Name Date

Chemistry of Carbohydrates

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Biologists today depend upon chemists for much of their understanding of life and life processes. Therefore, an understanding of some chemical concepts important to living things is necessary. Carbohydrates make up a large group of chemical compounds found in cells. Carbohydrates are used for energy or cell structures.

In this investigation, it is expected that you:

(a) apply information about water to answer questions about carbohydrates
(b) distinguish between paper molecule models and actual chemical formulas of molecules
(c) determine the molecular characteristics of carbohydrates

Materials

scissors

Procedure

Part A. Water

Information can be gained from an examination of the chemical formula of water, H_2O.

Question: What elements make up water?

Answer: H represents the element hydrogen. O represents the element oxygen.

Question: What does the number 2 following H tell you?

Answer: The number 2 represents the number of atoms of hydrogen. A number following a chemical symbol, called a subscript, indicates the number of atoms for that particular element.

Question: Why does oxygen not have a subscript?

Answer: No subscript indicates there is only one atom.

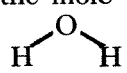
Question: How many molecules of water are represented by the formula H_2O?

Answer: One molecule is represented. The number of molecules is indicated by a number to the left of the formula. No number indicates one molecule.

Question: What is a molecular formula? What is the molecular formula of water?

Answer: A molecular formula shows the *total number* of atoms for *each element* in a molecule. The molecular formula of water is H_2O.

Question: What is a structural formula? What is the structural formula of water?

Answer: A structural formula attempts to show the three-dimensional organization of the molecule. The structural formula of water is 

Question: What do the lines between O and H in the structural formula of water represent?

Answer: These lines represent chemical bonds or points of attachment between the atoms.

Part B. Carbohydrates

An important group of biological compounds are the saccharides, or more commonly, the sugars of carbohydrates. Carbohydrates contain carbon (C), hydrogen, and oxygen. The many different types of sugars have been grouped into three main categories: monosaccharides, disaccharides, and polysaccharides.

Monosaccharides or Single Sugars

• Examine the structural formulas and the corresponding models for the three monosaccharides on page 29.

The paper models *do not* represent the true three-dimensional shapes of the molecules. They are to be used to illustrate that individual molecules of carbohydrates do differ from one another in general structural shape. Also, they show how it is possible for molecules to join together to form different carbohydrates.

1. What three elements are present in monosaccharides? _____

_____

2. How many atoms of carbon are there in each molecule of glucose, fructose, and galactose?

_____

3. Write the molecular formulas for glucose, fructose, and galactose. Add the proper subscripts to the following: glucose, C H O ; fructose, C H O ; galactose, C H O .

4. Compare the number of hydrogen atoms to the number of oxygen atoms in each sugar. What is the ratio of hydrogen to oxygen (that is, how many hydrogen atoms are there for each oxygen atom)? _____

5. How do the ratios of hydrogen to oxygen atoms compare in galactose, glucose, and fructose? _____

_____

How do they compare to the ratio in water? ____

_____

6. The structural arrangement of C, H, and O in glucose, fructose and galactose differs. Does this difference help to explain why different model shapes are used for each monosaccharide? _____

7. Molecules of monosaccharides may have the same molecular formula but differ in three-dimensional structure. This is called isomerism. Describe isomerism in your own words using the models and structural formulas as a guide. _____

_____

_____

_____

Disaccharides or Double Sugars

Two monosaccharide sugar molecules can join together chemically to form a larger carbohydrate molecule called a double sugar, or disaccharide. By chemically joining a glucose molecule with another glucose molecule, a double sugar called maltose is formed. By joining a glucose molecule with a fructose molecule, a different double sugar called sucrose is produced. Use the paper models on page 29 to illustrate this process.

• Cut out a glucose and a fructose paper model molecule from page 29. You may want to paste the page on lightweight cardboard before cutting out the models. *Cut along solid lines only.* Attempt to join the two molecules to show a sucrose molecule.

8. Will the sucrose molecule stay together? _____

• In order to join the molecules, remove an -OH end from one molecule and an -H end from another. Cut along dotted lines.

9. Does this aid in joining the two molecules?

_____

10. The -H and -OH ends removed from the glucose and fructose can join to form what familiar compound? _____

• Construct a maltose molecule by joining together two glucose paper model molecules. Remember to remove -H and -OH ends to ensure proper joining.

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11. Write the molecular formula for maltose by adding the correct subscripts. (Use structural formulas as a guide and remember that H_2O was lost.) C H O

12. Write the molecular formula for sucrose by adding the correct subscripts. C H O

13. Determine 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? _____

14. Does isomerism exist in double sugars? (Compare your model of sucrose to your model of maltose.) _____

15. How many monosaccharide molecules are needed to construct a disaccharide molecule? _____

Polysaccharides or Complex Sugars

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

• Construct a starch molecule by joining three glucose molecules. This will represent only a small part of a starch molecule because starch consists of hundreds of glucose molecules. Before beginning, reattach the -H and -OH ends to all glucose molecules.

