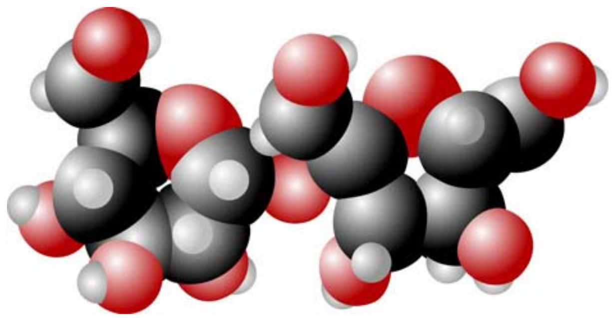
Chapter 17

An Introduction to Organic Chemistry, Biochemistry, and Synthetic Polymers



Section Goals and Introductions

Section 17.1 Organic Compounds

Goals

- *To describe carbon-based compounds, called organic compounds.*
- *To describe the different ways that organic molecules can be represented and show you how to convert from one way to the others.*
- *To show how you can recognize different types of organic compounds.*

There are millions of different organic (carbon-based) compounds. The task of studying them becomes much easier when you recognize that organic compounds can be categorized according to structural similarities that lead to similarities in the compounds' important properties. For example, instead of studying the alcohols methanol, ethanol, and 2-propanol separately, you can study the characteristics of alcohols in general, because all alcohols have very similar characteristics. This section introduces you to some of the different types of organic compounds, shows you how your can recognize substances in each category, and shows you several ways of describing the structures of organic compounds.

Section 17.2 Important Substances in Food

Goal: To describe the different types of chemicals found in our food: carbohydrates, amino acids and proteins, fats and oils (triglycerides), and steroids.

Your understanding of organic compounds can be applied to understanding biomolecules, which are organic compounds that are important in biological systems. Like the organic compounds described in Section 17.1, recognizing that biomolecules can be placed in categories facilitates learning about them. You will learn about the structures of biomolecules in the categories of carbohydrates, amino acids, proteins, triglycerides, and steroids.

Section 17.3 Digestion

Goal: To describe the chemical changes that take place in digestion.

This section gives you a glimpse at the subject of biochemistry by describing some of the chemical changes of digestion. This includes a brief description of how enzymes facilitate this process. See the section on our Web site that describes a proposed mechanism for an enzyme reaction.

Internet: Chymotrypsin Protein Hydrolysis

Section 17.4 Synthetic Polymers

Goals

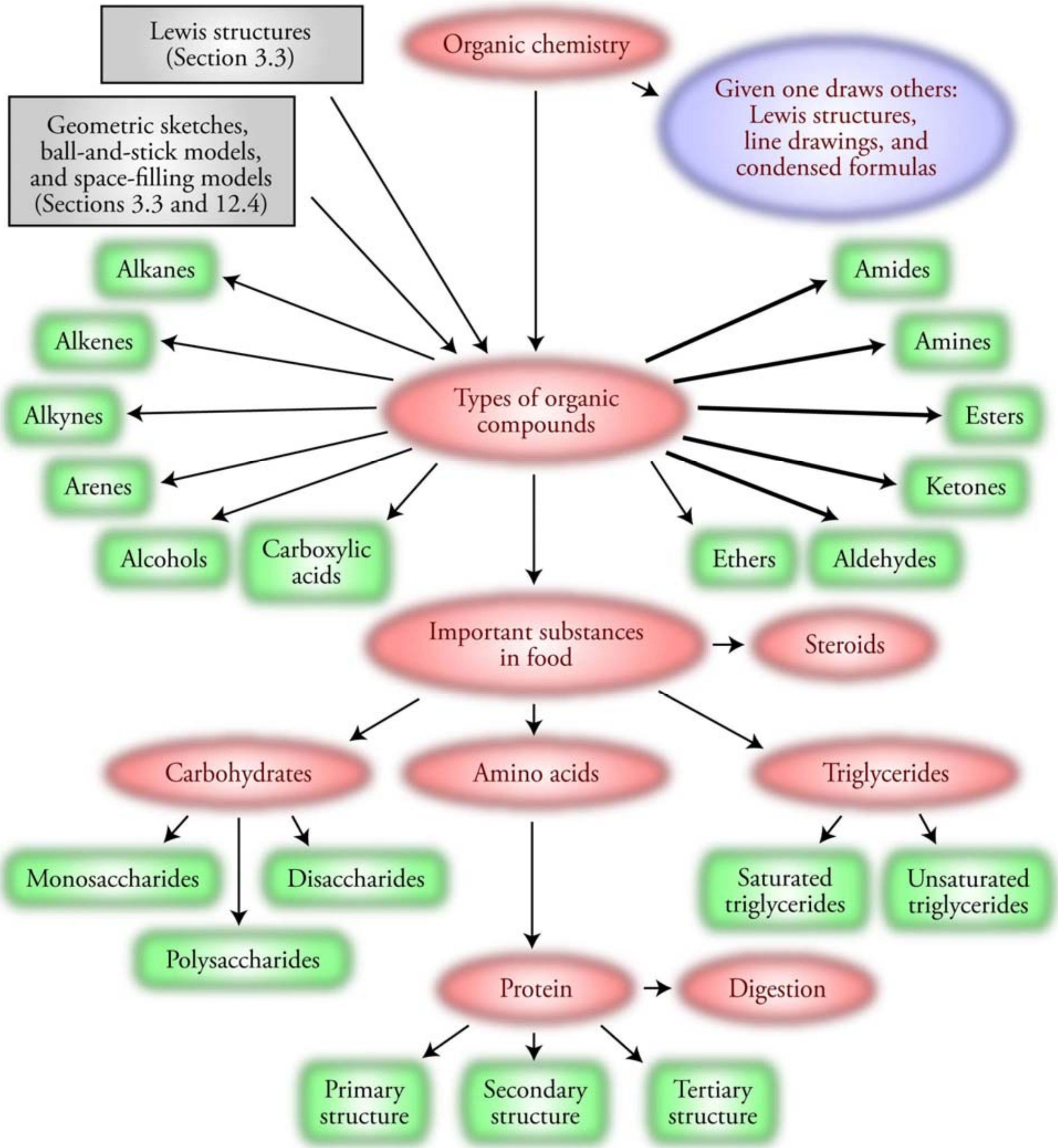
- *To describe synthetic polymers, including nylon, polyester, polyethylene, polypropylene, poly(vinyl chloride), and polystyrene.*
- *To describe the recycling of synthetic polymers.*

