose in milk.
- During digestion and cellular metabolism, carbohydrates are converted into glucose,
- which is oxidized further in our cells to provide our bodies with energy and to provide the cells with carbon atoms for building molecules of protein, lipids, and nucleic acids.
- In plants, a polymer of glucose called cellulose builds the structural framework. Cellulose has other important uses, too.
- The wood in our furniture, the pages in your notebook, and the cotton in our clothing are made of cellulose.

Function of Carbohydrates in Cells

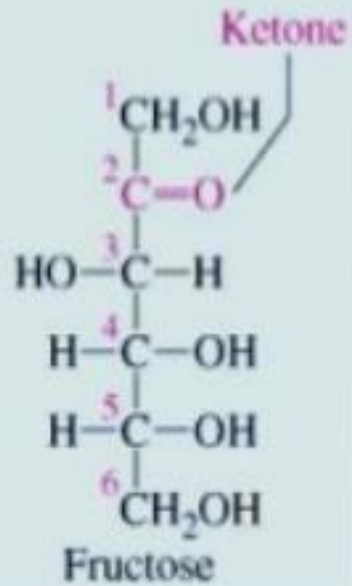
- ✓ Major source of energy for the cell
- ✓ Major structural component of plant cell
- ✓ Immediate energy in the form of GLUCOSE
- ✓ Reserve or stored energy in the form of GLYCOGEN



Glucose



Galactose



Fructose

Classification of Carbohydrates

- Carbohydrates are classified according to the number of subunits that make them up

3 Types of Carbohydrates

- ❑ Monosaccharides
- ❑ Oligosaccharides
  - Disaccharides
  - Trisaccharides
  - Tetrasaccharides
- ❑ Polysaccharides

Monosaccharides are simple sugars, or the compounds which possess a free aldehyde (CHO) or ketone (C=O) group and two or more hydroxyl (OH) groups. They are the simplest sugars and cannot be hydrolysed further into smaller units.

Monosaccharides contain a single carbon chain and are classified on the basis of number of carbon atoms they possess, and as aldoses or ketoses depending upon their groups.

Monosaccharides

Classification by Carbon Atoms

	Sugar	Structure formula	Aldoses	Ketoses
1.	Triose	$C_3H_6O_3$	Glyceraldehydes	Dehydroxy acetone
2.	Tetroses	$C_4H_8O_4$	Erythrose, Threose	Erthrulose
3.	Pentoses	$C_5H_{10}O_5$	Xylose Ribose Arabinose	Ribulose
4.	Hexoses	$C_6H_{12}O_6$	Glucose Galactose Mannose	Fructose

Carbohydrates with free carbonyl groups or in hemiacetal form give positive tests to Benedict's and Fehling's reagents without having been hydrolyzed are referred as **'reducing'** sugars; others (*i.e.*, the acetal types) are then **'non-reducing'** sugars

Reducing sugar	*Nonreducing sugar*
1. Carbohydrates with a free aldehyde (at C-1) or a free ketone (at C-2) group. 2. They are in hemiacetal or hemiketal form. 3. Do exhibit mutarotation. 4. Do form osazones with phenyl hydrazine. 5. Do form oximes with hydroxylamine. *Examples* – Glucose, Fructose, Lactose, Maltose, Cellobiose	1. Aldehyde or ketone group is not free but instead utilized in bond formation. 2. They are in acetal or ketal form. 3. Do not exhiblit mutarotation. 4. Do not form osazones. 5. Do not form oximes. Examples – Sucrose, Glycogen, Inulin

Oligosaccharides

These are *compound sugars* that yield 2 to 10 molecules of the same or different monosaccharides on hydrolysis. Accordingly, an oligosaccharide yielding 2 molecules of monosaccharide on hydrolysis is designated as a disaccharide, and the one yielding 3 molecules of monosaccharide as a trisaccharide and so on.

