Chapter 12 Review Problems

INSTRUCTIONS:

You do not need to write the question, ONLY WRITE THE PROBLEM NUMBER and ANSWERS/SOLUTIONS.

• For problems that involve calculations, you must show your work to get full credit.
• For multiple choice questions, you can simply write the letter (a, b, c, or d) of the correct response.
• Use the navigation buttons at the bottom of the pages to get hints, check your answers, move to the next problem, or go back to previous pages.

Chapter Review Problems are due at the end of class period on the dates shown in the CHEM 108 Schedule.

• Late submissions will not be accepted unless the student can prove to the instructor that something outside of their control prevented them from turning in the problem set on the due date (see the course syllabus for more details).
12.1) In chapter 4, you learned that organic compounds are categorized into various families based on the presence of certain functional groups. For example, an organic molecule with a hydroxyl group (OH) bonded to a hydrocarbon part is in the alcohol family. Lipids, in contrast, are not defined by the presence of specific functional groups.

i) Lipids are defined as biological compounds that are insoluble in ________________.
   a) organic solvents
   b) water
   c) oil
   d) all solvents

ii) Biological compounds are organic compounds that occur in living organisms. There are three solubility classes for biological compounds: hydrophilic, hydrophobic, and amphipathic. Of these three classes, ________________ are water insoluble.
   a) hydrophilic and hydrophobic
   b) hydrophilic and amphipathic
   c) amphipathic and hydrophobic

iii) Amphipathic molecules form ________________ when placed in water.
   a) solids
   b) suspensions
   c) waxes
   d) monolayers and micelles
12.1) In chapter 4, you learned that organic compounds are categorized into various families based on the presence of certain functional groups. For example, an organic molecule with a hydroxyl group (OH) bonded to a hydrocarbon part is in the alcohol family. **Lipids**, in contrast, are not defined by the presence of specific functional groups.

i). Lipids are defined as biological compounds that are insoluble in ________________.

**HINT:**
- a) organic solvents
- b) water
- c) oil
- d) all solvents

ii) Biological compounds are organic compounds that occur in living organisms. There are three solubility classes for biological compounds: hydrophilic, hydrophobic, and amphipathic. Of these three classes, ________________ are water insoluble.

**HINT:**
- a) hydrophilic and hydrophobic
- b) hydrophilic and amphipathic
- c) amphipathic and hydrophobic

iii) Amphipathic molecules form ________________ when placed in water.

**HINT:**
- a) solids
- b) suspensions
- c) waxes
- d) monolayers and micelles

**For more help:** See chapter 12 part 1 video or chapter 12 section 3 in the textbook.
In chapter 4, you learned that organic compounds are categorized into various families based on the presence of certain *functional groups*. For example, an organic molecule with a hydroxyl group (OH) bonded to a hydrocarbon part is in the alcohol family. **Lipids**, in contrast, are *not* defined by the presence of specific functional groups.

1. Lipids are defined as biological compounds that are **insoluble in** ____________________.
   a) organic solvents  
   b) water  
   c) oil  
   d) all solvents

2. Biological compounds are organic compounds that occur in living organisms. There are three solubility classes for biological compounds: hydrophilic, hydrophobic, and amphipathic. Of these three classes, ____________________ are water insoluble.
   a) hydrophilic and hydrophobic  
   b) hydrophilic and amphipathic  
   c) amphipathic and hydrophobic

3. Amphipathic molecules form ____________________ when placed in water.
   a) solids  
   b) suspensions  
   c) waxes  
   d) monolayers and micelles

For more details: See chapter 12 part 1 video or chapter 12 section 3 in the textbook.
12.2) The *abbreviated* condensed structures for two fatty acid molecules are shown below. Draw a *standard* (*unabbreviated*) condensed structure for each of these molecules.

\[
\begin{align*}
&\text{CH}_3(\text{CH}_2)_{12}C-OH \\
&\text{CH}_3(\text{CH}_2)_{7} \text{CH} = \text{CH} (\text{CH}_2)_{7}C-OH
\end{align*}
\]
12.2) The *abbreviated* condensed structures for two fatty acid molecules are shown below. Draw a *standard* (*unabbreviated*) condensed structure for each of these molecules.

\[
\begin{align*}
\text{O} & \\
\text{CH}_3(\text{CH}_2)_{12} & \text{C} \text{— OH}
\end{align*}
\]

\[
\begin{align*}
\text{O} & \\
\text{CH}_3(\text{CH}_2)_7 & \text{CH} = \text{CH}(\text{CH}_2)_7 \text{C} \text{— OH}
\end{align*}
\]

**HINT:**

In abbreviated condensed structures, repeating structural units are shown in parenthesis with a subscripted number where the subscript is equal to the number of times that the structural unit within the parenthesis is repeated. Carbons that are *single bonded* to each other in a linear sequence, along with the hydrogens that are bonded to them, are abbreviated as \((\text{CH}_2)_n\), where \(n\) is equal to the number of times that the \(\text{CH}_2\) is repeated.

**For more help:** See chapter 12 part 1 video or chapter 12 section 3 in the textbook.
12.2) The *abbreviated* condensed structures for two fatty acid molecules are shown below. Draw a *standard* (unabbreviated) condensed structure for each of these molecules.

EXPLANATION: In order to save time when drawing structural formulas for large molecules such as fatty acids, an abbreviated condensed structure is used. Repeating structural units are shown in parenthesis with a subscripted number where the subscript is equal to the number of times that the structural unit within the parenthesis is repeated. For example, carbons that are single bonded to each other in a linear sequence, along with the hydrogens that are bonded to them, are abbreviated as \((\text{CH}_2)_n\), where \(n\) is equal to the number of number of times that the \(\text{CH}_2\) is repeated.