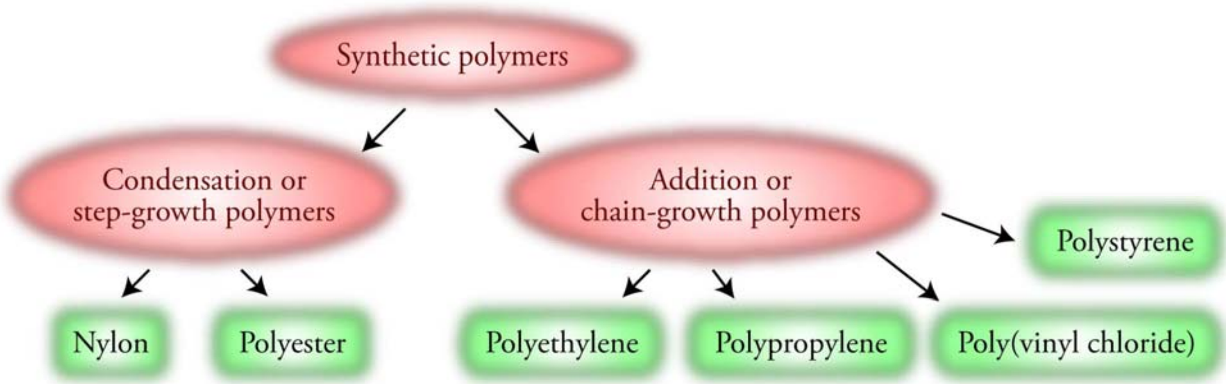
Scientists have developed ways of making many synthetic polymers that are similar to natural biomolecules. This section shows you how some of these polymers are made and describes their many different uses.

See the section on our Web site that provides more information on one type of polymer.

Internet: Addition (Chain-growth) Polymers

Chapter 17 Maps





Chapter Checklist

- ☐ Read the chapter quickly before the lecture that describes it.
- ☐ Attend class meetings, take notes, and participate in class discussions.
- ☐ Work the Chapter Exercises, perhaps using the Chapter Examples as guides.
- ☐ Study the Chapter Glossary and test yourself on our Web site:

  Internet: Glossary Quiz
- ☐ Study all of the Chapter Objectives. You might want to write a description of how you will meet each objective.
- ☐ To get a review of the most important topics in the chapter, fill in the blanks in the Key Ideas section.
- ☐ Work all of the selected problems at the end of the chapter, and check your answers with the solutions provided in this chapter of the study guide.
- ☐ Ask for help if you need it.

Web Resources

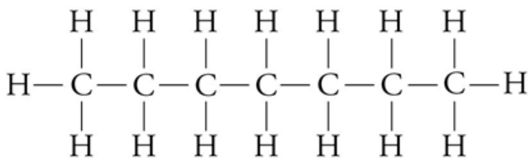
Internet: Chymotrypsin Protein Hydrolysis

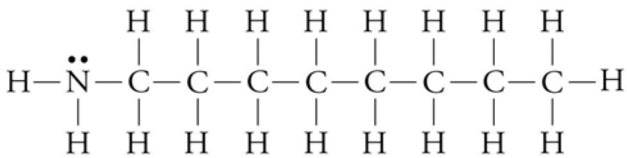
Internet: Addition (Chain-growth) Polymers

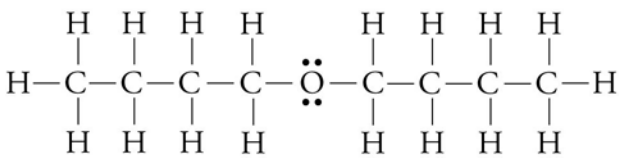
Internet: Glossary Quiz

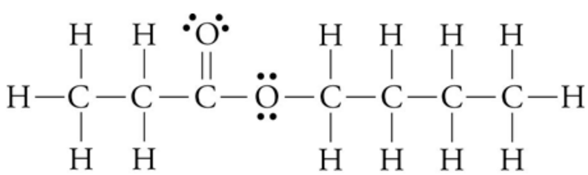
Exercises Key

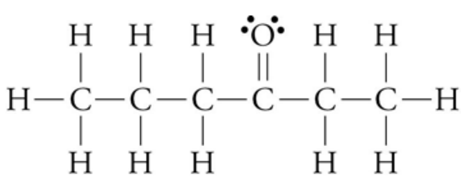
Exercise 17.1 - Organic Compounds: Identify each of these structures as representing an alkane, alkene, alkyne, arene (aromatic), alcohol, carboxylic acid, ether, aldehyde, ketone, ester, amine, or amide. *(Obj 3)*

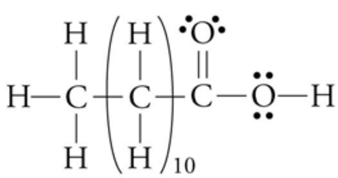
a.  **alkane**

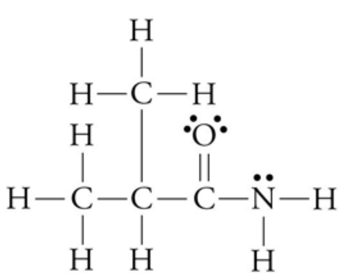
b.  **amine**

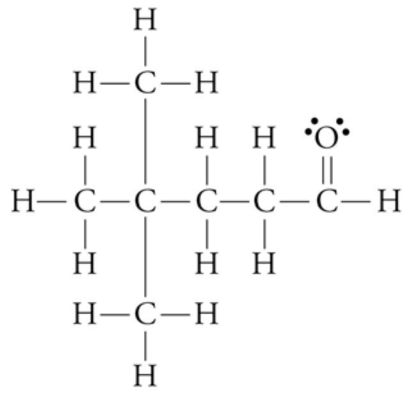
c.  **ether**

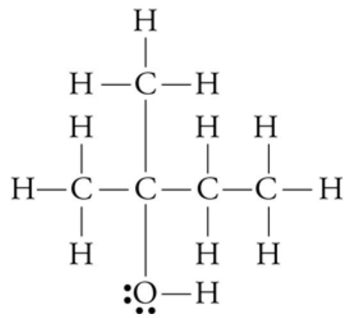
d.  **ester**

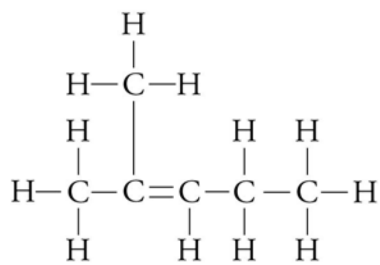
e.  **ketone**

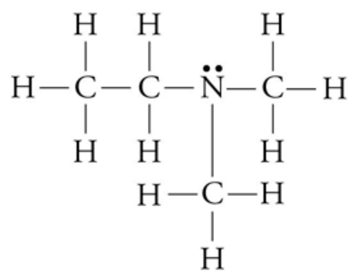
f.  **carboxylic acid**

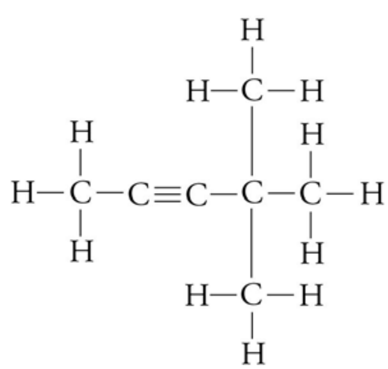
g.  **amide**

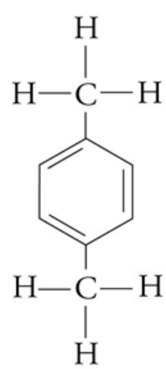
h.  **aldehyde**

i.  **alcohol**

j.  **alkene**

k.  **amine**

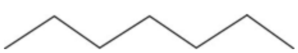
l.  **alkyne**

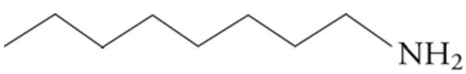
m.  **arene**

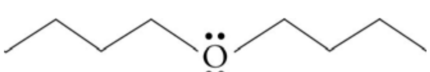
Exercise 17.2 - Condensed Formulas: Write condensed formulas to represent the Lewis structures in parts (a) through (l) of Exercise 17.1. *(Obj 2)*

