MEGA MOLECULES

Name: ____________________
Date: ____________________

Modeling Activity for Carbohydrates

Time required: one 50-minute period

Introduction

Carbohydrates are naturally occurring compounds that are produced by green plants in the process of photosynthesis. Carbohydrates are an important part of a healthy diet. Carbohydrates provide the body with the fuel it needs for physical activity and for proper organ function. Carbohydrates come from a wide array of foods such as bread, beans, milk, popcorn, potatoes, cookies, spaghetti, corn, and cherry pie.

In this activity, you will;
(a) learn to interpret the molecular and structural formulas of some carbohydrates.
(b) construct molecular models of some carbohydrates.

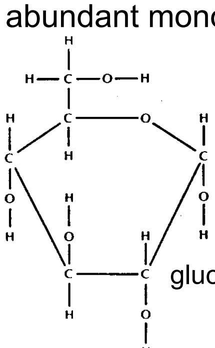
Materials

The Chemistry of Carbohydrates Kit or Food Chemistry Set

The Structure of Monosaccharides

Carbohydrates contain three different elements—carbon (C), hydrogen (H), and oxygen (0). There are many different types of carbohydrates. They have been placed into three groups based on size: monosaccharides, disaccharides, and polysaccharides.

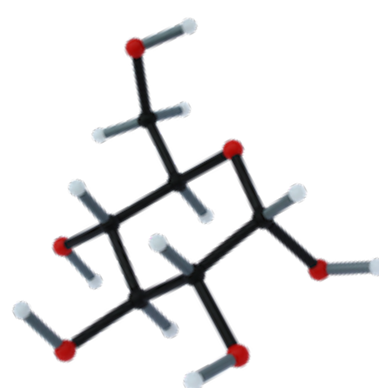
The simplest group of carbohydrates is the monosaccharides. The prefix "mono" means one. Monosaccharides are sugars that are made up of only one molecule. Thus, they are called single sugars. The one molecule, however, can have different shapes due to a different arrangement of atoms. Common hexose monosaccharides are glucose, fructose, and galactose. Glucose is the most abundant monosaccharide in the body.



glucose

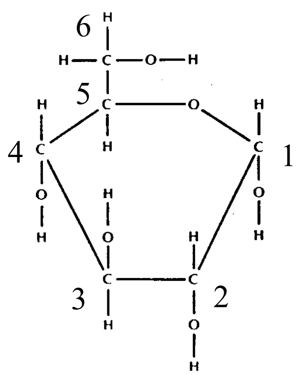
Examine the structural formula and the molecular model of glucose.

Carbon: black models
Hydrogen: white models
Oxygen: red models

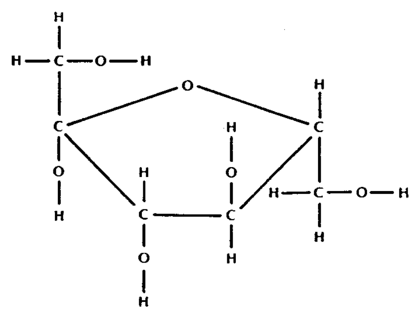


Fructose is found in fruit, honey, and high-fructose corn syrup, and is used in the production of soft drinks, desserts, and confections. The presence of fructose in these products makes it a major sugar in our diet. Galactose is the third major monosaccharide of nutritional importance. Notice that glucose and galactose are almost identical except that the hydrogen (-H) and the hydroxyl group (-OH) on carbon-4 are reversed. Galactose is not usually found free in nature in large quantities but, rather, combines with glucose to form a disaccharide called lactose that is present in milk and other dairy products.

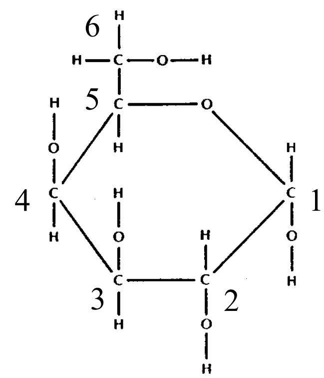
glucose



fructose



galactose



Examine the structural formulas for these three sugars. Using the Chemistry of Carbohydrates Kit of molecular models and the structural formulas for the three monosaccharides above, build models of glucose, fructose, and galactose.

