Chapter 27: Carbohydrate

1. Carbohydrates: Organic molecules with the general formula $C_n \cdot (H_2O)_n$
   a. 3 types of carbohydrates
      i. Monosaccharides – can not be hydrolyzed to a simpler carbohydrate
      ii. Disaccharides – hydrolyzes to 2 monosaccharides
      iii. Polysaccharides – hydrolyzes to many monocaccharides
   b. Biologically important
      i. Effective source of energy
      ii. Building materials for cell wall
      iii. Give food a sweet taste
2. Terminology:
   a. Generally 3-7 carbons long

# Carbons	**Name**
3	Triose
4	Tetrose
5	Pentose
6	Hexose

   b. Aldose = Aldehyde group present
   c. Ketose = Ketone group present (normally on number 2 carbon)
   d. D and L isomers:
      i. Most carbohydrates contain 1 or more chiral carbons. To differentiate between the isomers the notation D and L (which is not related to the (+)/(-) notation from chapter 26)
      ii. To determine if a carbohydrate is the D or L isomer
         1. Draw the projection formula (Called a Fishcer projection when talking about carbohydrates.
         2. Orient the molecule so that the most oxidized group (generally the aldehyde or ketone) group is at the top.
         3. Examine the chiral carbon furthest from the most oxidized group (at the bottom of the molecule)
         4. If the OH group is on the left = L, if the OH group is on the right = D
   e. Ring structure: Carbohydrates often form ring structures
      i. 5 member ring = furanose
      ii. 6 member ring = pyranose
   f. **Epimer:** Two monosaccharides that differ in only the configuration around **one** carbon atom.
3. Important Monosaccharides:
   a. D-Glucose – aldohexose – forms 6 member ring
      i. most common
      ii. found in fruits, vegetables, corn syrup, honey
      iii. primary building block for important disaccharides – sucrose, lactose, maltose
      iv. primary building block for important polysaccharides – starch, cellulose, glycogen
   b. D-Galactose – aldohexose – forms 6 member ring
      i. not found as a monosaccharide in nature but important in many di- and poly- saccharides
      ii. found in cellular membranes in brain and nervous system
      iii. if the enzyme to convert galactose to glucose is missing can lead to cataracts, mental retardation and cirrosis.
   c. D-Fructose – ketohexose – forms 5 member ring
      i. sweetest carbohydrate
      ii. ½ of sucrose disaccharide

4. Haworth Structures: (Fig. 27.3 p 772)
    a. Monosaccharides are generally in a ring conformation instead of a linear/straight chain conformation
    b. To draw the ring, take the Fischer projection of the monosaccharide and rotate it so that the bottom is on the left and the top (most oxidized part) is on the right. This will allow you to see which –OH groups are up and which are down.
    c. The ring is formed by forming an ether bond between carbons 1 and 5 which leads to a hexagonal ring structure where one carbon is replaced by an oxygen
    d. The ring is numbered as shown below.
    e. The position of the –OH group on carbon 1 can end up pointing up or down (the carbon was not chiral to begin with).
        i. –OH is up = β (Beta)
        ii. –OH is down = α (alpha)
        iii. A simple way to remember this is "Buda" (Beta = up, Down = alpha)
    f. Mutarotation: process by which anomers are interconverted.
    g. **Anomer:** Two cyclic isomers that only differ in the stero arrangement about the carbon involved in mutarotation (ie carbon number 1)
    h. Naming: To identify a monosaccharide in ring form:
        i. Add the α or β information in front of the molecule
        ii. Change the "se" → "furanose" (5-member rings) or "pyranose" (6-member rings)
        iii. Example: β-D-glucopyranose

5. Disaccharides – 2 monosaccharides connected by a glycosidic bond
    a. Maltose: Glucose + Glucose (see page 780 for structure)
        i. Malt sugar, obtained from starch
        ii. When hydrolyzed forms glucose and can be fermented to form ethanol
        iii. Reducing sugar
        iv. Connected together by an α-1,4 glycosidic bond
    b. Lactose: Glucose + Galactose (see page 781, top of page for structure)
        i. Found in milk and milk products
        ii. Some people missing enzyme to break it down (lactose intolerance)
        iii. Reducing sugar
        iv. Connected together by a β-1,4 glycosidic bond
    c. Sucrose: Glucose + Fructose (see page 781, bottom of page for structure)
        i. Not a reducing sugar
        ii. Most often known as table sugar.
        iii. Connected together by a α-1,2-glycosidic bond
    d. Glycosidic bonds:
        i. Formed when two alcohol groups on two sugars react and lose water, the resulting ether bond (R-O-R') between the sugars is termed a glycosidic bond.
        ii. Naming:
            1. Generally number 1 carbon on one monosaccharide bonds with an alcohol group on the second monosaccharide.
            2. The bond is labeled α or β based on the number 1 carbon on the first monosaccharide
            3. The bond is then labeled by the numbers for the carbon atoms that are now bonded.