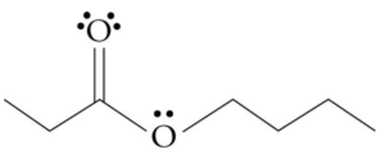
a. **$CH_3CH_2CH_2CH_2CH_2CH_2CH_3$ or $CH_3(CH_2)_5CH_3$**
b. **$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2NH_2$ or $CH_3(CH_2)_7NH_2$**
c. **$CH_3CH_2CH_2CH_2OCH_2CH_2CH_2CH_3$**
d. **$CH_3CH_2CO_2CH_2CH_2CH_2CH_3$ or $CH_3CH_2COOCH_2CH_2CH_2CH_3$**
e. **$CH_3CH_2CH_2COCH_2CH_3$**
f. **$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CO_2H$ or $CH_3(CH_2)_{10}CO_2H$ or $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2COOH$ or $CH_3(CH_2)_{10}COOH$**
g. **$(CH_3)_2CHCONH_2$**
h. **$(CH_3)_3CCH_2CH_2CHO$**
i. **$(CH_3)_2C(OH)CH_2CH_3$**
j. **$(CH_3)_2CCHCH_2CH_3$**
k. **$CH_3CH_2N(CH_3)_2$**
l. **$CH_3CCC(CH_3)_3$**

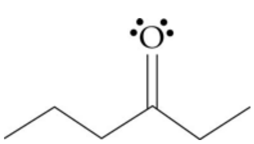
Exercise 17.3 - Line Drawings: Make line drawings that represent the Lewis structures in parts (a) through (j) of Exercise 17.1. *(Obj 2)*

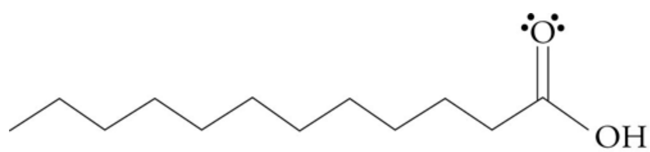
a. 

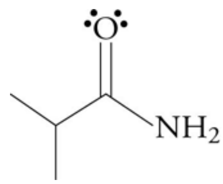
b. 

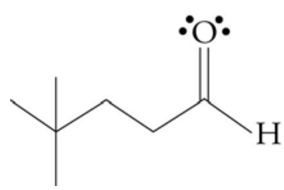
c. 

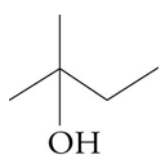
d. 

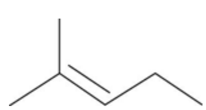
e. 

f. 

g. 

h. 

i. 

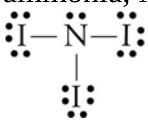
j. 

Review Questions Key

1. Draw a Lewis structure, a geometric sketch, a ball-and-stick model, and a space-filling model for methane, CH_4.

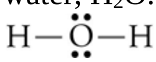
   See Figure 12.4 of the textbook.

2. Draw a Lewis structure, a geometric sketch, a ball-and-stick model, and a space-filling model for ammonia, NH_3.

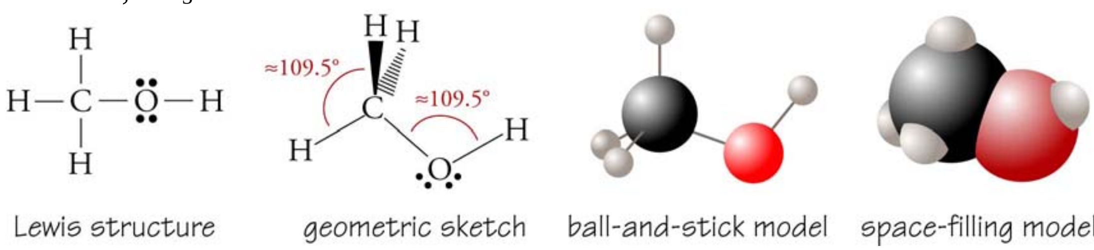
   See Figure 3.11 of the textbook.

3. Draw a Lewis structure, a geometric sketch, a ball-and-stick model, and a space-filling model for water, H_2O.

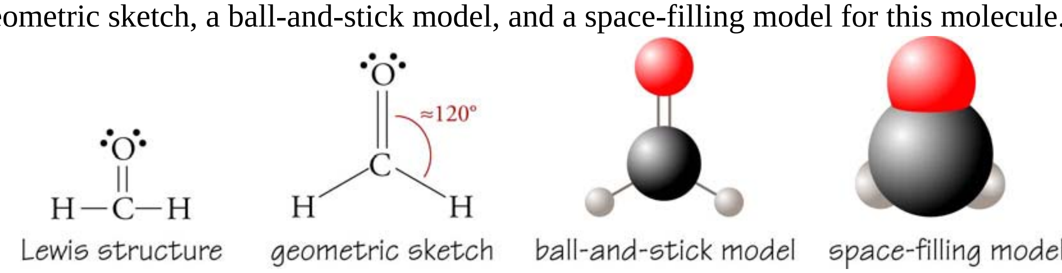
   

   See Figure 3.12 of the textbook.

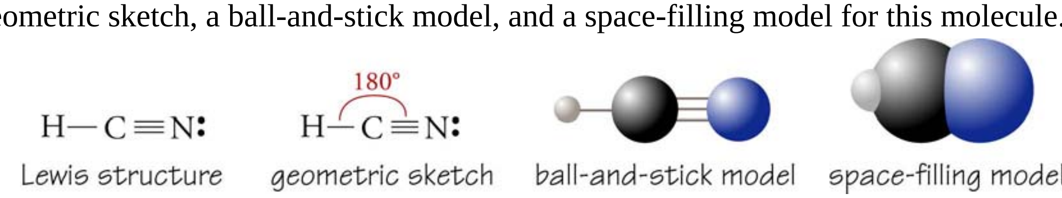
4. Draw a Lewis structure, a geometric sketch, a ball-and-stick model, and a space-filling model for methanol, CH_3OH.