1. What three elements are present in glucose, fructose, and galactose? ______
____

2. How many atoms of carbon are present in a molecule of
glucose? ____
fructose? ____
galactose? ____

3. Add subscripts to the following that indicate the proper molecular formula. Do this by counting the total number of carbon, hydrogen, and oxygen atoms in each molecule.
glucose C__H__O__
fructose C__ H__O__
galactose C__H__O__

4. How many times larger is the number of hydrogen atoms than oxygen atoms in a molecule of
glucose? ____
fructose? ____
galactose? ____

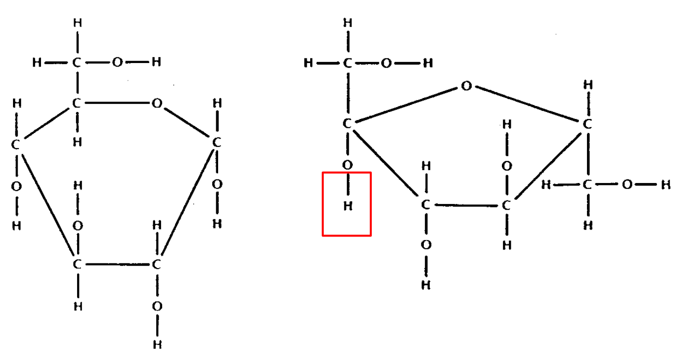
5. The molecular formula for water is H_2O.
(a) How many times larger is the number of hydrogen atoms than oxygen atoms in a molecule of water? ____
(b) Is the number the same for monosaccharides and for water? _____________

6. Compare the model of glucose to fructose.
(a) Are they exactly the same in shape? _______________________________
(b) Are they both monosaccharides? __________________________________

Procedure for the Construction of a Disaccharide

Two monosaccharide sugar molecules can join together chemically to form a larger carbohydrate molecule called a double sugar, or disaccharide. The prefix "di-" means two. By chemically joining a glucose molecule with a fructose molecule, a double sugar called sucrose and a water molecule are produced.

glucose fructose



In order to join the molecules, remove an –OH end from one molecule and an -H end from another.

7. Does removing the -H and –OH ends allow the molecules to fit together? ____

8. The -H and –OH ends that were removed can also fit together with each other to form a molecule. This new molecule has a molecular formula of ___________ and is called ____

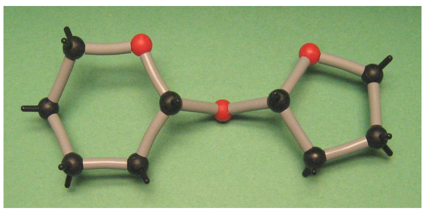
9. Write the molecular formula for sucrose. ______________________________

10. How many times larger is the number of hydrogen atoms than oxygen atoms in a disaccharide? ____

11. How many monosaccharide molecules are needed to form one sucrose molecule? ____

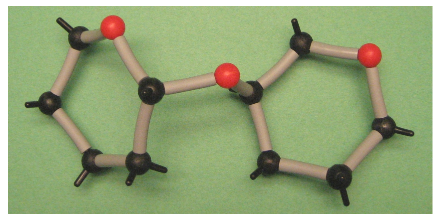
The production of a disaccharide is a chemical reaction called a dehydration synthesis reaction. In such a reaction, the elements of water are removed and the glucose and fructose molecules are joined to form the disaccharide. One carbon on each participating monosaccharide is chemically bound together by oxygen. Two forms of this C–O–C bond exist in nature, called alpha (α) bonds and beta (β) bonds. The beta bond makes lactose difficult to digest for individuals who show a low activity of the enzyme lactase. Human intestinal enzymes cannot digest long chains of glucose molecules that are joined together by beta bonds.

Ring-structure of sucrose, table sugar



Alpha (α) bond between glucose and fructose

Ring-structure of lactose, milk sugar



Beta (β) bond between glucose and galactose

Procedure for the Construction of a Polysaccharide

Just as double sugars were formed from two single sugar molecules using a dehydration synthesis reaction, polysaccharides and water are formed when many single sugars are chemically joined together. The prefix "poly-" means many. Starch, glycogen, and cellulose are the three most common polysaccharides in biology. Starch, the major digestible polysaccharide in our diet, is composed of many glucose units linked by alpha bonds and is the storage form of energy in plants. Glycogen, the storage form of carbohydrate in humans and other animals, is a glucose polymer with alpha bonds and numerous branches. Cellulose, dietary fiber, is a straight-chain glucose polymer with beta bonds that are not broken down by human digestive enzymes.

