Science-1A Lab: Week 11, Wednesday, March 24, 2021

I will be stressing biochemistry for most of the chemistry part of the course.

Lipids

This week, we are studying **lipids** (a generic term for **fatty acids**, **triglycerides**, **phospholipids**, and **cholesterol**) as well as things made from them – cell walls and soap. I have placed additional groups of animated gif molecule images at
https://yosemitefoothills.com/Science-1A/MolecularAnimations/Lipids
that can help you understand the 3-D shapes of these complex organic molecules. As before, the names of the molecules that have animations will be written bold face with capital initial letters to remind you to look at them. Other words in bold face are scientific terms that are new to our discussions.

Fatty Acids and Triglycerides

We will also be using our 11-page molecular diagrams handout at
https://yosemitefoothills.com/Science-1A/Handouts/Week-09/AllMolecularStructureImages.pdf
In particular, this note will refer to the following pages in that 11-page handout:

page 3 for diagrams of fatty acids
page 5 for more glycerol
page 10 for cholesterol

Some of the discussion below is also provided with additional details in the handout at
https://yosemitefoothills.com/Science-1A/Handouts/Week-10/SaturatedTransAndCisFattyAcids.pdf

Let's first consider the fatty acid **Palmitic Acid** at the top of page 3 of the 11-page Molecular Diagrams handout and shown in an animated gif at
https://yosemitefoothills.com/Science-1A/MolecularAnimations/Lipids/Palmitic%20Acid.gif .

Acids are molecules that easily loose a hydrogen in a solution such as blood or water. The –OH **functional group** at one end of **Palmitic Acid** makes it an acid because it easily gives up the H from the OH when in a living organism. That freed hydrogen becomes an H^+ ion, and an abundance of H^+ ions is what is meant by an acidic solution. (We will discuss acids, bases and pH later in the course.)

All fatty acids start with a –COOH at one end which becomes $–COO^-$ when it has given up its hydrogen upon being immersed in blood. The remaining part of all fatty acids is made from a chain of carbon atoms with an appropriate number of hydrogens. That chain may or may not have some double bonds. **Palmitic Acid** has none, and is therefore called a **saturated fatty acid** because it is "saturated" with as many hydrogens as are possible for its number of carbons.

We learned about double and triple bonds last week and saw that a pair of double bonds make CO_2 a linear molecule where the O=C=O all were in a straight line. To better understand how double bonds affect carbon chains, let's look **butylene** (also called **butene**) which is like **Butane**, but which as a double bond that gives butylene four possible configurations. See *https://en.wikipedia.org/wiki/Butene* for diagrams.

Here we are concerned with two configurations, **Cis-2-Butylene** and **Trans-2-Butylene**. When you study their animations, you can see that the double bond can be made in two different ways. (This is much easier to understand when you can actually play with the molecular models.) These two molecules are distinct chemicals that react in different ways with other molecules. You should also notice that adding the double bond causes the molecule to have 2 fewer hydrogens. **Butane** is C_4H_{10}, but **Cis-2-Butylene** and **Trans-2-Butylene** are C_4H_8.

It turns out that although double bonds in fatty acids can be **cis** or **trans**, nearly all fatty acids in nature use cis bonds. Most with trans bonds were fabricated by food companies to make creamy things, but were eventually found to increase the risk of heart disease. They are now being phased out by the food industry.

A fatty acid with a single cis double bond is **Olenic Acid** shown as part of the **Triglyceride** at the bottom of page 3 of our 11-page molecular diagrams handout. The illustration there does not show the kink in its tail caused by its cis double bond, but that kink is accurately depicted in the **Olenic Acid** animation.

The next fat shown on page 3 of our molecular diagrams handout is **Linolenic Acid** which has two cis double bonds. It is called an **omega-6 fatty acid** because it has a double bond between the **6th** and 7th carbons from its tail end. The depiction of **Linolenic Acid** in our molecular diagrams handout is not very realistic because it does not show that each cis double bond adds a kink to its **hydrocarbon** tail. The animation shows a more realistic image, but remember that at normal temperatures these molecules can swivel at each single bond.

The third fatty acid shown in our molecular diagrams handout is **Alpha-Linolenic Acid**. It is an **omega-3 fatty acid** because its closest double bond to its hydrocarbon tail is between the **3rd** and 4th carbons from its tail end. Since it has three cis double bonds, it curls more than **Linolenic Acid**.

Two other important omega-3 fatty acids are on page 3 of the 11-page molecular diagrams handout: **Eicosapentaenoic Acid**, abbreviated as EPA, which has 20 carbons and 5 cis double bonds and **Docosahexaenoic Acid**, abbreviated as DHA, which has 22 carbons and 6 cis double bonds. Since their closest double bond to the end of their carbon chains start at the **3rd** carbon from the end, they are also omega-3 fatty acids. **Docosahexaenoic Acid**'s six cis bonds can cause it to curl up even more than **Eicosapentaenoic Acid** as is shown in its animation. The diagram on page 3 of our molecular diagrams handout, however, has one of its single bonds rotated 180 degrees for clarity.

