#7: Carbohydrate Structure

BIOCHEM2280

Carbohydrate Functions

The main functions of carbohydrates are:

1. Sources of energy (Polysaccharides are energy storage molecules; monosaccharides are oxidized to form ATP)
2. Used for structural purposes (e.g. Cellulose)
3. Part of nucleotides
4. Linked to lipids or proteins on the surfaces of cells to protect the cells, make them slippery, and for recognition purposes

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Monosaccharides

- **Monosaccharides:** Simplest sugars with molecular formula (CH2O)n, where n = 3 to 7
- Monosaccharides can be classified by carbon atoms:
  - **Triose:** 3 carbons (3C)
  - **Tetrose:** 4 carbons (4C)
  - **Pentose:** 5 carbons (5C)
  - **Hexose:** 6 carbons (6C)
  - **Heptose:** 7 carbons (7C)

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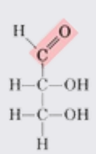
Fischer Projections

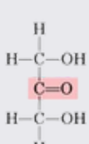
- The most common way you'll see monosaccharides depicted is using **Fischer projections**
- Fischer projections depict stereochemistry:
  - **Horizontal bonds:** *towards* the viewer
  - **Vertical bonds:** *away from* the viewer

- The **carbonyl group** of a monosaccharide is important and serves a role in classifying monosaccharides as **aldoses** or **ketoses**:
  - **Aldose:** Carbonyl group at the end (Aldehyde group)



Sourced from: https://www.bocsci.com/resources/what-is-a-monosaccharide-and-examples.html

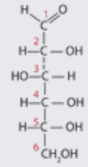
  - **Ketose:** Carbonyl group not at the end (Ketone group)



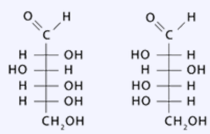
Sourced from: https://www.bocsci.com/resources/what-is-a-monosaccharide-and-examples.html

Fischer Projections Cont'd

- Carbon numbering in monosaccharides starts from **the end closest to the carbonyl group** which will be given the designation of carbon 1 (C1)
  - The **anomeric carbon** is the carbon in the carbonyl group in a Fischer projection



- Using Fischer projections, monosaccharides can be classified as **D and L isomers:**
  - Determined by hydroxyl group orientation at the chiral carbon farthest from the carbonyl (highest numbered chiral carbon)
  - D isomers are common in biological sugars
  - In a Fischer projection, D isomers have the hydroxyl group on the right while L isomers have it on the left
  - L isomers are mirror images of their D counterparts



D-Glucose L-Glucose

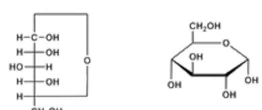
- **Epimers** are monosaccharides that differ in stereochemistry at only one chiral carbon in Fischer projections (e.g. Glucose and mannose)

D-Glucose

D-Mannose

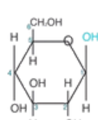
Cyclic Carbohydrates

- **Pentoses** and **hexoses** in cells predominantly exist in ring or cyclic structures
- **Haworth projections** are commonly used to depict these cyclic forms:



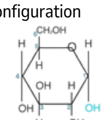
D-Glucopyranose

- Ring formation involves a **hydroxyl group** reacting with the **anomeric carbon (C*)**
- Monosaccharide rings exist in **alpha (α) or beta (β) configuration** based on stereochemistry at the C*
- α or β configuration determination:
  - Compare the position of hydroxyl at the anomeric carbon with the highest-numbered carbon
  - If the hydroxyl on the anomeric carbon is on the same side as the highest numbered carbon, the sugar is in β configuration:



Sourced from: https://www.sciencedirect.com/topics/chemistry/ketohexose

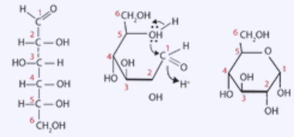
  - If the hydroxyl on the anomeric carbon is on the opposite side to the highest numbered carbon, the sugar is in α configuration



Sourced from: https://www.sciencedirect.com/topics/chemistry/ketohexose

Cyclic Carbohydrates Cont'd

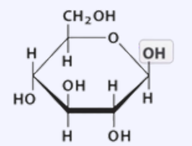
- When rings are formed a random configuration is taken up (Either α or β)
- Cyclization reaction are **reversible** which leads to conversion between α and β forms in solution



Sourced from: Ball, D.W., Hill, H.W., and Scott, R.J. (2012)

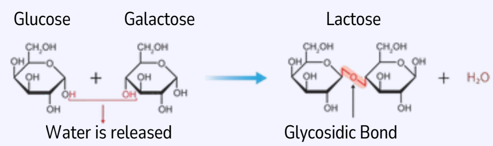
This process isn't permanent, the ring can open up again and reform in a different configuration

- Despite appearance, atoms in the ring of a cyclic monosaccharide do not all lie in the same plane



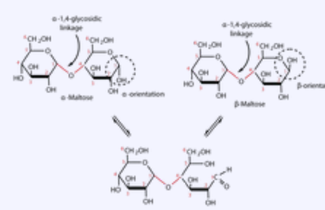
The highlighted -OH group is above the plane whereas the -H attached to the same carbon is below

- Monosaccharides can condense in a reaction to form disaccharides, which changes naming conventions



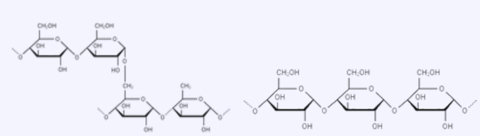
Sourced from: https://www.sciencephoto.com/media/1387932/view

- The disaccharide is designated as α or β depending on **the orientation of the -OH on the free anomeric carbon**
- The glycosidic bond is designated as α or β depending on **where the sugar with the free anomeric carbon is located**
  - For example, in the image below, the disaccharide (maltose; made of 2 glucose molecules) is given α or β designation based on how the -OH group is oriented on the free anomeric carbon
  - The glycosidic bond between glucose molecules forming maltose is given α or β configuration depending on how the glucose with the free anomeric carbon (Right) is oriented relative to the glucose which participates in the glycosidic bond (Left). They are on the same side so the bond is α



Sourced from: https://www.tutorsglobe.com/homework-help/chemistry/disaccharides-78922.aspx

- Monosaccharides can combine to form longer chains called **oligosaccharides (3-10 sugar units)** or **polysaccharides (10+ sugar units)**
- Polysaccharides, such as **glycogen**, consist of linear chains of glucose monomers in α(1→4) linkage, with α(1→6) branch points (The 1→4 just means the glycosidic bond is between carbons 1 and 4 of the 2 monosaccharides)
  - Animals store glucose primarily as glycogen
  - Plants store glucose as **starch**, made of **amylose** (polyglucose in α(1→4) linkages with few branch points) and **amylopectin** (polyglucose in α(1→4) linkages with α(1→6) branch points every 24 to 30 glucose units)



Amylopectin Amylose

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-The WebStraw team

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Note: Marvin was used for drawing, displaying and characterizing chemical structures, substructures and reactions, Marvin 24.4.1, Chemaxon (https://www.chemaxon.com)

biochem 2280.

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MADE WITH LOVE BY

Ali Alimorad
Sara Cordoba Reyes
Lucy Yang
Quynh Phi

Questions? Ask us at team@webstraw.org