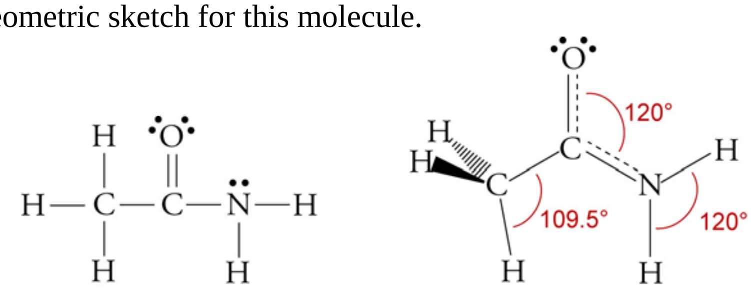
5. The following Lewis structure represents a molecule of formaldehyde, CH_2O. Draw a geometric sketch, a ball-and-stick model, and a space-filling model for this molecule.

6. The following Lewis structure represents a molecule of hydrogen cyanide, HCN. Draw a geometric sketch, a ball-and-stick model, and a space-filling model for this molecule.

7. The following Lewis structure represents a molecule of ethanamide, CH_3CONH_2. Draw a geometric sketch for this molecule.

Key Ideas Answers

8. Hydrocarbons (compounds composed of carbon and hydrogen) in which all of the carbon-carbon bonds are **single** bonds are called alkanes.
10. When a(n) **small section** of an organic molecule is largely responsible for the molecule's chemical and physical characteristics, that section is called a functional group.
12. Compounds that contain the **benzene ring** are called arenes or aromatics.
14. Ethers consist of two **hydrocarbon groups** surrounding an oxygen atom.
16. Sugars are monosaccharides and **disaccharides**. Starches and cellulose are **polysaccharides**.
18. Maltose, a disaccharide consisting of two **glucose** units.
20. Sucrose is a disaccharide that contains glucose and **fructose**.
22. Almost every kind of plant cell has **energy** stored in the form of starch. Starch itself has two general forms, **amylose** and **amylopectin**.
24. All the polysaccharides are polymers, a general name for large molecules composed of **repeating units**, called monomers.
26. Protein molecules are polymers composed of **monomers** called **amino acids**.
28. Condensation is a chemical reaction in which two substances combine to form a larger molecule with the release of a small molecule, such as **water**.
30. The arrangement of atoms that are **close to each other** in the polypeptide chain is called the secondary structure of the protein.
32. The fat stored in our bodies is our primary **long-term** energy source.
34. A process called **hydrogenation** converts liquid triglycerides to solid triglycerides by adding hydrogen atoms to the double bonds and so converting them to single bonds.
36. A triglyceride that still has one or more carbon-carbon **double bonds** is an unsaturated triglyceride.
38. As the starting material for the production of many important body chemicals, including hormones (compounds that help regulate chemical changes in the body), the steroid **cholesterol** is necessary for normal, healthy functioning of our bodies.
40. In digestion, disaccharides are broken down into **monosaccharides** (glucose, galactose, and fructose), polysaccharides into glucose, **protein** into amino acids, and fat into **glycerol** and **fatty acids**.
42. The digestion of proteins begins in the stomach. The **acidic** conditions there weaken the links that maintain the protein molecules' tertiary structure. This process is called **denaturation**, because the loss of tertiary structure causes a corresponding loss of the protein's "natural" function.
44. For an enzyme-mediated reaction to take place, the reacting molecule or molecules, which are called **substrates**, must fit into a specific section of the enzyme's structure called the **active site**. A frequently used analogy for the relationship of substrate to active site is the way a key must fit into a lock in order to do its job. Each active site has (1) a(n) **shape** that fits a specific substrate or substrates only, (2) side chains that attract the enzyme's particular substrate(s), and (3) side chains specifically positioned to speed the reaction.
46. When small molecules, such as water, are released in the formation of a polymer, the polymer is called a condensation (or sometimes **step-growth**) polymer.
48. Polyesters are made from the reaction of a(n) **diol** (a compound with two alcohol functional groups) with a di-carboxylic acid.

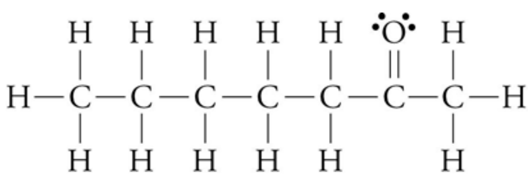
Problems Key

Section 17.1 Organic Compounds

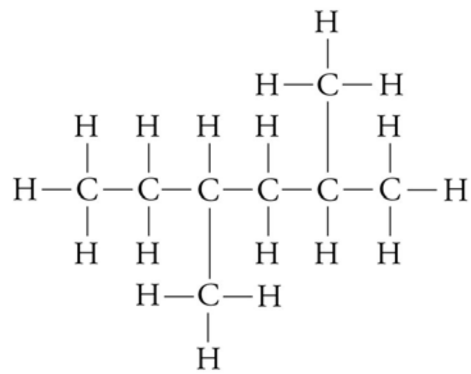
50. Classify each of the following as organic or inorganic (not organic) compounds.

a.	sodium chloride, NaCl, in table salt	**inorganic**
b.	hexane, C_6H_{14}, in gasoline	**organic**
c.	ethyl butanoate, $CH_3CH_2CH_2CO_2CH_2CH_3$, in a pineapple	**organic**
d.	water, H_2O, in your body	**inorganic**

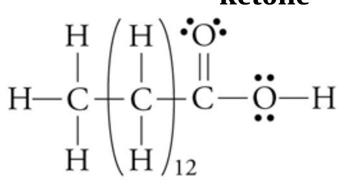
52. Identify each of these Lewis structures as representing an alkane, alkene, alkyne, arene (aromatic), alcohol, carboxylic acid, aldehyde, ketone, ether, ester, amine, or amide. *(Obj 3)*

a. 

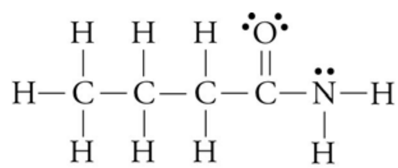
ketone

b. 

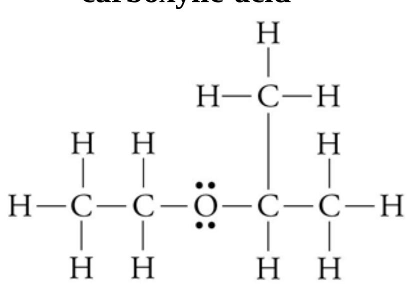
alkane

c. 

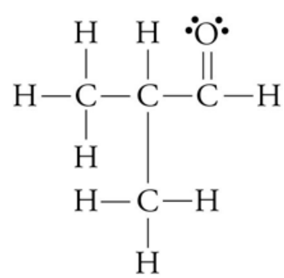
carboxylic acid

d. 

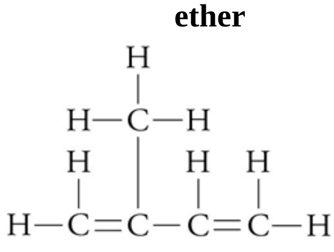
amide

e. 

