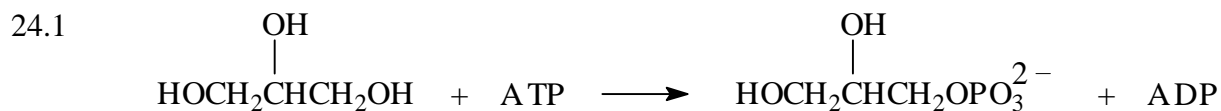
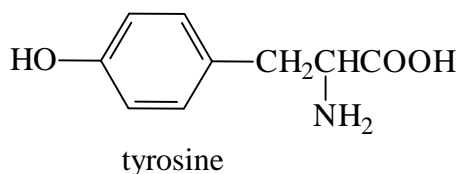
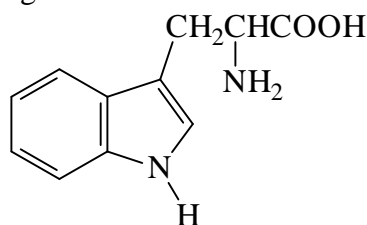
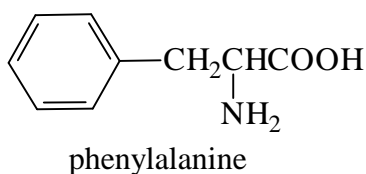


# 24

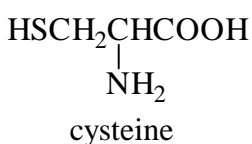
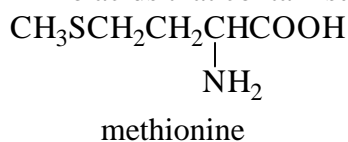
## Biochemistry



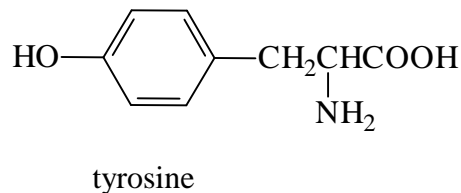
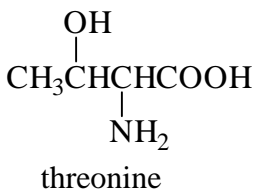
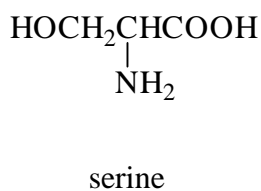
24.2 Amino acids that contain an aromatic ring:



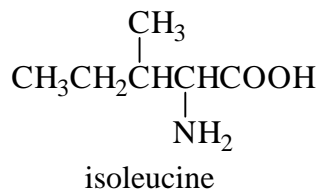
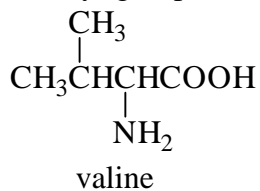
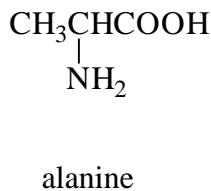
Amino acids that contain sulfur:

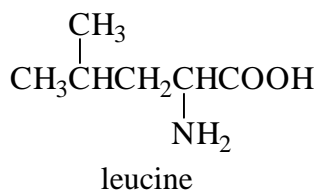


Amino acids that are alcohols:

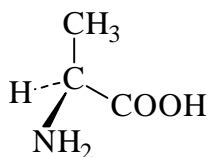


Amino acids that have alkyl-group side chains:





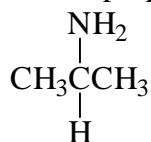
24.3



24.4 The amino acid is threonine with a neutral polar side chain.

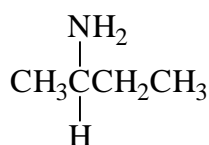
24.5 (a) a glove and (c) a screw are chiral

24.6 2-aminopropane



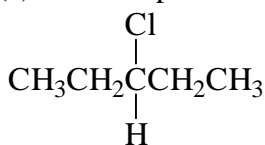
No carbon in 2-aminopropane has four different groups attached to it so the molecule is achiral.

2-aminobutane



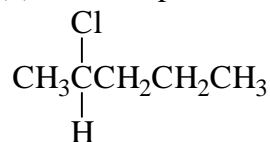
The second carbon in 2-aminobutane has four different groups attached to it so the molecule is chiral.

24.7 (a) 3-chloropentane

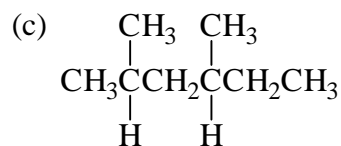


No carbon in 3-chloropentane has four different groups attached to it so the molecule is achiral.

(b) 2-chloropentane



The second carbon in 2-chloropentane has four different groups attached to it so the molecule is chiral.



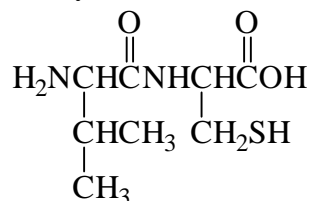
The fourth carbon in the straight chain has four different groups attached to it so the molecule is chiral.

## Chapter 24 – Biochemistry

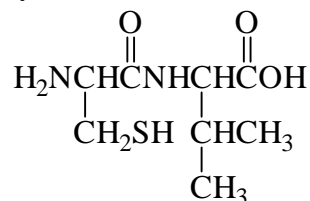
24.8 isoleucine and threonine

24.9 (b) and (c) are identical. (a) is an enantiomer.

