PEER-LED TEAM LEARNING
ANATOMY & PHYSIOLOGY

MODULE 3: BIOLOGICAL (ORGANIC) MOLECULES

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I. Introduction

Living things are made up of large **organic molecules** constructed of a carbon skeleton to which other atoms are attached, especially hydrogen, oxygen and nitrogen. These include familiar names like **carbohydrates**, **lipids** (like fats and steroids), and **proteins**. These larger molecules create the structural parts of the cell (like phospholipids in cell membranes), carry information (like DNA in our genes), and control the rate of chemical reactions in the cells (like enzymes). A working knowledge of these organic molecules is so essential for mastering biology that this entire workshop module is devoted to the basics of their structure and function in living things. Prepare for your workshop by reading in your textbook (Chapter 2, pages 66-87) and completing the Pre-Workshop Activities below. Show your work in these pages.

II. Pre-Workshop Activities

Activity A. Using the terms provided complete the table below:

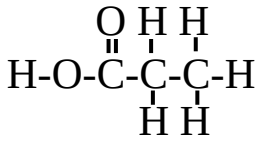


Figure 3.1 Structural formula

Nucleotide
Catalyzes biochemical reactions
Glycogen
Amino acid
Fatty acids & glycerol
Storage compound for glucose
Nucleic acid
Polysaccharide
Forms cell membranes
DNA
Lipid
Enzyme

Monomer (building block)	Polymer (macromolecule)	Example	Function of "example molecule"
			Stores genetic information
Monosaccharide			
		Membrane Phospholipids	
	Protein		

Activity B. Structural formulae and functional groups

1. A kind of symbolism used in biochemistry is the structural formula. A simple example is shown in Fig 3.1. It shows the atoms making up a molecule and their connections.
   a) What do the letters stand for?

   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.

2. Carbon atoms form the backbone of organic molecules in living things.
   a) Draw the carbon atom. How many valence electrons does carbon have? How many covalent bonds can it form?

   b) Draw the structural formula for CH_4 (look back at Fig 3.1 if you need to).

   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.

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 3.1 complete the information for each column, doing research in your textbook or from lecture notes:

Group	**Molecular formula**	**Structural Formula**	**Types of molecules that group is found in**	**Chemical Reactivity (hydrophobic/hydrophilic or acidic/basic…)**

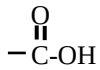
Hydroxyl			Alcohols Sugars	
Methyl				Hydrophobic. This group is soluble in lipids and will associate with other hydrophobic groups.
Carboxyl				
Phosphate				
Amino	$-NH_2$			

Table 3.1 Functional groups and their properties

III. Workshop Activities

Activity A. 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. The first pair to complete a row (horizontal, vertical, or diagonal) and shout "BINGO!" wins. Answers must be verified with the workshop leader in order for a winner to be declared.

Activity B. Proteins are large molecules with complex structures. Arrange the following items from largest to smallest by putting each item on a sticky note**.** Work in pairs and then share your answers with a neighboring team. You may want to draw the items or label them according to the hierarchy before you begin.

single-stranded protein with 50 amino acids
amino group
dipeptide
carboxyl group
carbon atom
proton
amino acid with 6-C chain as an R group
amino acid with a methyl R group
protein with several subunits folded together

Activity C: 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 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 general type of molecule that you have just drawn
   i) identify the **R**-group
   j) circle and label all the functional groups that are present (except hydrogens)
   k) now follow the directions to build Molecule #6

2. Molecule #2:
   a) draw an oxygen atom showing its potential for bonding to other atoms (2 bonds, left and right side)
   b) draw a chain of 5 carbons in which both ends of the carbon chain connect to the oxygen
   c) number the carbons from 1 to 5 from left to right (counter clockwise) and show the potential for bonding for each carbon
   d) draw another carbon atom bonded above carbon 1
   e) to this carbon, add two hydrogens and a hydroxyl group

f) add hydrogens above to carbons 2, 4, and 5
g) add hydroxyl groups below on the same carbons
h) add a hydroxyl group above on carbon 3
i) add hydrogens to the remaining bonding positions on the carbon atoms
j) identify the general type of molecule that you've just created
k) identify the specific name of the molecule
l) now follow the directions to build Molecule #7

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 (horizontally)
c) add a carboxyl group to the last carbon on the left
d) identify the general type of molecule that you've just created
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
i) now follow the directions to build Molecule #5

Activity C. Complex molecules and polymerization
Break into three small groups with each member taking the lead for one of the problems. Afterwards, each group should demonstrate to the others the solution for the problem, step-by-step.

