The Workshop Project Newsletter

PROGRESSIONS:
PEER-LED TEAM LEARNING

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Module 2: Biological Molecules

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I. Introduction

Living things construct medium to large-sized **organic molecules** constructed of a carbon skeleton to which are attached other atoms, especially hydrogen, oxygen and nitrogen. These include familiar names like **carbohydrates**, **lipids** (including fats and steroids), and **proteins**. These larger molecules are organized into cell parts (ex. Phospholipids in cell membranes), carry information (ex., DNA in genes), and control the rate of chemical reactions in the cells (ex., enzymes). A working knowledge of these organic molecules is so essential for mastering biology that we provide a special workshop module devoted to the basics of their structure and function in living things.

Prepare for your workshop by reading in your textbook (ex., Audesirk, et al. 6th edition, Chapter 3; Campbell, 4th edition, Chapters 4 & 5) and completing the Pre-Workshop Activities below. Show your work in these pages.

II. Pre-Workshop Activities

Activity 1. In defining each of the following give information about structure, location and connections to other molecules or objects, and function in living things as is appropriate.

1. amino acid
2. dehydration synthesis
3. hydrolysis
4. lipid
5. monomer
6. nucleic acid
7. nucleotide
8. peptide bond
9. polymer
10. protein
11. sugar

12. triglyceride

13. carbohydrate

14. enzyme

Activity 2. Structural formulae and functional groups

1. A kind of symbolism used in biochemistry is the structural formula. A simple example is shown in Fig 2.1. It shows the atoms making up a molecule and their connections.
   a. The letters stand for what?
   b. What do the *single* and *double lines* between letters represent?
   c. Draw a structural formula for water and for carbon dioxide. Check them in your book.

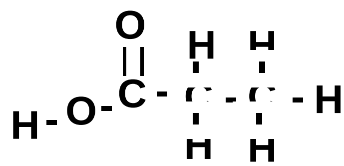

Figure 2.1 Structural formula

2. Carbon atoms form the backbone of organic molecules in living things.
   a. Determine the number of valence electrons in carbon and how many bonds it can form.
   b. What types of bonds are formed? Covalent, ionic, hydrogen?
   c. The capacity to form multiple connections and long branching molecules enables carbon to be part of a large variety of complex molecules. Draw a molecule with three carbons in a chain and with six hydrogen atoms and two hydroxyl groups attached to the other positions. Check your book to determine the type of molecule you have created.
   d. In a similar way draw a larger molecule with more carbons that has a branch off the main chain. Fill in the side groups.

3. Biological molecules are characterized by having *functional groups* of various kinds. These groups enable the molecules to be chemically reactive with other molecules and connect to various ions and water. The simplest functional group is –H (the hydrogen atom) which dissociates from (breaks off) a molecule to give a hydronium ion (H+) and leave a negative charge on the molecule. You have also been introduced to the hydroxyl ion (-OH^-). For each of the functional groups in Table 2.1 complete the information for each column, doing research in your textbook or from lecture notes:

Group	Structural formula	Molecules in which it occurs	Chemical reactivity (acid /base; polar/non-polar)
hydrogen			
hydroxyl			
carboxyl			
amino			

phosphate			
methyl			

Table 2.1 Functional groups

Activity 3. Classes of biological molecules

1. What are five important elements that make up biological molecules?

2. What are the major classes of biological molecules? Give an example of each one.

3. Most large biological molecules are made up of smaller units connected to one another. The small units themselves are molecules. For **carbohydrates, lipids and proteins**:
   a. determine what the small units are
   b. make a drawing of one example for each
   c. on your drawing circle any functional units you can find referring to Table 2.1
   d. put the name of the type of molecular unit under your drawing.

III. Workshop Activities

Activity 1. Review of important concepts: BINGO

Your peer leader will give you a game card and game pieces. Work with a partner as the questions are read to complete your BINGO card.

