Macromolecule worksheet Name: _____
Johnson, 2021

Macromolecular math

Learning objectives:
Through this worksheet, students should be able to…
- Understand and describe the basic makeup of different types of biological macromolecules
- Review the chemical bonds that are important in macromolecular structure

In this activity, you will use a nutrition label to answer questions about the types and quantities of macromolecules found in your food. Note that these are simplified values so that you do not get overwhelmed by calculations using huge numbers. In reality, there are hundreds to thousands of monomers in every polymer, and there may be millions of monomers in a "serving size". You may want to draw out the polymers showing how the monomers make up the polymer, in order to better visualize the calculations you will make.

Nutrition Facts

Serving Size 2/3 cup (55g)
Servings Per Container About 8

Amount Per Serving

Calories 230	Calories from Fat 40
	% Daily Value*
Total Fat 8g	**12**%
Saturated Fat 1g	**5**%
Trans Fat 0g	
Cholesterol 0mg	**0**%
Sodium 160mg	**7**%
Total Carbohydrate 37g	**12**%
Dietary Fiber 4g	**16**%
Sugars 1g	
Protein 3g	
Vitamin A	10%
Vitamin C	8%
Calcium	20%
Iron	45%

* Percent Daily Values are based on a 2,000 calorie diet. Your daily value may be higher or lower depending on your calorie needs.

	Calories:	2,000	2,500
Total Fat	Less than	65g	80g
Sat Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

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NOTE: The calculations on the next several pages are an exercise in being able to read the question correctly. The math examples are not accurate representations of the macromolecules within the product.

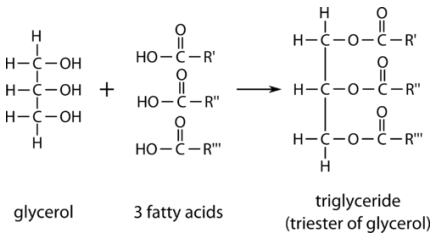
Fatty acids

1. Calculations – assume that all fats found in this food are triglycerides. How many **fatty acids** are there in one serving size of this food if there are 10 triglycerides per gram? (*In reality, there may be more than 10^{20} trigycerides per gram of material.)*

   8 g triglycerides per serving size * 10 triglycerides per g * 3 fatty acids per triglyceride =

   240 fatty acids

2. Questions about lipids

a.	What is the general structure of a triglyceride?	Glycerol bound to three fatty acid chains (can draw)  glycerol 3 fatty acids triglyceride (triester of glycerol)
b.	What is the name of the covalent bond holding the parts of a triglyceride together?	Ester linkage
c.	How can a fatty acid vary within a triglyceride?	The length and saturation of the fatty acids can vary
d.	What is the difference between a saturated and unsaturated fatty acid?	A saturated fatty acid has no double bonds between carbon atoms and is therefore straight

e.	What is the general structure of a phospholipid?	A phospholipid consists of a glycerol bound to two fatty acid chains and the third carbon is bound to a phosphate and a head group.
f.	How can the structure of a phospholipid vary?	The head group can vary as well as the saturation and length of the fatty acid tails (there are also sphingolipids that have a 3-carbon molecule that is different than glycerol – but not needed for BIO151 discussions).
g.	Where would you most expect to find a phospholipid in a cell?	Phospholipids are a major component of the lipid bilayer of cellular membranes.
h.	Molecules like phospholipids have both hydrophilic and hydrophobic structures. What is the general name for a molecule with both hydrophilic and hydrophobic structures?	Amphipathic
i.	What part of a phospholipid is hydrophilic and what part is hydrophobic?	Head group is hydrophilic Fatty acid tails are hydrophobic
j.	What are two roles of lipids in cells?	Here are some - Membrane structure, (long-term) energy storage, signaling (sterols), protection (waxes)
k.	On the nutrition label, there are 8 g of total fat. What other compound(s) listed is(are) a lipid(s)?	Cholesterol & vitamin A

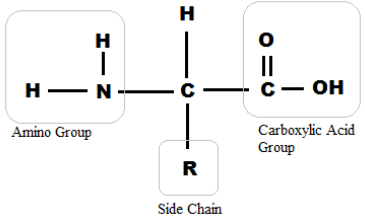
Amino acids

3. Calculations - How many **amino acids** are found in one serving size of this food if every individual protein contains 100 amino acids and there are 20 individual proteins for every gram of "protein"?

   3 g protein per serving * 20 individual proteins per g * 100 amino acids per protein =

   6,000 amino acids

4. Questions about amino acids, polypeptides and proteins

a.	What is the general structure of an amino acid (draw)?	Amino group – central carbon- carboxy group with a variable R chain group 
b.	How many amino acids are found naturally in polypeptides? How are amino acids different from one another?	There are primarily 20 naturally occurring amino acids in polypeptides (others have been identified and some have been created in the laboratory). They differ in the R group (side chain).
c.	What is the name of the covalent bond that holds amino acids together in a linear chain?	Peptide bond
d.	What does the primary structure of a polypeptide refer to?	Linear chain of amino acids
e.	What are the ends of the linear chain of amino acids called and what are the functional groups at each end?	Amino group (N terminus) Carboxy group (C terminus)
f.	What are two examples of non-covalent bonds in macromolecules? *These may be found in other types of macromolecules as well.*	Hydrogen (H) bonds, hydrophobic bonds, ionic interactions and van der Waals interactions
g.	What type(s) of bonds hold together the secondary structure of a polypeptide?	Hydrogen bonds
h.	What are the two (2) examples of polypeptide secondary structures?	Alpha helices and beta sheets

