LAB-AIDS® #505-10 Molecules of Life Kit
Student Worksheet and Guide

Biologists nowadays depend upon chemists for much of their understanding of life and the life processes. Therefore an understanding of some chemical concepts important to living things is necessary.

Carbohydrates, fats, proteins and nucleic acids are the four major groups of organic molecules found in living organisms. Carbohydrates make up a large group of organic compounds found in cells. They are generally used for energy or cell structures.

With this lab exercise you will be expected to: **1)** build on information about water in order to develop ideas about carbohydrates; **2)** construct carbohydrate molecular models; **3)** be able to distinguish between models and actual chemical formulas or molecules; and, **4)** be able to determine the molecular characteristics of carbohydrates.

Procedure:

Students should work independently or in teams as directed by their instructor. It will be necessary for each student to complete his own worksheet while *possibly* sharing a packet of molecular parts with other students. The packet of molecular parts consists of:

12	Carbon (C) - tetrahedral electrons - black	26	Hydrogen (H) - single electron - white
13	Oxygen (O) - double electrons - blue	26	Electron bond - plastic tube - white

I. WATER: The chemical formula of water is H_2O. By examining this formula, some information can be gained.

1. What elements make up water? _____
2. What does the subscript number 2 following the H represent? _____
3. Why doesn't the **O** have a subscript? _____
4. How many molecules of water are represented by the formula H_2O? _____
5. What is a molecular formula? _____
   What is the molecular formula of water? _____
6. Build a structural model of water with the parts provided.
7. Draw the structural formula for water.
8. What is a structural formula? _____
9. What do the lines between **O** and **H** represent? _____

II. CARBOHYDRATES: An important group of biological compounds are the saccharides (the sugars of carbohydrates). Carbohydrates contain carbon, hydrogen, and oxygen. The many different types of sugars have been grouped into three main categories:

monosaccharides **disaccharides** **polysaccharides**

A. Single sugars or monosaccharides:

1. Study the structural formulas of the three monosaccharides in Fig. 1.

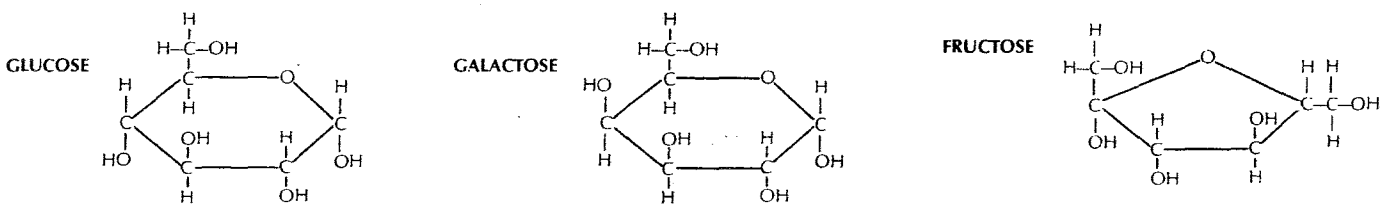


FIG. 1. Structural formulas of three monosaccharides.

2. Construct two different models of the monosaccharides. Join with another team so that all three monosaccharides are built and available for two teams.

The models constructed represent the three-dimensional shapes of the molecules. They illustrate that individual molecules of carbohydrates do differ from one another in general structural shape even though their molecular formulas are the same. They also will illustrate how it is possible for molecules to join together to form different carbohydrates.

3. How many atoms of carbon are there in each molecule of glucose? _____
   fructose? _____ and galactose? _____
4. Write the molecular formulas for glucose_____ fructose_____ and galactose _____
5. Compare the number of hydrogen atoms to the number of oxygen atoms in each sugar. What is the ratio of hydrogen to oxygen? (i.e., how many hydrogen atoms are there for each oxygen atom?) _____
   How do they compare to the ratio in water? _____
6. The structural arrangement of **C, H,** and **O** in glucose, fructose, and galactose differs. This helps explain why different model shapes are used for each monosaccharide.