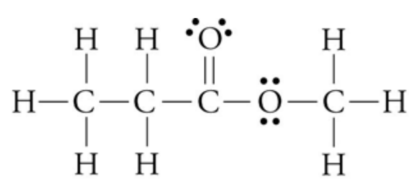
ether

f. 

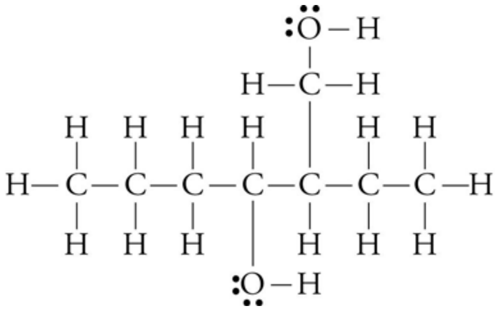
aldehyde

g. 

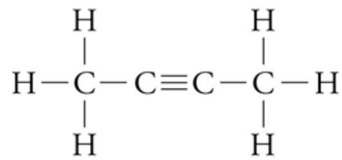
alkene

h. 

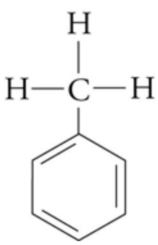
ester

i. 

alcohol

j. 

alkyne

k. 

arene

54. Write condensed chemical formulas to represent the Lewis structures in parts (a) through (j) of Problem 52. (For example, 2-propanol can be described as $CH_3CH(OH)CH_3$.) *(Obj 2)*

   a. **$CH_3(CH_2)_4COCH_3$ or $CH_3CH_2CH_2CH_2CH_2COCH_3$**

   b. **$CH_3CH_2CH(CH_3)CH_2CH(CH_3)_2$**
   or $CH_3CH_2CH(CH_3)CH_2CH(CH_3)CH_3$

   c. **$CH_3(CH_2)_{12}COOH$ or $CH_3(CH_2)_{12}CO_2H$**

   d. **$CH_3CH_2CH_2CONH_2$**

   e. **$CH_3CH_2OCH(CH_3)_2$ or $CH_3CH_2OCH(CH_3)CH_3$**

   f. **$(CH_3)_2CHCHO$ or $CH_3CH(CH_3)CHO$**

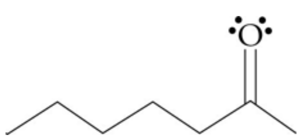
   g. **$CH_2C(CH_3)CHCH_2$**

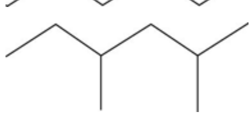
   h. **$CH_3CH_2COOCH_3$ or $CH_3CH_2CO_2CH_3$**

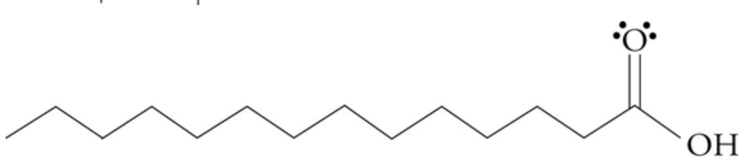
   i. **$CH_3CH_2CH_2CH(OH)$ $CH(CH_2OH)CH_2CH_3$**

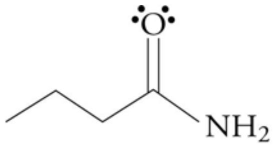
   j. **CH_3CCCH_3**

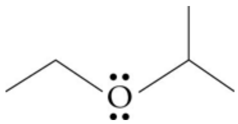
56. Write line drawings to represent the Lewis structures in Parts (a) through (i) of Problem 52. *(Obj 2)*

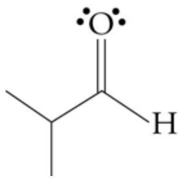
   a. 

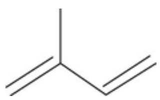
   b. 

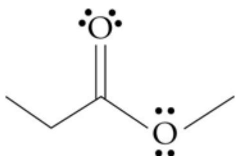
   c. 

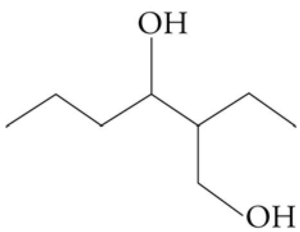
d. 

e. 

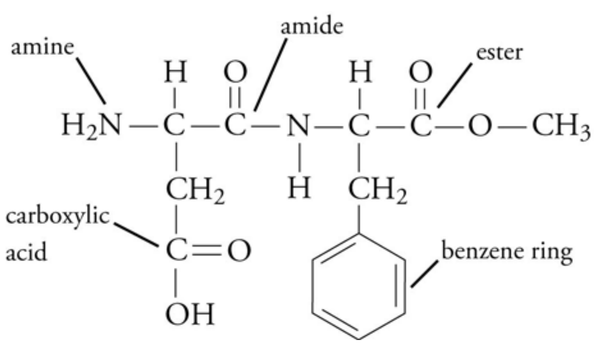
f. 

g. 

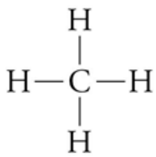
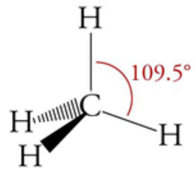
h. 

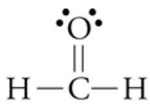
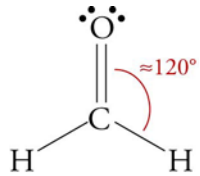
i. 

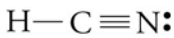
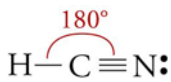
58. The chemical structure of the artificial sweetener aspartame is below. Identify all of the organic functional groups that it contains.



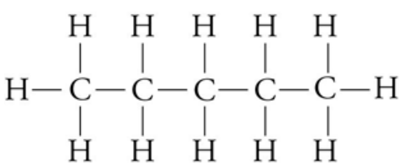
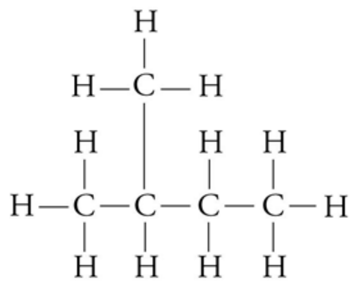
60. Draw geometric sketches, including bond angles, for each of the following organic molecules.

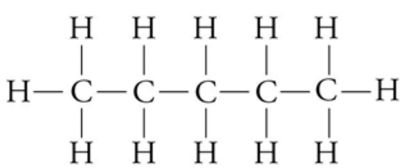
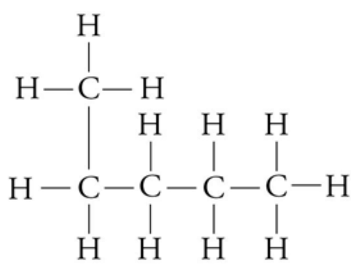
a.  

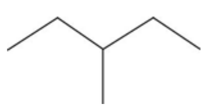
b.  

