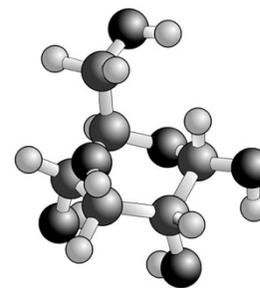


Lab 3 - Organic Molecules of Biological Importance

(April 2014)



Section 1 - Organic Molecules

[2] Hi this is Lyn Koller and I would like to welcome you to this week's lab. We will explore the organic molecules that are important to living organisms. Organic compounds provide organisms with structural elements, energy, and they control chemical reactions necessary for life.

[3] You have probably seen many commercial products labeled "organic". What makes a compound organic? It isn't that it is natural or nutritious; in fact many very toxic substances are organic.

[4] Here you see the definition of an organic compound. In your lab manual in Section I, write this definition.

[5] Take a look at these formulas of different organic compounds. Notice that each molecule contains both carbon and hydrogen along with other elements.

[6] Now look at these inorganic molecules. As you look at each one, you can see that they might have carbon atoms, or they might have hydrogen atoms, but they don't have both at the same time.

[7] See if you can recognize organic the molecules by clicking each one that you think is organic.

[8] OK now try the molecules in your lab manual in Section 1.

[9] There are many different categories of organic compounds, but four are the most important to biology. These are Carbohydrates, Lipids, Nucleic Acids, and Proteins. List these categories which we will be exploring further in this lab to finish-up Section I in your manual.

Section 2 - Functional Groups

[10] You can see that along with carbon and hydrogen organic molecules have atoms of other elements as well. Some of these atoms are in specific combinations that are called functional groups. These groups give the molecule certain properties. Write the definition of a functional group in Section 2 and then we'll continue.

[11] While there are many functional groups, I'll just point out four that are common in the organic molecules we are studying. In these molecules you can see the hydroxyl group, the acid or carboxyl group, the amino group, and the phosphate group.

[12] Where have you seen this group before? You should remember the discussion of acids and bases from lab 2. Hydroxyl groups are found in all of the organic compounds we will study and are of importance in putting these molecules together and taking them apart.

[13] The acid or carboxyl group is found in lipids and proteins. The term “acid” often appears in the name of molecules with this functional group.

[14] The amino group is found in proteins.

[15] The phosphate group is found in a type of lipid called a phospholipid and as you will discover later in the semester, they are of great importance to cell membranes. This group is also found in nucleic acids. If you have not already done so, complete the table in section 2.

Section 3 - From building blocks to macromolecules

[16] When you look at organic molecules you can see that many are very large and complex. How does our body make these molecules? Or conversely, how does our body break down these compounds found in the food we eat?

[17] All of the organic molecules we are studying can be made from simpler building blocks or broken down into the building blocks through two processes - dehydration reactions and hydrolysis. Dehydration reactions can also be referred to as condensation, just another name for the same process.

[18] When you think of the words dehydration and condensation certain things probably come to mind. If you dehydrate something, you take out water. If you condense something, you make it more compact.

[19] Building blocks are often referred to as monomers. “Mono” translates to one and “mer” translates as part. Monomers will be bonded together to form polymers or many parts.

[20] Study this diagram which also appears in Section 3. Notice that the molecules are shown in skeletal form. In this way we can look at just the portions of the molecules involved in the reaction. Each building block has hydroxyl groups that will participate in the bonding of the molecules.

[21] Dehydration reactions remove water and result in the condensation of the building blocks. Let's see how this works. Here you can see the same molecule skeletons with several atoms highlighted. These atoms will be removed so the subunits can bond together. You should remember from lab 2 that all energy levels are satisfied in a stable molecule so that there are no empty pegs or bonds in the molecular models you built. In order to have an available bonding site, one or more atoms must be removed.

[22] Let's now remove the highlighted atoms and see what we have. You should notice that between each subunit we have removed two hydrogen atoms and one oxygen atom. You are probably thinking – “How handy, these three atoms can be combined to form a molecule of water. We're taking out water.” That is the essence of dehydration.

[23] Now all we have to do is bond the subunits together. The bonds formed are covalent and thus strong bonds. The new bonds formed are highlighted. This reaction has produced a larger molecule from smaller subunits. A reaction that produces a larger, more complex molecule is called an anabolic reaction.

[24] In Lab 2 you learned that bonds are a force that holds atoms together. This force is an energy relationship. This means when bonds are formed they can store energy. Reactions that form these energy storing bonds are referred to as endergonic. You will see these energy storage reactions again in a later lab. Using this information, answer the questions at the beginning of Section 3.

[25] OK, now that we know how organic compounds are built, let's see if we can take them apart.

[26] See if you can figure this out – if you need to take water out when you build molecules, what do we need to add in to break the subunits apart?