24.10 Val-Cys



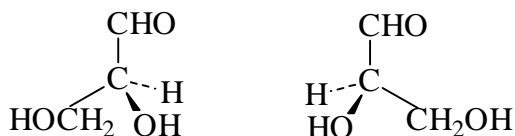
Cys-Val



24.11 Val-Tyr-Gly; Val-Gly-Tyr; Tyr-Gly-Val; Tyr-Val-Gly; Gly-Tyr-Val; Gly-Val-Tyr

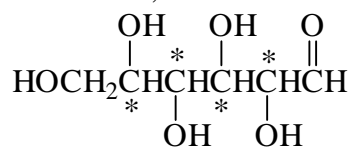
24.12 (a) aldopentose (b) ketotriose (c) aldotetrose

24.13

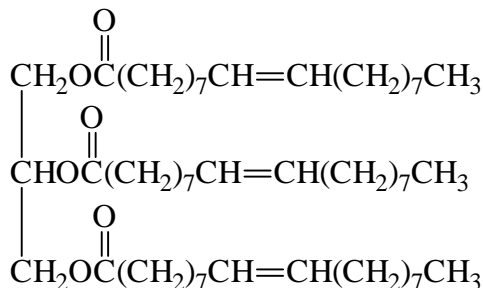


24.14 In general, a compound with  $n$  chiral carbon atoms has a maximum of  $2^n$  possible forms. Because ribose has three chiral carbon atoms, the maximum number of ribose forms =  $2^3 = 8$ .

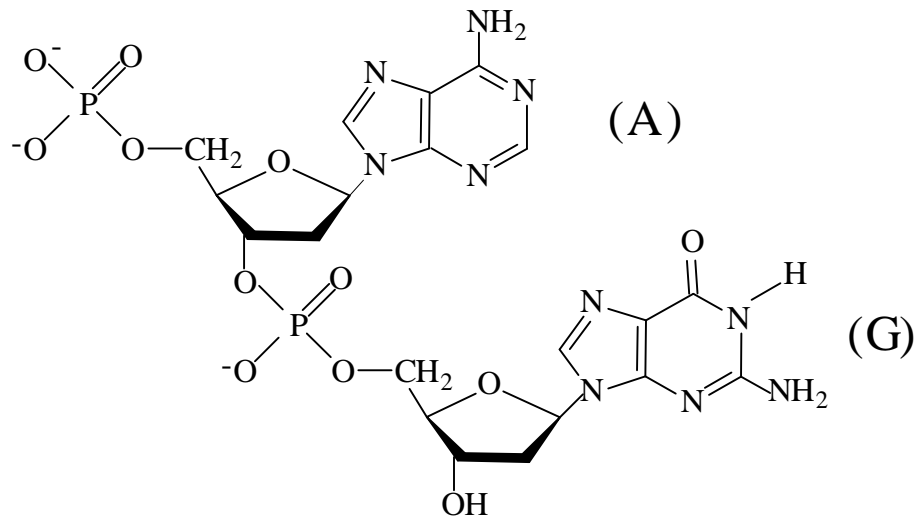
24.15 Aldohexose; 4 chiral carbons



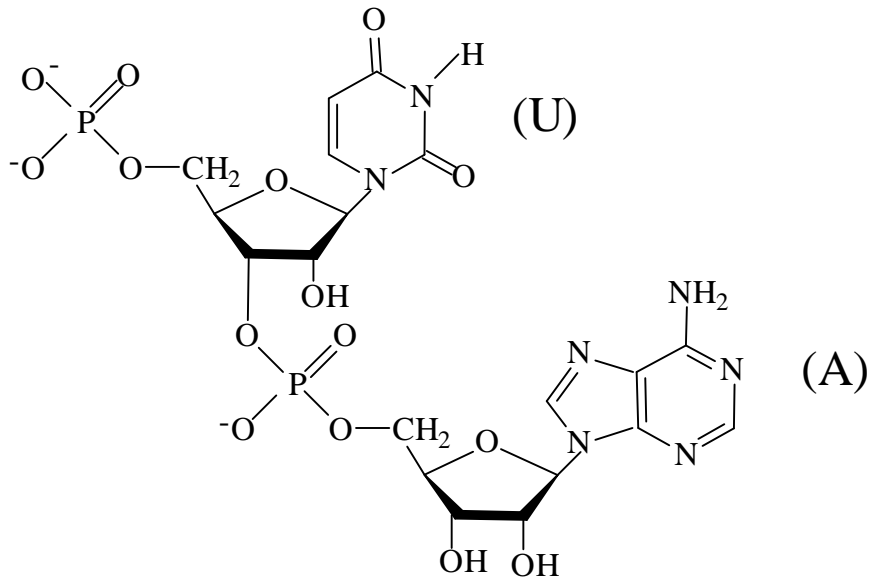
24.16



24.17 DNA dinucleotide A – G.



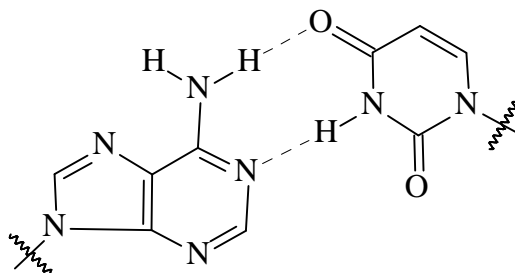
24.18 RNA dinucleotide U – A.



24.19 (a) adenine (DNA, RNA) (b) thymine (DNA)

24.20 Original: G-G-C-C-C-G-T-A-A-T  
Complement: C-C-G-G-G-C-A-T-T-A

24.21



## Chapter 24 – Biochemistry

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- 24.22 C-G-T-G-A-T-T-A-C-A (DNA)  
G-C-A-C-U-A-A-U-G-U (RNA)
- 24.23 U-G-C-A-U-C-G-A-G-U (RNA)  
A-C-G-T-A-G-C-T-C-A (DNA)
- 24.24 Human genes contain short, repeating sequences of noncoding DNA, called short tandem repeat (STR) loci. The base sequences in these STR loci are slightly different for every individual.

