Answers

Activity 4.1/5.1 How can you identify organic macromolecules?

Refer to the figure (Some Simple Chemistry) on the next page when doing this activity.

Part A. Answer the questions. Then use your answers to develop simple rules for identifying carbohydrates, lipids, proteins, and nucleic acids.

1. What is the approximate C:H:O ratio in each of the following types of macromolecules?

Carbohydrates	Lipids	Proteins	Nucleic acids
1:2:1	1:2:very few	There is no reliable C:H:O ratio for proteins.	There is no reliable C:H:O ratio for nucleic acids.

2. Which of the compounds listed in question 1 can often be composed of C, H, and O alone?

   Carbohydrates and lipids can often be composed of C, H, and O alone.

3. Which of the compounds can be identified by looking at the C:H:O ratios alone?

   Only carbohydrates and some lipids can be identified using C:H:O ratios alone.

4. What other elements are commonly associated with each of these four types of macromolecules?

	Carbohydrates	Lipids	Proteins	Nucleic acids
Always contain P	No	No (except for phospholipids)	No	Yes
Generally contain no P*	Yes	Yes (except for phospholipids)	Yes	No
Always contain N	No	No	Yes	Yes
Generally contain no N	Yes	Yes	No	No
Frequently contain S	No	No	Yes	No
Generally contain no S	Yes	Yes	No	Yes

**Note:* It is possible to find some exceptions in each of these categories where "Yes" is the answer to "Generally contain no ___." For example, in reaction sequences many compounds undergo phosphorylation. However, if the natural state of the compound does not contain P (for example) the answer to "Generally contain no P" would be yes.

5. Functional groups can modify the properties of organic molecules. In the following table, indicate whether each functional group is polar or nonpolar and hydrophobic or hydrophilic. Which of these functional groups are found in proteins and lipids?

Functional group	Polar or nonpolar	Hydrophobic or hydrophilic	Found in all proteins	Found in many proteins	Found in many lipids
—OH	Polar	Hydrophilic	No	In some R groups	In fatty acids as terminal reactive group
$—CH_2$	Nonpolar	Hydrophobic	No	Yes in side groups	Yes
—COOH	Polar	Hydrophilic	Yes		No
$—NH_2$	Polar	Hydrophilic	Yes		No
—SH	Polar	Hydrophilic	No	No Found in cysteine	No
$—PO_4$	Polar	Hydrophilic	No	Only if they have been phosphorylated	In phospholipids

6. You want to use a radioactive tracer that will label only the protein in an RNA virus. Assume the virus is composed of only a protein coat and an RNA core. Which of the following would you use? Be sure to explain your answer.

   a. Radioactive P b. Radioactive N c. Radioactive S d. Radioactive C

   To distinguish between protein and RNA in a virus, you could use radioactively labeled S compounds. If you grew viruses on cells with radioactively labeled S compounds, the sulfhydryl groups in the virus's protein would become labeled but the RNA would not become labeled.

7. Closely related macromolecules often have many characteristics in common. For example, they share many of the same chemical elements and functional groups. Therefore, to separate or distinguish closely related macromolecules, you need to determine how they differ and then target or label that difference.

   a. What makes RNA different from DNA?

      RNA contains ribose sugar, whereas DNA contains deoxyribose sugar. In addition, RNA contains uracil and not thymine. DNA contains thymine but not uracil.

   b. If you wanted to use a radioactive or fluorescent tag to label only the RNA in a cell and not the DNA, what compound(s) could you label that is/are specific for RNA?

      You could label either ribose or uracil.

c. If you wanted to label only the DNA, what compound(s) could you label?

You could label either deoxyribose or thymine.

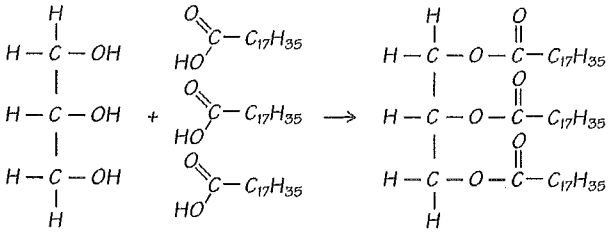
8. Based on your answers to questions 1–7, what simple rule(s) can you use to identify the following macromolecules?