[27] If you figured out that we need to add water that's great. If not, don't worry, we'll take it step by step.

[28] Can you see that this example of hydrolysis is the opposite of dehydration?

[29] First we split the subunits. Notice we are breaking the bonds we formed during dehydration.

[30] Then we insert the missing atoms by using the atoms from water molecules – the hydrogen atom from water will bond with the oxygen on one subunit and the Hydroxyl group from water will bond with the other subunit.

[31] We have broken down the large molecule into smaller subunits. A reaction that takes a larger complex molecule and breaks it into smaller less complex subunits is called a catabolic reaction. You probably all know that the root word “hydro” means water, but you might not know that the root word “lysis” essentially means to split. We have split the water molecule and the large organic molecule.

[32] These catabolic reactions can also release energy and are termed exergonic. This is the way your body gets energy from food.

[33] See if you can match the terms for the reactions we have been talking about. Just drag the terms to show the proper relationships. Finish Section 3 then we'll continue.

Section 4 – Carbohydrates

[34] We will now take a look at each of the four categories of organic compounds. Let's start with the carbohydrates which include the compounds we commonly call sugars and starches.

[35] Here you can see a description and several examples of the types of molecules included in this group. Start section four by describing a carbohydrate and listing some examples.

[36] The basic building block or monomer of the carbohydrates is the monosaccharide. The prefix “mono” means one, and “saccharide” means sugar. These are also referred to as simple sugars. Study these chemical formulas of monosaccharides here and in your lab manual. Look

at the subscripts telling you about the number of each atom. Can you see a relationship? For instance for every one carbon atom, how many hydrogen atoms are there? For every one carbon atom, how many oxygen atoms are there?

[37] I hope you came up with this relationship. All monosaccharides have this relationship. Write this relationship in your lab manual and then build your glucose molecule. If you have any problems, just remember how you used your molecular model kits last week. When you have completed your glucose molecule, return to the program.

[38] All done building your glucose molecule? That wasn't so bad, was it? If your molecule doesn't look quite right, now is the time to fix it because you will need it later. You will also need the correct number of parts to construct another molecule.

[39] Glucose, as a monosaccharide, is a building block of larger carbohydrates. If we, through dehydration, attach our glucose molecule to another monosaccharide we will have produced a disaccharide. If you are thinking "di" means two you are absolutely correct. Disaccharides are also considered sugars.

[40] If we keep bonding more monosaccharides together, we get a polysaccharide. The larger complex polysaccharides can be what we call starches.

[41] Write the definition of these terms and then continue Section 4 by building your fructose molecule and then come back to see if the fructose you build looks OK.

[42] Well, how does your fructose look? If it looks OK, you are ready to continue. If not, take a minute to fix it and then continue.

[43] Using the information in your lab manual answer the questions and combine your glucose and fructose molecules. Return once you have had your giant molecule checked and signed off by the instructor.

[44] Hopefully you are beginning to understand the process of dehydration! Before we leave the carbohydrates, I might mention if you haven't noticed it already, many of the names of sugars and starches end in "ose".

Section 5 – Lipids

[45] The next category of organic compounds we will examine is the lipids. This group is not as cohesive as the carbohydrates. As you can see by the definition shown here they all have this common quality. Take a minute to start section 5 by writing the definition and listing examples of lipids.

[46] To demonstrate a lipid's insolubility in water, think about oil and vinegar dressing. When you shake the bottle of dressing, the oil is distributed throughout the vinegar, but as soon as you stop shaking, the two separate.

[47] Another way to look at molecules is their polarity – you remember from lab 2 that water molecules are polar and stick together. Water molecules can also stick to any other polar molecule. Lipid molecules are either all or partially non-polar. The non-polar parts don't interact with water since there are no charges to stick to either the positive hydrogen or negative oxygen part of the water molecule. Thus the lipids don't dissolve.

[48] Lipids are quite varied but we will only study two general types of lipids, the triglycerides including fats and oils, and the phospholipids.

[49] Here are the building blocks of triglycerides and phospholipids.

[50] The first building block forms the basis for both triglycerides and phospholipids. Remember we are going to use dehydration to build larger molecules. Can you see where we might have dehydration occurring? Click on one of the sites where dehydration might occur to see if you are correct.

[51] The next building block is a fatty acid. These are either saturated, as you see here, or they are unsaturated. Notice that this saturated fatty acid has two hydrogen atoms on each carbon atom between the carboxyl or acid group on the left end and the terminal carbon atom on the right end. It is saturated with hydrogen atoms.

[52] Unsaturated fatty acids are missing some hydrogen atoms. When the hydrogen atoms are not there, double bonds form so all energy shells of the carbon atoms are satisfied. These unsaturated fatty acids can be mono unsaturated with only one double bond, or poly unsaturated with more than one double bond. You have probably heard the terms saturated and unsaturated many times on commercials!