Activity 2: Structural groups & biological molecules

Use a Round-robin format to answer the following questions: Sequentially each person will add to the drawing of a molecule on the blackboard as described. Leave the molecule when you are finished. All participants are encouraged to draw it and add their own notes.

1. Molecule #1:
   a. draw a carbon atom showing its potential for bonding to other atoms
   b. add five more carbons in a horizontal chain
   c. number the carbons from 1 to 6 from right to left
   d. add hydrogens above to carbons 2, 4, 5 and 6
   e. add hydroxyl groups below on the same 4 carbons
   f. add a hydroxyl group above on carbon 3 and a double bonded oxygen to carbon 1
   g. add hydrogens to the remaining bonding positions on the carbon atoms
   h. write the molecular formula for the molecule
   i. identify the molecule: general type and specific name

2. Molecule #2:
   a. draw a carbon atom showing its potential for bonding to other atoms
   b. add a carboxyl group to the right of the first carbon
   c. add an amino group to the left of the first carbon (N connects to C)
   d. add a hydrogen above the first carbon
   e. attach a chain of 4 carbons extending below the first carbon
   f. add a amino group below the last carbon in the chain
   g. add hydrogens to the remaining positions for bonding on the carbons
   h. identify the molecule: general type and specific name

i. circle and label all the functional groups that are present except hydrogens
j. identify the **R-**group
k. leave it on the board

3. Molecules #3 and #4:
a. draw a carbon atom showing its potential for bonding to other atoms
b. add a linear chain of 14 carbons to the first carbon going from right to left
c. add a carboxyl group to the last carbon on the left.
d. identify the molecule: general type and specific name if possible
e. to the left of the molecule draw a vertical chain of 3 carbons
f. add hydroxyl groups to the right of each carbon
g. complete the molecule with hydrogens in the other bonding positions
h. identify the molecule: general type and specific name if possible. Use you book or notes.

Activity 3. Complex molecules and polymerization

Pairs of students should do the following exercises, preferably on a large sheet of paper or on the blackboard. Each pair should do at least two exercises with each member taking the lead for one of the problems. Depending on time, more exercises could be done by each pair. Afterward each group should demonstrate to the others the solution for the problem, step-by-step. Another group that has done the same problem should comment on the solution: corrections, different approach, etc.

1. Molecule #5:
a. Using molecules #3 and #4, draw a chemical bond between the carboxyl group of long-chain molecule and the top hydroxyl group of the three-carbon molecule as follows: remove the –H of the hydroxyl and the –OH of the carboxyl
b. connect the carbons with an oxygen between them
c. name the kind of chemical reactions you represented in this simulation
d. name the kind of molecule you created by class and type.
e. if you added two more long chain molecules like Molecule #3 above, show how they would be connected (you don't need to draw out all the carbons in the chain)
f. what small molecules would be by-products of the reactions?
g. identify the molecule you have created: general type and name
h. leave it on the board.

2. Molecule #6:
a. to the left of molecule #2 draw the central carbon of a new molecule
b. to the left of the new central carbon add an amino group
c. to the right of the central carbon add a carboxyl group
d. add the R-group which is a methyl functional group
e. identify the molecule: general type and specific name if possible
f. link the new molecule to molecule #2 by dehydration synthesis. Show the by-product.
g. name the newly formed molecule
h. explain in detail how this molecule is related to a protein

3. Molecule #7: Should be done with question 4 below
a. go back to molecule #1. Redraw it if necessary on a sheet of paper; otherwise work on the board next to it.
b. molecule #1 usually occurs in a ring form. To show this, draw a regular hexagon (six-sided polygon).
c. place carbons 1-5 at five corners of the hexagon.
d. show carbon 6 attached above carbon 5, but not part of the hexagon
e. add the side groups above and below the carbons in chalk or pencil so they can be erased
f. remove the –H from the hydroxyl group of Carbon 5 and add it to the double-bonded oxygen on Carbon 1 forming a hydroxyl group

g. place the remaining oxygen on Carbon 5 on the 6th corner of the hexagon, with a connection now to Carbon 1 to complete the ring.

h. the lines joining the corners of the hexagon represent what?

i. draw another hexagon and number the corners 1-5 to represent the carbons

j. place the oxygen at the top corner but leave the other carbons out

j. connect the side groups that occur on each carbon *to the corners*, above or below

k. be sure to show the 6th carbon in its correct position.

l. this short-hand way of drawing the structural diagram uses what to represent C 1-5?