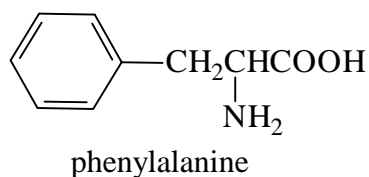
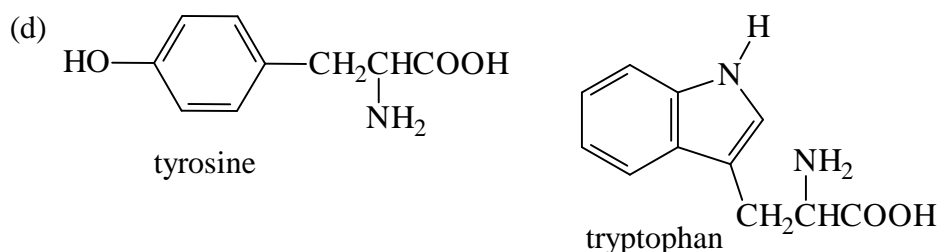
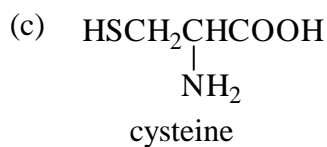
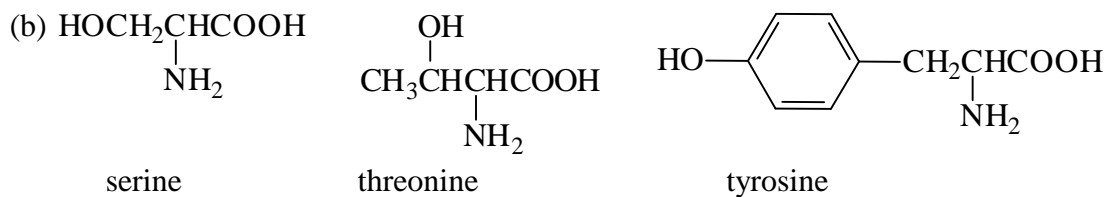
### Key Concept Problems

- 24.25 (a) isoleucine (neutral) (b) histidine (basic)
- 24.26 (a) serine (b) methionine
- 24.27 D-valine
- 24.28  $\beta$  form
- 24.29 Ribose is an aldose with 3 chiral carbons.
- 24.30 Ser-Val
- 24.31 (a) guanine (b) cytosine

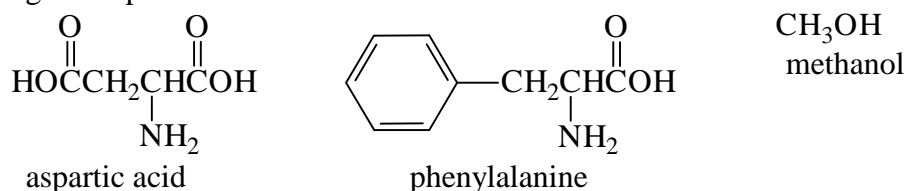
### Section Problems

#### Amino Acids, Peptides, and Proteins (Sections 24.2–24.5)

- 24.32 The “ $\alpha$ ” in  $\alpha$ -amino acids means that the amino group in each is connected to the carbon atom alpha to (next to) the carboxylic acid group.
- 24.33 The naturally occurring amino acids are called L-amino acids because they are chiral molecules in the "left-handed" L-form (from *levo*, Latin for "left").
- 24.34 (a) serine (b) threonine (c) proline (d) phenylalanine (e) cysteine
- 24.35 (a)
- |   |  |
|---|--|
| $\begin{array}{c} \text{CH}_3 \\   \\ \text{CH}_3\text{CHCHCOOH} \\   \\ \text{NH}_2 \end{array}$ | $\begin{array}{c} \text{CH}_3 \\   \\ \text{CH}_3\text{CHCH}_2\text{CHCOOH} \\   \\ \text{NH}_2 \end{array}$ |
| valine  | leucine  |



24.37 Aspartic acid and phenylalanine are the amino acids in aspartame.  
 Digestion products:



24.38 Val-Ser-Phe-Met-Thr-Ala

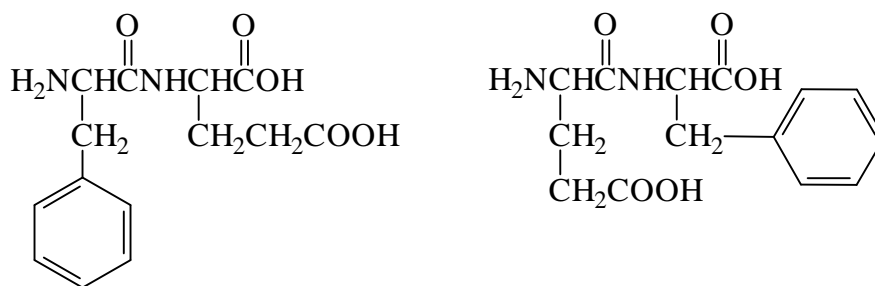
24.39 The N-terminal amino acid is aspartic acid.  
 The C-terminal amino acid is phenylalanine.

24.40 (a) The primary structure of a protein is the sequence in which amino acids are linked together.  
 (b) The secondary structure of a protein is the orientation of segments of a protein chain into a regular pattern.  
 (c) The tertiary structure of a protein is the way in which a protein chain folds into a specific three-dimensional shape.

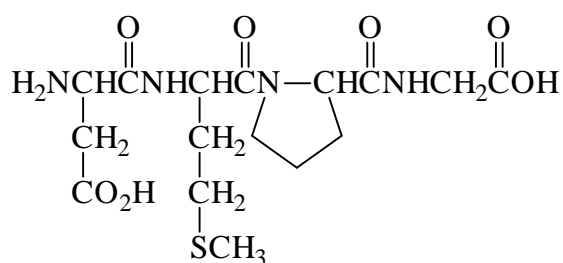
## Chapter 24 – Biochemistry

- 24.41 Proteins are classified according to their three-dimensional shape as either fibrous or globular. Fibrous proteins consist of polypeptide chains arranged side by side in long filaments. Globular proteins are usually coiled into compact, nearly spherical shapes.
- 24.42 A protein's tertiary structure is stabilized by amino acid side-chain interactions, which include hydrophobic interactions, covalent disulfide bridges, electrostatic salt bridges, and hydrogen bonds.
- 24.43 Hydrogen bonding stabilizes helical and  $\beta$ -pleated-sheet secondary protein structure.
- 24.44 Cysteine is an important amino acid for defining the tertiary structure of proteins because the nearby cysteine residues can link together forming a disulfide bridge.
- 24.45 outside: (c) and (d), hydrophilic; inside: (a) and (b), hydrophobic
- 24.46 Met-Ile-Lys, Met-Lys-Ile, Ile-Met-Lys, Ile-Lys-Met, Lys-Met-Ile, Lys-Ile-Met
- 24.47 There are 24 tetrapeptides containing alanine, serine, leucine, and glutamic acid. For example: Ala-Ser-Leu-Glu, Ser-Ala-Leu-Glu, Leu-Glu-Ala-Ser