For more details: See chapter 12 part 1 video or chapter 12 section 3 in the textbook.
12.3) Classify each of the fatty acids shown below as either saturated, monounsaturated, or polyunsaturated.

a) \( \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{COOH} \)

b) \( \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{COOH} \)

c) \( \text{CH}_3(\text{CH}_2)_4(\text{CH} \equiv \text{CHCH}_2)_2(\text{CH}_2)_6\text{COOH} \)

d) \( \text{CH}_3(\text{CH}_2)_{10}\text{COOH} \)

e) \( \text{CH}_3(\text{CH}_2)_5\text{CH} \equiv \text{CH(CH}_2)_7\text{COOH} \)

f) \( \text{CH}_3\text{CH}_2(\text{CH} \equiv \text{CHCH}_2)_3(\text{CH}_2)_6\text{COOH} \)
12.3) Classify each of the fatty acids shown below as either saturated, monounsaturated, or polyunsaturated.

a) \( \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{COOH} \)

b) \( \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{COOH} \)

c) \( \text{CH}_3(\text{CH}_2)_4(\text{CH} \equiv \text{CHCH}_2)_2(\text{CH}_2)_6\text{COOH} \)

d) \( \text{CH}_3(\text{CH}_2)_{10}\text{COOH} \)

e) \( \text{CH}_3(\text{CH}_2)_5\text{CH} \equiv \text{CH}(\text{CH}_2)_7\text{COOH} \)

f) \( \text{CH}_3\text{CH}_2(\text{CH} \equiv \text{CHCH}_2)_3(\text{CH}_2)_6\text{COOH} \)

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**Classification of Fatty Acids Based on the Degree of Saturation**

- **Saturated Fatty Acids**
  - Contain *no* carbon-carbon double bonds.

- **Monounsaturated fatty acids**
  - Contain *one* carbon-carbon double bond.

- **Polyunsaturated fatty acids**
  - Contain *more than one* carbon-carbon double bond.

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*For more help:* See chapter 12 part 1 video or chapter 12 section 3 in the textbook.

*Click here to check your answer*
12.3) Classify each of the fatty acids shown below as either **saturated**, **monounsaturated**, or **polyunsaturated**.

a) \( \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{COOH} \)  **saturated**

b) \( \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH} \equiv \text{CHCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{COOH} \)  **monounsaturated**

c) \( \text{CH}_3(\text{CH}_2)_4(\text{CH} \equiv \text{CHCH}_2)_2(\text{CH}_2)_6\text{COOH} \)  **polyunsaturated** – Contains two carbon-carbon double bonds. Note that the structural unit with the carbon-carbon double bond occurs *twice*.

d) \( \text{CH}_3(\text{CH}_2)_{10}\text{COOH} \)  **saturated**

e) \( \text{CH}_3(\text{CH}_2)_5\text{CH} \equiv \text{CH(CH}_2)_7\text{COOH} \)  **monounsaturated**

f) \( \text{CH}_3\text{CH}_2(\text{CH} \equiv \text{CHCH}_2)_3(\text{CH}_2)_6\text{COOH} \)  **polyunsaturated** – Contains three carbon-carbon double bonds. Note that the structural unit with the carbon-carbon double bond is repeated *three* times.

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**Classification of Fatty Acids Based on the Degree of Saturation**

- **Saturation**
  - Contain *no* carbon-carbon double bonds.
  - **Saturated Fatty Acids**

- **Monounsaturation**
  - Contain *one* carbon-carbon double bond.
  - **Monounsaturated fatty acids**

- **Polyunsaturation**
  - Contain *more than one* carbon-carbon double bond.
  - **Polyunsaturated fatty acids**

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**For more details:** See chapter 12 part 1 video or chapter 12 section 3 in the textbook.
Although not used in IUPAC naming, *omega notation* is frequently seen in popular nutrition literature. In omega notation, the carbon at the *end* of a fatty acid’s hydrocarbon chain is designated as the “*omega* carbon” or “ω-carbon.” Omega (ω) is the last letter of the Greek alphabet, making the omega designation appropriate for the “last” carbon in a fatty acid’s hydrocarbon chain. *Unsaturated* fatty acids are put into omega notation classes by the position of the *first* double bond that occurs, counting from the omega carbon.

Classify each of the fatty acids shown below by its *omega* notation (ω-?).

![Fatty acid structure 1](attachment:image1.png)

![Fatty acid structure 2](attachment:image2.png)
Although not used in IUPAC naming, **omega notation** is frequently seen in popular nutrition literature. In omega notation, the carbon at the end of a fatty acid’s hydrocarbon chain is designated as the “**omega** carbon” or “ω-carbon.” Omega (ω) is the last letter of the Greek alphabet, making the omega designation appropriate for the “last” carbon in a fatty acid’s hydrocarbon chain. *Unsaturated* fatty acids are put into omega notation classes by the position of the *first* double bond that occurs, counting from the omega carbon.

Classify each of the fatty acids shown below by its omega notation (ω?).

For more help: See chapter 12 part 1 video or chapter 12 section 3 in the textbook.
12.4) Although not used in IUPAC naming, *omega notation* is frequently seen in popular nutrition literature. In omega notation, the carbon at the **end** of a fatty acid’s hydrocarbon chain is designated as the “**omega** carbon” or “**ω**-carbon.” Omega (ω) is the last letter of the Greek alphabet, making the omega designation appropriate for the “last” carbon in a fatty acid’s hydrocarbon chain. *Unsaturated* fatty acids are put into omega notation classes by the position of the *first* double bond that occurs, counting from the omega carbon.

Classify each of the fatty acids shown below by its omega notation (ω-?)

**ANSWER: ω-3**

```
CH₃CH₂CH₂CH₂CH₂CH₂CH₂C≡CCH₂CH₂CH₂CH₂CH₂CH₂CH₂CH₂CH₂CH₂CH₂C − OH
O
||
```

The double bond occurs at the third carbon, counting from the omega carbon, so this fatty acid is classified as ω-3.

**ANSWER: ω-6**

```
CH₃CH₂CH₂CH₂CH₂CH₂CH₂C ≡ CCH₂CH₂CH₂CH₂CH₂CH₂CH₂CH₂CH₂CH₂CH₂C − OH
O
||
```

The double bond occurs at the sixth carbon, counting from the omega carbon, so this fatty acid is classified as ω-6.

For more details: See chapter 12 part 1 video or chapter 12 section 3 in the textbook.
Predict the order of increasing **boiling points** for the fatty acids shown below.

