Carbohydrates

Definition of Carbohydrates

- Carbohydrates are organic compounds composed of carbon (C), hydrogen (H), and oxygen (O), usually in the ratio $\mathbf{C_n(H_2O)_n}$.
- They are also called saccharides (from the Greek word for sugar) and serve as a major source of energy in living organisms.

General Formula:

- Most carbohydrates have the empirical formula:

$$(CH_2O)_n$$

where *n* is a whole number.

Functions of Carbohydrates:

- **Primary source of energy** (e.g., glucose)
- **Structural role** (e.g., cellulose in plants, chitin in fungi)
- **Storage molecules** (e.g., glycogen in animals)
- **Components of nucleic acids** (e.g., ribose in RNA)
- **Cell recognition and signaling** (e.g., glycoproteins, glycolipids)

Classification of Carbohydrates

- Carbohydrates are classified based on:
  - **Number of sugar units** (monomeric or polymeric)
  - **Complexity** of their structure

A. Monosaccharides (Simple Sugars)

- These are the simplest form of carbohydrates and cannot be hydrolyzed into smaller units.

  Examples:

  - **Glucose ($C_6H_{12}O_6$)** – blood sugar; main energy source
  - **Fructose** – found in fruits; sweetest natural sugar
  - **Galactose** – part of lactose (milk sugar)
  - **Ribose** – component of RNA

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- **Deoxyribose** – component of DNA

Based on number of carbon atoms:

- **Triose** (3 C atoms): Glyceraldehyde
- **Tetrose** (4 C atoms): Erythrose
- **Pentose** (5 C atoms): Ribose, Xylose
- **Hexose** (6 C atoms): Glucose, Fructose, Galactose

B. Disaccharides

- Formed by the condensation of two monosaccharide units, linked by a glycosidic bond.

Examples:

Disaccharide	Composition	Source
Sucrose	Glucose + Fructose	Table sugar
Lactose	Glucose + Galactose	Milk
Maltose	Glucose + Glucose	Malt products

C. Oligosaccharides

- Contain 3 to 10 monosaccharide units, usually found in glycoproteins and glycolipids involved in cell recognition.

Examples:

- Raffinose (Glucose + Galactose + Fructose)
- Found in legumes, beans

D. Polysaccharides (Complex Carbohydrates)

- Long chains (more than 10 units) of monosaccharides linked by glycosidic bonds.

Types:

1. Storage Polysaccharides:

- **Starch**: Plant storage form of glucose
  - Amylose (linear)
  - Amylopectin (branched)
- **Glycogen**: Animal storage form of glucose; highly branched; stored in liver and muscles

2. Structural Polysaccharides:

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- **Cellulose**: Found in plant cell walls; humans can't digest
- **Chitin**: Found in insect exoskeletons and fungal cell walls

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Chemical Properties of Carbohydrates

Carbohydrates undergo several important chemical reactions, many of which are biologically significant:

A. Reducing and Non-Reducing Sugars

- Reducing sugars have a free aldehyde or ketone group that can reduce Fehling’s or Benedict’s reagent.
  - **Examples:** Glucose, Fructose, Maltose, Lactose
- Non-reducing sugars do not have a free reducing group.
  - **Example:** Sucrose

B. Oxidation Reactions

- Aldehyde group in monosaccharides can be oxidized to:
  - **Aldonic acids** (e.g., gluconic acid)
  - **Uronic acids** (e.g., glucuronic acid)
- Important in detoxification and metabolism.

C. Reduction Reactions

- Monosaccharides can be reduced to sugar alcohols (alditols).
  - Glucose → Sorbitol
  - Mannose → Mannitol
- Sugar alcohols are used in sugar-free products.

D. Glycosidic Bond Formation

- Monosaccharides react via their -OH groups to form glycosidic bonds, creating disaccharides and polysaccharides.

E. Dehydration and Hydrolysis

- **Dehydration reaction (condensation):** Two monosaccharides join and release water.
- **Hydrolysis**: Polysaccharides or disaccharides are broken down into simpler sugars using water and enzymes.

F. Esterification

- Hydroxyl groups of sugars can react with acids to form esters.

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- Example: Glucose-6-phosphate in glycolysis

G. Isomerism in Carbohydrates

- Carbohydrates show various forms of isomerism, especially:
- **Structural isomers**: Different arrangement of atoms (e.g., glucose vs. fructose)
- **Stereoisomers**: Same formula, different spatial configuration (D- and L-forms)
- **Anomers**: Differ at the anomeric carbon (α-glucose vs. β-glucose)

Monosaccharides

Definition

- Monosaccharides are the simplest form of carbohydrates, consisting of a single sugar unit.
- They cannot be hydrolyzed into smaller carbohydrates.
  - General formula: $\mathbf{C_nH_{2n}O_n}$
  - Classified by:
    - Number of carbon atoms: triose (3C), tetrose (4C), pentose (5C), hexose (6C)
    - Functional group:
      - **Aldose** – contains an aldehyde group (–CHO)
      - **Ketose** – contains a ketone group (>C=O)

Structure and Function of Common Monosaccharides

A. Glucose (Aldohexose)

- Molecular formula: $\mathbf{C_6H_{12}O_6}$
- Functional group: **Aldehyde**
- Structure:
  - 6 carbon atoms
  - Straight-chain (Fischer projection) and cyclic (Haworth) forms
  - In cyclic form: forms a six-membered ring (pyranose)
  - Has **four chiral centers** → several isomers
- D-Glucose is the biologically active form

Function:

- Primary source of energy in cells

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- Enters glycolysis to form ATP
- Stored as glycogen in liver/muscles
- Precursor for synthesis of amino acids, fatty acids

B. Fructose (Ketohexose)

- **Molecular formula:** $C_6H_{12}O_6$
- **Functional group:** Ketone
- **Structure:**
  - Six carbon atoms
  - Ketone at C2 position
  - Forms five-membered ring (furanose)
- Found in fruits, honey

Function:

- Sweetest natural sugar
- Enters glycolysis after conversion to glucose or fructose-6-phosphate
- Part of **sucrose** (glucose + fructose)
- Excess fructose metabolized in liver → contributes to lipogenesis

C. Galactose (Aldohexose)

- **Molecular formula:** $C_6H_{12}O_6$
- Structural isomer of glucose
- Differs at C4 (an epimer of glucose)
- Cyclic structure similar to glucose

Function:

- Found in lactose (milk sugar)
- Converted to glucose in the liver
- Essential for glycoproteins, glycolipids, and galactolipids in the brain

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Disaccharides

Definition

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