Molecules of monosaccharides may have the same molecular formula but differ in three-dimensional structures. This is called isomerism. Using the three models and structural formulas, describe isomerism in you own words. _____

_____

B. Double sugars or disaccharides:

Two monosaccharide molecules can chemically join together to form a large carbohydrate molecule called a double sugar, or disaccharide. When a glucose molecule chemically joins with another glucose molecule, a double sugar know as maltose is formed. When a glucose molecule joins with a fructose molecule, a different double sugar called sucrose is produced.

1. In your team, construct a glucose and a fructose model using the illustration in Fig. 1 as a guide.
2. Attempt to join the two molecules and build a sucrose molecule. Will the sucrose molecule stay together? _____
3. It will be necessary to remove an **—OH** end from one molecule and an **—H** end from another in order to join the molecules. Does this enable the two molecules to be joined together? _____ If so, do so.
4. The **—OH** and **—H** ends removed from the glucose and fructose can now be joined to form what familiar compound? _____ Do so.
5. In your team, construct a maltose by joining together two glucose molecules. Remember to remove **—OH** and **—H** ends to ensure proper joining.
6. Write the molecular formula for maltose. _____
   (Use structural formulas as a guide and remember that $\mathbf{H_2O}$ was lost.)
7. Write the molecular formula for sucrose _____
8. What are the ratios of hydrogen atoms to oxygen atoms for both molecules? _____
   How does the ratio of **H** to **O** atoms compare in sucrose and maltose? _____
   In glucose and fructose? _____ In water? _____
9. Compare the model of sucrose to the model of maltose. Does isomerism exist in double sugars? _____
10. How many monosaccharide molecules are needed to form a disaccharide molecule? _____

C. Complex sugars or polysaccharides:

Just as double sugars were formed from two monosaccharide molecules, complex sugars are formed when many single sugars are joined together chemically. The exact number of glucose molecules attached to form these polysaccharides is not known. The two most common polysaccharides in biology are starch and cellulose. They consist of long chains of glucose molecules joined together.

1. With another team, construct a starch molecule by joining four glucose molecules. This represents only a small part of a starch molecule because starch consists of hundreds of glucose molecules. It will be necessary to dismantle the previously made molecules.
2. What must be removed from some of the glucose molecules in order to join them? _____
3. Using only one of the middle "glucose" molecules of the model, determine the molecular formula of starch. (Remember that a molecule of water has been lost from each glucose molecule when it joined with the others.) _____
4. How does the ratio of **H** to **O** atoms in starch compare with the ratio in double sugars? _____
   In single sugars? _____ In water? _____

Interpretations:

1. **Synthesis** means the "process by which simple compounds are united to form more complex materials." **Dehydration** means "loss of water." Explain why chemists refer to the joining of monosaccharide molecules to form disaccharides as a dehydration synthesis reaction. _____
2. Why is the joining of four glucose molecules in forming a polysaccharide an example of dehydration synthesis? _____
3. The word carbohydrate is derived from carbon and water (hydrate). Explain why this combination correctly describes this chemical group. _____

Student's Name _____ Date _____

LAB-AIDS® #505-11 Molecules of Life Kit
Student Worksheet and Guide

Biologists nowadays depend upon chemists for much of their understanding of life and the life processes. Therefore, an understanding of some chemical concepts important to living things is necessary.

Carbohydrates, fats, proteins and nucleic acids are the four major groups of organic molecules found in living organisms.

The lipids are the fats, oils and waxes. Like carbohydrates, fats contain carbon, hydrogen and oxygen, but the proportion of energy when combined with oxygen.

With this lab exercise you will be expected to: 1) Understand the structures of alcohols and fatty acids; 2) Construct molecular models of fat; 3) Be able to distinguish between models and actual chemical formulas of molecules; and 4) Be able to determine the molecular characteristics of fats.

