CHAPTER 28

LIPIDS

SOLUTIONS TO REVIEW QUESTIONS

1. The lipids, which are dissimilar substances, are arbitrarily classified as a group on the basis of their solubility in fat solvents and their insolubility in water.

2. Although caproic acid, \( \text{CH}_3(\text{CH}_2)_4\text{COOH} \), has the same number of polar bonds as stearic acid, \( \text{CH}_3(\text{CH}_2)_{16}\text{COOH} \), caproic acid has a shorter nonpolar hydrocarbon chain and, therefore, is more water soluble.

3. Arachidonic acid is used to synthesize the eicosanoids, hormone-like substances, which include the prostaglandins, the leukotrienes, the prostacyclins and the thromboxanes.

4. The three essential fatty acids are linoleic, linolenic, and arachidonic acids. Diets lacking these fatty acids lead to impaired growth and reproduction, and skin disorders such as eczema and dermatitis.

5. Fats contain more biochemical energy than carbohydrates because (a) the carbons of fat are more reduced than those found in carbohydrates and (b) there are more reduced carbons per gram of fat than from the same mass of carbohydrate.

6. Aspirin relieves inflammation by blocking the conversion of arachidonic acid to prostaglandins.

7. Waxes serve as a protective coating because they are very hydrophobic. They do not dissolve in water and many compounds cannot pass through a wax coating.

8. A membrane lipid must be (a) partially hydrophobic to act as a barrier to water and (b) partially hydrophilic, so that the membrane can interact with water along its surface.

9. Phospholipids are mainly produced in the liver.

10. The four classes of eicosanoids are prostaglandins, prostacyclins, thromboxanes and leukotrienes.

11. The omega-3 fatty acids can substitute for arachidonic acid and block its action as a trigger for heart attack and stroke.
12. In general, a membrane lipid will have both hydrophilic and hydrophobic parts. Sphingomyelin can serve as a membrane lipid because its phosphate and choline groups are hydrophilic and its two long carbon chains are hydrophobic.

\[
\begin{align*}
\text{OH} & \\
\text{O} & \text{CHCH=CH(CH}_2\text{)}_{12}\text{CH}_3 \\
\text{RC—NH—CH} & \text{ O} \\
\text{CH}_2—\text{O—P—O—CH}_2\text{CH}_2—\text{N}_+\text{CH}_3 & \text{ hydrophilic} \\
\text{O} & \\
\text{ch} & \\
\text{sphingomyelin} & \text{ hydrophobic}
\end{align*}
\]

13. Atherosclerosis is the deposition of cholesterol and other lipids on the inner walls of the large arteries. These deposits, called plaque, accumulate, making the arterial passages narrower and narrower. Blood pressure increases as the heart works to pump sufficient blood through the restricted passages. This may lead to a heart attack, or the rough surface can lead to coronary thrombosis.

14. Dietary cholesterol is transported first to the liver where it is bound to other lipids and proteins to form the very low density lipoprotein (VLDL). This aggregate moves through the blood stream delivering lipids to various tissues. As lipids are removed, the VLDL is converted to a low density lipoprotein (LDL). Cells needing cholesterol can absorb LDL. Cholesterol is transported back to the liver by the high density lipoprotein (HDL).

15. Dietary fish oils provide fatty acids which inhibit formation of thromboxanes, compounds which participate in blood clotting.

16. HDL is a cholesterol scavenger, picking up this steroid in the serum and returning it to the liver.

17. Because the interior of a lipid bilayer is very hydrophobic, molecules with hydrophilic character only cross the lipid bilayer with difficulty. A lipid bilayer acts as a barrier to water-soluble compounds.

18. Liposomes can package drugs so that only the target organ/tissue is exposed to the drug’s effects.

19. Both facilitated diffusion and active transport catalyze movement of compounds through membranes. Active transport requires an input of energy while facilitated diffusion does not.
20. All steroids possess a 17-carbon unit structure containing four fused carbocyclic rings known as the steroid nucleus. Many steroids could be shown; these are two common ones:

- Cholesterol

- Cortisone

21. Up to 80% of the total body cholesterol is metabolically produced. The statin drugs block metabolic production of cholesterol.
CHAPTER 28

SOLUTIONS TO EXERCISES

1. 
   \[ \text{CH}_2\text{O} - \text{C} - (\text{CH}_2)_7 \text{CH}_2 \text{CH} = \text{HC} \text{CH} = \text{HC} \text{CH} = \text{HC} \text{(CH}_2)_4\text{CH}_3 \]
   \[ \text{CHOH} \]
   \[ \text{CH}_2\text{OH} \]

   (Linoleic acid can be located at any one of the three hydroxyls of glycerol.)