**Lauric acid** $\text{CH}_3(\text{CH}_2)_{10}\text{COOH}$

**Palmitic acid** $\text{CH}_3(\text{CH}_2)_{14}\text{COOH}$

**Myristic acid** $\text{CH}_3(\text{CH}_2)_{12}\text{COOH}$

**Highest boiling point**

1. __________________
2. __________________
3. __________________

**Lowest boiling point**
12.5) Predict the order of increasing boiling points for the fatty acids shown below.

\[
\begin{align*}
\text{CH}_3(\text{CH}_2)_{10}\text{COOH} & \quad \text{lauric acid} \\
\text{CH}_3(\text{CH}_2)_{14}\text{COOH} & \quad \text{palmitic acid} \\
\text{CH}_3(\text{CH}_2)_{12}\text{COOH} & \quad \text{myristic acid}
\end{align*}
\]

HINT:
Stronger/more noncovalent interactions = higher boiling and melting points

For more help: See chapter 12 part 1 video or chapter 12 section 3 in the textbook.
12.5) Predict the order of increasing *boiling points* for the fatty acids shown below.

1. ___________
2. ___________
3. ___________

**EXPLANATION:**
Stronger/more noncovalent interactions = higher boiling and melting points
- The larger the nonpolar hydrocarbon part, the stronger the London forces and the higher the melting point.

**For more details:** See chapter 12 part 1 video or chapter 12 section 3 in the textbook.
12.6) Predict the order of increasing **boiling points** for the fatty acids shown below.

Highest boiling point

1. linoleic acid  \( \text{CH}_3\text{(CH}_2\text{)}_4\text{CH} \equiv \text{CHCH}_2\text{CH} \equiv \text{CH(CH}_2\text{)}_7\text{COOH} \)

2. stearic acid  \( \text{CH}_3\text{(CH}_2\text{)}_{16}\text{COOH} \)

3. linolenic acid  \( \text{CH}_3\text{CH}_2\text{CH} \equiv \text{CHCH}_2\text{CH} \equiv \text{CHCH}_2\text{CH} \equiv \text{CH(CH}_2\text{)}_7\text{COOH} \)

Lowest boiling point
12.6) Predict the order of increasing **boiling points** for the fatty acids shown below.

**highest boiling point**
1. ____________________
2. ____________________
3. ____________________

**lowest boiling point**

- **linoleic acid**  \( \text{CH}_3(\text{CH}_2)_4\text{CH} \equiv \text{CHCH}_2\text{CH} \equiv \text{CH(CH}_2)_7\text{COOH} \)
- **stearic acid**  \( \text{CH}_3(\text{CH}_2)_{16}\text{COOH} \)
- **linolenic acid**  \( \text{CH}_3\text{CH}_2\text{CH} \equiv \text{CHCH}_2\text{CH} \equiv \text{CHCH}_2\text{CH} \equiv \text{CH(CH}_2)_7\text{COOH} \)

**HINT:**  Stronger/more noncovalent interactions = higher boiling and melting points

The strength of the noncovalent interactions, and therefore, boiling and melting points, of fatty acids depends on two parameters:

1. The **number or carbon atoms** - the more carbon atoms a fatty acid contains, the **higher** the boiling and melting point.
2. The **degree of saturation** - the more double bonds a fatty acid contains, the **lower** the boiling and melting point.
   
   - The inability of rotation around double bonds prevents less saturated molecules from getting as close to each other as is possible for more highly saturated molecules. The strength of London forces - and all other noncovalent interactions - are distant dependent; the closer the particles are to each other, the stronger the attractive force.

**For more help:**  See chapter 12 part 1 video or chapter 12 section 3 in the textbook.
12.6) Predict the order of increasing *boiling points* for the fatty acids shown below.

**EXPLANATION:** Stronger/more noncovalent interactions = higher boiling and melting points

The strength of the noncovalent interactions, and therefore, boiling and melting points, of fatty acids depends on two parameters:

1. The **number or carbon atoms** - the more carbon atoms a fatty acid contains, the *higher* the boiling and melting point.
2. The **degree of saturation** - the more double bonds a fatty acid contains, the *lower* the boiling and melting point.

- The inability of rotation around double bonds prevents less saturated molecules from getting as close to each other as is possible for more highly saturated molecules. The strength of London forces - and all other noncovalent interactions - are distance-dependent; the closer the particles are to each other, the stronger the attractive force.

All of the molecules in this problem have the *same number of carbon atoms*, so the boiling point order is predicted based on the **degree of saturation** (number of double bonds).

For more details: See chapter 12 part 1 video or chapter 12 section 3 in the textbook.
12.7) 

i) Predict the products of the reaction that occurs when myristic acid (below) reacts with water.

\[
\begin{align*}
\text{CH}_3(\text{CH}_2)_{12} \text{C} \rightleftharpoons \text{OH} & + \ \text{H}_2\text{O} \\
\text{myristic acid}
\end{align*}
\]

ii) Name the base form of myristic acid.

iii) In previous chapters, you learned that the relative amounts of a conjugate pair’s acid form and base form that are present in an aqueous solution depends on the pH of the solution and the pK$_a$ of the particular acid (as described by the Henderson-Hasselbalch Equation). The pK$_a$ of carboxylic acids \textit{(including fatty acids)} is about 5.

For the myristic acid/myristate ion pair, predict the species that is predominant at physiological pH (~7.4).
12.7)

i) Predict the products of the reaction that occurs when myristic acid (below) reacts with water.

\[
\text{CH}_3(\text{CH}_2)_{12}\text{C}==\text{OH} + \text{H}_2\text{O} \rightleftharpoons \quad \text{HINT:} \quad \text{Fatty acids will react with water in the same manner as all carboxylic acids.}
\]

ii) Name the base form of myristic acid.

\[\text{myristic acid} \rightarrow ? \quad \text{HINT:} \quad \text{The base forms of fatty acids are named by replacing the “-ic acid” suffix of the fatty acid name with “-ate ion.”}\]

iii) In previous chapters, you learned that the relative amounts of a conjugate pair’s acid form and base form that are present in an aqueous solution depends on the pH of the solution and the pK\(_a\) of the particular acid (as described by the Henderson-Hasselbalch Equation). The pK\(_a\) of carboxylic acids (including fatty acids) is about 5.