Disaccharides – Sucrose, Lactose, Maltose, Cellobiose, Trehalose, Gentiobiose, Melibiose
Trisaccharides – Rhamninose, Gentianose, Raffinose (= Melitose), Rabinose, Melezitose
Tetrasaccharides – Stachyose, Scorodose
Pentasaccharide – Verbascose
The molecular composition of the 3 legume oligosaccharides (viz., raffinose, stachyose and verbascose) is shown below :
α-Galactose (1–6) α-Glucose (1–2) β-Fructose Raffinose
α-Galactose (1–6) α-Galactose (1–6) α-Glucose (1–2) β-Fructose Stachyose
α-Galactose (1–6) α-Galactose (1–6) α-Galactose (1–6) α-Glucose (1–2) β-Fructose Verbascose

$$\text{Maltose} + H_2O \xrightarrow{H^+ \text{ or maltase}} \text{glucose} + \text{glucose}$$

$$\text{Lactose} + H_2O \xrightarrow{H^+ \text{ or lactase}} \text{glucose} + \text{galactose}$$

$$\text{Sucrose} + H_2O \xrightarrow{H^+ \text{ or sucrase}} \text{glucose} + \text{fructose}$$

Disaccharides

- Composed of 2 monosaccharides
- cells can make disaccharides by joining two monosaccharides by biosynthesis.

Glucose + fructose = sucrose

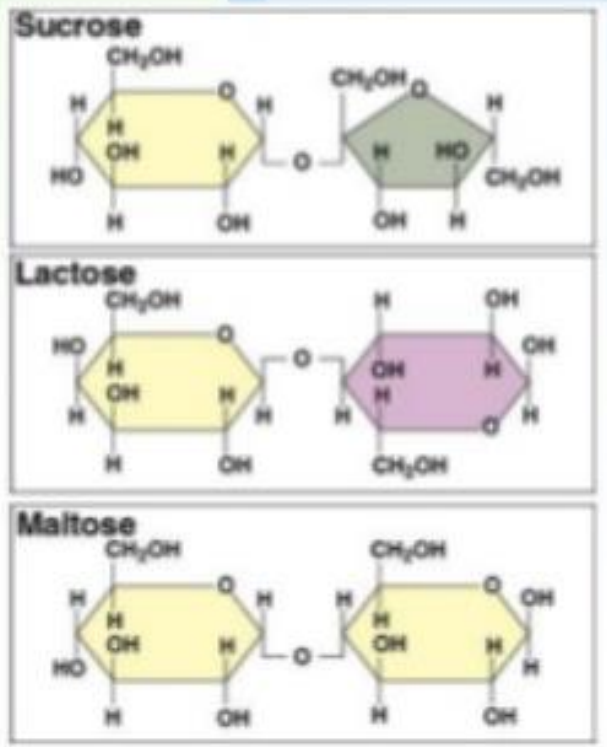
- Table sugar
- Found naturally in plants: sugar cane, sugar beets, honey, maple syrup
- Sucrose may be purified from plant sources into Brown, White and Powdered Sugars.

Glucose + galactose = lactose

- The primary sugar in milk and milk products.
- Many people have problems digesting large amounts of lactose (lactose intolerance)

Glucose + glucose = Maltose

- Produced when starch breaks down.
- Used naturally in fermentation reactions of alcohol and beer manufacturing.



