Topic 2: Biochemistry – 2a. Chemical versus Structural Formula (Ball and Stick Macromolecules)

Resources: Miller, K., Levine, J. (2004). *Biology.* Boston, MA: Pearson Prentice Hall.

Ophardt, C. Sweeteners – Introduction, *Virtual ChemBook* [Internet]. Elmhurst College, Elmhurst, IL. 2003. Cited 23 July 2009. Available from: http://www.elmhurst.edu/~chm/vchembook/549sweet.html

Building on: Glucose has the chemical formula $C_6H_{12}O_6$, but so does fructose. Carbon forms four bonds and oxygen forms two bonds, so carbon dioxide must contain double bonds. These are concepts that often confuse students. This lab forces students to construct molecules knowing only their molecular formula and the number of bonds that each type of atom will form. The lab deals with *the nature of atoms, the outer electron shell, electronegativity, polar/non-polar covalent bonds, polar and non-polar molecules, and the importance of the structural formula* for macromolecules.

Students are given three different colors of Play-Doh. They decide which color will represent which element, carbon, hydrogen, and oxygen. They break toothpicks in half and each half toothpick represents a covalent bond (a pair of shared electrons). They will lay out a piece of paper towel, section it into six sections and write the molecular formula for each separate molecule they will construct in each section. They will be told how many bonds each atom forms and then they are left to build their molecules. They generally have very little trouble with water (H_2O) and they might struggle a little with methanol (CH_3OH), but most students get tripped up when they attempt either carbon dioxide (CO_2) or oxygen (O_2). Once they get the idea of a double bond, they are ready for $C_6H_{12}O_6$, and then their imaginations take off. Each time a group successfully follows the bonding rules and constructs a molecule with six carbons, twelve hydrogens, and six oxygens, ask them to go up and write it on the board (regardless if it is a naturally occurring molecule or not). At the end of class, we count up how many different variations for $C_6H_{12}O_6$ the class has produced. Identify a drawing as glucose and one of fructose (hopefully they will be on the board; otherwise you will need to draw them). Cross out all designs that do not occur naturally and discuss the difference between glucose and fructose.

You can talk about the fact that glucose is an aldehyde and fructose is a ketone. The fact that glucose will give a positive result for the presence of reducing sugar with the Benedict's test, but fructose will not.

Links to Chemistry:	Atomic structure Electron orbitals Octet rule Electronegativity Chemical bonds Polarity Organic molecules Functional groups
Links to Physics:	Atomic structure Molecules Compounds Electrons Chemical Bonds Energy of bond formation

Stories:

When discussing the differences between glucose and fructose, you can talk about the fact that fructose tastes much sweeter than glucose. You can ask the kids if anyone has a candy bar, or a non-diet pop with them (you might want to have one at your desk) and ask a student to please read the list of ingredients. It is highly likely that one of the first five ingredients in the product will be high fructose corn syrup. Why would the candy manufacturers use fructose instead of glucose? And what about sucrose? This might be the time to talk about monosaccharides and disaccharides. You could list the six most common "sugars":

Glucose ($C_6H_{12}O_6$)
Fructose ($C_6H_{12}O_6$)
Galactose ($C_6H_{12}O_6$)
Sucrose (glucose + fructose and a formula of $C_{12}H_{22}O_{11}$)
Lactose (glucose + galactose and a formula of $C_{12}H_{22}O_{11}$)
Maltose (glucose + glucose and a formula of $C_{12}H_{22}O_{11}$)

The students could rank them in what they think is the order of sweetness with 1 being the sweetest and 8 the least sweet. Then you can go to this website or make a transparency showing the relative sweetness of each of these carbohydrates. The website is located at:
http://www.elmhurst.edu/~chm/vchembook/549sweet.html

It also contains some very interesting stories about the discovery of several different artificial sweeteners and the lack of good lab safety techniques that lead to those discoveries.

Materials:

- Play-Doh (three different colors)
- Toothpicks

Lab: Build a Molecule

Introduction: Atoms can be combined using different combinations and orientations to make very different molecules. The kinds, number, and organization of atoms in a molecule give the molecule distinct properties. Often the molecular formula for molecule will not provide the information necessary to identify the molecule or its properties. The structural formula is needed to understand how the atoms in the molecule are arranged and which properties that molecule will possess.

Vocabulary:
Organic molecules
Inorganic molecules
Molecular formula
Structural formula
Chemical bonds

Procedure:

1. Complete the following table:

Element	**Symbol**	**# of Covalent Bonds Formed**
Carbon		
Oxygen		
Hydrogen		
Nitrogen		
Phosphorus		

2. Spread a piece of paper towel across your lab table. Write a key on your paper towel to indicate which color Play-Doh represents each element from the table above.

3. On the table located on the back of this paper you will find a chart showing the molecular formula for several common molecules. Look carefully at the molecular formula and use the correct color Play-Doh "atoms" and toothpick "bonds" to build a representative of the molecular structure of that molecule. Place each structure on your paper towel and label it with its molecular formula and its name. When you think you have correctly built your molecules, call your instructor over to check the molecules and to sign your lab sheet.

4. Write out the structural formulas on your lab sheet. You may also be asked by your instructor to write one or more of your formulas on the board.

Molecular Formula	**Name**	**Structural Formula**
O_2		
H_2O		
CO_2		
CH_4		
CH_3OH		
$C_6H_{12}O_6$		

Analysis Questions:

1. Why do you think the formula for Ch_3OH was written that way instead of Ch_4O?

2. How many different structural formulas did your class come up with for the molecular formula $C_6H1_2O_6$? Using these various structural formulas as your example, explain why it is important to know both the molecular and structural formulas for some molecules while the molecular formula alone is enough for others.