For the myristic acid/myristate ion pair, predict the species that is predominant at physiological pH (~7.4).

For more help: See chapter 12 part 1 video or chapter 12 section 3 in the textbook.
i) Predict the products of the reaction that occurs when myristic acid (below) reacts with water.

\[
\text{CH}_3(\text{CH}_2)_{12}\text{C} \equiv \text{OH} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3(\text{CH}_2)_{12}\text{C} \equiv \text{O}^- + \text{H}_3\text{O}^+ 
\]

myristic acid (acid form)  
myristate ion (base form)

Fatty acids, like all carboxylic acids, can react with water to produce their corresponding carboxylate ion forms (base forms).

ii) Name the base form of myristic acid.

myristic acid  \rightarrow\text{ myristate ion}  
The base forms of fatty acids (carboxylate ions) are named by replacing the "-ic acid" suffix of the fatty acid name with "-ate ion."

iii) In previous chapters, you learned that the relative amounts of a conjugate pair’s acid form and base form that are present in an aqueous solution depends on the pH of the solution and the pK\(_a\) of the particular acid (as described by the Henderson-Hasselbalch Equation). The pK\(_a\) of carboxylic acids (including fatty acids) is about 5.

For the myristic acid/myristate ion pair, predict the species that is predominant at physiological pH (~7.4).

**ANSWER:** At physiological pH, the pH (7.4) > pK\(_a\)(5), so the base form (myristate ion) is predominant

Since the physiological pH in cells, blood, and intercellular solutions is greater than 5, the carboxylate (base) form of a fatty acid is predominant in these solutions (pH > pK\(_a\)).

**For more details:** See chapter 12 part 1 video or chapter 12 section 3 in the textbook.
12.8)

i) Waxes are members of the ____________ family of organic compounds.
   a) carboxylic acid
   b) alcohol
   c) ether
   d) ester

ii) Waxes contain a ____________ group that is bonded between two long hydrocarbon parts.
   a) carboxylate
   b) hydroxyl
   c) carboxyl
   d) amino

iii) Waxes are ________________ because of their large and nonpolar hydrocarbon parts.
    a) hydrophilic
    b) amphipathic
    c) hydrophobic

iv) Waxes are formed by the esterification reaction of fatty acids with ________________.
    a) large carboxylic acids
    b) large alcohols
    c) large hydrocarbons
12.8)

i) Waxes are members of the ______________ family of organic compounds.

HINT:  
a) carboxylic acid
b) alcohol
c) ether  
d) ester

ii) Waxes contain a ______________ group that is bonded between two long hydrocarbon parts.

HINT:  
a) carboxylate  
b) hydroxyl  
c) carboxyl  
d) amino

iii) Waxes are ______________ because of their large and nonpolar hydrocarbon parts.

HINT:  
a) hydrophilic  
b) amphipathic  
c) hydrophobic

iv) Waxes are formed by the esterification reaction of fatty acids with ______________.

HINT:  
a) large carboxylic acids  
b) large alcohols  
c) large hydrocarbons

For more help: See chapter 12 part 2 video or chapter 12 section 4 in the textbook.
i) Waxes are members of the ____________ family of organic compounds.
   a) carboxylic acid
   b) alcohol
   c) ether
   d) ester

ii) Waxes contain a ____________ group that is bonded between two long hydrocarbon parts.
   a) carboxylate
   b) hydroxyl
   c) carboxyl
   d) amino

iii) Waxes are ____________ because of their large and nonpolar hydrocarbon parts.
   a) hydrophilic
   b) amphipathic
   c) hydrophobic

iv) Waxes are formed by the esterification reaction of fatty acids with ________________.
   a) large carboxylic acids
   b) large alcohols
   c) large hydrocarbons

For more details: See chapter 12 part 2 video or chapter 12 section 4 in the textbook.
12.9) Draw the condensed structure of the wax that is produced in the reaction shown here.

\[
\text{CH}_3(\text{CH}_2)_{18}\text{C} - \text{OH} + \text{H} - \text{O} - \text{CH}_2(\text{CH}_2)_{20}\text{CH}_3 \rightleftharpoons
\]
12.9) Draw the condensed structure of the wax that is produced in the reaction shown here.

\[
\text{CH}_3(\text{CH}_2)_{18}\text{C} - \text{OH} + \text{H} - \text{O} - \text{CH}_2(\text{CH}_2)_{20}\text{CH}_3 \rightleftharpoons \text{ } \]

**HINT:** Waxes are formed by the esterification reaction of fatty acids with large alcohols.

- The general form of the esterification reaction of a fatty acid with a large alcohol is shown below.

For more help: See chapter 12 part 2 video or chapter 12 section 4 in the textbook.
12.9) Draw the condensed structure of the wax that is produced in the reaction shown here.

\[
\text{CH}_3(\text{CH}_2)_{18}\text{C}(-\text{OH}) + \text{H}(-\text{O})-\text{CH}_2(\text{CH}_2)_{20}\text{CH}_3 \rightleftharpoons \text{CH}_3(\text{CH}_2)_{18}\text{C}(-\text{O})-\text{CH}_2(\text{CH}_2)_{20}\text{CH}_3 + \text{H}_2\text{O}
\]

**EXPLANATION:** Waxes are formed by the esterification reaction of fatty acids with large alcohols.

- The general form of the esterification reaction of a fatty acid with a large alcohol is shown below.

- In this reaction, the OH from the fatty acid and an H from the alcohol are removed, and then combined to form H\textsubscript{2}O. The oxygen (O) and hydrocarbon that was originally part of the alcohol, forms a new bond to the fatty acid’s carbonyl carbon.

**For more details:** See chapter 12 part 2 video or chapter 12 section 4 in the textbook.
12.10

(i) Triglycerides - also referred to as triacylglycerides - contain three ________- type bonds.
   a) ether
   b) ester
   c) amide
   d) amine

(ii) Triglycerides are composed of contain three ________ residues and one __________ residue.
   a) alcohol, ester
   b) fatty acid, ester
   c) fatty acid, glycerol
   d) alcohol, glycerol

(iii) Draw the general form of a triglyceride molecule.
12.10)

i) Triglycerides - also referred to as triacylglycerides - contain three ________ - type bonds.