Carbohydrates	Look for a 1:2:1 C:H:O ratio. Many carbohydrates will contain no P, N, or S.
Lipids	Look for a 1:2 ratio of C:H and only very small amounts of O. Most will contain no S. Phospholipids can contain P and N (as part of the choline group; see Figure 5.12 in *Campbell Biology*, 9th edition).
Proteins	Look for amino and carboxyl groups. Some contain S. All proteins can be identified by the presence of peptide bonds. (See Figure 5.17 for the structure of a peptide bond.)
Nucleic acids	Look for nucleotides made up of a five-carbon sugar, a phosphate group, and a nitrogenous base.
DNA vs RNA	DNA contains phosphate, deoxyribose sugar, and adenine, guanine, cytosine, and thymine. RNA contains phosphate, ribose sugar, and adenine, guanine, cytosine, and uracil.

Part B. Carbohydrate, lipid, protein, or nucleic acid? Name that structure!

Based on the rules you developed in Part A, identify the compounds below (and on the following page) as carbohydrates, lipids, amino acids, polypeptides, or nucleic acids. In addition, indicate whether each is likely to be polar or nonpolar, hydrophilic or hydrophobic.

1)



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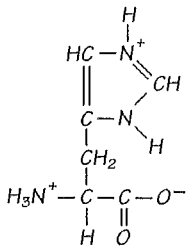

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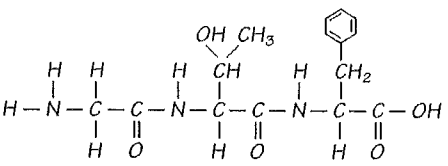


1) lipid (fat or triglyceride)

Hydrophobic and nonpolar

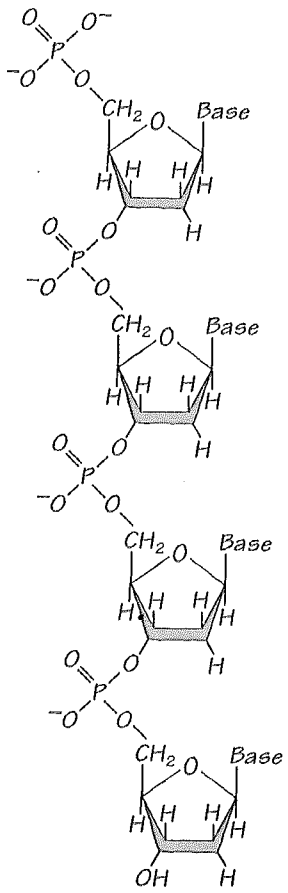
2) amino acid

The amino and carboxyl group would make this somewhat polar and hydrophilic.

3) a tripeptide made up of 3 amino acids

The R groups are hydrophobic with the possible exception of the −OH group. The amino and carboxyl groups are hydrophilic and polar.

4)



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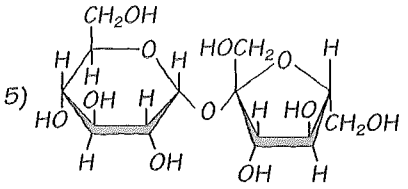

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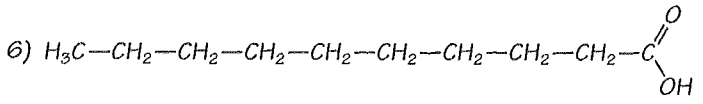

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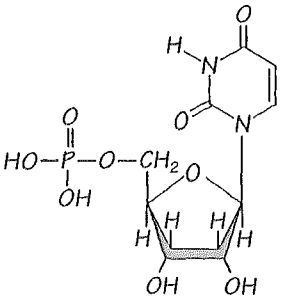

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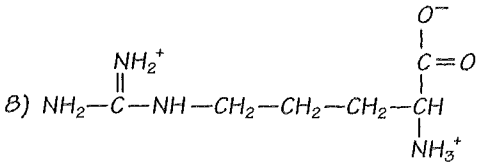
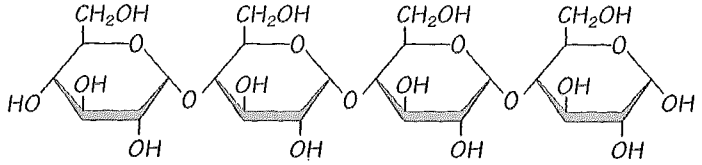


9)



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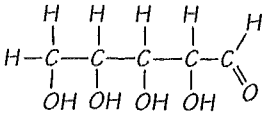


4) single strand of 4 bases in DNA

Because of the phosphate groups DNA tends to be negatively charged and therefore somewhat polar.

5) disaccharide sugar or carbohydrate

This compound is hydrophilic and polar.

6) fatty acid

Hydrophobic and nonpolar with the exception of the carboxyl group.

7) ribonucleotide

Again the phosphate group is polar.

8) amino acid

The amine and carboxyl groups are polar.