24.48



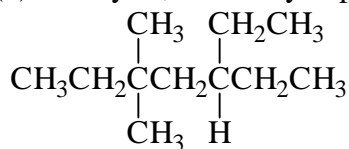
24.49



### Molecular Handedness (Section 24.3)

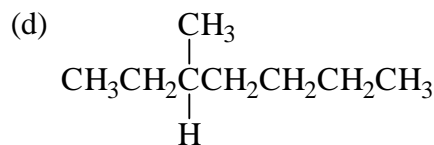
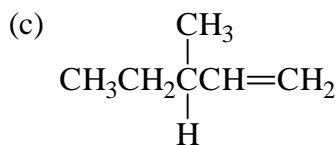
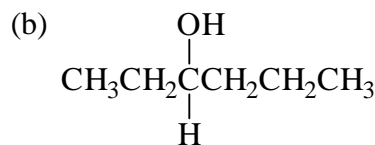
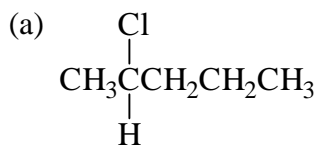
- 24.50 (a) a shoe and (c) a light bulb are chiral.
- 24.51 chiral: screw, glove; achiral: pencil, tire tread pattern
- 24.52 (a) 2,4-dimethylheptane
- The fourth carbon in the straight chain has four different groups attached to it so the molecule is chiral.
-

(b) 5-ethyl-3,3-dimethylheptane

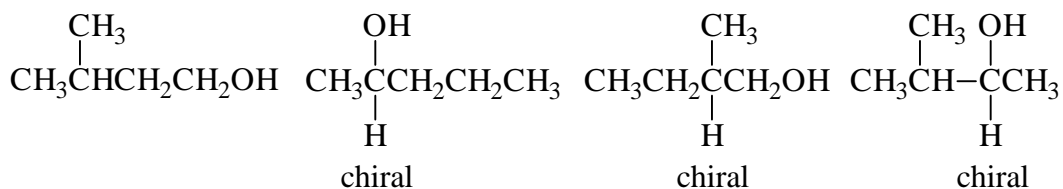
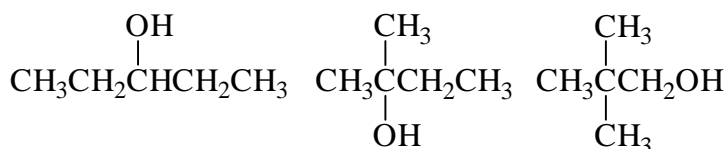
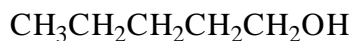


No carbon in 5-ethyl-3,3-dimethylheptane has four different groups attached to it so the molecule is achiral.

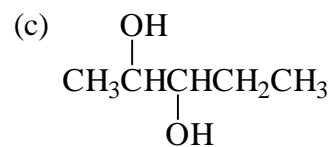
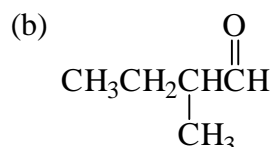
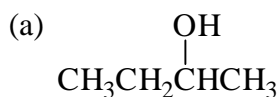
24.53



24.54



24.55



### Carbohydrates (Sections 24.6–24.9)

24.56

An aldose contains the aldehyde functional group while a ketose contains the ketone functional group.

24.57

(a) aldopentose      (b) aldohexose      (c) ketohexose

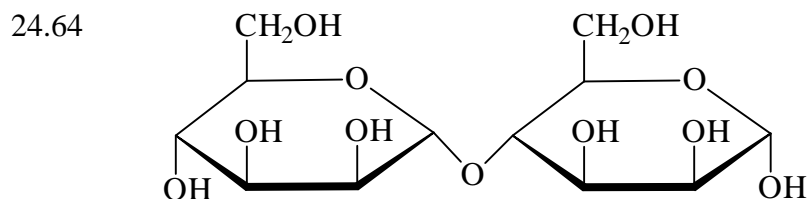
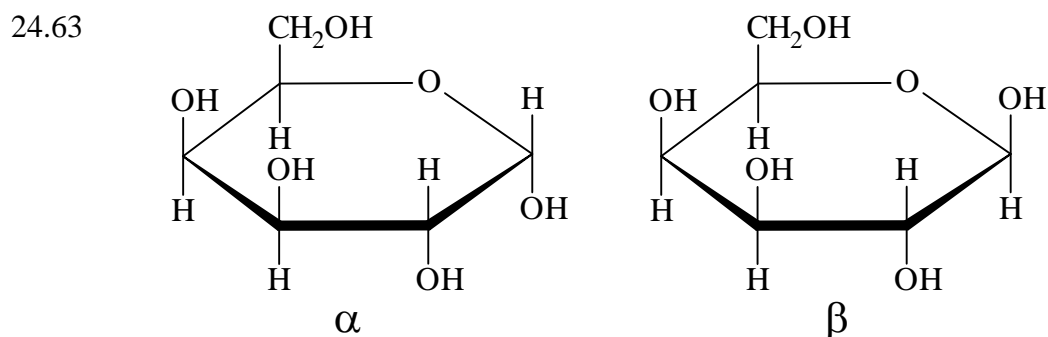
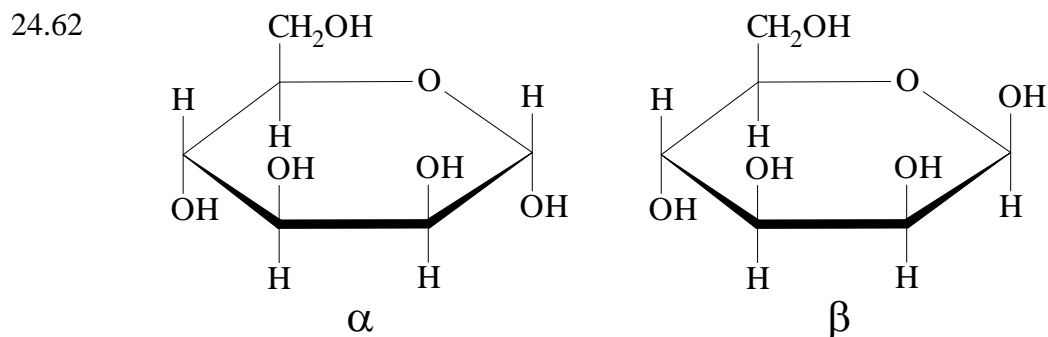
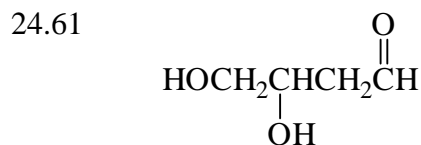
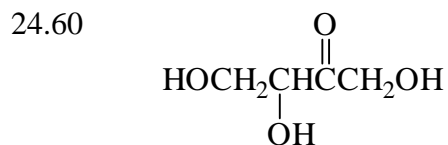
24.58