**HINT:**
- a) ether
- b) ester
- c) amide
- d) amine

ii) Triglycerides are composed of contain three ________ residues and one ________ residue.

**HINT:**
- a) alcohol, ester
- b) fatty acid, ester
- c) fatty acid, glycerol
- d) alcohol, glycerol

iii) Draw the general form of a triglyceride molecule.

**HINT:** You will find the general form in your lecture notes and the textbook.

For more help: See chapter 12 part 3 video or chapter 12 section 5 in the textbook.
12.10)

i) Triglycerides - also referred to as triacylglycerides - contain three _______ - type bonds.
   a) ether
   b) **ester**
   c) amide
   d) amine

   The ester bonding pattern is highlighted yellow in the general form of a triglyceride (on the bottom of this page).

ii) Triglycerides are composed of contain three _______ residues and one __________ residue.
   a) alcohol, ester
   b) fatty acid, ester
   c) **fatty acid, glycerol**
   d) alcohol, glycerol

iii) Draw the general form of a triglyceride molecule.

For more details: See chapter 12 part 3 video or chapter 12 section 5 in the textbook.
12.11) Classify each of the triglycerides below as either **saturated** or **unsaturated**.

a) 
\[
\begin{align*}
\text{CH}_3\text{(CH}_2\text{)}_{10} & \text{C} - \text{O} - \text{CH}_2 \\
\text{CH}_3\text{(CH}_2\text{)}_6\text{CH}_2 & \text{C} - \text{O} - \text{CH} \\
\text{CH}_3\text{(CH}_2\text{)}_{16} & \text{C} - \text{O} - \text{CH}_2
\end{align*}
\]

b) 
\[
\begin{align*}
\text{CH}_3\text{(CH}_2\text{)}_{10} & \text{C} - \text{O} - \text{CH}_2 \\
\text{CH}_3\text{(CH}_2\text{)}_{12} & \text{C} - \text{O} - \text{CH} \\
\text{CH}_3\text{(CH}_2\text{)}_{16} & \text{C} - \text{O} - \text{CH}_2
\end{align*}
\]

c) 
\[
\begin{align*}
\text{CH}_3\text{(CH}_2\text{)}_{14} & \text{C} - \text{O} - \text{CH}_2 \\
\text{CH}_3\text{(CH}_2\text{)}_6\text{CH}_2 & \text{C} - \text{O} - \text{CH} \\
\text{CH}_3\text{(CH}_2\text{)}_{10} & \text{C} - \text{O} - \text{CH}_2
\end{align*}
\]

d) 
\[
\begin{align*}
\text{CH}_3\text{(CH}_2\text{)}_{14} & \text{C} - \text{O} - \text{CH}_2 \\
\text{CH}_3\text{(CH}_2\text{)}_6\text{CH}_2 & \text{C} - \text{O} - \text{CH} \\
\text{CH}_3\text{(CH}_2\text{)}_{10} & \text{C} - \text{O} - \text{CH}_2
\end{align*}
\]
12.11) Classify each of the triglycerides below as either saturated or unsaturated.

HINT:
We classify triglyceride molecules as either saturated or unsaturated using the same criteria as we used for fatty acids.

- **Saturated** triglyceride molecules **do not** contain carbon-carbon double bonds.
- **Unsaturated** triglyceride molecules contain **one or more** carbon-carbon double bonds.

For more help: See chapter 12 part 3 video or chapter 12 section 5 in the textbook.
12.11) Classify each of the triglycerides below as either **saturated** or **unsaturated**.

**EXPLANATION:**
We classify *triglyceride* molecules as either **saturated** or **unsaturated** using the same criteria as we used for *fatty acids*.

- **Saturated** triglyceride molecules do not contain *carbon-carbon* double bonds.
- **Unsaturated** triglyceride molecules contain *one or more* carbon-carbon double bonds.

For more details: See chapter 12 part 3 video or chapter 12 section 5 in the textbook.
12.12) Classify each of the triglycerides below as either monounsaturated or polyunsaturated.

a)  
\[ \text{CH}_3(\text{CH}_2)_{10} \text{C} - \text{O} - \text{CH}_2 \]  
\[ \text{CH}_3(\text{CH}_2)_{6} \text{CH}_2 \text{C} = \text{C} \text{CH}_2(\text{CH}_2)_{6} \text{C} - \text{O} - \text{CH} \]  
\[ \text{CH}_3(\text{CH}_2)_{16} \text{C} - \text{O} - \text{CH}_2 \]

b)  
\[ \text{CH}_3(\text{CH}_2)_{12} \text{C} - \text{O} - \text{CH}_2 \]  
\[ \text{CH}_3(\text{CH}_2)_{6} \text{CH}_2 \text{C} = \text{C} \text{CH}_2(\text{CH}_2)_{6} \text{C} - \text{O} - \text{CH} \]  
\[ \text{CH}_3(\text{CH}_2)_{3} \text{CH}_2 \text{CH}_2(\text{CH}_2)_{6} \text{C} - \text{O} - \text{CH}_2 \]

c)  
\[ \text{CH}_3(\text{CH}_2)_{14} \text{C} - \text{O} - \text{CH}_2 \]  
\[ \text{CH}_3(\text{CH}_2)_{6} \text{CH}_2 \text{C} = \text{C} \text{CH}_2(\text{CH}_2)_{6} \text{C} - \text{O} - \text{CH} \]  
\[ \text{CH}_3(\text{CH}_2)_{16} \text{C} - \text{O} - \text{CH}_2 \]

d)  
\[ \text{CH}_3(\text{CH}_2)_{12} \text{C} - \text{O} - \text{CH}_2 \]  
\[ \text{CH}_3(\text{CH}_2)_{6} \text{CH}_2 \text{C} = \text{C} \text{CH}_2(\text{CH}_2)_{6} \text{C} - \text{O} - \text{CH} \]  
\[ \text{CH}_3(\text{CH}_2)_{3} \text{CH}_2 \text{CH}_2(\text{CH}_2)_{6} \text{C} - \text{O} - \text{CH}_2 \]  
\[ \text{CH}_3(\text{CH}_2)_{2} \text{CH}_2 \text{CH}_2(\text{CH}_2)_{6} \text{C} - \text{O} - \text{CH}_2 \]
12.12) Classify each of the triglycerides below as either **monounsaturated** or **polyunsaturated**.