Polysaccharides

Containing 10 or more monosaccharide units attached together

- Examples

1. **Starch- digestible**
2. **Glycogen- digestible**
3. **Fiber- indigestible**

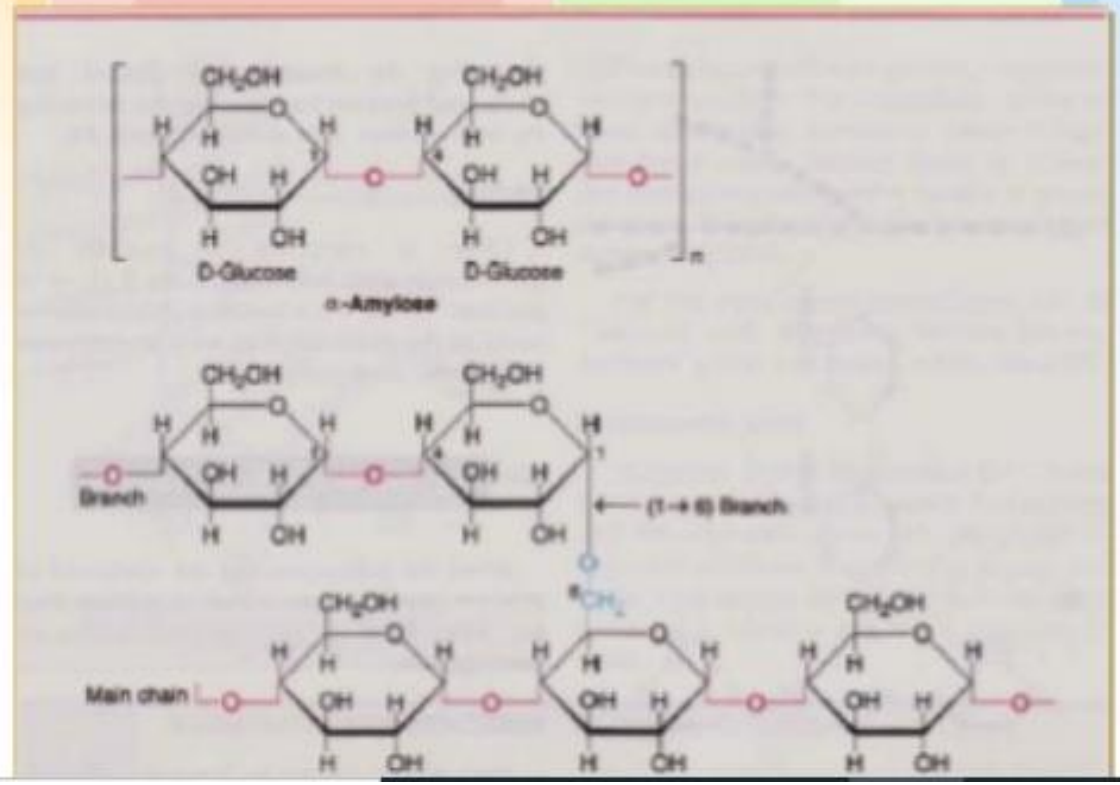
Long chains of glucose units form these polysaccharides

- Cellulose gives structure to plants, fiber to our diet
- Glycogen is an energy storage sugar produced by animals
- Liver cells synthesize glycogen after a meal to maintain blood glucose levels

Types of Polysaccharides

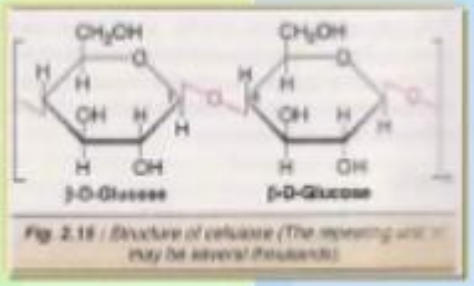
1. Starch

- The major digestible polysaccharide in our diet.
- The storage form of carbohydrate in plants.
- Sources: Wheat, rice, corn, rye, barley, potatoes, tubers, yams, etc.
- Two types of plant starch: 1. Amylose
  2. Amylopectin



Types of Polysaccharides

2. **Cellulose** - form cell walls in plant cells
   - also called fiber or ruffage
   - indigestible by humans