4. Molecule #8: should be done with item 3

a. draw a second molecule identical to #7 using the short-hand version from question 3 above so that C-1 of the molecule on the left is opposite C-4 on the right

b. simulate a dehydration synthesis by removing the hydroxyl group from C-4 and a –H from the hydroxyl group on C-1

c. connect the two rings by means of the remaining oxygen

d. name the class and specific type of molecule that is formed

e. explain exactly how this molecule is related to a large polymer like cellulose or glycogen

f. draw two hexose rings with an oxygen connecting them. Number the carbons and show the position of the oxygen atom at one corner. You need not show other side groups

g. simulate hydrolysis by adding water at the bond between the rings so that two monomers are reformed.

h. When or where might hydrolysis occur in living things? Try to give two examples.

(Instructors might add similar exercises for phospholipids and steroids.)

Activity 4. Questions

Pairs of students should work on each problem and share the results with the class. Ideally two pairs of students would do each problem, one presenting their solution and the other commenting on the solutions

1. Proteins are large molecules with complex structures. Arrange the following items from largest to smallest: single-stranded protein with 50 amino acids, carboxyl group, amino acid with a methyl R group, carbon atom, a dipeptide, amino acid with a 6-carbon chain as an R group, a protein with several subunits folded together, a proton, amino group.

2. Organize the following concept family into a small concept map using the proper conventions for representing concepts and connecting statements.

Monosaccharide, hydroxyl group, carbon, oxygen, hydrogen, carboxyl group, polysaccharide, glucose, starch, dehydration synthesis, ring form, chain form.

3. Compare the three major types of organic molecules studied in this workshop in terms of:

a. elements that make them up

b. chemical reactions that form them

c. interactions with water

d. functions in living things

One way to answer this question is by making a table.

4. Using drawings, movements of your body, folding paper or other creative approaches explain and compare the following aspects of protein organization: primary structure, secondary structure, tertiary structure, quarternary structure.

5. Explain the names of the biochemical processes that build and break down polymers. Be as specific as you can. Give examples and diagrams.

6. Figure 2.2 shows three molecules.
   a. What are they?
   b. What do they all have in common?
   c. What differences exist among them?
   d. Circle the functional groups you can identify in each.
   e. How do they interact or bond with other molecules? What is the result?
   f. Where might they occur in the human body? Suggest some functions.

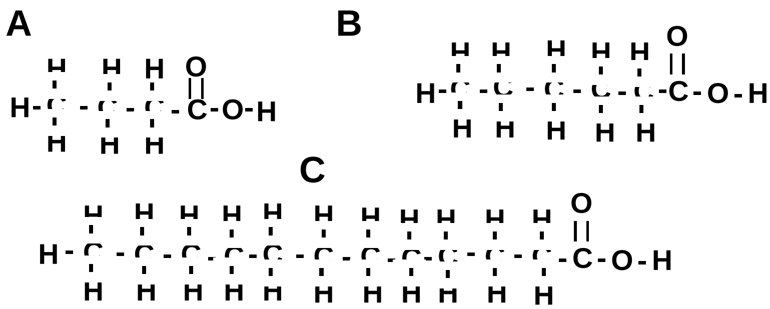

Fig. 2.2 . ___________________________________molecules

7. Figure 2.3 show four molecules.
   a. What are they?
   b. What do they all have in common?
   c. Circle the functional groups you can identify in each.
   d. What differences exist among them?
   e. How do they interact or bond with other molecules? What is the result?
   f. Where might they occur in the human body? Suggest some functions.