9) polysaccharide

Polysaccharides made up of many monosaccharide subunits (like this part of a glycogen molecule) are used for storage. While the hydroxyl groups on this molecule may be somewhat polar, the molecule as whole is relatively insoluble and therefore hydrophobic.

10) 5 carbon sugar

This molecule is both polar and hydrophilic.

4.1/5.1 Test Your Understanding

A student, Mary, is given four samples and told they are lysine (an amino acid), lactose (a disaccharide), insulin (a protein hormone), and RNA. The samples are in test tubes marked 1, 2, 3, and 4, but Mary doesn't know which compound is in which tube. She is instructed to identify the contents of each tube.

a. In her first test, she tries to hydrolyze a portion of the contents of each tube. Hydrolysis occurs in all tubes except tube 3.

b. In Mary's next test, she finds that tubes 1, 2, and 3 are positive for nitrogen but only tube 2 gives a positive result for the presence of sulfur.

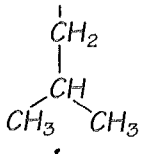
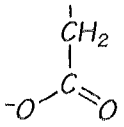
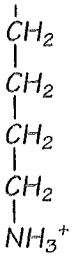
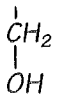
c. The last test Mary performs shows that the compound in tube 1 contains a high percentage of phosphate.

Based on these data, fill in the following table and explain your answers.

Tube number	Contents	Explanation
1	RNA	Like DNA, RNA contains a sugar-phosphate backbone.
2	Insulin	Sulfur is a component of some amino acid side chains. It is not found in lysine, lactose, or RNA.
3	Lysine	All of the compounds except lysine are composed of macromolecular monomers joined by dehydration reactions.
4	Lactose	Since the contents of all the other tubes were determined in tests a to c, this tube must contain the lactose, a disaccharide.

Activity 4.2/5.2 What predictions can you make about the behavior of organic macromolecules if you know their structure?

1. Twenty amino acids are commonly utilized in the synthesis of proteins. These amino acids differ in the chemical properties of their side chains (also called R groups). What properties does each of the following R groups have? (*Note:* A side chain may display more than one of these properties.)

R group	Basic, acidic, or neutral?	Polar or nonpolar?	Hydrophilic or hydrophobic?
a. 	Neutral	Nonpolar	Hydrophilic
b. 	Acidic	Polar	Hydrophilic
c. 	Basic	Polar	Hydrophilic
d. 	Neutral	Polar	Hydrophilic

2. Polypeptides and proteins are made up of linear sequences of amino acids. In its functional form, each protein has a specific three-dimensional structure or shape. Interactions among the individual amino acids and their side chains play a major role in determining this shape.

   a. How are amino acids linked together to form polypeptides or proteins? What is this type of bond called?

      Amino acids are covalently linked together via peptide bonds to form polypeptides or proteins. (See Figure 5.17 in *Campbell Biology*, 9th edition.)

b. Define the four structures of a protein.	c. What kinds of bonds hold each of these structures together?
Primary: The linear sequence of amino acids in a polypeptide or protein	Covalent peptide bonds formed by dehydration reactions hold the individual amino acids together in the polypeptide chain.
Secondary: α helix or β pleated sheet conformations occurring at regular intervals along the polypeptide	The secondary structure results from H bonding relationships set up between the H attached to the N in one amino acid and the O attached to the C of another amino acid. (See Figure 5.20.)
Tertiary: The folded or functional conformation of a protein	Hydrogen and covalent bonds between side chains (R groups) of various amino acids contribute, as do hydrophobic interactions and van der Waals interactions.
Quaternary: The folded or functional conformation of a protein made up of more than one polypeptide chain	Hydrogen and covalent bonds between side chains (R groups) of various amino acids contribute, as do hydrophobic interactions and van der Waals interactions.

3. Lipids as a group are defined as being hydrophobic, or insoluble in water. As a result, this group includes a fairly wide range of compounds—for example, fats, oils, waxes, and steroids like cholesterol.

   a. How are fatty acids and glycerol linked together to form fats (triglycerides)?

      Dehydration reactions between the OH of the carboxyl group on the fatty acid and the OH group on the glycerol molecule bond the fatty acids to the glycerol molecules.

   b. What functions do fats serve in living organisms?

      In general, fats are energy storage molecules.

c. How do phospholipids differ from triglycerides?

Phospholipids have one of the OH groups of the glycerol interacting with a phosphate-containing side group—for example, phosphatidylcholine as in Figure 5.14.

d. What characteristics do phospholipids have that triglycerides do not have?

Phospholipids are amphipathic because the phosphate-containing side group is hydrophilic and the remainder of the molecule is hydrophobic. Triglycerides are hydrophobic.