2. 
   \[ \text{CH}_2\text{O} - \text{C} - (\text{CH}_2)_7 \text{CH}_2 \text{CH} = \text{HC} \text{CH} = \text{HC} \text{CH} = \text{HC} \text{CH}_2\text{CH}_3 \]
   \[ \text{CHOH} \]
   \[ \text{CH}_2\text{OH} \]

   (Linolenic acid can be located at any one of the three hydroxyls of glycerol.)
3. A triacylglycerol containing one unit each of palmitic, stearic, and oleic acids:

\[
\begin{align*}
\text{CH}_2\text{O} & \quad \text{C(CH}_2\text{)}_{14}\text{CH}_3 \\
\text{CHO} & \quad \text{C(CH}_2\text{)}_{16}\text{CH}_3 \\
\text{CH}_2\text{O} & \quad \text{C(CH}_2\text{)}_{7}\text{CH} = \text{CH(CH}_2\text{)}_{7}\text{CH}_3
\end{align*}
\]

palmitic acid  
stearic acid  
oleic acid

There would be two other triacylglycerols possible from these same components. Since the top and bottom attachments are equivalent, it only matters which acid is attached to the middle carbon of glycerol.

4. A triacylglycerol containing two units of palmitic acid and one unit of oleic acid:

\[
\begin{align*}
\text{CH}_2\text{O} & \quad \text{C(CH}_2\text{)}_{14}\text{CH}_3 \\
\text{CHO} & \quad \text{C(CH}_2\text{)}_{14}\text{CH}_3 \\
\text{CH}_2\text{O} & \quad \text{C(CH}_2\text{)}_{7}\text{CH} = \text{CH(CH}_2\text{)}_{7}\text{CH}_3
\end{align*}
\]

palmitic acid  
palmitic acid  
oleic acid

There is one other possible triacylglycerol with the same components; this triacylglycerol would have palmitic acid units at both ends with the oleic acid unit bound to the middle carbon of glycerol.

5. No, a triacylglycerol that contains three units of lauric acid would be less hydrophobic than a triacylglycerol that contains three units of stearic acid. Smaller molecules tend to be less hydrophobic than larger molecules, and, a triacylglycerol with three lauric acid units is smaller than a triacylglycerol with three stearic acid units.

6. Yes, a triacylglycerol that contains three units of stearic acid would be more hydrophobic than a triacylglycerol that contains three units of myristic acid. Larger molecules tend to be more hydrophobic than smaller molecules and, a triacylglycerol with three stearic acid units is larger than a triacylglycerol with three myristic acid units.
7. Hydrolysis of a triacylglycerol will yield three fatty acids and glycerol. The products will be:

CH₂OH  
CHOH  glycerol  
CH₂OH

CH₃(CH₂)₁₄COOH  palmitic acid
CH₃(CH₂)₇CH═CH(CH₂)₇COOH  oleic acid
CH₃(CH₂)₄CH═CHCH₂CH═CH(CH₂)₇COOH  linoleic acid

8. Hydrolysis of a triacylglycerol will yield three fatty acids and glycerol. The products will be:

CH₂OH  
CHOH  glycerol  
CH₂OH

CH₃(CH₂)₇CH═CH(CH₂)₇COOH  oleic acid
CH₃(CH₂)₁₄COOH  palmitic acid
CH₃(CH₂)₁₆COOH  stearic acid

9. CH₃(CH₂)₂₄CH₂─O─C─(CH₂)₁₆CH₃

10. CH₃(CH₂)₂₈CH₂─O─C─(CH₂)₁₄CH₃

11. CH₂O─C─(CH₂)₁₈CH₃

CHOH  
CH₃OH

(The arachidic acid may be located at any one of the three hydroxyls of glycerol.)
12. The oleic acid may be located at any one of the three hydroxyls of glycerol.

