Biology 1200: Biochemistry Worksheet

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Introduction

- Read chapters 4 & 5 - Campbell & Reece Biology

The Chemistry of Life

Chemistry and physics study how things happen in the physical world. Biochemistry and biophysics narrow the field to how living things respond on the molecular level. To understand life processes we must know some fundamental chemistry as applied to living things. CHONPS is an acronym for the most common elements found in living organisms. With these six elements we can construct the four major organic compounds of life... carbohydrates, proteins, lipids, and nucleic acids. To accomplish this you must learn the bonding patterns for these six elements.

Review of structural bonding patterns.

Show the structural bonding patterns for the common elements listed. Use a Periodic Chart of the Elements to find the Z-number (atomic number) that indicates the number of protons in the element. Remember that in an atom the number of protons equals the number of electrons. When showing the structural patterns consider only the electrons in the outer most shell. Electrons n the outermost cell are called **valence electrons**. They are the ones that are involved bonding and thus determine the chemical properties of the element. Oxygen has been done as an example. (p. 28)

Element	**Number of valence electrons in the outer most electron shell**	**Number of covalent bonds formed to achieve stability**	**Structural bonding pattern for the element**
Carbon	.	.	.
Hydrogen	.	.	.
Oxygen	6	2	
Nitrogen	.	.	.
Phosphorus	.	.	.
Sulfur	.	.	.

What relationship exists between the number of electrons needed to fill the outer most energy level (shell) of an atom and the number of covalent bonds that element can form?

Functional Groups

Certain atoms will bond together in groups called radicals. These groups of atoms produce specific properties in the compounds in which they occur. They are often referred to as functional groups and each has its own name and structural formula.

They can be useful in recognizing and classifying the major groups of compounds in living things.

Functional Groups Table

Name	Chemical Formula	Sructural formulas	Significance
Methyl	(CH_3)		Common in hydrocarbons
Ethyl	(C_2H_5)		Common in hydrocarbons
Carboxyl (acid)	(COOH)		Produces acid properties. Found in proteins and lipids.
Carbonyl			Found in carbohydrates.
ketone			
aldehyde			
Amino	(NH_2)		Found in proteins
Hydroxyl	(OH)	-OH	Found in alcohols
Phosphate	(PO_4)		Found in nucleic acids and energy compounds.
Sulfhydryl			
Aromatic Ring (Benzene Ring)	(C_6H_6)		Found in proteins, steroids

Organic Chemistry

Definitions:

Organic -

Inorganic -

Hydrocarbon -

Types of carbon chains

Carbon is the fundamental building block of living systems. Their ability to form four covalent bonds permits them to be linked in chains of infinite length. Such chains maybe straight, branched, or ringed. Draw an example of each type of carbon chain listed.

Straight chain **Branched chain** **Carbon ring**

Types of covalent bonds

Covalent bonds involve the sharing of pairs of electrons. Carbon atoms form single, double and triple covalent bonds. Draw examples of each below.

Single covalent bonds **Double covalent bond** **Triple covalent bond**

The most stable bond between atoms is the single covalent bond. In a chemical reaction the least stable bond is generally the one to be broken. Based on this information, rank the above three covalent bonds based on their reactivity .

____________________ ______________________ ___________________

--- Increasing Reactivity --->

Isomers

The bonding nature of carbon to form chains of differing length creates an infinite number of possible hydrocarbon compounds. Write the chemical formulas for the following two compounds beside their name, and draw their chemical structures underneath.

butane ____________________ isobutane _______________________

1. What do the above two compounds have in common?

____

2. How are they different.

____

Because the same number and kind of atoms can be arranged in different ways it is not enough to give just the chemical formula for a compound. Chemists use **structural formulas** to distinguish between compounds with the same chemical formula. Complete the following formula comparison chart using a yes/no response.

Characteristics	Chemical formula	Structural formula
Shows the kinds of atoms		
Shows the number of atoms		
Shows the types of bonds		
Shows the arrangement of the atoms		

Compounds with the same chemical formula but different arrangements of the atoms are called **isomers**. Isomers have different chemical properties because of the way the atoms are arranged. As we shall see later, this is extremely important in living systems.

Biologically important reactions (p. 58)

There are four major groups of organic compounds in living systems. They are carbohydrates, proteins, lipids, and nucleic acids. Most are large organic molecules referred to as **macromolecules** because of their size. While they may appear to be complex they are composed of simple repeating units called **monomers** (mono = one). Joining monomers together produces chains referred to as **polymers** (poly = many).

Think of monomers as bricks. The bricks can be used to build walls (polymers) that eventually become buildings (macromolecules). Identical bricks can be used to construct an infinite number of different structures. So it is with monomers. They can produce an infinite variety of macromoleules.