Procedure:

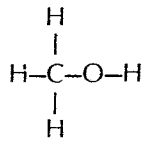
Students should work independently or in teams as directed by their instructor. It will be necessary for each student to complete his own worksheet while *possibly* sharing a packet of molecular parts with other students. The packet of molecular parts consists of:

15	Carbon (C) - tetrahedral electrons - black	32	Hydrogen (H) - single electron - white
5	Oxygen (O) - double electrons - blue	51	Electron bond - plastic tube - white

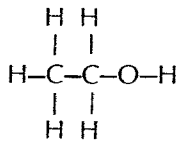
I. FATS

On a molecular basis, all fats are somewhat similar. Just as carbohydrates are composed of smaller molecules called monosaccharides, all fats are composed of smaller molecules. The smaller molecules in fats are glycerol (an alcohol) and fatty acids.

A. Alcohols are organic compounds that have the hydroxide (—OH) radical. Two examples of common alcohols are shown in Fig. 1.
B. Glycerol is an alcohol with three hyroxide groups as shown in Fig. 2.



METHYL ALCOHOL
CH_3OH



ETHYL ALCOHOL
CH_3CH_2OH

FIG. 1. Two common alcohols: Methyl alcohol and Ethyl alcohol.

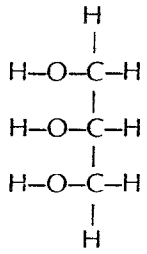


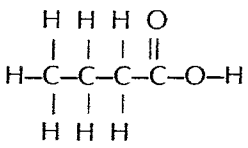
FIG. 2. Glycerol.

1. What elements are present in glycerol? _____
2. Are there any elements in glycerol that are not in carbohydrates? _____
3. What is the molecular formula for methyl alcohol? _____
   ethyl alcohol? _____ ; glycerol? _____
4. Build a structural model of methyl alcohol, ethyl alcohol and glycerol.
5. What is the ratio of hydrogen atoms to oxygen atoms in glycerol? _____
   How does this ratio compare with the hydrogen atoms to oxygen atoms ratio in carbohydrates? _____
6. Dismantle the models of methyl alcohol and ethyl alcohol. _____

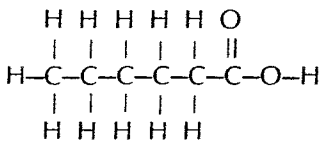
C. Fatty Acids

The second molecule which contributes to forming fat is a long molecule called a fatty acid. Many different fatty acids exist, but all are similar in several ways.

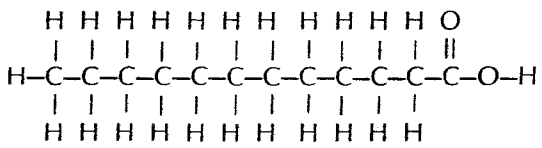
1. The structural formulas of three fatty acids are shown in Fig. 3.



BUTYRIC ACID



CAPROIC ACID



LAURIC ACID

FIG. 3. Structural formulas of Butyric acid, Caproic acid, and Lauric acid.

2. Construct **one** model of the fatty acids. (Each one of three students will build a different model so that all three models will be available for each group of three students.)

The models constructed represent the three-dimensional shape of the molecules. They illustrate that individual molecules of fatty acids do differ from one another in the **R** group (a long hydrocarbon chain) and that they all contain a carboxyl group (–COOH). Therefore, a general formula for organic acids is **R–COOH.**

3. Examine the structural formulas and the models of the three fatty acids.
4. What elements are present in all fatty acids? _____
5. What is the molecular formula of Butyric acid? _____
   Caproic acid? _____ ; Lauric acid? _____
6. Does a 2 to 1 ratio of hydrogen atoms to oxygen atoms exist in fatty acids? _____
7. Is the ratio of hydrogen atoms to oxygen atoms the same in each fatty acid? _____
   Give specific examples of the ratios for each acid. Butyric acid? _____
   Caproic acid? _____ ; Lauric acid? _____
8. Note that the carboxyl group ($-\overset{\overset{\displaystyle O}{\|}}{C}-O-H$) is found in all three fatty acids.