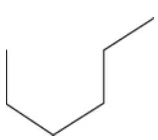
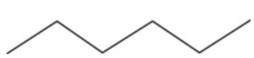
c.  

63. Because the structure for a particular alkane can be drawn in different ways, two drawings of the same substance can look like isomers. Are each of the following pairs isomers or different representations of the same thing?

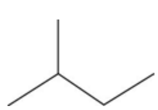
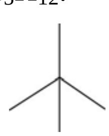
a.  and  **isomers**

b.  and  **same**

c.  and  **isomers**

d.  and  **same**

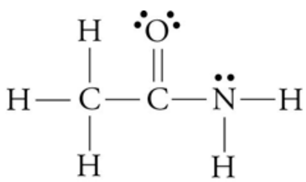
65. Draw line drawings for three isomers of C_5H_{12}.

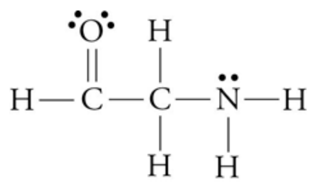
  

67. Two of the three isomers of C_3H_8O are alcohols and one is an ether. Draw condensed structures for these three isomers.

$CH_3CH_2CH_2OH$ **$CH_3CH(OH)CH_3$** **$CH_3OCH_2CH_3$**

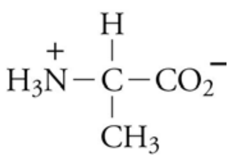
69. Draw a Lewis structure for an isomer of C_2H_5NO that is an amide, and draw a second Lewis structure for a second isomer of C_2H_5NO that has both an amine functional group and an aldehyde functional group.

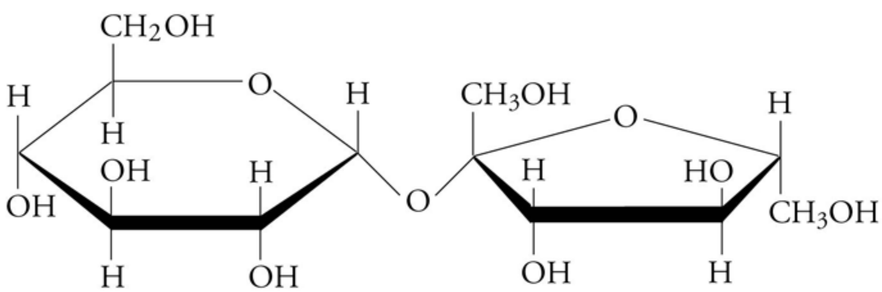


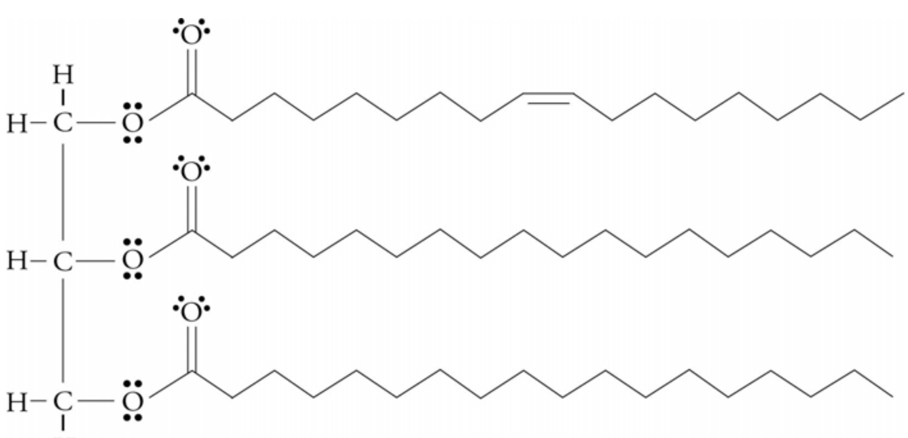


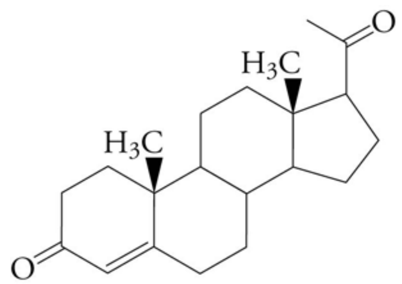
Section 17.2 Important Substances in Food

72. Identify each of the following structures as representing a carbohydrate, amino acid, peptide, triglyceride, or steroid. *(Obj 4)*

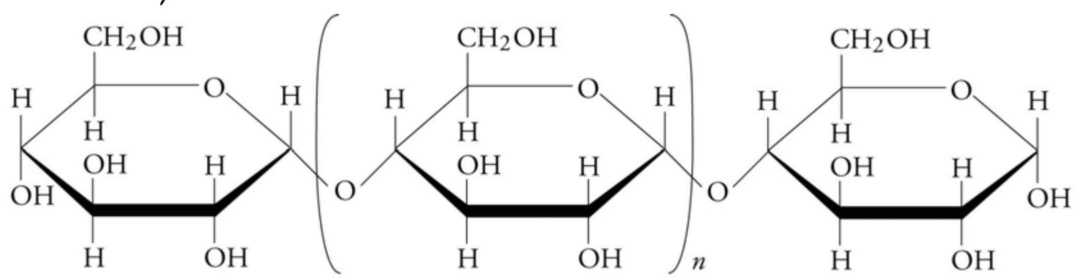
a.  **amino acid**

b.  **carbohydrate**

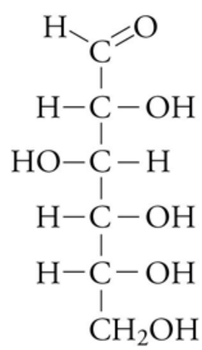
c.  **triglyceride**

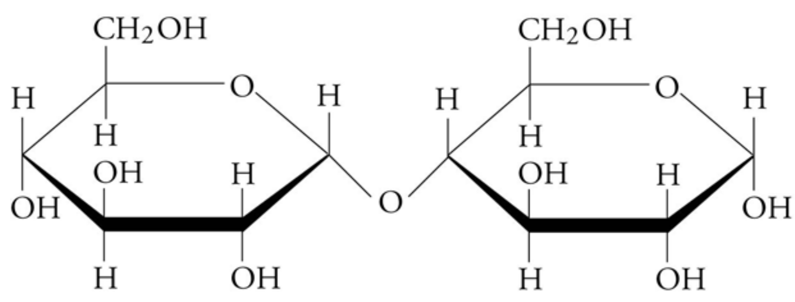
d.  **steroid**

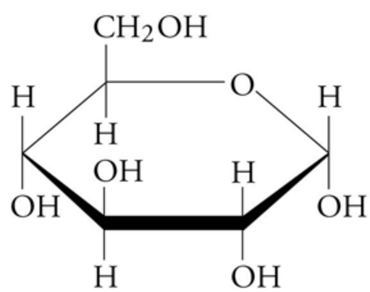
74. Identify each of the following structures as representing a monosaccharide, disaccharide, or polysaccharide. *(Obj 5)*

a. 