Structurally, starch differs from cellulose in that it contains  $\alpha$ - rather than  $\beta$ -glucose units.

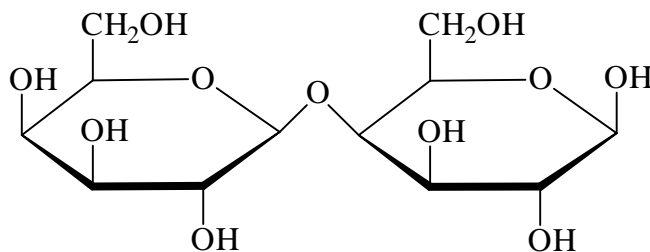
Cellulose is the fibrous substance used by plants as a structural material in grasses, leaves, and stems. It consists of several thousand  $\beta$ -glucose molecules joined together by 1,4 links to form an immense polysaccharide.

Starch is a polymer made up of  $\alpha$ -glucose units. Unlike cellulose, starch is easily digested. The starch in beans, rice, and potatoes is an essential part of the human diet.

24.59 Structurally, glycogen is similar to amylopectin in being a long polymer of  $\alpha$ -glucose units with branch points in its chain. Glycogen has many more branches than amylopectin, however, and is much larger -- up to 1 million glucose units per molecule. Glycogen, sometimes called animal starch, serves the same food-storage role in animals that starch serves in plants.



24.65

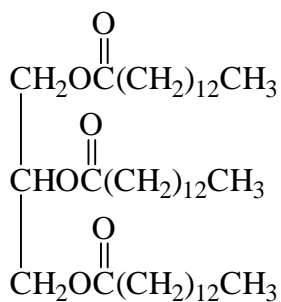


**Lipids (Section 24.10)**

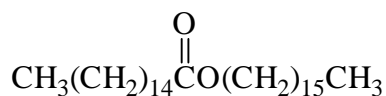
24.66 Long-chain carboxylic acids are called fatty acids. Fatty acids are usually unbranched and have an even number of carbon atoms in the range of 12-22.

24.67 All fats and oils are triesters of glycerol (1,2,3-propanetriol) with three long-chain carboxylic acids, hence they are called triacylglycerols, or triglycerides.

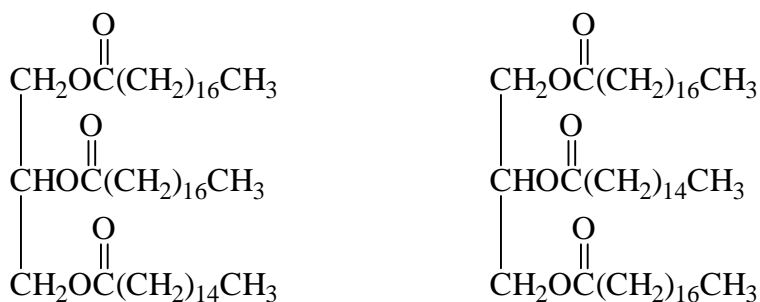
24.68



24.69

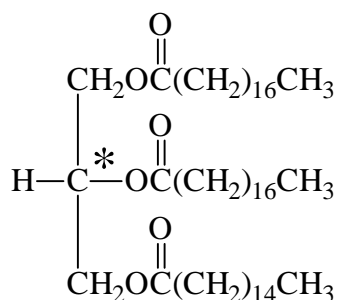


24.70



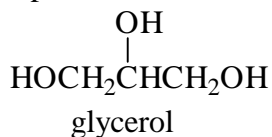
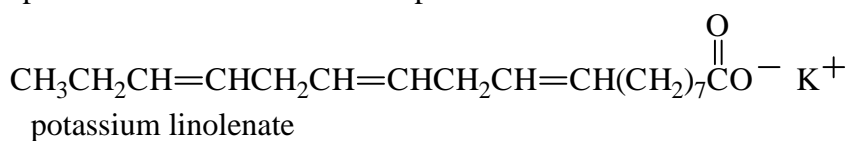
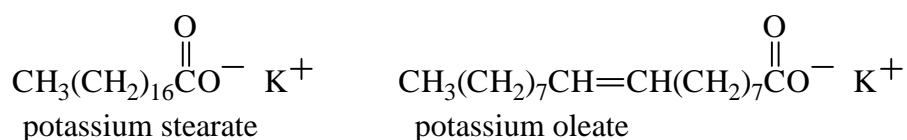
The two fat molecules differ from each other depending on where the palmitic acid chain is located. In the first fat molecule, palmitic acid is on an end and in the second it is in the middle.