**HINT:**
Unsaturated triglycerides are often further subcategorized as either **monounsaturated** or **polyunsaturated**.
- **Monounsaturated** triglycerides contain only **one** carbon-carbon double bond.
- **Polyunsaturated** triglycerides contain **two or more** carbon-carbon double bonds.

**For more help:** See chapter 12 part 3 video or chapter 12 section 5 in the textbook.
12.12) Classify each of the triglycerides below as either **monounsaturated** or **polyunsaturated**.

**EXPLANATION:**

Unsaturated triglycerides are often further subcategorized as either monounsaturated or polyunsaturated.

- **Monounsaturated** triglycerides contain only *one* carbon-carbon double bond.
- **Polyunsaturated** triglycerides contain *two or more* carbon-carbon double bonds.

**For more details:** See chapter 12 part 3 video or chapter 12 section 5 in the textbook.
12.13)

i) What is the term that is generally used for a triglyceride that is liquid at room temperature?

ii) What is the term that is generally used for a triglyceride that is solid at room temperature?

iii) What is the name of the tissue that is composed of cells that store triglycerides?

iv) What are four primary biological roles of triglycerides in animals?

v) What is the term that is generally used for liquid triglycerides that are produce from plants?

vi) What is the term that is generally used for solid triglycerides that are produce from animals?

vii) In which nutritional labeling category are all triglycerides, whether from plants or animals, solid or liquid?
12.13)

i) What is the term that is generally used for a triglyceride that is liquid at room temperature?

ii) What is the term that is generally used for a triglyceride that is solid at room temperature?

iii) What is the name of the tissue that is composed of cells that store triglycerides?

iv) What are four primary biological roles of triglycerides in animals?

v) What is the term that is generally used for liquid triglycerides that are produce from plants?

vi) What is the term that is generally used for solid triglycerides that are produce from animals?

vii) In which nutritional labeling category are all triglycerides, whether from plants or animals, solid or liquid?

HINT: You will find the answers to all of these questions in the “triglycerides” section of your lecture notes and the textbook.

For more help: See chapter 12 part 3 video or chapter 12 section 5 in the textbook.
i) What is the term that is generally used for a triglyceride that is liquid at room temperature? oil

ii) What is the term that is generally used for a triglyceride that is solid at room temperature? fat

iii) What is the name of the tissue that is composed of cells that store triglycerides? adipose tissue

iv) What are four primary biological roles of triglycerides in animals? energy storage, the production of energy when metabolized, provision of fatty acids for the production of other lipids, and insulation

v) What is the term that is generally used for liquid triglycerides that are produce from plants? vegetable oil

vi) What is the term that is generally used for solid triglycerides that are produce from animals? animal fat

vii) In which nutritional labeling category are all triglycerides, whether from plants or animals, solid or liquid? “total fat”

The answers to all of these question are found in the “triglycerides” section of your lecture notes and the textbook.

For more details: See chapter 12 part 3 video or chapter 12 section 5 in the textbook.
12.14) Draw the **condensed** structure of the triglyceride that is formed from the esterification reaction of **three** stearic acid molecules and a glycerol molecule.
12.14) Draw the condensed structure of the triglyceride that is formed from the esterification reaction of three stearic acid molecules and a glycerol molecule.

HINT: In this esterification reaction, the OH’s from the fatty acids and three H’s from glycerol’s hydroxyl groups are removed, and then combined to form three H₂O molecules. The three oxygens, (O) that were originally in glycerol, each form anew bond to a fatty acid’s carbonyl carbon.

For more help: See chapter 12 part 3 video or chapter 12 section 5 in the textbook.
12.14) Draw the \textit{condensed} structure of the triglyceride that is formed from the esterification reaction of \textit{three} stearic acid molecules and a glycerol molecule.

\begin{center}
\begin{tikzpicture}
\node (a) at (0,0) {$\text{CH}_3(\text{CH}_2)_{16} \text{C} \text{-OH}$};
\node (b) at (0,-1) {$\text{CH}_3(\text{CH}_2)_{16} \text{C} \text{-OH}$};
\node (c) at (0,-2) {$\text{CH}_3(\text{CH}_2)_{16} \text{C} \text{-OH}$};
\node (d) at (1,0) {$\text{H} \text{-O-CH}_2$};
\node (e) at (1,-1) {$\text{H} \text{-O-CH}_2$};
\node (f) at (1,-2) {$\text{H} \text{-O-CH}_2$};
\draw[->,blue] (a) to [bend right=90] (d);
\draw[->,blue] (b) to [bend right=90] (e);
\draw[->,blue] (c) to [bend right=90] (f);
\end{tikzpicture}
\end{center}

\textbf{EXPLANATION:} In this esterification reaction, the OH’s from the fatty acids and three H’s from glycerol’s hydroxyl groups are removed, and then combined to form three H$_2$O molecules. The three oxygens, (O) that were originally in glycerol, each form anew bond to a fatty acid’s carbonyl carbon.

\textbf{For more details:} See chapter 12 part 3 video or chapter 12 section 5 in the textbook.
12.15) Using the table of fatty acids, draw the condensed structure of an unsaturated triglyceride.
12.15) Using the table of fatty acids, draw the condensed structure an **unsaturated** triglyceride.