polysaccharide

b.  **monosaccharide**

c.  **disaccharide**

d.  **monosaccharide**

76. Identify each of the following as a monosaccharide, disaccharide, or polysaccharide.

   a. Maltose **disaccharide**

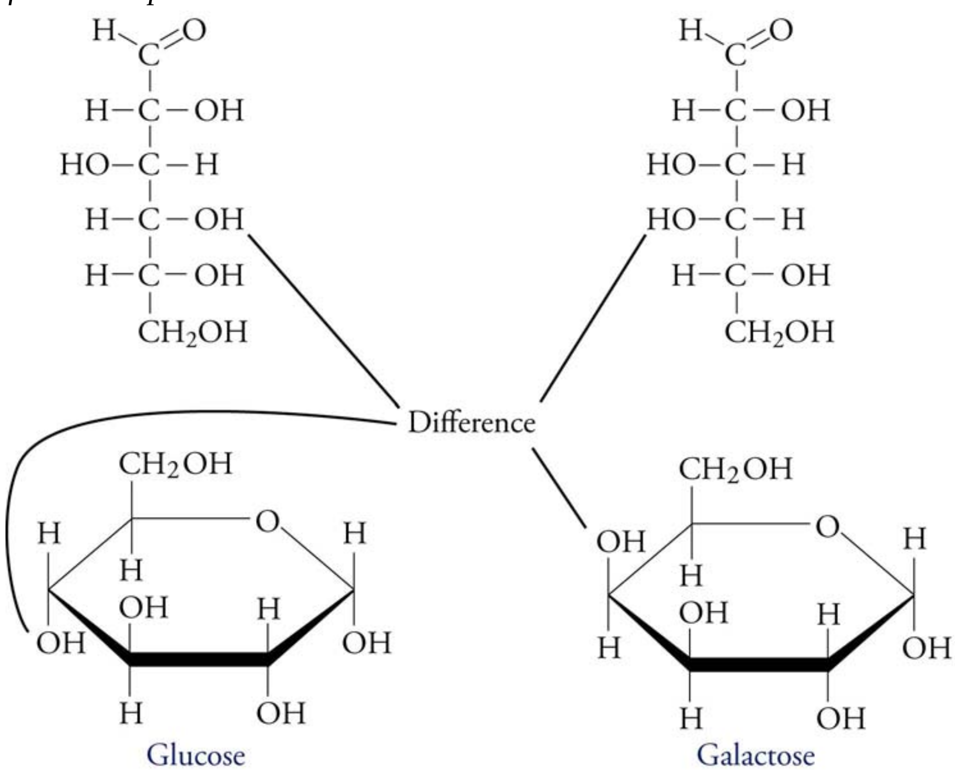
   b. fructose **monosaccharide**

   c. amylose **polysaccharide**

   d. cellulose **polysaccharide**

78. Describe the general difference between glucose and galactose. *(Obj 6)*

   Glucose and galactose differ in the relative positions of an –H and an –OH on one of their carbon atoms. In the standard notation for the open-chain form, glucose and galactose differ only in the relative position of the –H and –OH groups on the fourth carbon from the top.



80. What saccharide units form maltose, lactose, and sucrose? *(Obj 7)*

   maltose – 2 glucose units

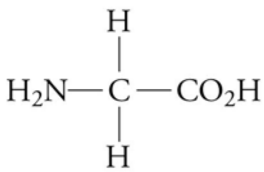
   lactose – glucose and galactose

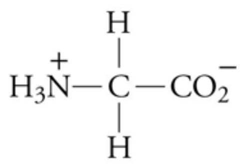
   sucrose – glucose and fructose

82. Describe the similarities and differences between starches (such as amylose, amylopectin, and glycogen) and cellulose. *(Obj 8)*

   Starch and cellulose molecules are composed of many glucose molecules linked together in a similar way, but cellulose has different linkages between the molecules than starch. See Figure 17.21 in the textbook.

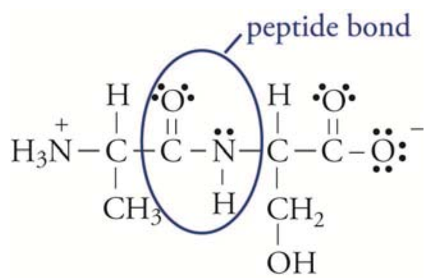
84. Explain why glycine amino acid molecules in our bodies are usually found in the second form shown below rather than in the first. *(Obj 11)*



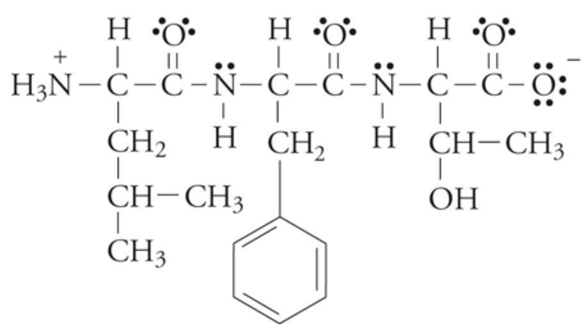


One end of the amino acid has a carboxylic acid group that tends to lose an H^+ ion, and the other end has a basic amine group that attracts H^+ ions. Therefore, in the conditions found in our bodies, amino acids are likely to be in the second form.

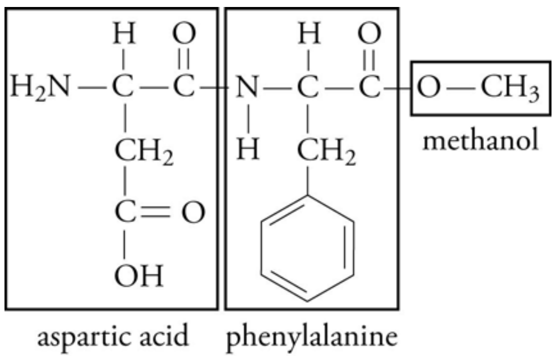
85. Using Figure 17.22 of the textbook, draw the Lewis structure of the dipeptide that has alanine combined with serine. Circle the peptide bond in your structure.



