VII Carbohydrates

**Carbohydrates**: A polyhydroxy-aldehyde or ketone; the polymers and derivatives of such compounds

General formula:

**Examples:**

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7.1 Nomenclature

**Monosaccharide**: A single carbohydrate unit

**Oligosaccharide**: A polymer of two to ten saccharide units (sometimes also called disaccharides (for two units), trisaccharide (for three units) etc.)

**Polysaccharide**: A polymer with more than ten saccharide units

- **Aldose**: A polyhydroxy aldehyde
- **Ketose**: A polyhydroxy ketone

**Examples:**
7.2 Monosaccharides

7.2.1 Aldoses

• Most carbohydrates have one or more chiral center(s)

Example:

- Remember Fischer projection

**D-Sugar:** the most common carbohydrate; D-refers to the right hand orientation of the -OH group on the chiral carbon FARTHEST from the carbonyl group

**L-Sugar:** L-refers to the left hand orientation of the -OH group on the chiral carbon FARTHEST from the carbonyl group

Examples:

**Epimer:** One of two diastereomers that differ in the orientation of groups at only one carbon

Examples:
• Most common naturally occurring monosaccharides are derived from D-glyceraldehyde
Hand out 1 (or page 303 in the book) illustrate all D-Aldoses (aldotroses, pentoses, hexoses)

*Example of some important D-Aldoses:*

7.2.2 Ketoses
• Ketoses do not have a terminal aldehyde group but a ketone on the C2.
• Ketoses can also be categorized into D and L ketoses
• Hand out 2 (or page 305 in the book) illustrate some D-ketoses

*Examples:*
• Remember functional isomers: D-Glucose and D-Fructose are functional isomers

7.2.3 Cyclic Structures

• We have drawn all carbohydrates as a chain
• However most carbohydrates are not linear but cyclic
• Formation of a hemiacetal or hemiketal results in a cyclic structure

**Hemiacetal:** The alcohol-ether product of the reaction between an aldehyde and one mole of an alcohol

**Acetal:** The diether product of the reaction between an aldehyde and two moles of alcohol

*Example:*
**Hemiketal:** The alcohol-ether product of the reaction between a ketone and one mole of alcohol

**Ketal:** The diether product of the reaction between ketone and two moles of alcohol

*How can we translate this into a ring formation?*

- A new chiral center has been formed

**Anomer:** One of two optical isomers formed at the new chiral carbon produced when an aldehyde forms a hemiacetal or a ketone forms a ketal

- **α-Anomer:** The cyclic hemiacetal that has the -OH group on the new chiral carbon below the ring; on the right in a Fischer projection

- **β-Anomer:** The cyclic hemiacetal that has the -OH group on the new chiral carbon above the ring; on the left in a Fischer projection

*Examples:*
**Haworth Structures (Projection):** Two dimensional five- or six-membered ring representation of the cyclic form of a monosaccharide; -OH groups that appear on the right in a Fischer projection are drawn down (below the plane of the ring) in a Haworth structure and those -OH groups on the left in a Fischer projection are drawn up (above the plane of the ring)

*Examples:*

- Sometimes an abbreviation is used:

  **Furanose:** Five membered ring form of a monosaccharide
  **Pyranose:** Six membered ring form of a monosaccharide

These names come from Furan and Pyran:
Conformational Structure: Relating to carbohydrates, this is the chair form of the cyclic hemiacetal or hemiketal

Examples:

7.3 Reactions of Monosaccharides

Monosaccharides contain a number of functional groups

⇒ These functional group can undergo reactions

A) Oxidation of Sugars

• Sugars are easily oxidized that means they are good reducing agents

Reducing Sugar: Carbohydrate that has one or more anomeric carbons available for oxidation by a mild oxidizing agent
Examples:

Tautomerization of Ketoses:

- **onic Acid**: A carbohydrate derivative wherein the aldehyde functionality has been oxidized to a carboxylic acid
- **uronic Acid**: A carbohydrate derivative wherein the last, primary alcohol has been oxidized to a carboxylic acid

**Nonreducing Sugar**: A carbohydrate with all of its anomeric carbons bonded to other groups, unavailable for opening to an aldehyde or ketone carbonyl
B) Reduction of Sugars

- Sugars can be reduced. The aldehyde or ketone group can be reduced to the corresponding alcohol

Examples:

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7.4 Disaccharides and Polysaccharides

7.4.1 The Glycoside Bond

*How do you connect several monosaccharides together?*

Acetal Formation:

**Glycoside Bond**: Acetal or ketal formed from the reaction of a cyclic monosaccharide with another monosaccharide
7.4.2 Disaccharides

Disaccharides:  Two monosaccharide units linked by a glycosidic bond

A) Lactose (β-D-Galactose and α-D-Glucose)

• Found only in milk (lac Latin for milk)
B) Sucrose (Table Sugar) ($\alpha$-D-Glucose and $\beta$-D-Fructose)

Levulose: Another name for fructose

Dextrose: Another name for glucose

Invert Sugar: A mixture of fructose and glucose produced by the breakdown of sucrose

C) Celllobiose ($\beta$-D-Glucose and $\beta$-D-Glucose) linked by a 1,4 glycosidic bond
D) Maltose (α-D-Glucose and β-D-Glucose) linked by a 1,4 glycosidic bond
• Produced by the hydrolysis of starch using the enzyme amylase

7.4.3 Polysaccharides

A) Starch
• Plants store glucose as starch based on two components: amylose and amylopectin

**Amylose:** A component of starch; linear polymer of glucose units connected by a α-1,4 glycosidic bond

**Amylopectin:** A component of starch; branched polymer of glucose units connected with α-1,4 glycosidic bonds in its linear chains with α-1,6 branching in intervals of about 25 units

Animals (that means us) have enzymes that cleave the glycosidic bonds and can digest starch
Starch:

B) Animals store glucose as **glycogen**

**Glycogen:** Branched polymer of glucose units connected with $\alpha$-1,4 glycosidic bonds in its linear chains with $\alpha$-1,6 branching in intervals of 8-10 units

C) Cellulose

**Cellulose:** A linear polymer of glucose units linked by $\alpha$-1,4 glycosidic bonds
Summary of Chapter 7:

⇒ Carbohydrates
  → Nomenclature
  → Aldoses
  → Ketoses
⇒ Monosaccharides
  → Fischer Projection
  → D- and L Sugars
  → Cyclic Structures and Representations
⇒ Reactions of Monosaccharides
  → Oxidations
  → Reductions
⇒ Glycosidic Bonds
⇒ Disaccharides
  → Lactose
  → Sucrose
  → Maltose
  → Cellobiose
⇒ Polysaccharides
  → Starch
  → Cellulose
  → Glycogen