Science-1A Lab: Week 12, Wednesday, October 27, 2021
Molecular Handedness, Sugars, Starches, Cellulose and Chitin

Animations of most of the molecules (written in bold face with capitals) that are discussed in this note are at *https://yosemitefoothills.com/Science-1A/MolecularAnimations/Sugars/* .

Molecules can be Left- or Right-Handed

There is a tragic story about a medicine called **Thalidomide** where one form was beneficial for morning sickness during pregnancy, but another form caused birth defects where limbs failed to fully develop. See *https://en.wikipedia.org/wiki/Thalidomide* for the more details. A heroine in preventing the distribution of **Thalidomide** in the United States was an official at our Food and Drug Administration that believed its testing had been inadequate. She had to withstand considerable industry and political pressure, and prevented a disaster in the United States. Check out her story at *https://en.wikipedia.org/wiki/Frances_Oldham_Kelsey* . There are several books about this tragedy including one entitled “Frankie: The Woman Who Saved Millions from Thalidomide” which I plan to read this winter.

The two forms of **Thalidomide** are shown at the top of page 10 of our Molecular Structures handout at
https://yosemitefoothills.com/Science-1A/Handouts/Week-09/AllMolecularStructureImages.pdf
as well as in an animation at
https://yosemitefoothills.com/Science-1A/MolecularAnimations/Sugars/Thalidomide.gif .
Compare the paper representations of **Thalidomide** with their combined animation; the two versions are mirror images of each other. Twisting single bonds, rotating, and flipping around cannot make one look like the other. It is just like left- and right-handed gloves. They are different chemicals that react in different ways.

Life on Earth strongly favors right-handed sugars and left-handed amino acids. On another planet, it might be the reverse. Science is still trying to figure out if there is a fundamental reason for this preference on Earth and perhaps in the Universe.

Diagrams of handed molecules use wedge, dashed-wedge, and zig-zag bonds to indicate depth. This was explained in 2nd page of the handout at
https://yosemitefoothills.com/Science-1A/Handouts/Week-09/SimplifiedMoleculeDiagrams.pdf ,

The simple molecules we have considered up to this point do not have left- and right-handed versions. We will now, however, study sugars which come in left- and right-handed versions. Some are shown on page 5 of our Molecular Structures Handout. **Glycerol** at the upper-left corner of that page is an alcohol, not a sugar, and has only one version, but if one of its end –OH functional groups is replaced with a double bond to an oxygen molecule =O, two versions are possible. They are shown at the upper-right part of that page and are named **L-Glyceraldehyde** and **D-Glyceraldehyde**. Hydrogens directly attached to the carbons are not shown, but dashed and solid wedges are used to show that the middle –OH functional group is descending below or rising above the paper surface. They are presented as a mirrored pair in an animation named **Glyceraldehyde** which should help you understand the relation between these paper representations and their 3-D structures.

A second diagram at the top of page 5 simply labeled **Glyceraldehyde** illustrates how both L- and D- forms are sometimes written in one diagram. The narrow zig-zag bond symbolizes that its bond has not yet been specified as being a dashed wedge or a solid wedge; it represents both possibilities together.

Sugars

Sugars are a vast class of organic molecules having the general formula $C_n(H_2O)_m$ where m and n are integers. They are called **carbohydrates** because of this relation. (The term **carbohydrate** is not to be confused with **hydrocarbon** which describes molecules or parts of molecules made only of hydrogen and carbon.)

An overview of right-handed sugars is at

https://yosemitefoothills.com/Science-1A/Handouts/Week-11/SugarFamiliesIncludingChitin.pdf .
A complementary set of left-handed sugars can be synthesized, but are exceedingly rare in nature.

We will, however, focus on **Glucose** and **Fructose** with diagrams shown at the left side of page 5 of our Molecular Structures Handout. The "D-" versions are called right-handed because they rotate polarized light in a right-handed (clockwise) manner, and the "L-" versions are left-handed (counter-clockwise). Both right- and left-handed versions of **Glucose** are shown. Only the right-handed version of fructose (**D-Fructose**) is shown, but its diagram is also shown at the bottom-left corner when it has been turned over to illustrate how the dashed and solid wedges reverse when a diagram is flipped.