13. The phospholipid structure is:

The phosphoric acid and ethanolamine must be linked to the bottom glycerol carbon. Since a typical phospholipid contains two fatty acid units, a palmitic acid unit must be linked to the top glycerol carbon and another to the middle glycerol carbon.

14. The phospholipid structure is:

The phosphoric acid and choline units must be linked to the bottom glycerol carbon. Since a typical phospholipid contains two fatty acid units, one stearic acid unit must be linked to the top glycerol carbon and a second stearic acid unit must be linked to the middle glycerol carbon.
15. The sphingolipid structure is:

\[
\begin{align*}
\text{OH} \\
\text{CHCH} = \text{CH(CH}_2)_{12}\text{CH}_3 \\
\text{O} \\
\text{CHNH} - \text{C(CH}_2)_7\text{CH} = \text{CH(CH}_2)_7\text{CH}_3 \\
\text{O} \\
\text{CH}_2\text{O} - \text{P} - \text{OCH}_2\text{CH}_2\text{N}^+ - \text{CH}_3 \\
\text{O}^-
\end{align*}
\]

The phosphate and choline units are linked to the bottom glycerol carbon of sphingosine (when the molecules is written as above). The oleic acid unit is then linked to the nitrogen to form the sphingolipid.

16. The sphingolipid structure is:

\[
\begin{align*}
\text{OH} \\
\text{CHCH} = \text{CH(CH}_2)_{12}\text{CH}_3 \\
\text{O} \\
\text{CHNH} - \text{C(CH}_2)_{16}\text{CH}_3 \\
\text{O} \\
\text{CH}_2\text{O} - \text{P} - \text{OCH}_2\text{CH}_2\text{NH}_3 \\
\text{O}^-
\end{align*}
\]

The phosphate and ethanolamine units are linked to the bottom sphingosine carbon (when the molecules is written as above). The stearic acid unit is then linked to the nitrogen to form the sphingolipid.
17. The glycolipid structure is:

\[
\begin{align*}
\text{OH} & \quad \text{CHCH}=\text{CH}(\text{CH}_2)_{12}\text{CH}_3 \\
\text{CHCH}=\text{CH}(\text{CH}_2)_{12}\text{CH}_3 & \quad \text{or} \quad \text{CHCH}=\text{CH}(\text{CH}_2)_{12}\text{CH}_3
\end{align*}
\]

The D-glucose unit is linked to the bottom sphingosine carbon (when the molecule is written as above). The palmitic acid unit is then linked to the nitrogen to form the glycolipid.

18. The glycolipid structure is:

\[
\begin{align*}
\text{OH} & \quad \text{CHCH}=\text{CH}(\text{CH}_2)_{12}\text{CH}_3 \\
\text{CHCH}=\text{CH}(\text{CH}_2)_{12}\text{CH}_3 & \quad \text{or} \quad \text{CHCH}=\text{CH}(\text{CH}_2)_{12}\text{CH}_3
\end{align*}
\]

The D-galactose is linked to the bottom sphingosine carbon (when the molecule is written as above). The oleic acid unit is then linked to the nitrogen to form the glycolipid.
19. The micelle is a sphere with the fatty acid carboxyl groups on the hydrophilic exterior and the fatty acid alkyl chains in the hydrophobic interior. A condensed structural formula has been used to show the palmitic acid.

\[ \text{HO-C(CH}_2\text{)}_{14}\text{CH}_3 \]

hydrophilic hydrophobic

The micelle is a sphere with the fatty acid carboxyl groups on the hydrophilic exterior and the fatty acid alkyl chains in the hydrophobic interior. A condensed structural formula has been used to show the palmitic acid.

20. The micelle is a sphere with the fatty acid carboxyl groups on the hydrophilic exterior and the fatty acid alkyl groups in the hydrophobic interior. A condensed structural formula has been used to show the myristic acid.

\[ \text{HO-C(CH}_2\text{)}_{12}\text{CH}_3 \]

hydrophilic hydrophobic

21. LDL (low density lipoprotein) differs from VLDL (very low density lipoprotein) in that
   (a) VLDL has a lower density than LDL.
   (b) VLDL is formed in the liver while LDL is formed from VLDL as the lipoproteins circulate in the blood.
   (c) VLDL is larger than LDL.