D. Forming fats

A fat molecule consists of one glycerol molecule and three fatty acid molecules joined together.

9. With two other students (teams), attempt to join together the glycerol molecule with the three different fatty acids. Will the fat molecule stay together? _____
10. It will be necessary to remove three –OH ends from the glycerol molecule and the –OH ends from the glycerol molecule and the –H end from each of the fatty acids carboxyl end in order to join the molecules. Does this enable the molecules to be joined together? _____ If so, do so.
11. Join the –H and –OH ends. What chemical substance is found when the –H and –OH ends are joined? _____
12. Production of a fat molecule is a chemical reaction. A chemical shorthand way of expressing the formation of a fat is as follows: **Fatty acids + Glycerol → Fat + Water**
13. How many water molecules are formed when one fat molecule is produced? _____

Many fats exist in living things. The wide variety of fats are formed by different combinations of fatty acid molecules.

Interpretations:

1. Dehydration means "water loss." Synthesis means "to put together." Explain why the chemical process responsible for building a fat or protein molecule is call dehydration synthesis. _____
2. What two types of molecules are needed to form a fat molecule? _____
3. How does a glycerol molecule differ from a carbohydrate molecule? (Use structural formulas for comparison.) _____
4. How does a fatty acid molecule differ from a carbohydrate molecule? _____

Student's Name _____ Date _____

LAB-AIDS® #505-12 Molecules of Life Kit
Student Worksheet and Guide

Carbohydrates, fats, proteins and nucleic acids are the four major groups of organic molecules found in living organisms.

This Lab-Aids kit deals with the important class of organic molecules known as proteins. They are the main structural and growth components of cells in tissues such as skin, hair, muscle and blood. Other proteins serve in a regulatory capacity as enzymes or hormones. Proteins always contain nitrogen in addition to carbon, hydrogen and oxygen. Phosphorus and sulfur are also found in many proteins.

The **amino acid** is the basic structural unit of all proteins. There are only about 20 different amino acids known to exist in proteins; all of them have a similar basic structure. The general structural formula of an amino acid is shown in Fig. 1.

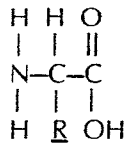


FIG. 1 The generalized structure of an amino acid molecule.

Procedure:

Students should work independently or in teams of 2 as directed by their instructor. It will be necessary for each student to complete his own worksheet while *possibly* sharing a packet of molecular parts with another student. The packet of molecular parts consists of:

14	Carbon (C) - tetrahedral electrons - black
4	Nitrogen (N) - tetrahedral electrons - red
9	Oxygen (O) - double electrons - blue
32	Hydrogen (H) - single electron - white
58	electron bond - plastic tube - white

1. Examine the structural formula for an amino acid in Fig. 1. Construct a model using the molecular parts provided leaving the R portion open.

2. Note that the amino acid has an amino (NH_2) group at one end and an acid (carboxyl) - (COOH) group at the other end. R stands for radical (an atom or a group of atoms). The uniqueness of each amino acid is determined by the atoms in the R position.

3. The structural formulas of four (4) representative amino acids are shown in Fig. 2. Glycine is the simplest amino acid, with only a single hydrogen atom in the R position. Complete the model previously constructed.