Outside of water or blood, these sugars have a zig-zag form shown at the far left, but once in water or blood, they form two types of ring structures depending on how their double-bonded oxygen breaks apart and connects with the base of the molecule's tail. The two forms then created are called alpha and beta.

Glucose forms 6-sided rings called **alpha-D-Glucopyranose** and **beta-D-Glucopyranose**. Their animations and the diagrams in the middle of page 3 show that just one carbon reversing its connection to its –OH group makes the alpha form become the beta form.

Fructose forms the 5-sided (furanose) and 6-sided (pyranose) rings shown near the bottom of page 5. Animations are provided for **alpha-D-Fructofuranose** and **beta-D-Fructofuranose**.

Single sugar molecules are called **monosaccharides**, two paired together are called a **disaccharide**, and more sugars chained together are called a **polysaccharide**. When a junction between sugars is formed, a water molecule is freed. We discussed a similar freeing of water last week when fatty acids were joined to glycerol to make a triglyceride.

Common table sugar is a **disaccharide** called **Sucrose** shown in the middle of page 5 of the 11-page Chemical Structures Handout and the animation at
https://yosemitefoothills.com/Science-1A/MolecularAnimations/Sugars/Sucrose.gif

Starch

The bottom of page 2 of our Molecular Structures handout shows how **alpha-D-Glucopyranose** molecules can be chained together to make the helical starch **Amylose**. See also the animation of a section of **Amylose** at *https://yosemitefoothills.com/Science-1A/MolecularAnimations/Sugars/Amylose.gif* . The same starch is shown without its curl in the upper **polymer** (a chain of similar molecules) on page 6 of the Molecular Structures handout. Our saliva easily dissolves **Amylose** and similar starches, releasing the glucose monosaccharides.

Cellulose

A section of **Cellulose** is shown as the lower **polymer** on page 6 and in an animation. It makes up the stalks of plants and the wood of trees, but we cannot digest it because a special enzyme is needed to break its polymers into its component **beta-D-Glucopyranose** sugars. Only microbes in the stomachs of termites and **herbivores** produce the **enzymes** that can break apart **Cellulose** polymers.

The polymers of **Cellulose** do not curl like those of **Amylose**, because every second **beta-D-Glucopyranose** sugar is flipped over undoing the tendency to curl. That is why straw and trees are straight. The story of **Cellulose** also involves hydrogen bonds that hold together adjacent polymers into layers, and the layers into stronger, 3-D structural components. This is shown in the 2^{nd} page of the handout entitled "Making Sugars, Starch, and Cellulose" at
https://yosemitefoothills.com/Science-1A/Handouts/Week-11/PlayingWithGlucose.pdf .
That handout was intended as a guide for student groups building sugars in the lab with molecular models. Unfortunately, we must just imagine doing it.

Chitin

Chitin is a more complicated polymer that Nature uses to make insect and crustacean exoskeletons as well as the cell walls of fungi. It is based on glucosamine, a derivative of glucose with an amine functional group attached as shown on the second page of the handout at
https://yosemitefoothills.com/Science-1A/Handouts/Week-11/SugarFamiliesIncludingChitin.pdf .
See also the Wikipedia article *https://en.wikipedia.org/wiki/Chitin* .

To earn credit for this lab, report that you have done the following:

1. Studied the molecule animations at
https://yosemitefoothills.com/Science-1A/MolecularAnimations/Sugars/
paying close attention to the handness of thalidomide, but also looking at the others.

2. Learned the importance of handedness and the role of Frances Kelsey in protecting the United States from Thalidomide by reading
https://en.wikipedia.org/wiki/Frances_Oldham_Kelsey
(A co-worker of mine at the National Bureau of Standards had a missing forearm on one side and a missing hand on the other because his mother was prescribed thalidomide as the wife of a US serviceman stationed in Germany.)

3. Appreciate how both starch (which we disolve with our saliva) and cellulose (which is indigestible by humans) are both made from variations of the sugar glucose.