[53] The last building block is the phosphate group that is found in phospholipids connecting other subunits to the basic molecule. If you haven't done so already, write in the name of each building block in your lab manual in Section 5.

[54] Triglycerides form when a glycerol combines with three fatty acids. If the fatty acids are saturated, the triglyceride is a fat and is solid at room temperature. On the other hand, if unsaturated fatty acids are included, the triglyceride is an oil and liquid at room temperature. These two types of lipids are the most common types of lipids you find in the food you eat. We'll talk more about these later in the semester.

[55] You probably don't want to have to copy down such a complicated molecule, so fortunately chemists have come up with a shorthand way of doing this. Take a moment and complete the generic triglyceride in your lab manual.

[56] Study the phospholipids seen here. In your lab manual, describe how phospholipids differ from triglycerides. You might want to consider the number of fatty acids and the phosphate group.

[57] Phospholipids are important to you in two ways. First of all, they are an important part of your cell membranes. You will learn more about this in another lab. Second, some phospholipids are emulsifying agents. We will look briefly at these.

[58] Remember in describing lipids, we said that they were insoluble in water. It turns out that phospholipids are only partially insoluble. One end of the molecule is insoluble while the other end can interact with water molecules. We say that the molecule has a hydrophilic or water loving end and a hydrophobic or water fearing end.

[59] Knowing what you do about the interaction of water with polar molecules, is the hydrophilic or hydrophobic end of a phospholipid polar?

[60] When you eat food, your digestive system breaks down the food you eat into organic components. The fats in food will be used by your cells, but must be transported to them through your bloodstream. Since blood is mostly water, the lipids won't dissolve and must be transported by emulsifying agents.

[61] The hydrophilic and hydrophobic portions of phospholipids make them useful as emulsifying agents. Look at the arrangements of emulsifying agents and fat droplets shown here. Based on what you know about phospholipids, which is the correct arrangement? Be sure you understand this relationship before you continue. Remember emulsifying agents are critical for transporting lipids throughout your bloodstream.

[62] You should have selected this arrangement between the emulsifying agent and lipid droplet. It is the only arrangement that accounts for the interaction of hydrophilic and hydrophobic portions of the molecules. Now finish up section 5 by describing the role of and drawing a diagram of an emulsifying agent and writing a brief description of how emulsifying agents transport the lipid droplets.

Section 6 - Nucleic Acids

[63] Our next category of organic compounds is the nucleic acids. We will be seeing these molecules in greater detail later in the semester, so we won't go into much detail here.

[64] You have probably heard of two of the nucleic acids, namely DNA and RNA. These complex molecules are made up of building blocks just like the other organic compounds.

[65] Here you can see the building block of nucleic acids. It is made up of three smaller molecules, a sugar, a phosphate group, and a nitrogenous base. Complete section 6 and return to the program for the last group of organic compounds.

Section 7 - Proteins

[66] Proteins are some of the most complex molecules we will look at in this lab. Write down the definition you see here, and then we'll continue.

[67] As with the other organic compounds, proteins are made from a building block which you see illustrated here. There are three important parts of this building block; the amino group, the

carboxyl or acid group, and the “R” group. Draw this building block in the space provided in your lab book and label the requested portions of the molecule.

[68] While all amino acids have the same basic parts, it is the “R” group that allows for their variation. The “R” stands for a variable side group. Study the few amino acids shown here and you can see that the side group can be very simple, or very complex.

[69] Just like the other compounds, amino acids are joined during a dehydration reaction to form the larger molecules we call proteins. The covalent bond that holds amino acids together is given a special name. It is called a peptide bond and hence proteins are sometimes called polypeptides. With this information you should be able to complete the first part of section 7 under “Building a dipeptide”.

[70] Here are two of the simpler amino acids, glycine and alanine. Using your molecular model kits, build these molecules. Remember, you only use short bonds for bonding hydrogen atoms. When you have built them, return to the program.

[71] Study this diagram of a dipeptide. The side groups have been removed and all you can see are the nitrogen and carbon atoms making up the backbone of the dipeptide. The peptide bond is pointed out for you. Now look at your two amino acids. If you have them lined up on your desk as they appear in your lab book you should be able to see where the peptide bond will form. Build your dipeptide, answer the questions about the reaction, and then return to the program.

[72] I hope your amino acids and dipeptide looked like the picture here. If you had any trouble answering the questions, you might want to review the materials on dehydration and hydrolysis.

[73] When you look at this molecule, perhaps you can appreciate the complexity of proteins. In fact when describing proteins we actually find that they have four different levels of complexity.

[74] There are 20 different kinds of amino acids that can be combined to produce different proteins. The order or sequence of the amino acids in the protein is the protein’s primary structure. Remember the bond between amino acids is the peptide bond which is a strong covalent bond.