<table>
<thead>
<tr>
<th>Number of Carbon-Octanoic Double Bonds</th>
<th>Common Name</th>
<th>Condensed Structure</th>
<th>Major Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>lauric acid</td>
<td>CH₃(CH₂)₁₀COOH</td>
<td>coconut</td>
</tr>
<tr>
<td>14</td>
<td>myristic acid</td>
<td>CH₃(CH₂)₁₂COOH</td>
<td>nutmeg</td>
</tr>
<tr>
<td>16</td>
<td>palmitic acid</td>
<td>CH₃(CH₂)₁₄COOH</td>
<td>palm</td>
</tr>
<tr>
<td>16</td>
<td>palmitoleic acid</td>
<td>CH₃(CH₂)₅CH=CH(CH₂)₇COOH</td>
<td>macadamia, animals</td>
</tr>
<tr>
<td>18</td>
<td>stearic acid</td>
<td>CH₃(CH₂)₁₆COOH</td>
<td>animal fat</td>
</tr>
<tr>
<td>18</td>
<td>oleic acid</td>
<td>CH₃(CH₂)₇CH=CH(CH₂)₇COOH</td>
<td>olives</td>
</tr>
<tr>
<td>18</td>
<td>linoleic acid</td>
<td>CH₃(CH₂)₄(CH=CH(CH₂)₂)(CH₂)₆COOH</td>
<td>safflower, soy</td>
</tr>
<tr>
<td>18</td>
<td>linolenic acid</td>
<td>CH₃CH₂(CH=CHCH₂)₃(CH₂)₆COOH</td>
<td>flax, corn</td>
</tr>
</tbody>
</table>

**HINT:**
- **Saturated** triglyceride molecules do not contain carbon-carbon double bonds.
- **Unsaturated** triglyceride molecules contain one or more carbon-carbon double bonds.

For more help: See chapter 12 part 3 video or chapter 12 section 5 in the textbook.
12.15) Using the table of fatty acids, draw the condensed structure of an unsaturated triglyceride.

**Unsaturated** triglyceride molecules contain **one or more** carbon-carbon double bonds. **Your answer is CORRECT** if the triglyceride that you drew has the correct esterification bonding patterns between the fatty acid residues and the glycerol residue AND has **one or more** carbon-carbon double bonds. Two examples of correct answers are shown below.

**EXAMPLE OF A CORRECT ANSWER:**

\[
\begin{align*}
\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH} \equiv \text{CHCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH} & -\text{O}\text{-CH} \\
\text{CH}_3(\text{CH}_2)_12\text{C} & -\text{O}\text{-CH} \\
\text{CH}_3(\text{CH}_2)_12\text{C} & -\text{O}\text{-CH}_2
\end{align*}
\]

**EXAMPLE OF A CORRECT ANSWER:**

\[
\begin{align*}
\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH} \equiv \text{CHCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH} & -\text{O}\text{-CH} \\
\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH} & -\text{O}\text{-CH} \\
\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH} & -\text{O}\text{-CH}_2
\end{align*}
\]

**For more details:** See chapter 12 part 3 video or chapter 12 section 5 in the textbook.
12.16) Using the table of fatty acids, draw the **SKELETAL** structure of an **unsaturated** triglyceride.

<table>
<thead>
<tr>
<th>Number of Carbon</th>
<th>Number of Carbon-Carbon Double Bonds</th>
<th>Common Name</th>
<th>Condensed Structure</th>
<th>Major Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>0</td>
<td>lauric acid</td>
<td>(\text{CH}_3(\text{CH}_2)_10\text{COOH})</td>
<td>coconut</td>
</tr>
<tr>
<td>14</td>
<td>0</td>
<td>myristic acid</td>
<td>(\text{CH}_3(\text{CH}<em>2)</em>{12}\text{COOH})</td>
<td>nutmeg</td>
</tr>
<tr>
<td>16</td>
<td>0</td>
<td>palmitic acid</td>
<td>(\text{CH}_3(\text{CH}<em>2)</em>{14}\text{COOH})</td>
<td>palm</td>
</tr>
<tr>
<td>16</td>
<td>1</td>
<td>palmitoleic acid</td>
<td>(\text{CH}_3(\text{CH}<em>2)</em>{15}\text{CH}==\text{CH}(\text{CH}<em>2)</em>{7}\text{COOH})</td>
<td>macadamia, animals</td>
</tr>
<tr>
<td>18</td>
<td>0</td>
<td>stearic acid</td>
<td>(\text{CH}_3(\text{CH}<em>2)</em>{16}\text{COOH})</td>
<td>animal fat</td>
</tr>
<tr>
<td>18</td>
<td>1</td>
<td>oleic acid</td>
<td>(\text{CH}_3(\text{CH}<em>2)</em>{17}\text{CH}==\text{CH}(\text{CH}<em>2)</em>{7}\text{COOH})</td>
<td>olives</td>
</tr>
<tr>
<td>18</td>
<td>2</td>
<td>linoleic acid</td>
<td>(\text{CH}_3(\text{CH}<em>2)</em>{19}(\text{CH}==\text{CHCH}_2)_2(\text{CH}<em>2)</em>{3}\text{COOH})</td>
<td>safflower, soy</td>
</tr>
<tr>
<td>18</td>
<td>3</td>
<td>linolenic acid</td>
<td>(\text{CH}_3\text{CH}_2(\text{CH}==\text{CHCH}_2)_3(\text{CH}<em>2)</em>{6}\text{COOH})</td>
<td>flax, corn</td>
</tr>
</tbody>
</table>
12.16) Using the table of fatty acids, draw the **SKELETAL** structure of an **unsaturated** triglyceride.