6. Polysaccharides: polymers of monosaccharides, all are made up of D-glucose molecules
    a. Starch
        i. Storage form of glucose in potato, rice, wheat, corn and many other plants
        ii. Amylose: (20%) α-D-glucose connected by α-1,4-glycosidic bonds, generally 250-4000 units long, and forms a coiled/helix structure (Figure 27.7 part a/b p 790)
        iii. Amylopectin: (80%) α-D-glucose connected by α-1,4-glycosidic bonds, but every 25 units a β-1,6 glycosidic bond is formed leading to a branched structure (Figure 27.7 part c/d p 790)
        iv. Generally about 50% of nutritional calories
    b. Glycogen (Animal Starch)
        i. Stored in liner/muscles
        ii. Hydrolyzes between meals to maintain blood sugar levels
        iii. Similar to amylopectic structure except more branched (every 10-15 units)
    c. Cellulose (Structural polysaccharide)
        i. Major structural unit of plants and wood
        ii. Long unbranched chains similar to amylose except linked by β-1,4-glycosidic bonds
        iii. Does not form coils, instead forms aligned layers connected by hydrogen bonds
        iv. Insoluable in water/resistant to hydrolysis
        v. Human enzymes can hydrolyze α-1,4-glycosidic bonds in starch but we don't have enzymes to hydrolyze β-1,4-glycosidic bonds therefore we can eat starch and don't tend to eat wood/grass etc. Many creatures do have the enzymes though and can eat grass and wood.

7. Chemical Reactions:
    a. Kiliani-Fischer (Figure 27.2 p 771). This reaction **will be on the test**.
        i. $\text{Aldehyde} + \text{HCN} \longrightarrow \text{Cyanohydrin} \xrightarrow{H_2O/H^+} \text{Carboxylic Acid} \xrightarrow{\text{Na(Hg)}} \text{Aldehyde} + 1\,\text{Carbon}$
        ii. The key to this reaction is that an Aldose molecule has a carbon added to it creating a new Aldose with 1 more carbon, thus allowing us to build big molecules from small molecules.
    b. Formation of Disaccharides:
        i. Be able to take individual monosaccharides and react them to form disaccharides, by linking them together with glycosidic bonds.
        ii. Understand naming nomenclature in section 5d above
    c. Oxidation reactions: (see Figure on bottom of page 785)
        i. Mild Oxidation: The aldehyde group in monosaccharides is oxidized to a carboxylic acid group.
        ii. Strong Oxidation: The aldehyde group and the OH on the number 6 carbon are oxidized to carboxylic acid groups
        iii. The name of the molecule is changed from "ose" → "onoic acid"
    d. Reduction reactions: (See Figure at top of page 786.)
        i. The aldehyde group on a monosaccharide is reduced to an alcohol group.
        ii. The name of the molecules is changed from "ose" → "itol"
    e. Redox Tests for Carbohydrates (This will be on test)
        i. Reducing sugars = sugars that contain a hemiacetal structure that can be oxidized. (See page 775 for pictures if you don't recall the structure)
        ii. Essentially this is the same reaction (Benidicts test that was covered in Chapter 23). If a molecule has an aldehyde group or hemiacetal group it will give a positive reaction.
        iii. Aldehyde/Hemiacetal + Cu^{2+} (blue color) → Carboxylic Acid + Cu_2O (brick red precipitate)

iv. This is the same reaction we did in lab (experiment 32?).
   1. Benidicts will give a positive reaction for any aldehyde/hemiacetal
   2. Barfords will only give a reaction to monosaccharides (they react fast, whereas disaccharides react slow).

Summary (things that are almost 100% guaranteed to be on test)

1. Definitions/Drawing: isomerism, stereoisomers, enantiomers, diastereomers, meso, chiral, achiral, epimer, aldose/ketose, number of carbons in a sugar, D/L notation, α/β notation, furanose/pyranose, Haworth structures.

2. Identifying chiral and achiral carbons, enantiomers, diastereomers, meso compounds, and being able to draw them.

3. Structure of common monosaccharides, disaccharides, and polysaccharides and any miscellaneous information given about them.

4. Kiliani-Fischer reaction + one or two other reactions, Redox tests for carbohydrates.