[75] As amino acids are bonded together into a polypeptide chain, the parts of the molecule interact with each other causing a coiling or pleating shape to form. This is the secondary structure of a protein.

[76] You should remember from lab 2 that hydrogen bonds can form when a hydrogen atom is attracted to parts of a molecule with a negative charge. Here you can see the hydrogen bonds between water molecules. Hydrogen bonds form between the different parts of the polypeptide chain and hold the secondary structure in place. Are these hydrogen bonds strong or weak?

[77] As the polypeptide chain coils or pleats, it can fold back on itself creating the tertiary structure you see here. This folding is also held in place with hydrogen bonds.

[78] Finally some proteins are made of two or more polypeptide chains. This combination of polypeptide chains is the quaternary structure. And once again the quaternary structure is held together with hydrogen bonds.

[79] Now find the display on “protein complexity” and finish section 7 by filling in the table on the “levels of protein complexity”.

[80] Take a look at the complex shapes of these proteins. Their shape is very important to their function. If they are not the correct shape, they won't be able to function correctly. We'll return to this concept later.

Section 8 - The Roles of Biologically Important Organic Molecules

[81] Now that we have looked at the structures of the organic compounds that are biologically important, let's see what a few of them do for living organisms. The next few frames will take you through the examples found in section 8, so you may want to fill the table in as you proceed.

[82] Here are just a few examples of carbohydrates and the role each plays.

[83] We didn't look at all types of lipids, but here are the two we discussed plus cholesterol, a well known lipid.

[84] The roles of the two most well known nucleic acids are shown here.

[85] Since proteins are so complex and varied, we will only look at the role of two types.

Section 9 – Enzymes and Denaturation

[86] Let's take a closer look at the enzymes and how they work to speed up reactions.

[87] Last week you learned that an enzyme is a catalyst and is used to speed up a reaction. The way in which the enzyme does this is by lowering the activation energy.

[88] Since enzymes are proteins they have complex shapes. Part of the enzyme molecule, the active site, exactly fits the shapes of the reactant molecules. You can think of this as the way a key fits a lock. Here is a diagram of two reactants, an enzyme with its active site, and a product. Label these in your lab manual in Section 9.

[89] Now let's see how enzymes speed up a reaction. Look at this great little animation. As the reactants are pulled into the enzyme's active site, they are held in the correct position and they are tweaked enough to cause them to react quickly. Then the product is released and the enzyme can pick up more reactants.

[90] Here is an egg before and after frying. You probably know that egg white is protein. So what happens to the protein when you cook an egg? The heat obviously does something to the egg white.

[91] What happened to the egg white in the last frame is that it became denatured. A protein's shape is destroyed when the hydrogen bonds are broken during denaturation. In addition to high heat, extremes of pH can also denature a protein.

[92] This animation shows you our enzyme being denatured. As the temperature rises above a certain point, the enzyme shape changes as the hydrogen bonds are broken.

[93] Once the enzyme is denatured, the active site is no longer the correct shape and does not "fit" the reactants. No active site – no reaction. Take a minute to finish up Section 9.

Section 10 -The Effect of Temperature on Enzyme Activity

[94] Let's see how you did. The last experiment you performed in Lab 2 determined the effect of pH on the reaction using the enzyme tyrosinase. OK, tyrosinase is a protein, so you should suspect that when the reaction didn't occur in the low and high pH solutions it had been destroyed. The hydrogen bonds were broken and the shape of the protein was altered.

[95] To finish up lab this week, we will look at the same reaction you saw last week. However, this week we will look at the effect of different temperatures.

[96] Enzymes lower the amount of energy needed for a reaction to occur, but don't eliminate the need for energy. Heat is one type of energy. The lower the temperature, the less energy is available for a reaction. You might want to consider this fact when you are answering the questions at the end of the lab.

[97] It's time to get this experiment started and get you on your way. Section 10 will complete the lab with an experiment similar to the one you performed last week. Take a moment to review what you did by completing the first part of this section, and then come right back.

[98] Doing OK? Of course you are. I'll leave you with a few hints to complete the experiment successfully. First – be sure to fill the tubes no more than $\frac{1}{4}$ full. If you put too much water in the tubes, the solutions won't heat or cool fast enough.

[99] Second – when you are adding the pyrocatechol, leave the tubes where they are, just take the dropper bottle over to the cold bath or hot block.

[100] Third – compare your tubes with the standards immediately after removing them from the hot block and cold bath. Remember to look down your tubes while holding them over a white background to detect slight color changes.

[101] Fourth – be sure you save your tubes to show the instructor when you take your experimental results and graph to be signed.

[102] Now complete the lab by finishing section10. Be sure to clean your tubes and leave them upside down in the rack when you are done and make sure your booth is neat and tidy for the next student. And have a great week.