i.	What parts of an amino acid interact in the secondary structure?	Backbone functional groups are interacting (not the R group structures)
j.	What type(s) of non-covalent bonds hold together the tertiary structure of a polypeptide?	Hydrogen bonds, ionic interactions, hydrophobic interactions and van der Waals forces
k	In general, what amino acid functional groups are interacting with non-covalent bonds of the tertiary structure?	R-group R-group interactions as well as R-group backbone group interactions
l.	What covalent bond may be found between amino acids (not the one found in the primary structure) and between what specific amino acid(s)? *2 parts*	Disulfide bond between cysteine residues
m.	How are the tertiary and quaternary structures different in polypeptides?	Tertiary structures are how a polypeptide folds on itself, while quaternary structures involve two or more polypeptides
n.	What is the difference between a polypeptide and a protein?	A polypeptide is the linear chain of amino acids that may be folded. A protein is a functional unit. A polypeptide may be a protein if it has activity in its tertiary structure.
o.	What does denaturation of a protein refer to?	Denaturation refers to the polypeptide losing secondary, tertiary and quaternary (if applicable) structure. Denaturation is breaking non-covalent bonds. Primary structure is not affected.
p.	What are some conditions that could lead to protein denaturation?	Heat is most commonly thought of, although changing pH (acidic or basic) or addition of salt could also cause problems (as well as cold temperatures). Other chemical denaturants can also be used.
q.	What are some general functions of proteins?	Enzymes, structural components (actin, tubulin), signaling (receptors, ligands, peptides, hormone), and many more

Carbohydrates

5. Calculations – Assume "dietary fiber" consists of only cellulose. If cellulose fibers are polymers containing 50 dimers apiece and there are 20 cellulose fibers in every gram of "dietary fiber", how many **monosaccharides** from "dietary fiber" are there in one serving size of this food?

   4 g dietary fiber per serving * 20 cellulose per g * 50 dimers per cellulose * 2 monomers per dimer =

   8,000 monomers (glucose)

6. Questions:

a.	Cellulose polymers are made up of what monosaccharide?	Glucose
b.	What is the name of the covalent bond that links two monomers in cellulose?	Glycosidic
c.	What are two (2) additional polymers that are made up of the monomer found in cellulose (see part 6a above)?	Starch, glycogen, amylose
d.	What is a disaccharide found in milk?	Lactose
e.	For the disaccharide described in part 6d above, what are the two monosaccharides that make up this disaccharide?	Glucose and galactose
f.	Sucrose, common table sugar, is a disaccharide made of what two monosaccharides?	Glucose and fructose
g.	The monomer sugars that make up sucrose and the sugar found in part 6d have the same chemical makeup. These are called _____	Isomers
h.	What are two distinct roles of carbohydrates in cells?	Structure (cellulose), energy storage (starch, glycogen), protection (exoskeleton/chitin) and cell signaling
i.	What are the pentose sugars that are found in nucleic acids (see more in question 8 below)?	Ribose and deoxyribose

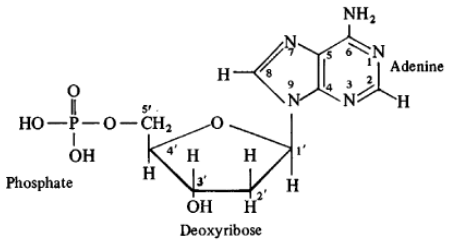
Nucleic acids

7. Calculations – Nucleic acids are not included in normal nutrition labels (they are present), but let's say that we know there is 1 gram of nucleic acids per serving in this food. If every gram is made up of 100 strands of DNA and each strand contains 100 base pairs, how many total **nucleotides** are found in one serving size of this food?

   1 g nucleic acid per serving * 100 strands per g * 100 bp per strand * 2 nucleotides per bp =

   20,000 nucleotides

8. Questions

a.	What are the three parts of a nucleotide?	Pentose sugar, nitrogenous base and phosphate group
b.	What are the monomeric units of a DNA strand called?	Deoxyribonucleotide
c.	What is the name of the covalent bond that holds monomers of a DNA strand together?	Phosphodiester bond
d.	Draw a generic monomer of the DNA strand. Label the carbons of the sugar correctly.	 Adenosine monophosphate shown
e.	What are the monomeric units of an RNA strand called?	Ribonucleotide
f.	What are two (2) differences between an RNA and a DNA?	Ribose vs. deoxyribose (pentose) sugar Uracil (in RNA) vs. thymine (in DNA)
g.	What are two significant structural differences between DNA and RNA molecules in a eukaryotic cell (do not include the differences between the monomeric structures)?	DNA is generally double stranded and RNA single stranded DNA is generally long (the chromosome) vs. RNA being relatively short (a transcribed region).
h.	One molecule used in cells for energy that we will talk a lot about later is ATP. What type of molecule is ATP? Note: GTP is used for energy in some processes)	Adenosine triphosphate is a ribonucleotide

Small molecules

9. Questions

a.	What are three small ions listed on the nutrition facts label? Are these cations or anions?	Sodium, calcium and iron All 3 are cations
b.	What is one significant role for each of these ions in cell function?	May have to work through Sodium and calcium can be signaling molecules across the membrane Calcium is used in bones Iron is used in hemoglobin to bind O_2 and in other heme containing proteins
c.	What is vitamin A?	Another name is retinol. This is a lipid (fat soluble) hydrocarbon.
d.	What is vitamin C?	Another name is ascorbic acid, a small molecule (not a macromolecule) found in citrus fruits and other foods.