16. What must be removed from some of the glucose molecules in order to join them? _____

17. Using only the middle "glucose" molecule of your model, determine the molecular formula of starch. (Remember that a molecule of water has been lost from the middle glucose molecule when it joined with the others.) Add the correct subscripts. C H O

18. How does the ratio of H to O atoms in starch compare with the ratio in double sugars? _____

In single sugars? _____

In water? _____

Analysis

1. What three elements make up all carbohydrates? _____

2. What is the ratio between H and O atoms in carbohydrates and water? _____

3. What small molecules make up all disaccharides? _____

4. What small molecules make up all polysaccharides? _____

_____

5. What common molecule is always formed when monosaccharide molecules are joined? _____

_____

6. "Mono" means one, "di" means two, and "poly" means many. Why are these terms used in describing the three types of sugars? _____

_____

_____

7. Synthesis means "putting together." Dehydration means "loss of water." Explain why chemists refer to the joining of monosaccharide molecules to form disaccharides as a dehydration synthesis reaction. _____

_____

_____

8. Why is the joining of three glucose molecules in forming a polysaccharide an example of dehydration synthesis? _____

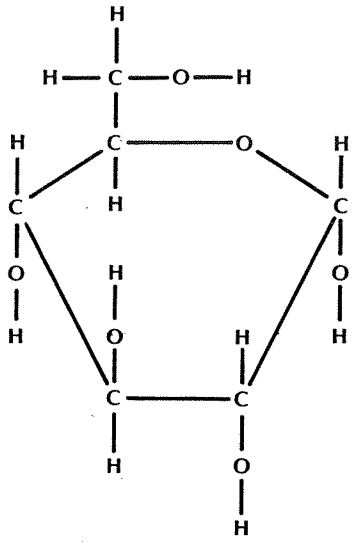
_____

9. The word carbohydrate is derived from carbon and water (hydrate). Explain why this combination correctly describes this chemical group. _____

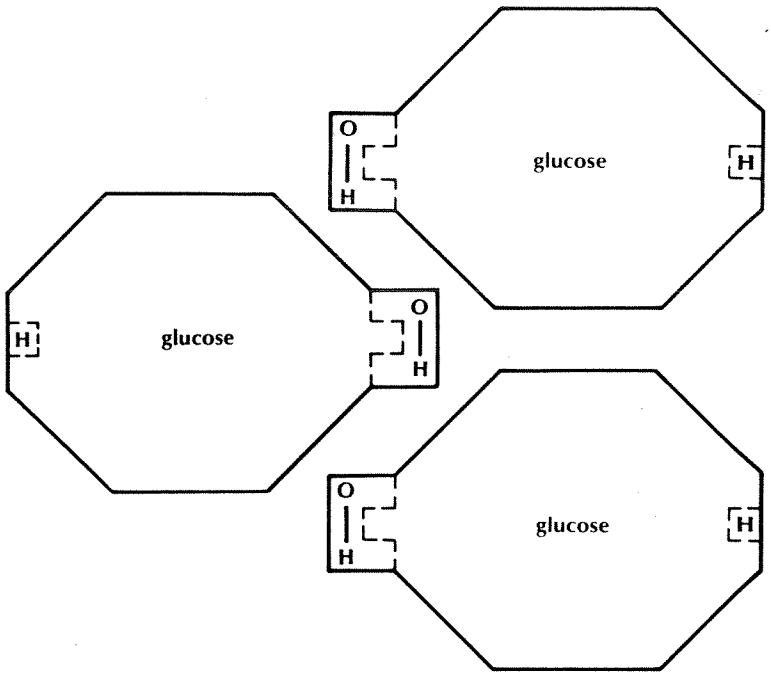
_____

_____

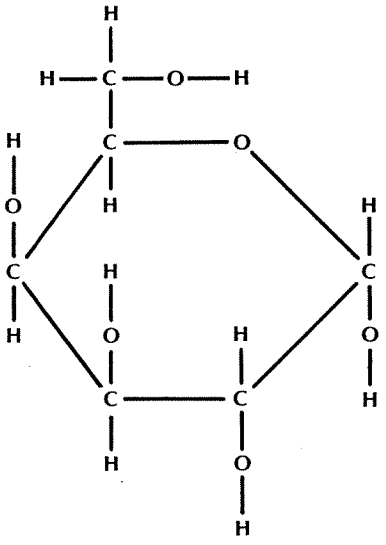
structural formula of glucose



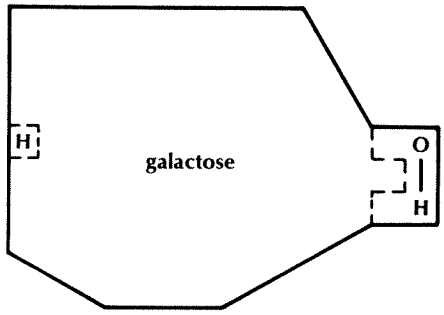
models of glucose



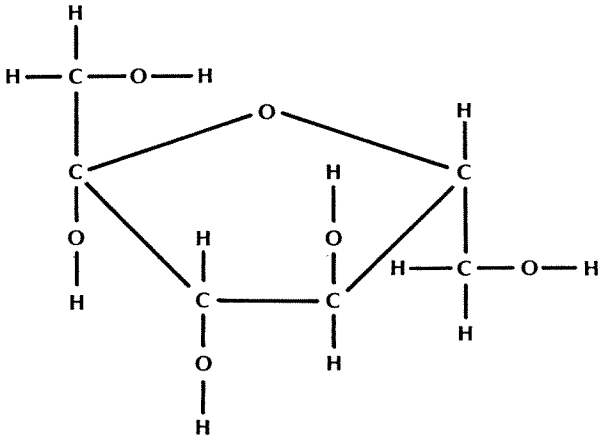
structural formula of galactose



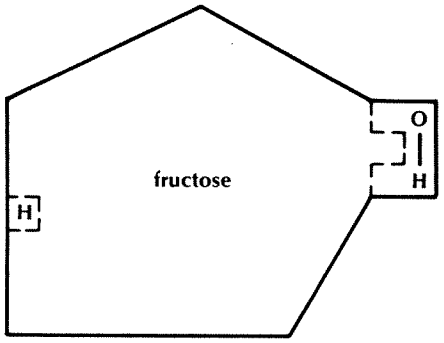
model of galactose



structural formula of fructose



model of fructose



(only end atoms of hydrogen and oxygen are shown in models)