22. HDL (high density lipoprotein) differs from LDL (low density lipoprotein) in that
   (a) LDL has a lower density than HDL.
   (b) LDL delivers cholesterol to peripheral tissues while HDL scavenges cholesterol and returns it to the liver.
23. Sphingosine is similar to the monoacylglycerol in that (a) both molecules contain a long hydrophobic chain, (b) the sphingosine amino group reacts with a fatty acid as does the secondary alcohol of the monoacylglycerol and, (c) for both compounds, the primary alcohol can react further with either acids (to form esters) or sugars (to form acetals).

24. Both compounds have two long hydrophobic chains.
   (b) For both compounds, the primary alcohol can react further with either acids (to form esters) or sugars (to form acetals).

25. Sodium ions will move from a region of high concentration to a region of low concentration as it moves from a 0.1 M solution across a membrane to a 0.001 M solution. This process does not require energy and can be accomplished by facilitated diffusion.

26. Phosphate ion will move from a region of low concentration to a region of high concentration as it moves from a 0.1 M solution across a membrane to 0.5 M solution. This process requires energy and must be accomplished by active transport.

27. Thromboxanes acts as vasoconstrictors and stimulate platelet aggregation while prostaglandins cause the redness, swelling and pain associated with tissue inflammation.

28. Thromboxanes act as vasoconstrictors and stimulate platelet aggregation while leukotrienes have been associated with many of the symptoms of an allergy attack (e.g., an asthma attack).
29. (a) palmitic acid  
   (b) oleic acid and stearic acid  
30. (a) palmitic acid  
   (b) stearic acid and linoleic acid  
31. (a) diacylglycerol (diglyceride)  
   (b) sphingolipid  
   (c) phospholipid (phosphatidyl serine)  
32. (a) glycolipid  
   (b) triacylglycerol (triglyceride)  
   (c) phospholipid (phosphatidyl ethanolamine)  
33. Ibuprofen (an NSAID) blocks the oxidation of arachidonic acid to form prostaglandins which, in turn, can cause inflammation, redness, and swelling.  
34. Both olestra and natural fats contain fatty acid units. However, in natural fats the fatty acid units are linked to glycerol while in olestra the fatty acid units are linked to sucrose. Olestra has many of the qualities of a fat. However, it is not shaped like a natural fat and is not attacked by digestive enzymes. Thus, olestra passes through the stomach and the intestines undigested and does not provide any caloric value to the cells.  
35. (a) The three essential fatty acids are:  
       linoleic acid \( \text{CH}_3(\text{CH}_2)_4\text{CH} \equiv \text{CHCH}_2\text{CH} \equiv \text{CH}(\text{CH}_2)_7\text{COOH} \)  
       linoleic acid \( \text{CH}_3\text{CH}_2\text{CH} \equiv \text{CHCH}_2\text{CH} \equiv \text{CHCH}_2\text{CH} \equiv \text{CH}(\text{CH}_2)_7\text{COOH} \)  
       arachidonic acid \( \text{CH}_3(\text{CH}_2)_4(\text{CH} \equiv \text{CHCH}_2)_4\text{CH}_2\text{CH}_2\text{COOH} \)  
   (b) A diet which is missing the essential fatty acids will lead to impaired growth and reproduction as well as skin disorders such as eczema and dermatitis.  
36. This meal is changed by increasing the fat content from 10 grams to 15 grams, an increase of 5 grams. Since each gram of fat yields an average of 9.5 Cal, an increase of 5 grams equates to an increase of 47.5 Cal (5 grams \( \times \) 9.5 Cal/g). Thus, this meal will now contain 234 Cal + 47.5 Cal = 282 Cal.  
37. Formula for beeswax  
\[ \begin{align*}  
\text{O} & \quad \text{CH}_3(\text{CH}_2)_{14}\text{C} \equiv \text{O} \equiv (\text{CH}_2)_{29}\text{CH}_3  
\end{align*} \]  
38. \( \text{CH}_3(\text{CH}_2)_{7}\text{CH} \equiv \text{CH}(\text{CH}_2)_7\text{COOH} \) oleic acid or 9-octadecenoic acid
39. *original triacylglycerol*

![Original Triacylglycerol Diagram]

(The order in which the fatty acids are connected to glycerol may vary.)

*final product*

![Final Product Diagram]

(The order in which the fatty acids are connected to glycerol may vary.)