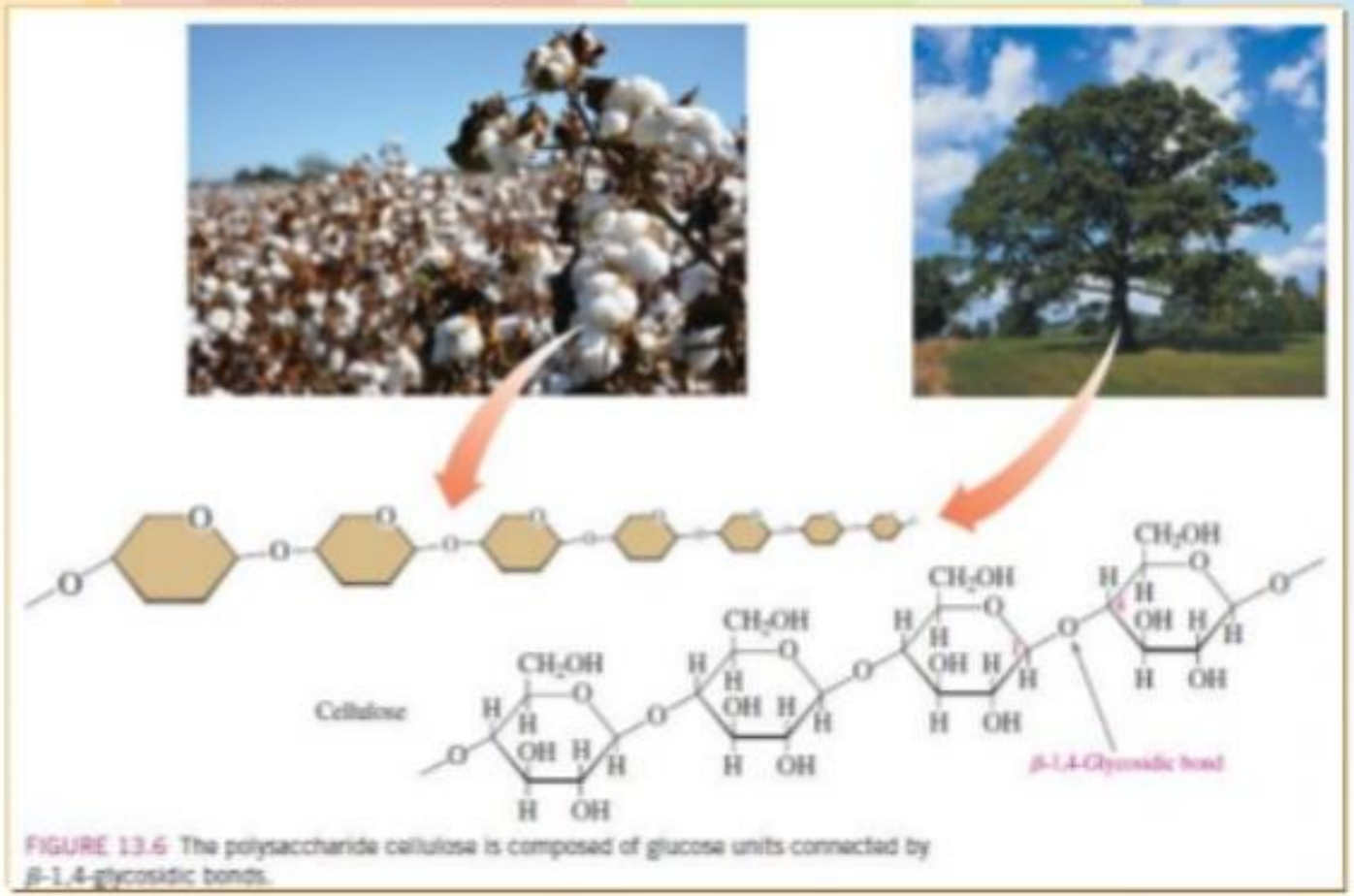


FIGURE 13.6 The polysaccharide cellulose is composed of glucose units connected by β-1,4-glycosidic bonds.