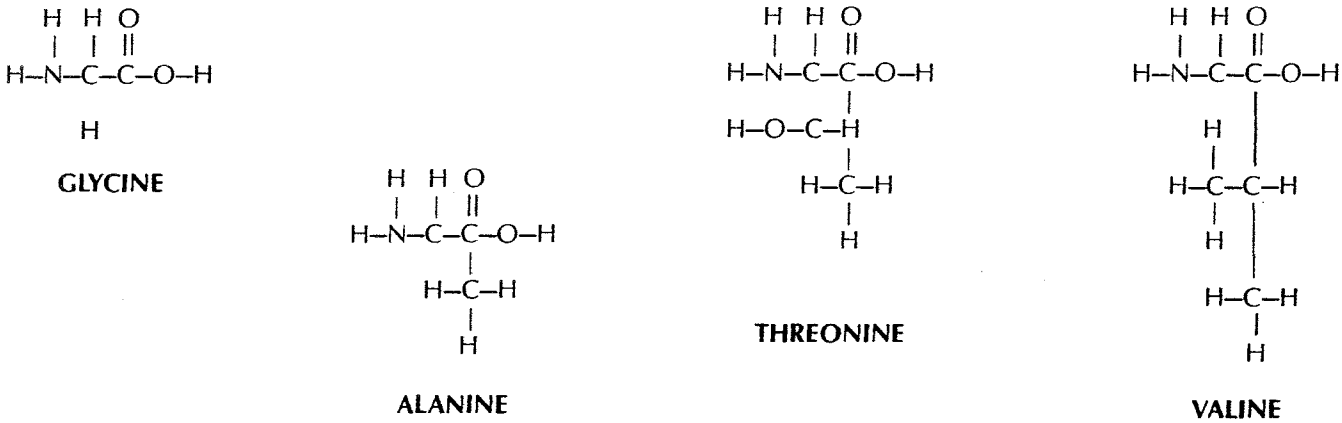


FIG. 2. Structural formulas of representative amino acids.

Student's Name _____ Date _____

Study the structural formulas of Fig. 2.

a. What is the molecular formula of glycine? (Add the correct subscripts) C H O N

b. What is the molecular formula of alanine? (Add the correct subscripts) C H O N

c. Are the molecular formulas for all amino acids the same? _____

If you have studied the chemistry of fats, can you identify the end arrangement found in fatty acids as well as amino acids? _____

What is it called? _____

The remaining amino acids have more complex arrangements of atoms in the R position.

4. Construct two different amino acids (dismantling glycine if necessary). Join with another team so that all four representative amino acids are built and available for two teams.

The models constructed represent the three dimensional shapes of the molecules.

A protein is formed by the chemical bonding of many amino acid molecules. Proteins may contain as few as 50 or as many as 5000 or more amino acids. The chemical combinations of two amino acids is called a **dipeptide**. The amino group of one amino acid molecule combines with the acid group of another in what is called a **peptide bond**. In this reaction one molecule of water is formed by the removal of a hydrogen atom from the amino group of one amino acid molecule and an OH group from the acid group of the other. This process is called **dehydration synthesis** and is shown in Fig. 3.

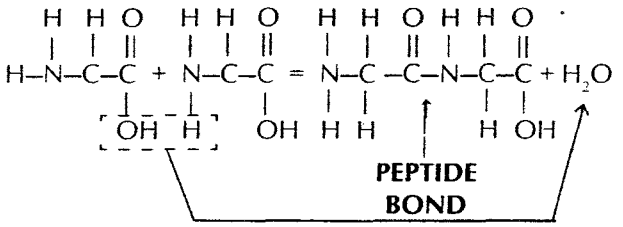


FIG. 3. Dehydration synthesis reaction involving two molecules of the amino acid glycine. Note that the reaction is reversible.

5. Combine the two amino acid molecules built by removing the proper –OH group and –H group as needed to form a protein. Rejoin the –OH and –H ends.

a. What chemical substance is formed when the –OH and –H is joined?

_____

As in fats and carbohydrates, the reverse of this reaction, called **hydrolysis**, restores a water molecule at the site from which it was originally removed.

Interpretations:

1. Dehydration means "water loss." Synthesis means "to put together." Explain why the chemical process responsible for building a protein molecule is called dehydration synthesis. _____

2. What type of molecule is needed to form protein molecules? _____

3. How do amino acid molecules differ from fatty acid molecules? _____

4. How might a human muscle protein molecule differ from a horse muscle protein molecule? _____

5. What purpose is served by the loss of an –H and –OH end from two molecules as they join together during dehydration synthesis? _____

6. A protein consisting of four amino acids undergoes hydrolysis. How many water molecules must be broken down and reattached to amino acid molecules during this process? _____