Finally, at the bottom of the page is a **Triglyceride**, three fatty acids attached to a **Glycerol** molecule. Each has its OH group attached to one of the OH groups of the **Glycerol**. During that attachment, a water molecule is freed. **Triglycerides** are the molecules that make up our body fat. Any three fatty acids can be used to make a **Triglyceride**. When we are short of energy, our bodies can burn our store of **Triglyceride** fatty acids.

Saturated fatty acids tend to melt above room temperature whereas fatty acids with one double bond (**monounsaturated fatty acids**) are soft at room temperature and those with more than one double bond (**polyunsaturated fatty acids**) are liquids at room temperature. It is generally felt that arterial sclerosis is connected with excess saturated fats in one’s diet while unsaturated fats, which generally come from plants, are good. There is also much talk of the benefit of eating omega-3 fatty acids like **Eicosapentaenoic Acid** and **Docosahexaenoic Acid** that are found in fish oils. Our body can make many fatty acids from other fats we ingest, but there are some that we cannot. Those are therefore called **essential fatty acids**.

Phosphatidylcholine and Cell Walls

Cell walls are made from fatty acids in the form of a **diglyceride** (glycerol with two fatty acids) called **Phosphatidylcholine**. Its diagram is at the bottom of the first page of the handout entitled "Triglycerides, Fatty Acids, Soap, and Cell Membranes" at
https://yosemitefoothills.com/Science-1A/Handouts/Week-10/TriglyceridesFattyAcidsSoapAndCellMembranes.pdf

Notice the R’s at the far left in that diagram. They represent the tails of fatty acids. The carbons with double-bonded oxygens next to those R’s are also from the fatty acids while the O’s next to them are where they join with the **Glycerol** molecule that holds **Phosphatidylcholine** together. Just as **Triglyceride**s are three fatty acids held together by a **Glycerol**, this **diglyceride** holds two fatty acids to a chain containing a negatively-charged phosphorus ion and a positively-charged nitrogen ion. The animation of **Phosphatidylcholine** shows it with **Palmitic** and **Olenic** fatty acids.

Study the beautiful handout (not made by me!) at
https://yosemitefoothills.com/Science-1A/Handouts/Week-10/CellMembraneDetails.pdf
which shows how nature has used **Phosphatidylcholine** molecules (a **phospholipid**) to construct cleverly-designed cell walls and partitions. The dual tails of the **Phosphatidylcholine** molecules are **hydrophobic** (they try to avoid water) while its charged phosphate/nitrogen head is **hydrophilic** (attracts water molecules). This is also shown in the diagrams at
https://yosemitefoothills.com/Science-1A/Handouts/Week-10/TriglyceridesFattyAcidsSoapAndCellMembranes.pdf
where the water surrounding these structures attracts the hydrophilic heads and the hydrophobic tails hide with each other in the interior. The cis kinks in the **Olenic** acids help lock all the **Phosphatidylcholine** tails together inside the cell wall.

Soap

See the discussion in the handout at
https://yosemitefoothills.com/Science-1A/Handouts/Week-10/Soap.pdf
for how soap is made using fatty acids and **lye**.

Lye is a very strong **base** (opposite of an **acid**) with lots of Na^+ and K^+ ions. I make it by collecting a jar of ashes from our fireplace, adding water to make a slushy mixture, stir, and wait overnight. A layer of liquid **lye** ends up on top of the remaining chunks of charcoal. It is then poured through a coffee filter into a beaker. The pioneers would make soap using **lye** and **lard** from animals. When combined in the proper ratio of lye to lard, the result is soap. How soap works is explained in the handout link given above.

Cholesterol

A **Cholesterol** molecule is shown on page 10 of our molecular diagrams handout and in an animation. It has a bad rap for killing people by helping plug up blood arteries, but it also has a very interesting essential use in our bodies. Our bodies use it to make a **myelin** coating surrounding our nerve axons which lets them carry their messages about **50 times faster** than they could without it. For more interesting pictures and information, see *https://en.wikipedia.org/wiki/Myelin* and *https://en.wikipedia.org/wiki/Cholesterol* .

For credit to this Lab-11, send me a note that you have done the following:

1. Understand the meaning of these words (you will not be asked to define them, just to understand what they refer to):
   lipids **fatty acids** **triglycerides** **diglyceride** **phospholipids**
   cis-fats **trans-fats** **saturated fatty acid** **monounsaturated fatty acid**
   polyunsaturated fatty acid **omega-6 fatty acid** **omega-3 fatty acid** **hydrophobic**
   hydrophilic **lye** **myelin coating**

2. Watched the rotating molecules at *https://yosemitefoothills.com/Science-1A/MolecularAnimations/Lipids* while paying attention to their double bonds.

3. Understand how nature makes cell walls using fatty acids:
   https://yosemitefoothills.com/Science-1A/Handouts/Week-10/CellMembraneDetails.pdf

4. Read *https://yosemitefoothills.com/Science-1A/Handouts/Week-10/Soap.pdf*