87. Show how the amino acids leucine, phenylalanine, and threonine can be linked together to form the tripeptide leu-phe-thr. *(Obj 12)*



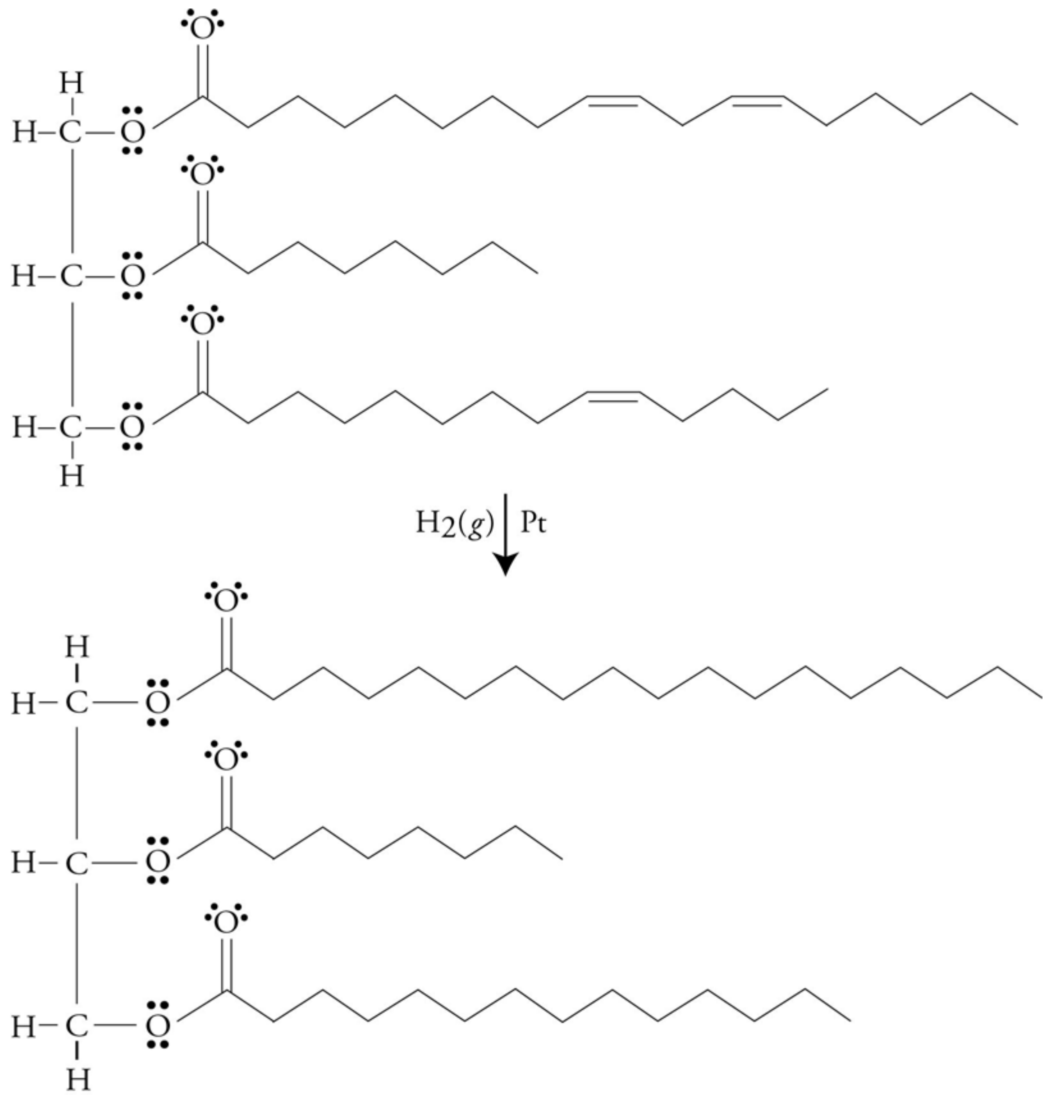
89. When the artificial sweetener aspartame is digested, it yields methanol as well as the amino acids aspartic acid and phenylalanine. Although methanol is toxic, the extremely low levels introduced into the body by eating aspartame are not considered dangerous, but for people who suffer from phenylketonuria (PKU), the phenylalanine can cause severe mental retardation. Babies are tested for this disorder at birth, and when it is detected, they are placed on diets that are low in phenylalanine. Using Figure 17.22 of the textbook, identify the portions of aspartame's structure that yield aspartic acid, phenylalanine, and methanol.



91. Describe how disulfide bonds, hydrogen bonds, and salt bridges help hold protein molecules together in specific tertiary structures. *(Obj 14)*

Each of these interactions draws specific amino acids in a protein chain close together, leading to a specific shape of the protein molecule. Disulfide bonds are covalent bonds between sulfur atoms from two cysteine amino acids (Figure 17.27 in the textbook). Hydrogen bonding forms between –OH groups in two amino acids, such as serine or threonine, in a protein chain (Figure 17.28 in the textbook). Salt bridges are attractions between negatively charged side chains and positively charged side chains. For example, the carboxylic acid group of an aspartic acid side chain can lose its H^+, leaving the side chain with a negative charge. The basic side chain of a lysine amino acid can gain an H^+ and a positive charge. When these two charges form, the negatively charged aspartic acid is attracted to the positively charged lysine by a salt bridge (Figure 17.29 in the textbook).

94. Draw the structure of the triglyceride that would form from the complete hydrogenation of the following triglyceride. *(Obj 19)*



Section 17.3 Digestion

96. When you wash some fried potatoes down with a glass of milk, you deliver a lot of different nutritive substances to your digestive tract, including lactose (a disaccharide), protein, and fat from the milk and starch from the potatoes. What are the digestion products of disaccharides, polysaccharides, protein, and fat? *(Obj 20)*

Disaccharides – monosaccharides *(glucose and galactose from lactose)*

Polysaccharides (starch) – glucose

Protein – amino acids

Fat – glycerol and fatty acids

98. Explain why each enzyme acts only on a specific molecule or a specific type of molecule. *(Obj 22)*

    Before an enzyme reaction takes place, the molecule or molecules that are going to react (called substrates) must fit into a specific section of the protein structure called the active site. Because the active site has a shape that fits specific substrates, because it has side chains that attract particular substrates, and because it has side chains in distinct positions that speed the reaction, each enzyme will only act on a specific molecule or a specific type of molecule.

Section 17.4 Synthetic Polymers

100. Explain why Nylon 66 is stronger than Nylon 610. *(Obj 24)*

    One of the reasons for the exceptional strength of nylon is the hydrogen bonding between amide functional groups. A higher percentage of amide functional groups in nylon molecules' structures leads to stronger hydrogen bonds between them. Thus changing the number of carbon atoms in the diamine and in the di-carboxylic acid changes the properties of nylon. Nylon 610, which has four more carbon atoms in the di-carboxylic acid molecules that form it than for Nylon 66, is somewhat weaker than Nylon 66 and has a lower melting point.

102. Describe the similarities and differences between the molecular structures of low-density polyethylene (LDPE) and high-density polyethylene (HDPE). *(Obj 26)*

    Polyethylene molecules can be made using different techniques. One process leads to branches that keep the molecules from fitting closely together. Other techniques have been developed to make polyethylene molecules with very few branches. These straight-chain molecules fit together more efficiently, yielding a high-density polyethylene, HDPE, that is more opaque, harder, and stronger than the low-density polyethylene, LDPE.

104. Both ethylene and polyethylene are composed of nonpolar molecules. Explain why ethylene is a gas at room temperature while polyethylene is a solid at the same temperature.

    Nonpolar molecules are attracted to each other by London forces, and increased size of molecules leads to stronger London forces. Polyethylene molecules are much larger than the ethylene molecules that are used to make polyethylene, so polyethylene molecules have much stronger attractions between them, making them solids at room temperature.