Disassemble the molecular models of sucrose and galactose and build three molecules of glucose as shown on page 1.

Construct a portion of 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.

12. What must be removed from the glucose model molecules in order to have them easily fit together? ____

The molecular formula for a polysaccharide is written as $(C_6H_{10}O_5)_n$. The n equals the number of times the $C_6H_{10}O_5$ group is repeated. You can see this group as the middle glucose of your model. REMEMBER: The -H and –OH ends of the middle molecule are missing.

13. How many times larger is the number of hydrogen atoms than oxygen atoms in a polysaccharide molecule? ____

14. Describe the process of dehydration synthesis. ________________________

____

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

____

____

16. Why are carbohydrates important in our diet? ________________________

17. Which elements are found in carbohydrates? _________________________

18. Name the three major groups of carbohydrates. _______________________

____

19. Name the most abundant monosaccharide in the human body. ___________

20. Name three foods that are good sources of carbohydrates. ______________

____

Modeling Activity for Proteins

Time required: one 50-minute period

Introduction

Consuming enough protein is vital for maintaining health. Proteins form important structures in the body, help regulate many body functions, and can fuel body cells. Thousands of substances in the body are made of proteins. Amino acids are the building blocks for proteins. Plants combine nitrogen from the soil with carbon and other elements to form amino acids. Then plants assemble the amino acids into proteins through the process of protein synthesis. Our daily protein intake comes mostly from vegetables, meat, poultry, fish, eggs, milk, and cheese. Proteins are ingested and chemically digested to produce amino acids. Those amino acids are then reassembled to generate specific proteins in many configurations and size that are crucial to the regulation and maintenance of the body.

In this activity, you will:

(a) learn that all protein molecules are made up of smaller molecules called amino acids.

(b) use structural formulas and molecular models of amino acids to determine how these molecules join together to form proteins molecules.

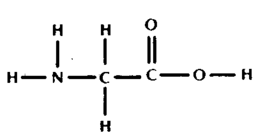
Materials

The Chemistry of Proteins Kit or Food Chemistry Set

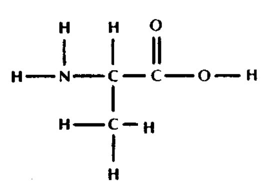
The Structure of Amino Acids

Amino acids contain carbon (C), hydrogen (H), oxygen (O), and nitrogen (N), and some contain sulfur (S). Body proteins are made using 20 amino acids. Examine the structural formulas of the three representative amino acids shown below.

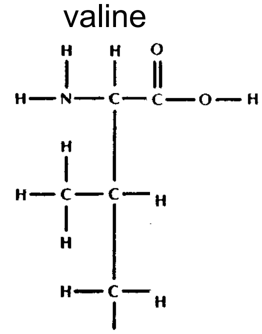
glycine



alanine



valine

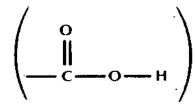


21. What is the molecular formula for the amino acid glycine? C__H__O__N__

What is the molecular formula for the amino acid alanine? C__H__O__N__
What is the molecular formula for the amino acid valine? C__H__O__N__

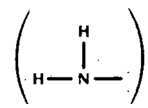
22. Are the molecular formulas for all amino acids the same? _______________

23. Note the end of each amino acid containing the oxygen atoms. This special end arrangement of carbon, hydrogen, and oxygen is called a carboxyl group.



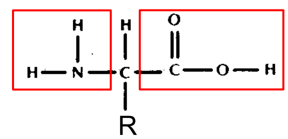
Is the carboxyl group present in all amino acids shown? ____________________

24. Another end arrangement in all amino acids consists of a nitrogen atom and two hydrogen atoms. This group is called an amino group.



Do structural formulas for all amino acids have amino groups? _______________

Each amino acid is composed of a central carbon bonded to four groups. The first three of these groups are the carboxyl group, the amino group, and a hydrogen atom. The fourth group, often signified by *R*, completes the amino acid. Each of the 20 amino acids has a unique *R* group.
If the *R* group is hydrogen, the amino acid is glycine.