8. Figure 2.4 shows three molecules.
   a. What are they?
   b. What do they all have in common?
   d. Circle the functional groups you can identify in each.
   d. What differences exist among them?
   e. How do they interact or bond with other molecules? What is the result?
   f. Where might they occur in the human body? Suggest some functions.

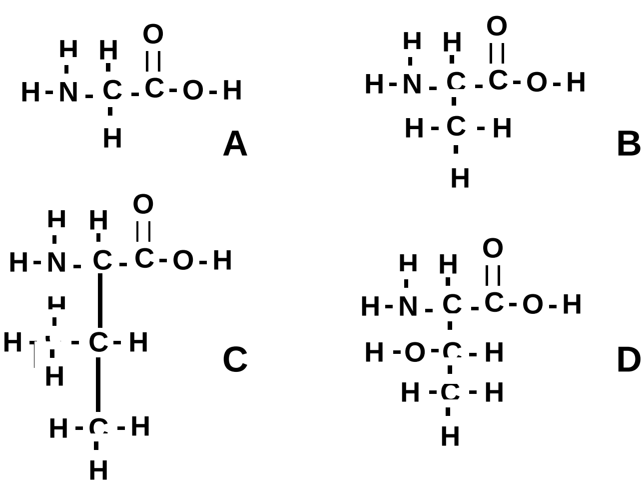

Figure 2.3. ________________ molecules

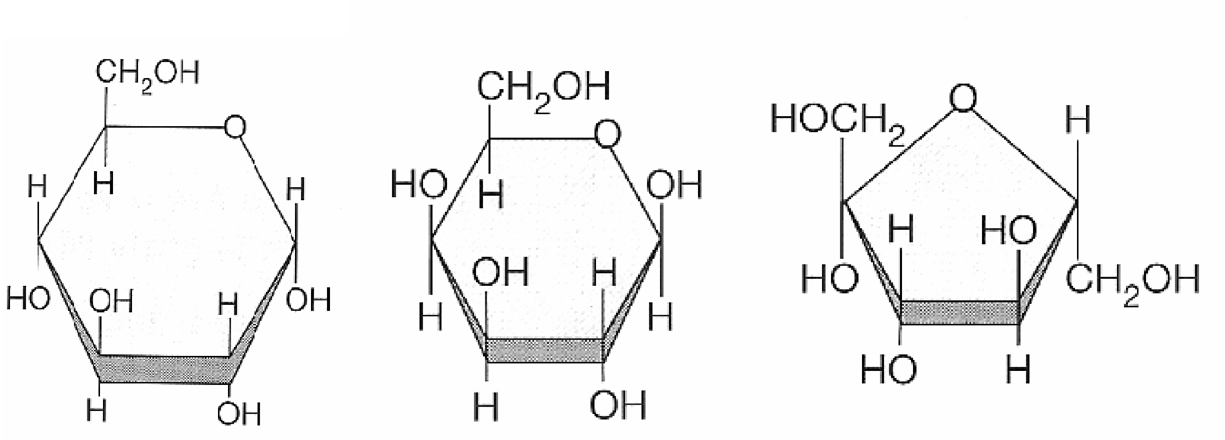

Figure 2.4. ______________________

9. Figure 2.5 shows a single molecule
   a. Identify it as specifically as possible.
   b. Identify its functional groups and major parts.
   c. Label the special bond(s) that connect the parts.
   d. Draw an additional part so you can add it to what is shown in the figure.

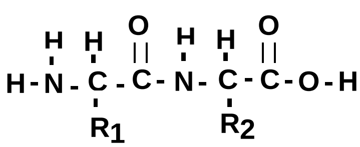

Figure 2.5. ______________________

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