24.71

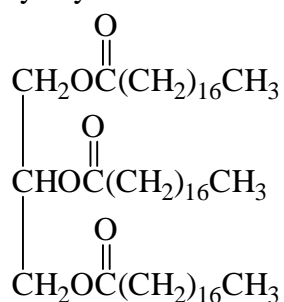


The molecule shown above is chiral. The carbon marked with an asterisk has four different groups attached to it.

24.72

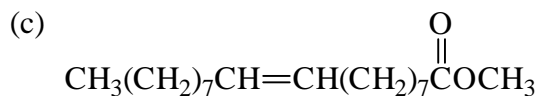
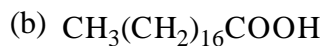
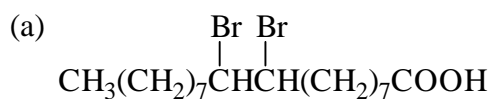


24.73 Glyceryl tristearate



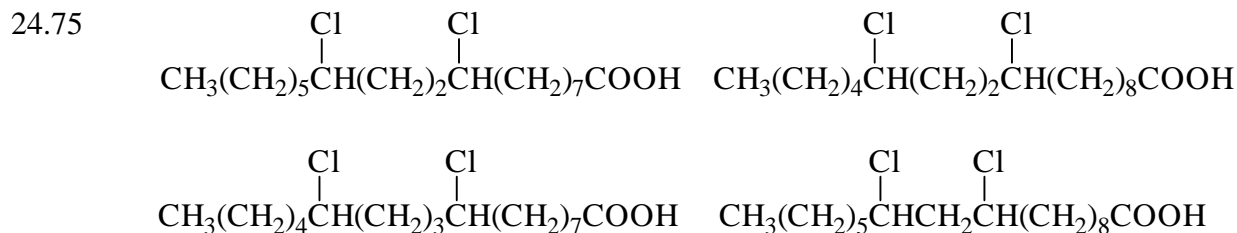
The hydrogenation product would have a higher melting point because it is saturated.

24.74



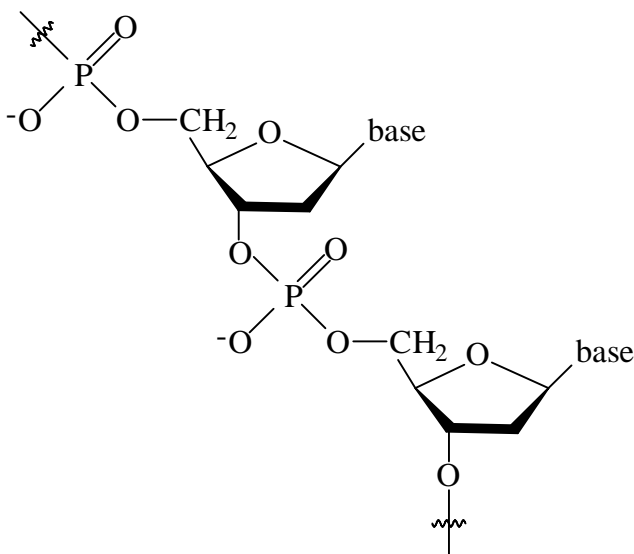
## Chapter 24 – Biochemistry

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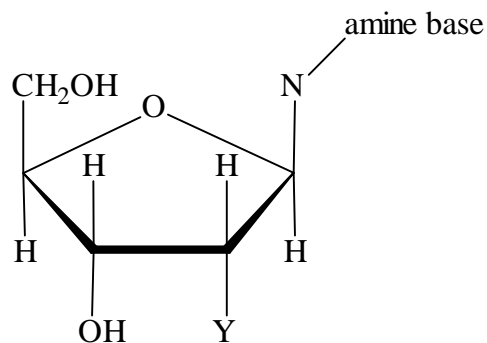


### Nucleic Acids (Sections 24.11–24.13)

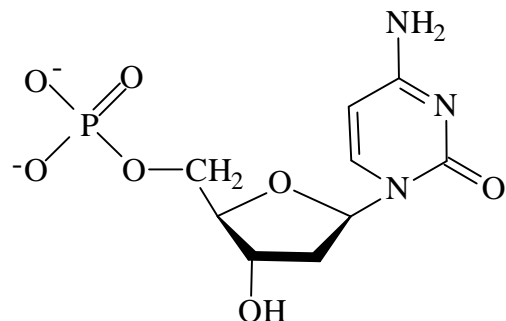
- 24.76 Just as proteins are polymers made of amino acid units, nucleic acids are polymers made up of nucleotide units linked together to form a long chain. Each nucleotide contains a phosphate group, an aldopentose sugar, and an amine base.
- 24.77 The sugar component in RNA is ribose, and the sugar in DNA is 2-deoxyribose (2-deoxy means that oxygen is missing from C2 of ribose).
- 24.78 Most DNA of higher organisms is found in the nucleus of cells.
- 24.79 (a) Base pairing in nucleic acids means that the amine bases are found in specific pairs. In DNA, for example, adenine and thymine form hydrogen bonds to each other, as do cytosine and guanine.  
(b) Replication is the process by which identical copies of DNA are made.  
(c) Translation is the process by which RNA builds proteins.  
(d) Transcription is the process by which information in DNA is transferred to RNA.
- 24.80 A chromosome is a threadlike strand of DNA in the cell nucleus. A gene is a segment of a DNA chain that contains the instructions necessary to make a specific protein.
- 24.81 A single gene contains the instructions necessary to make a specific protein.
- 24.82



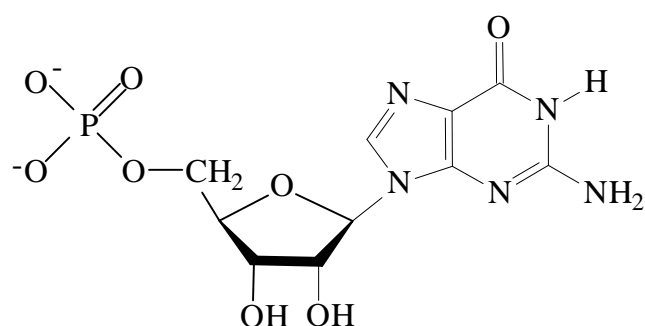
24.83



24.84



24.85



24.86 Original: T-A-C-C-G-A  
Complement: A-T-G-G-C-T

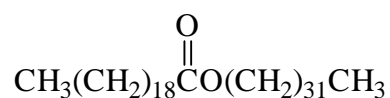
24.87 T-A-C-C-G-A (DNA)  
A-U-G-G-C-U (mRNA)

24.88 It takes three nucleotides to code for a specific amino acid. In insulin the 21 amino acid chain would require  $(3 \times 21) = 63$  nucleotides to code for it, and the 30 amino acid chain would require  $(3 \times 30) = 90$  nucleotides to code for it.