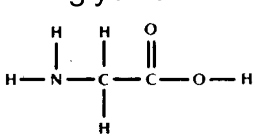


Procedure for Joining Amino Acids

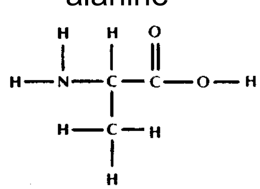
Amino acids are joined by a strong, covalent peptide bond. An amino group reacts with a carboxyl group and a water molecule is split off in an enzyme-catalyzed reaction called dehydration synthesis. The body can synthesize many different proteins by joining the 20 types of amino acids with peptide bonds.

Using the Chemistry of Proteins Kit of molecular models, construct the three amino acids: glycine, alanine, and valine. Atom models are easily inserted into the bonds by using a twisting motion.

glycine

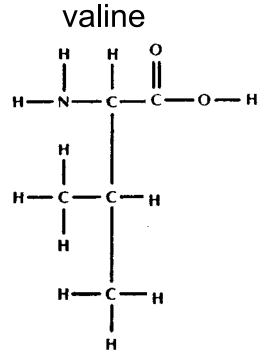


alanine

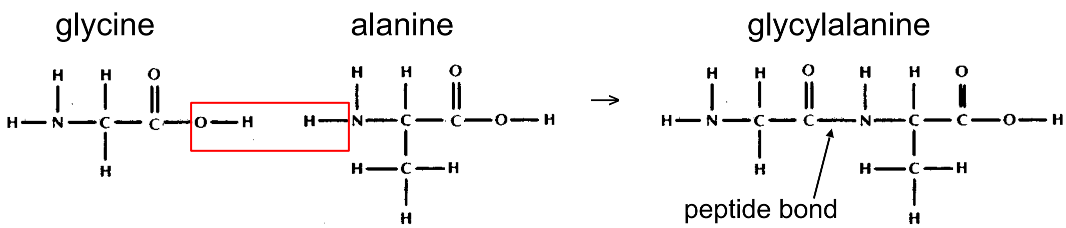


Carbon: black models
Hydrogen: white models
Oxygen: red models
Nitrogen: blue models

valine



Join the molecules by removing as many –OH and –H groups as needed from the amino acids. All three amino acid molecules can be joined in this manner to form a tripeptide. Join them in the order glycine (gly) - alanine (ala) - valine (val). Rejoin the leftover –OH and –H groups.



In the human body, amino acids are joined together by a dehydration synthesis reaction. In such a reaction, the elements of water are removed and the amino acids are joined forming a peptide bond. The sequential order of amino acids determines the protein's ultimate shape and function. Body functions such as blood clotting, fluid balance, hormone and enzyme production, visual processes, and cell repair require specific proteins. The human body uses 20 different amino acids from protein-containing foods. Of the 20 types of amino acids found in food, nine must be consumed as food. These nine amino acids are known as essential amino acids. If you fail to consume an adequate amount of protein containing the essential amino acids for weeks at a time, many metabolic processes slow down. This is because the body does not have enough of the essential amino acids available to build the proteins it needs. For example, the immune system no longer functions efficiently when it lacks key proteins, thereby increasing the risk of infections, disease, and eventually death.

25. What chemical elements are found in all proteins? ____________________

26. What small molecules are needed to form a large protein molecule? ______

____

27. How might one amino acid differ from another? ______________________

28. Describe the process of dehydration synthesis. ______________________

____

29. How might one protein differ from another? ___________________________

____

30. Name three foods that are good sources of proteins. __________________

Modeling Activity for Lipids (Fats)

Time required: two 50-minute periods

Introduction

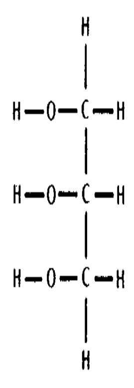
Lipids are a diverse group of chemical compounds that are related by their insolubility in water. Lipids include phospholipids, sterols, and triglycerides. Phospholipids are important parts of cell membranes. Sterols such as cholesterol form vital biological compounds including hormones. Triglycerides store energy, protect certain organs, transport fat-soluble vitamins, and help insulate the body. Triglycerides are the most common type of lipid found in the body and in foods. Triglycerides include the edible fats and oils in our diets - substances such as olive oil, corn oil, peanut oil, butterfat, and lard. Triglycerides that are solid or semisolid at room temperature are classified as fats, and occur predominantly in animals. Those triglycerides that are liquid are called oils and originate chiefly in plants. Fats and oils are made up of two different kinds of molecules, glycerol and fatty acids.

In this activity, you will
(a) examine the molecular structure of glycerol and fatty acids.
(b) use structural formulas and molecular models of glycerol and fatty acids to determine how these molecules join together to form fats and oils.

