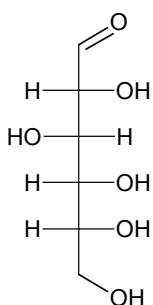
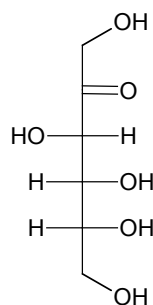


Carbohydrates, Sugars, and Soft Drinks

Carbohydrates make up one class of extremely important biomolecules. As the name implies, carbo-hydrates are molecules made from carbon (“carbo”) and “hydrates” (water - H_2O). The term carbohydrate is a general term that describes many different carbon/hydrogen/oxygen-containing biomolecules. A carbohydrate that is familiar to most is “**sugar**.” Simple sugars like **glucose** and **fructose** are the building blocks for larger carbohydrates such as **starch** and **cellulose**. Shown below are the chemical structures for the straight-chain representation of D-glucose and D-fructose (the prefix “D-“ will be discussed more in class). Note that these two sugars have the same chemical formula ($C_6H_{12}O_6$) and hence molar mass (_____ g/mol). **Please draw these chemical structures, record the molecular formula, and show molar mass calculations in your lab notebook.**

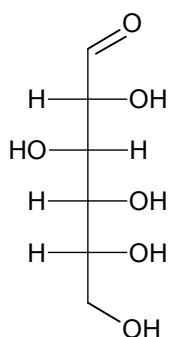


D-glucose

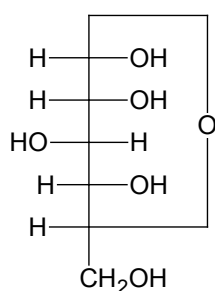


D-fructose

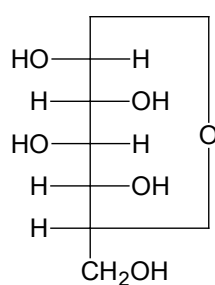
This straight-chain representation above is a convenient way to visualize the chemical make-up of these sugars, but these pictures do not clearly show the most common form of these sugars when they are found in an **aqueous** (water) environment. When a sugar like D-glucose is dissolved in water, a reaction takes place that “cyclizes” the sugar into either an α -form (below, second from the left) or a β -form (third from the left). The second and third structures are presented using a 2-dimensional drawing called a **Fisher projection**. The true chemical structure is 3-dimensional and is often represented using a **Haworth projection** (forth structure). The orientations of the -H and -OH groups with respect to each other are often important and will be discussed in **Activity 1**.



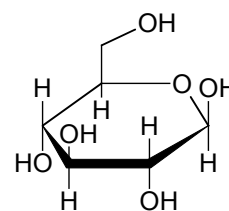
D-glucose
(straight-chain)



α -D-glucose
(Fisher projection)



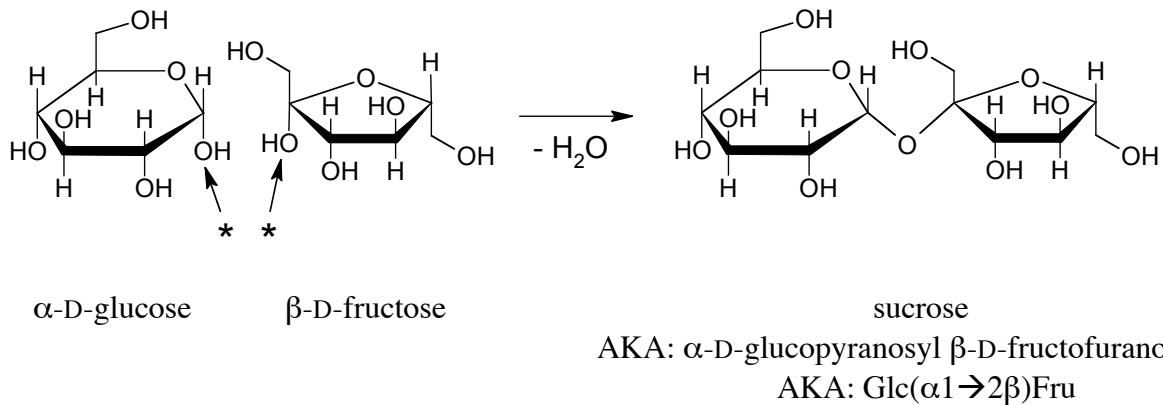
β -D-glucose
(Fisher projection)