Define the following terms, and give an example of each:

Monomers -

Polymers -

Macromolecule -

Important chemical reactions

Two of the most common chemical reactions in living systems are the building and breaking down of organic compounds. The reactions are simple involving either the removal or the addition of water molecules. The **condensation reaction (dehydration synthesis)** joins two monomers by removing a molecule of water.

monomer + monomer --------------> polymer + H_20

The other reaction called **hydrolysis** breaks up polymers by adding water.

monomer + monomer <-------------- polymer + H_20

1. How many molecules of water must be removed to join the following monomers together?

____

monomer + monomer + monomer + monomer + monomer + monomer --------> polymer + ? H_20

Carbohydrates

The term carbohydrates is derived the combination of the terms carbo and hydrate. It means carbon and water. Carbohydrates are commonly known as sugars and starches. The monomer building blocks of carbohydrates are called **monosaccharides**. The term saccharide is Latin for sweet. They are most important biologically for the production of energy.

Carbohydrates can be identified from their structural formulas. They are composed of C, H, and O and contain a functional group known as a **carbonyl**. The carbonyl group may appear in one of two forms, an **aldehyde** or a **ketone**. Draw the structure of each in the table.

aldehyde group	ketone group

The names of simple sugars generally end in the suffix **ose**. Their generic names are based on the number of carbon atoms in their formula. Latin and Greek names for numbers are used for the root word and the suffix ose is added. For example, the name for a 3-carbon sugar would be triose. A 4-carbon, tetrose. As the carbon chains become longer there is an increase in the number of isomers that can be formed and the need for more specific names. There is an international system for naming organic compounds, however; for our purposes we will use common names.

Examples of carbohydrates

Simple sugars		**Complex sugars (macromolecules)**
monosaccharides (monomers)	**disaccharides**	**polysaccharides (polymers)**
• glucose • fructose • galactose	• sucrose • maltose • lactose	• starch • cellulose • glycogen (animal starch) • chitin

1. Using the following Empirical formula = $C_n(H_2O)_n$ (n = any whole number) complete the table below..

Number of carbon atoms	Chemical formula	Generic name	Number of atoms in the chemical formula		
			C	H	O
3-carbon carbohydrate	$C_3(H_6O)_3$	triose			
4-carbon carbohydrate	$C_4(H_8O)_4$	tetrose			
5-carbon carbohydrate					
6-carbon carbohydrate					

2. What relationship exists between the number of carbon atoms and the number of water molecules in the above simple carbohydrates?

____

3. What do the names of the following sugars have in common? ____________________________

cellulose....ribose....glucose.....hexose....maltose

4. Write the chemical and structural formulas for the following simple sugars

Glucose = ________________	Fructose = ________________	Galactose = ________________

5. What do you call a compound that has the same chemical formula but a different structure?

____

6. How does glucose differ from fructose?

____

Disaccharide Formation

7. Using the dehydration synthesis (condensation) reaction construct each of the following disaccharides.Circle the atoms of water that will be removed from the reactants side of the equations.

glucose + fructose -------(Enzyme)-------------------> sucrose + water

Complex sugars - storage and structural polysaccharides	
	Characteristics
amylose	straight chain arrangement
amylopectin	branched chain arrangement (eg. pectin used in cooking)
Cellulose	major component of plant cell walls
Glycogen (animal starch)	starch stored in animal livers and muscles
Chitin	Starch combined with nitrogen compounds used in the formation of the exoskeleton of arthropods

Proteins

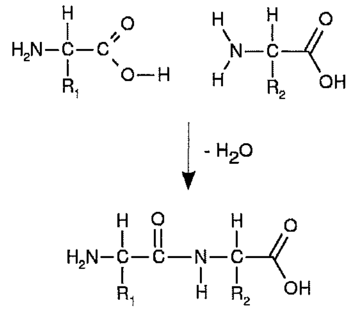
Proteins are most important for the building of cellular structure and the production of **enzymes**. No chemical reactions can occur inside a cell without the presence of a specific enzyme. Proteins contain the elements C, H, O, and N. They are built from the monomers known as amino acids. There are 20 different amino acids. (Amino acids = AA). The cells of humans can build most amino acids, but several are considered essential and must be obtained through our diet.

Each amino acid contains two functional groups; an **amino group** (NH_3-) and a **carboxyl group** (-COOH). The carboxyl group is also known as the "acid" group because it lowers pH whine in solution. Amino acids differ in the length of their hydrocarbon chains which are symbolized by the letter R (**R = remainder of the molecule**). in the generalized formula below.