Materials

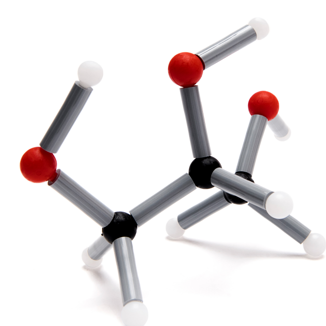
The Chemistry of Lipids (Fats) Kit or Food Chemistry Set

The Structure of Glycerol



Examine the structural formula and molecular model of glycerol.

Carbon: black models
Hydrogen: white models
Oxygen: red models



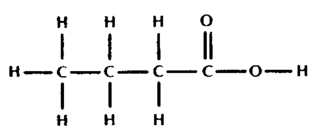
31. What elements are present in glycerol? ______________________________

32. What is the molecular formula for glycerol? (Add the number of atoms of each element and record the totals.) C__H__O__

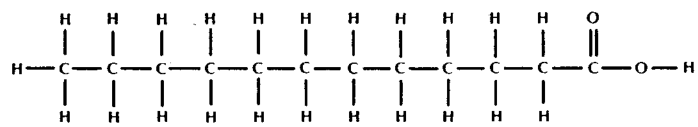
33. In carbohydrates there are twice as many hydrogen atoms as oxygen atoms. Are there twice as many hydrogen atoms as oxygen atoms in glycerol? _______

The Structure of Fatty Acids

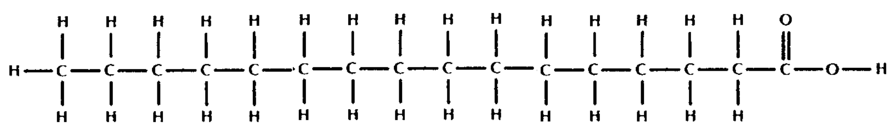
Fatty acids are the second kind of molecule found in triglycerides. Saturated fatty acids have no double bonds between the carbon atoms of the fatty acid chain and are fully saturated with hydrogen atoms. Some common examples of saturated fatty acids are butyric acid with 4 carbon atoms (contained in butter), lauric acid with 12 carbon atoms (contained in coconut oil, palm oil), and palmitic acid with 16 carbon atoms (contained in palm oil, hence the name, and meat). Studies have found that people whose diets are high in saturated fatty acids, including butyric, lauric, and palmitic acid, have a higher prevalence of coronary heart disease.



butyric acid



lauric acid



palmitic acid

34. What elements are present in all fatty acids? _________________________

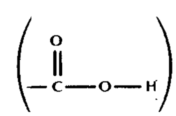
35. What is the molecular formula for butyric acid? C__H__O__

36. What is the molecular formula for lauric acid? C__H__O__

37. What is the molecular formula for palmitic acid? C__H__O__

38. What pattern appears in the fatty acid molecules regarding the number of oxygen atoms? ____

Note the end of each fatty acid containing the oxygen atoms. This special end arrangement of carbon, hydrogen, and oxygen is called a carboxyl group.