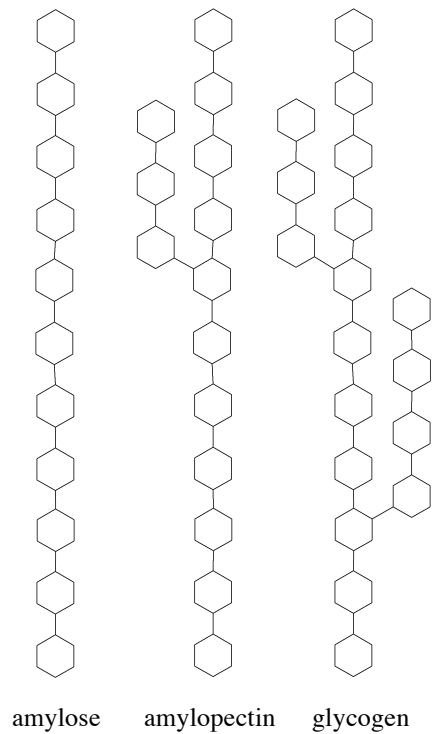
β -D-glucose
(Haworth projection)

Sugars are also referred to as **saccharides**. Sugars like glucose and fructose are **monosaccharides**. Mentioned above was the concept that “*simple sugars are the building blocks for larger carbohydrates such as starch and cellulose*”. **Sucrose** is one example of this concept. Sucrose is a **disaccharide** that results from the coupling of α -D-glucose and β -D-fructose (see next page). This

linkage is called a $\alpha 1 \rightarrow \beta 2$ linkage indicating the coupling (bonding) is between the “1-carbon” on the α -D-glucose and the “2-carbon” on the β -D-fructose; the numbering of carbon atoms will be discussed in lab. **Please draw the following scheme in your lab notebook; include atom numbering.**



Other common disaccharides include the $1 \rightarrow 4$ coupling as in **maltose** and **lactose**. Similar $1 \rightarrow 2$, and $1 \rightarrow 4$ linkages are formed when three or more sugars are coupled together. A sugar made from three sugar molecules is a **trisaccharide**. In general, we use the term **polysaccharide** to refer to sugars other than monosaccharides. Starch is an example of a polysaccharide containing 50-5000 glucose (Glc) molecules coupled together with an $\alpha 1 \rightarrow 4$ linkage (the $\alpha 1$ indicates that the first glucose is α -D-glucose). If the starch molecule is a linear chain of glucose molecules (i.e. α -D-Glc-Glc-Glc-Glc-etc.) then we call this type of starch **amylose** (left). If a starch molecule contains $\alpha 1 \rightarrow 6$ linkages in addition to the $\alpha 1 \rightarrow 4$ linkages, this results in a “branched” starch that is referred to as **amylopectin**. When a starch ($\alpha 1 \rightarrow 4$) molecule becomes highly branched ($\alpha 1 \rightarrow 6$), we call this molecule **glycogen**. **Cellulose** is very similar to starch except the β -D-glucose is used instead of α -D-glucose resulting in a **$\beta 1-4$ linkage**. Most animals have the ability to breakdown $\alpha 1 \rightarrow 4$ and $\alpha 1 \rightarrow 6$ linkages to produce simple sugars, although most animals are not able to break down $\beta 1 \rightarrow 4$ or $\beta 1 \rightarrow 6$ linkages.



Class Activity: Molecular Modeling of Sugars.

To better understand the chemical structure of molecules chemist often use ***molecular modeling***. Molecular modeling can be done using physical modeling kits or computers. Both methods have their advantages and disadvantages. This activity will expose you to both methods.