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 reaction you just performed
d) what small molecules are the by-products of the reactions?
e) if you added two more long chain molecules like Molecule #3 above, show how they would be connected to Molecule #4 (you don't need to draw out all the carbons in the chain)
f) identify the kind of molecule you created
g) now follow the directions for Molecule #8

2. Molecule #6:
a) to the left of molecule #1 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 a methyl functional group (this is your R-group)
e) identify the kind of molecule that you've created (specific and general)
h) remove an –H from the amino group on the right hand amino acid and an –OH from the carboxyl group on the left hand amino acid
i) connect the carbon from the left amino acid with the nitrogen of the right amino acid
j) name the kind of chemical reaction you just performed
k) what is the name of the bond that is formed?
l) what small molecules are the by-products of the reactions?
m) identify the kind of molecule you created
n) if you repeated this many times to create a long chain, what kind of molecule would you have?
o) now follow the directions for Molecule #8

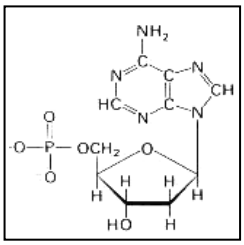
3. Molecule #7:
   a) draw two #2 molecules right next to each other
   b) remove an –H from the #2 carbon on the right hand molecule and remove an –OH from the #5 carbon on the left hand molecule
   c) connect the two rings by means of the remaining oxygen
   d) name the kind of chemical reaction you just performed
   e) what small molecules are the by-products of the reactions?
   f) identify the kind of molecule you created
   g) if you repeated this many times to create a long chain, what kind of molecule would you have?
   h) name the class and specific type of molecule that is formed
   i) explain exactly how this molecule is related to a large polymer like cellulose or glycogen
   j) now follow the directions for Molecule #8

4. Molecule #8:
   a) using the polymer that you just created, simulate hydrolysis by adding water at the bond between the rings so that two monomers are reformed
   b) when or where might hydrolysis occur in living things? Try to give two examples.

Activity 4. Questions

Pairs of students should answer the following questions. Each pair should do two questions with each member taking the lead for one of the problems. Afterwards, each group should explain the answer to the others. Another pair that has answered the same question should comment on the answer: corrections, different approach, etc..

1. There is a fourth type of organic molecule which we did not draw in the exercise above called a nucleotide. Using the picture to the right as a guide, write the directions for how to draw a nucleotide in the space below. When you are done, give your directions to your partner and have them try to draw it…while you draw the molecule according to your partner's directions. You might consider breaking the molecule into three stages: the sugar, the phosphate group, and the nitrogenous base.



2. 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.

3. Compare the four major types of organic molecules studied in this workshop in terms of (one way to answer this question is by making a table):
   a) elements that make them up
   b) chemical reactions that form them
   c) interactions with water
   d) functions in living things

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

5. Figure 3.2 shows three molecules.
   a) What are they?

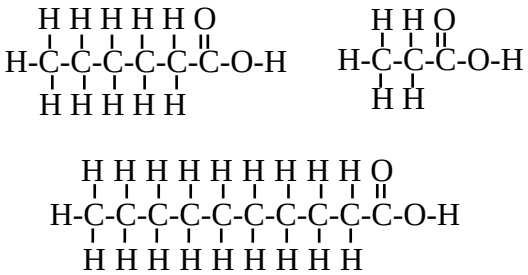


Fig. 3.2

   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.

6. Figure 3.3 shows 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?

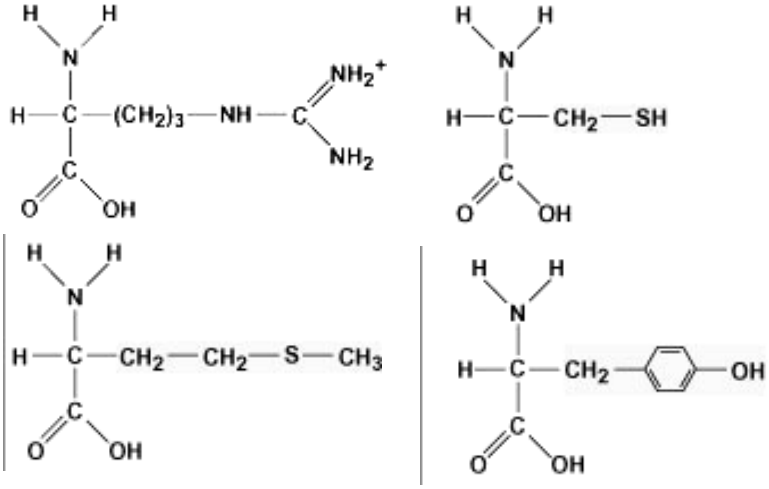


Figure 3.3. _____ molecules

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.

7. Figure 3.4 shows three molecules.

a) What are they?

b) What do they all have in common?

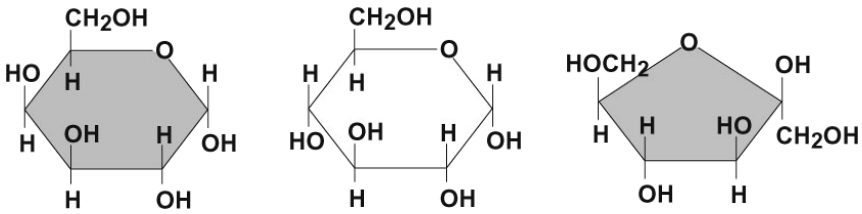


Figure 3.4. _____ molecules

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.

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