1. What two chemical groups do all amino acids contain?____________________

   ____

2. Circle the H and OH which will be removed as two amino acids are linked in the following equation.

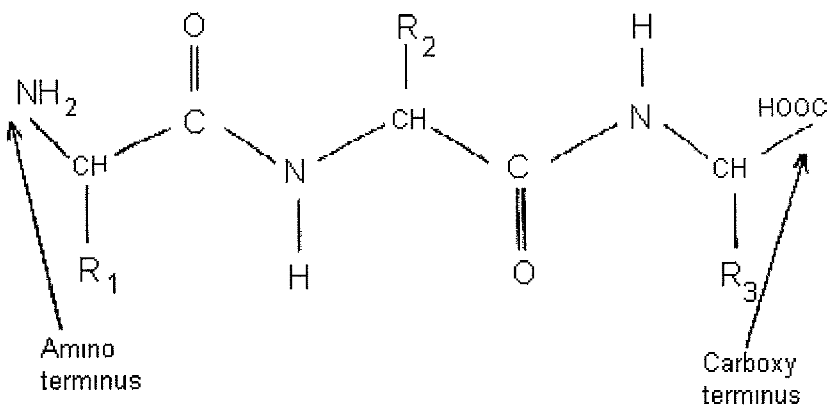


3. What is the name of the above chemical reaction?

____

When monomers of amino acids are linked together they are referred to as **peptides**. Two amino acids joined together is called a **dipeptide**. When more that 3 amino acids are linked it is referred to as a **polypeptide**. If the chain of peptides exceeds 50 in number we refer to them as proteins. Proteins are macromolecules. The covalent bond that connects the peptides (amino acids) is called a **peptide bond**. Peptide bonds always occur between the amino and the carboxyl groups of adjacent amino acids.

Circle the peptide bonds in the following polypeptide.



4. How many water molecules would be required to breakup (digest) the above polypeptide?

____

5. What is the name of the process that breaks-up polypeptides by the addition of water?

____

6. How many water molecules would have to be removed to join 50 amino acids together?

____

Define the following protein structures

- primary

- secondary

- tertiary

- quaternary

Lipids

Characteristics:

Lipids are fatty compounds with long chains of C,H, and O atoms. Fats, oils, and waxes are all examples of fatty compounds. Lipid compounds do not dissolve in water. The are most important for the formation of cell membranes and serve as the cell's secondary energy source. An equal amount of fat, by weight, can produce more energy that that of an equal amount of carbohydrate.

Most lipids are composed of fatty acids. Because they are acids they contain the carboxyl group (-COOH). There are 20 different fatty acids. Fatty acids have both a polar and a nonpolar end. The polar end is said to be **hydrophilic** ("water loving") is is attracted to water molecules. The hydrocarbon portion of the fatty acid is **hydrophobic** ("water fearing").

1. Diagram a fatty acid labelling the hydrocarbon chain, the carboxyl group, the hydrophobic (non-polar end) and the hydrophilic (polar end).

Define the following types of fatty acids (& give examples)

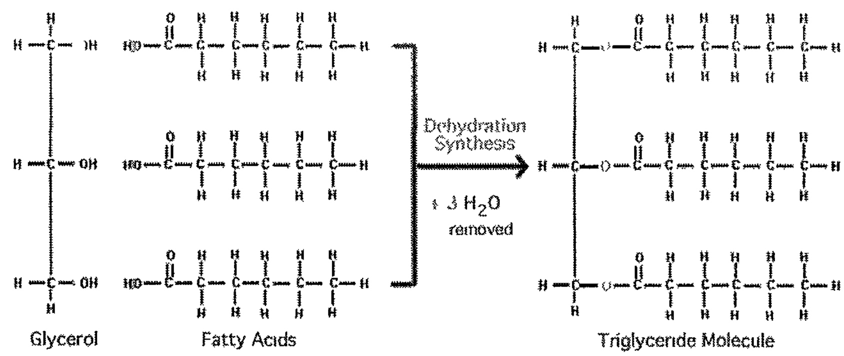
- Saturated

- Unsaturated

- Polyunsaturated - What do you call a parrot wearing a raincoat?

Triglyceride (neutral fat) formation

Triglyceride compounds consist of three fatty acids molecules joined to a single glycerol molecule by the removal of three water molecules. Complete the formation of a triglyceride by circling the atoms that will make up the three water molecules that are to be removed.



What is the name given to the above reaction? _________________________.

Phospholipids - triglycerides with a phosphate group substituted for one of the fatty acids. They are important in building cell membranes.

Steroids - consist of four interlocking rings with side chains. Found in vitamins, hormones and cholesterol.

Nucleic Acids

There are two types of nucleic acids, Ribonucleic Acid (**RNA**) and Deoxyribonucleic Acid (**DNA**). They control all cellular activity by directing the production of enzymes. They are also responsible for passing on the genetic information from one generation to the next. Like the other organic compounds they are constructed from repeating monomer units. In the case of nucleic acids they building blocks are known as **nucleotides**. The elements include C, H, O, N, and P. A more detailed coverage of nucleic acids will come later.

Using the information in this worksheet complete the following summary table.

Comparison of Organic Compounds

	Carbohydrates	Lipids	Proteins	Nucleic Acids
Examples	. .	.	.	
Elements present	.	.	.	.
Functional group(s) present	.	.	.	• phosphate • carboxyl
Building blocks (monomers)	.	.	.	.
Uses in living systems				

Appendix

Naming simple organic compounds

The naming of simple chain hydrocarbons is based on the number of carbon atoms and the type of covalent bond present. The table at the right show the prefix used for the number of carbon atoms in the chain. A suffix indicates the type of bond that is present.

Methane (CH_4), or natural gas, is composed of one carbon atom and four hydrogen atoms all with single covalent bonds.

Methene (CH_2), is composed of one carbon and two carbon atoms with one double covalent bond (the other two are single).

Prefix = #	
met	1
eth	2
pro	3
but	4
pent	5
hex	6
hept	7
oct	8
Suffix	
Single Bond	ane
Double Bond	ene
Triple Bond	yne