Using Physical Modeling Kit:

- 1) Make an entry in your lab notebook “Physical Modeling Activity”; include header info.
Although the lab activity is outlined below, you may wish to make some additional notes associated with this activity.
- 2) Acquire a physical modeling kit with the following:
 - 6 carbon atoms (black)
 - 6 oxygen atoms (red)
 - 12 hydrogen atoms (white)
 - 24 “single bonds”
 - 2 “flexible bonds”
- 3) The atom types are identified by color (carbon-black, hydrogen-white, oxygen-red)
- 4) **Each student** will build one molecule of D-glucose in the “straight-chain” representation as shown on the previous page. (*Note: although the orientation of the -H and -OH groups is very important, the proper orientation is more easily seen after the completion of step 5; at that point we will make any necessary corrections.*)
- 5) Identify someone as your partner...
- 6) Modify the straight-chain representation of D-glucose into cyclic-form. One of you will build α - D-glucose and the other will build β - D-glucose (*use supplemental page to assist in cyclizing*). Verify the correct -H and -OH orientation before continuing.
- 7) At this point you and your partner now have built one α - D-glucose molecule and one β - D-glucose molecule. Now form the 1 \rightarrow 4 disaccharide, maltose (*use supplemental page to assist*).
- 8) Can you sketch the 3D representation of maltose in your notebook? ...try.

INSTRUCTOR NOTES:

linear glucose requires 6-C, 6-O, 12-H, 22-single bonds, 1-double bond (or 2 flexible bonds).
cyclic glucose requires 6-C, 6-O, 12-H, 24-single bonds, 0-double bond.
Maltose can be built from 2 cyclic glucose molecules, less one H₂O.

Using the Computer software ChemSketch (FREE from <http://www.acdlabs.com>):

Make an entry in your lab notebook “Computer Modeling Activity” ON A SEPARATE PAGE. Include in the header info and as mentioned above, although the lab activity is outlined below, you may wish to make some additional notes associated with this activity.

The following activity will be demonstrated by the lab instructor.

- Launch the application “**ChemSketch**” under “All Programs”/Class Programs/Chemistry. ChemSketch is a “drawing program” that understands basic chemistry principles that underlie the formation of molecular structures. Some of these features will be demonstrated.



salicylic acid

caffeine

- Using “Templates”: under the “**Templates**” menu item choose “**Template Window**” and select “**Carbohydrates**” from the list.
- Single click on any atom or bond in the sugar “D-Glucose” (this will close the “Template Window” and return you to the ChemSketch document).
- Single Click in the middle of the document and a D-glucose molecule will appear. IMPORTANT: Each additional single click will generate an additional D-glucose molecule. You must “deselect” by clicking on the icon below the “**File**” menu item that looks like a sphere with a single arrow.
- At this point you should have a straight-chain representation of D-glucose with the molecular formula and formula weight (aka, molecular mass) listed along the bottom menu of the document.
- To view this molecule in 3-dimension, click the menu item “ACD/Labs” and select “3D Viewer”. We need to optimize the 3D structure by clicking on the “Tools” menu item and selecting “3D Optimization.” The resulting structure should be very similar to the physical model built earlier (although it may be difficult to tell at this point). The default representation is a “wireframe.” Change this to “Balls and Sticks” using the icon in the icon bar (9th from the left). To get a true 3D, dynamic view, click the icon that looks like the planet “Saturn” (3rd from the right) and sit back and enjoy.
- Now select the icon adjacent to (right) the “Saturn” icon (it looks like a cylinder with a ring) and the application will rotate and step thru all of the representations ChemSketch can generate.

End demonstration.

Now it is your turn! But since we do not have enough computer facilities here on the chem floor some of you will have to do the following on your own computer or in one of the many computer labs on campus or just wait for an open computer.

- Repeat the above to view the 3D structure of linear D-glucose and the cyclic D-glucose, “ α -D-Glucopyranose.” Note that the cyclic form is not under the “Carbohydrates” “Template Window” item, but rather under the heading “Sugars” alpha-D-Pyr.”

Transfer the 2D and 3D structures to a WORD document. It is desirable to change the background color to white while in the 3D viewer; select options/color/background.

The reporting sheet for this weeks activity is fairly simple; it consists of the single page WORD document with 2 – 2D Structures and 2 – 3D structures and a signed pledge saying that this is “my” work. I would like for you to complete this in the lab period.