24.89 32% A and T because they are complementary.  
18% G and C because they are complementary.

### Chapter Problems

24.90

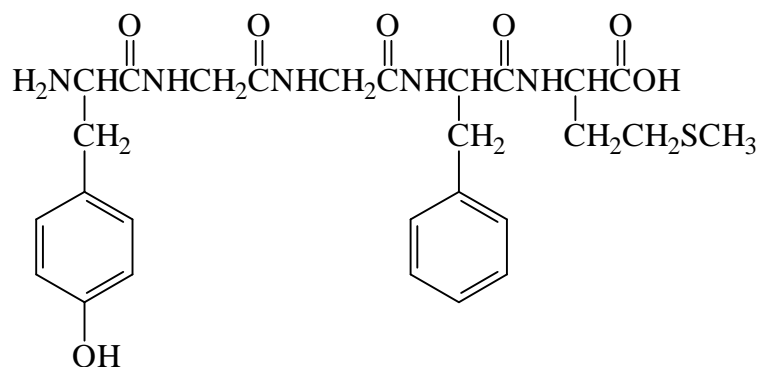


## Chapter 24 – Biochemistry

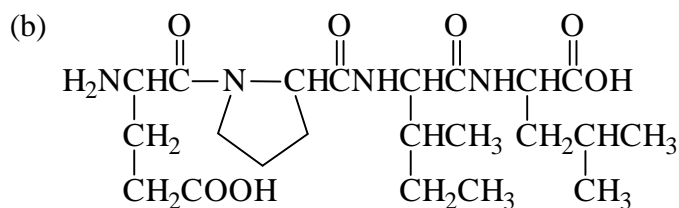
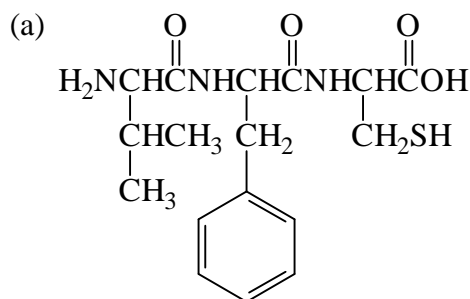
24.91  $\frac{55.847 \text{ amu Fe}}{\text{mol mass cyt c}} \times 100\% = 0.43\%$ ;  $\text{mol mass cyt c} = \frac{55.847 \text{ amu Fe}}{0.0043} = 13,000 \text{ amu}$

24.92  $\Delta G^\circ = +2870 \text{ kJ/mol}$ , because photosynthesis is the reverse reaction.

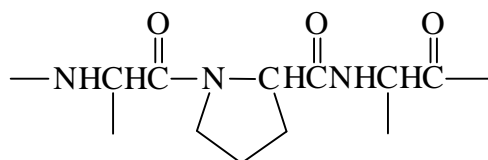
24.93



24.94



24.95 proline containing segment of a protein chain:

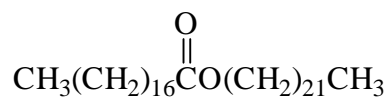


The  $\alpha$ -helix is stabilized by the formation of hydrogen bonds between the N–H group of one amino acid and the C=O group of another amino acid four residues away. The nitrogen in proline has no attached hydrogen and cannot hydrogen bond. Hence proline is never encountered in a protein  $\alpha$ -helix.

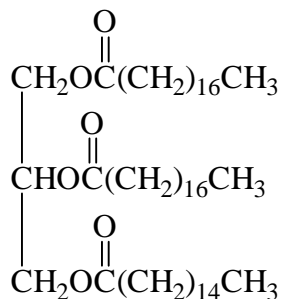
## Chapter 24 – Biochemistry

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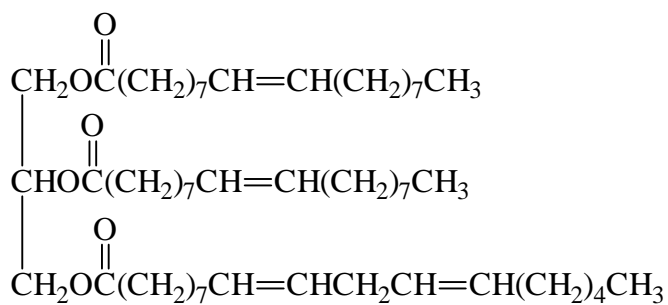
24.96