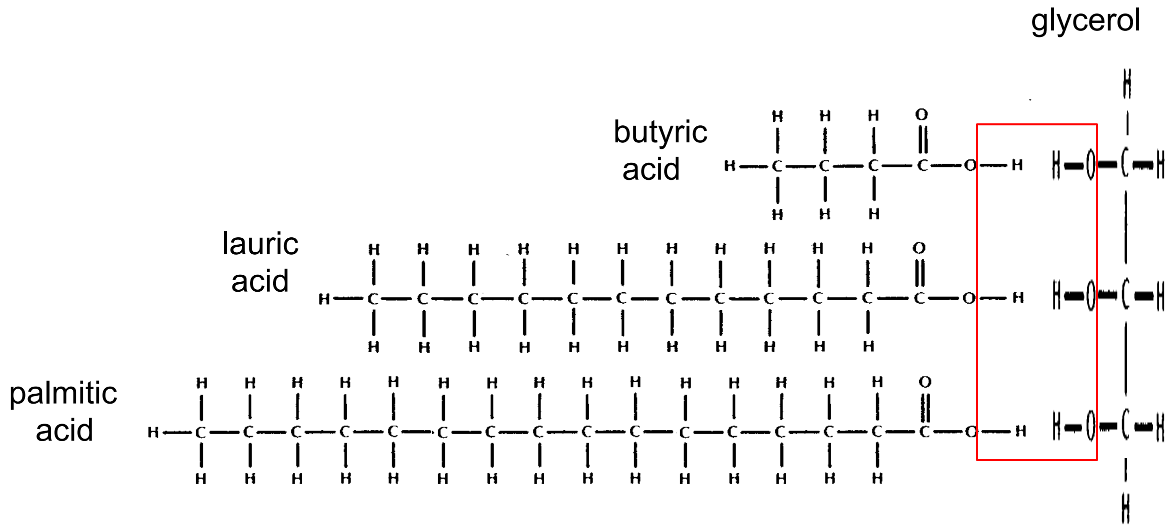


39. Is the carboxyl group present in all fatty acids shown? __________________

40. List a similarity between glycerol and fatty acids. ______________________

Procedure for Construction of a Saturated Fat

Using molecular models in the Chemistry of Lipids (Fats) Kit and the structural formulas for glycerol and the three fatty acids, build the models of glycerol, butyric acid, lauric acid, and palmitic acid.



Remove the three -OH ends from the glycerol molecule and the three -H ends from the fatty acids. Now join the molecules to form 1 molecule of saturated fat.

41. How many glycerol molecules are needed to form 1 molecule of fat? ______

42. How many fatty acid molecules are needed to form 1 molecule of fat? _____

43. Join the leftover –H and –OH ends from your models. What chemical substance is formed when the –H and –OH ends are joined? _______________

Production of a triglyceride (fat) is a chemical reaction called a dehydration synthesis reaction. In such a reaction, the elements of water are removed and the glycerol and fatty acid molecules are joined to form the triglyceride. A chemical shorthand way of expressing the formation of a triglyceride is as follows:

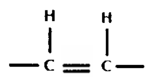
Glycerol + Fatty Acids → Triglyceride + Water Molecules

44. How many water molecules are formed when one triglyceride molecule is produced? ____

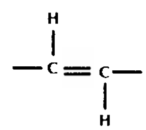
Procedure for Construction of an Unsaturated Fat

An unsaturated fatty acid has one or more double bonds between carbon atoms. Double bonds may be in either a *cis* or *trans* isomer, depending on the geometry of the double bond. In the *cis* conformation hydrogens are on the same side of the double bond, whereas in the *trans* conformation they are on opposite sides. Most fatty acids in the *trans* conformation are not found in nature and are the result of human processing (eg, hydrogenation).

cis isomer

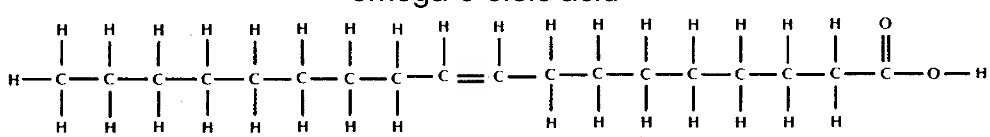


trans isomer

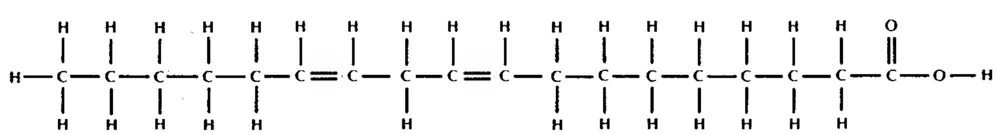


The geometry of the cis double bond introduces a bend in the molecule. Oleic acid (18:1, with 18 carbon atoms and one double bond), has a "kink" in it, while linoleic acid (18:2, with 18 carbon atoms and two double bonds), has a more pronounced bend. Linolenic acid (18:3, with 18 carbon atoms and three double bonds), favors a hooked shape. The location of the carbon-carbon double bonds in the carbon chain of an unsaturated fatty acid makes a big difference in how the body metabolizes it. If the first double bond starts at nine carbons from the methyl (H_3C-) end of the fatty acid, it is called an omega-9 fatty acid. In foods, oleic acid is the major omega-9 fatty acid; linoleic acid is the major omega-6 fatty acid; and alpha-linolenic acid is the major omega-3 fatty acid. The diet provides linoleic and linolenic acids, which are called "essential fatty acids," meaning fatty acids that are essential to life and health and cannot be synthesized by the human body.

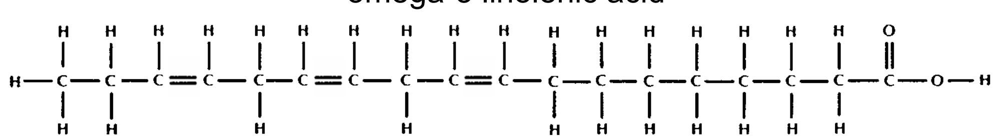
omega-9 oleic acid



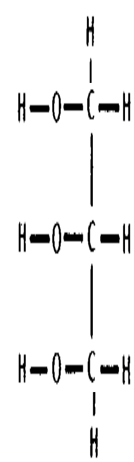
omega-6 linoleic acid



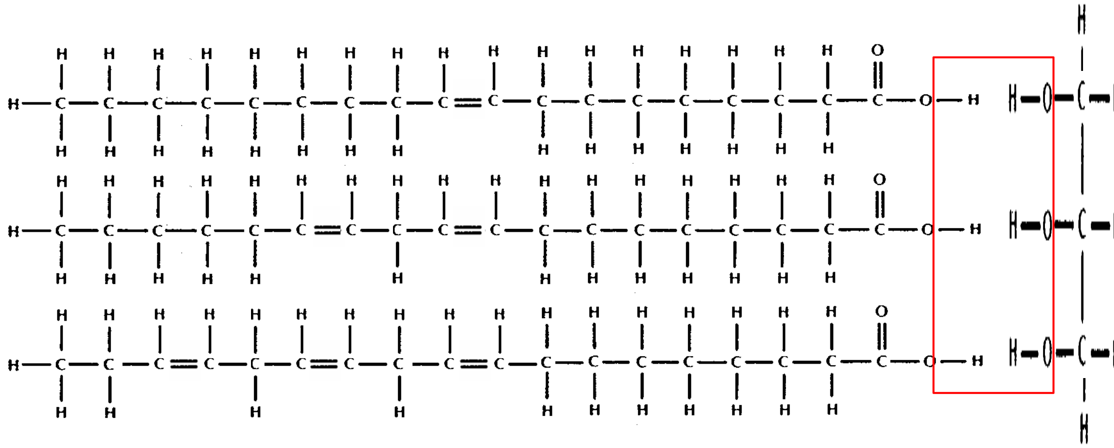
omega-3 linolenic acid



glycerol



Using your molecular models, construct the glycerol molecule and the three fatty acid molecules, oleic acid, linoleic acid, and linolenic acid, shown above.
Remove the three -OH ends from the glycerol molecule and the three -H ends from the fatty acids. Now join the molecules to form 1 molecule of an unsaturated fat.



45. How many glycerol molecules are needed to form 1 molecule of an unsaturated fat? ____

46. How many fatty acid molecules are needed to form 1 molecule of an unsaturated fat? ____

47. Join the leftover –H and –OH ends from your models. What chemical substance is formed when the –H and –OH ends are joined? _______________

48. How does the cis double bonds in the fatty acids affect the shape of the unsaturated fat molecule? ______________________________________

Plants predominately make unsaturated cis fats and these fats are called "oils" since these fats are liquid at room temperature. Unsaturated fats are liquids (oils) at room temperature because the cis bonds limit the ability of the fatty acids to pack closely together and increase the melting temperature of the unsaturated fat. Unsaturated cis fats obtained from plants (e.g., corn oil or olive oil) are preferred in the diet over saturated fats and trans unsaturated fats. The molecular geometry of saturated fats and unsaturated trans fats allows these molecules to assume a linear shape (since they have no kinks) that leads to efficient packing and plaque formation in blood vessels. Studies have found that people whose diets are high in saturated fats and trans unsaturated fats had higher levels of blood cholesterol and plaque formation on blood vessel walls, and a higher prevalence of coronary heart disease.

49. Why are lipids an important part of our diet? ___________________________

50. What chemical elements are found in all lipids? ________________________

51. What two molecule types are needed to form a triglyceride or fat molecule and how many of each type of these molecules are needed? _________________

52. What chemical substance is formed when the –H ends of the fatty acids and –OH ends of the glycerol are joined during the chemical reaction to form a triglyceride or fat molecule? ____

53. How does a saturated fatty acid differ from an unsaturated fatty acid? _____

____

____

54. Why are unsaturated fats liquids at room temperature? _________________

____

55. Which types of lipids should you avoid in your diet? ____________________