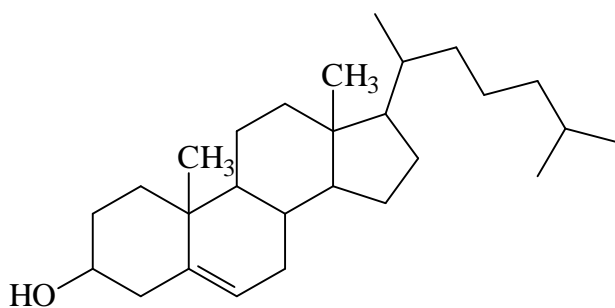
24.97 (a) a fat



(b) a vegetable oil



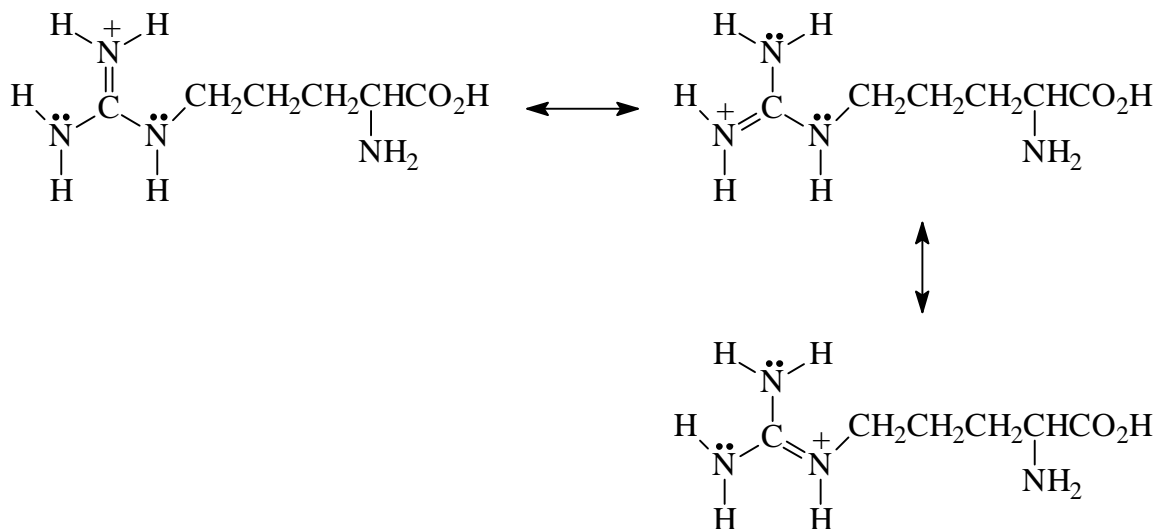
(c) a steroid



24.98

Original:           A-G-T-T-C-A-T-C-G  
Complement:       T-C-A-A-G-T-A-G-C

24.99



## Multi-Concept Problems

- 24.100 (a) grams  $I_2 = (0.0250 \text{ L})(0.200 \text{ mol/L}) \left( \frac{253.81 \text{ g } I_2}{1 \text{ mol } I_2} \right) = 1.27 \text{ g } I_2$
- (b) mol  $Na_2S_2O_3 = (0.08199 \text{ L})(0.100 \text{ mol/L}) = 8.20 \times 10^{-3} \text{ mol}$   
 grams excess  $I_2 = 8.20 \times 10^{-3} \text{ mol } Na_2S_2O_3 \times \frac{1 \text{ mol } I_2}{2 \text{ mol } Na_2S_2O_3} \times \frac{253.81 \text{ g } I_2}{1 \text{ mol } I_2} = 1.04 \text{ g } I_2$   
 grams  $I_2$  reacted =  $1.27 \text{ g} - 1.04 \text{ g} = 0.23 \text{ g } I_2$
- (c) iodine number =  $\frac{0.23 \text{ g } I_2}{0.500 \text{ g milkfat}} \times 100 = 46$
- (d) mol milkfat =  $0.500 \text{ g milkfat} \times \frac{1 \text{ mol milkfat}}{800 \text{ g milkfat}} = 6.25 \times 10^{-4} \text{ mol}$   
 mol  $I_2$  reacted =  $0.23 \text{ g } I_2 \times \frac{1 \text{ mol } I_2}{253.81 \text{ g } I_2} = 9.06 \times 10^{-4} \text{ mol}$   
 number of double bonds per molecule =  $\frac{9.06 \times 10^{-4} \text{ mol } I_2}{6.25 \times 10^{-4} \text{ mol milkfat}} = 1.4 \text{ double bonds}$
- 24.101 (a)  $-CO_2H$  is the more acidic group because it has the smaller  $pK_a$  (larger  $K_a$ ).  
 (b) At  $pH = 4.00$  only  $HA$  and  $H_2A^+$  are present in appreciable amounts.  
 $pH = pK_a + \log \frac{[Base]}{[Acid]}$   
 $4.00 = 2.34 + \log \frac{[HA]}{[H_2A^+]}$ ;  $4.00 - 2.34 = \log \frac{[HA]}{[H_2A^+]}$ ;  $1.66 = \log \frac{[HA]}{[H_2A^+]}$

$$\frac{[\text{HA}]}{[\text{H}_2\text{A}^+]} = 10^{1.66} = 45.7$$

Let  $[\text{HA}] = 100 - x$  and  $[\text{H}_2\text{A}^+] = x$

$$\frac{100 - x}{x} = 45.7; \quad 100 - x = 45.7x; \quad 100 = 46.7x; \quad x = \frac{100}{46.7} = 2.1$$

$\text{HA} = 100 - x = 98\%$  and  $\text{H}_2\text{A}^+ = x = 2.1\%$

(c) At  $\text{pH} = 8.50$  only  $\text{HA}$  and  $\text{A}^-$  are present in appreciable amounts.

$$\text{pH} = \text{pK}_a + \log \frac{[\text{Base}]}{[\text{Acid}]}$$

$$8.50 = 9.69 + \log \frac{[\text{A}^-]}{[\text{HA}]}; \quad 8.50 - 9.69 = \log \frac{[\text{A}^-]}{[\text{HA}]}; \quad -1.19 = \log \frac{[\text{A}^-]}{[\text{HA}]}$$

$$\frac{[\text{A}^-]}{[\text{HA}]} = 10^{-1.19} = 0.0646$$

Let  $[\text{HA}] = 100 - x$  and  $[\text{A}^-] = x$

$$\frac{x}{100 - x} = 0.0646; \quad 0.0646(100 - x) = x; \quad 6.46 - 0.0646x = x; \quad 6.46 = 1.0646x$$

$$x = \frac{6.46}{1.0646} = 6.1$$

$\text{HA} = 100 - x = 94\%$  and  $\text{A}^- = x = 6.1\%$

(d) The maximum amount of  $\text{HA}$  is found at a  $\text{pH}$  that is midway between the two  $\text{pK}_a$  values, 2.34 and 9.69. That  $\text{pH} = 6.01$ .