<table>
<thead>
<tr>
<th>Number of Carbons</th>
<th>Number of Carbon-Carbon Double Bonds</th>
<th>Common Name</th>
<th>Condensed Structure</th>
<th>Major Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>0</td>
<td>lauric acid</td>
<td>CH$_3$(CH$<em>2$)$</em>{10}$COOH</td>
<td>coconut</td>
</tr>
<tr>
<td>14</td>
<td>0</td>
<td>myristic acid</td>
<td>CH$_3$(CH$<em>2$)$</em>{12}$COOH</td>
<td>nutmeg</td>
</tr>
<tr>
<td>16</td>
<td>0</td>
<td>palmitic acid</td>
<td>CH$_3$(CH$<em>2$)$</em>{14}$COOH</td>
<td>palm</td>
</tr>
<tr>
<td>16</td>
<td>1</td>
<td>palmitoleic acid</td>
<td>CH$_3$(CH$_2$)$_9$CH=CH(CH$_2$)$_7$COOH</td>
<td>macadamia, animals</td>
</tr>
<tr>
<td>18</td>
<td>0</td>
<td>stearic acid</td>
<td>CH$_3$(CH$<em>2$)$</em>{16}$COOH</td>
<td>animal fat</td>
</tr>
<tr>
<td>18</td>
<td>1</td>
<td>oleic acid</td>
<td>CH$_3$(CH$_2$)$_7$CH=CH(CH$_2$)$_7$COOH</td>
<td>olives</td>
</tr>
<tr>
<td>18</td>
<td>2</td>
<td>linoleic acid</td>
<td>CH$_3$(CH$<em>2$)$</em>{14}$(CH=CHCH$_2$)$_2$(CH$_2$)$_2$COOH</td>
<td>safflower, soy</td>
</tr>
<tr>
<td>18</td>
<td>3</td>
<td>linolenic acid</td>
<td>CH$_3$CH$_2$(CH=CHCH$_2$)$_3$(CH$_2$)$_6$COOH</td>
<td>flax, corn</td>
</tr>
</tbody>
</table>

**HINT:**
- **Saturated** triglyceride molecules **do not** contain carbon-carbon double bonds.
- **Unsaturated** triglyceride molecules contain one or more carbon-carbon double bonds.

**For more help:** See chapter 12 part 3 video or chapter 12 section 5 in the textbook.
12.16) Using the table of fatty acids, draw the SKELETAL structure of an unsaturated triglyceride.

**Unsaturated** triglyceride molecules contain *one or more* carbon-carbon double bonds. Your answer is CORRECT if the triglyceride that you drew has the correct esterification bonding patterns between the fatty acid residues and the glycerol residue AND has *one or more* carbon-carbon double bonds. Two *examples* of correct answers are shown below.

**EXAMPLE OF A CORRECT ANSWER:**

```

```

**EXAMPLE OF A CORRECT ANSWER:**

```

```

**For more details:** See [chapter 12 part 3](#) video or chapter 12 section 5 in the textbook.
12.17) Draw the condensed structure of the product in the *complete hydrogenation* of the triglyceride shown below.

\[
\begin{align*}
\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH} &= \text{CHCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{C} - \text{O} - \text{CH}_2 \\
\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{C} - \text{O} - \text{CH} \\
\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{C} - \text{O} - \text{CH}_2
\end{align*}
\]
HINT:
The carbon-carbon double bonds of triglycerides will react with hydrogen gas (H₂) in the presence of a catalyst (at high temperatures). If enough H₂ is supplied, ALL of the carbon-carbon double bonds in unsaturated triglycerides become completely saturated; a saturated triglyceride is formed; we call this complete hydrogenation. A hydrogen atom is added to each of the double-bonded carbons, thereby converting them into single bonds.

For more help: See chapter 12 part 4 video or chapter 12 section 5 in the textbook.
EXPLANATION:
The carbon-carbon double bonds of triglycerides will react with hydrogen gas (H₂) in the presence of a catalyst (at high temperatures). If enough H₂ is supplied, ALL of the carbon-carbon double bonds in unsaturated triglycerides become completely saturated; a saturated triglyceride is formed; we call this complete hydrogenation. A hydrogen atom is added to each of the double-bonded carbons, thereby converting them into single bonds. The reaction must be done at a high temperature and on the surface of a metal catalyst. The catalysts used are typically platinum, palladium, rhodium, or ruthenium.

- Note that this unsaturated triglyceride molecule reactant contains three double bonds, therefore three H₂ molecules are needed to achieve complete saturation.

For more details: See chapter 12 part 4 video or chapter 12 section 5 in the textbook.
12.18) Using complete sentence(s), write the definition of the following:

a) partial hydrogenation

b) trans fat

c) rancidification

d) saponification
12.18) Using complete sentence(s), write the definition of the following:

a) partial hydrogenation

b) trans fat

c) rancidification

d) saponification

HINT:
You can find the definitions for all of these terms/phrases in the “reactions of triglycerides” section of your lecture notes or the textbook.

For more help: See chapter 12 part 4 video or chapter 12 section 5 in the textbook.
12.18) Using complete sentence(s), write the definition of the following:

a) partial hydrogenation

Partial hydrogenation is a chemical reaction that occurs if the amount of H$_2$ is limited or the chemical reaction time is reduced in the oxidation of a triglyceride so that the triglyceride product will contain unreacted carbon-carbon double bonds.

b) trans fat

Trans fats are triglycerides containing one or more carbon-carbon double bonds that have the trans configuration. An undesirable consequence of partial hydrogenation is the formation of trans fats.

- In the partial hydrogenation process, many of the unreacted cis carbon-carbon double bonds are converted to the trans configuration.

c) rancidification

Rancidification is a term used for the chemical reaction in which triglyceride food substances are oxidized to produce aldehydes and carboxylic acids that have foul odors.

- In order to prevent or slow the rancidification of foods, the oxygen supply can be limited by air-tight containers and packaging, and the food can be stored at low temperatures.

d) saponification

Saponification is a chemical reaction in which a triglyceride reacts with hydroxide ions to produce three long-chain carboxylate ions and glycerol.

- The saponification reaction is used to make soap. The long-chain carboxylate ions that are produced are amphipathic, and act as emulsifying agents to remove nonpolar molecules (i.e. grease or oil) from surfaces, including - very importantly – skin and clothing.

For more details: See chapter 12 part 4 video or chapter 12 section 5 in the textbook.
12.19) Draw the condensed structure of the products for the saponification reaction shown below. Include the cations when drawing the fatty acid salts.

\[
\begin{align*}
\text{CH}_3(\text{CH}_2)_{16} & \quad \text{CH}_3(\text{CH}_2)_{12} + 3 \text{NaOH} \\
\text{CH}_3(\text{CH}_2)_{14} &
\end{align*}
\]
12.19) Draw the condensed structure of the products for the saponification reaction shown below. Include the cations when drawing the fatty acid salts.

HINT:
The general form for the saponification reaction is shown below.

For more help: See chapter 12 part 4 video or chapter 12 section 5 in the textbook.
12.19) Draw the condensed structure of the products for the saponification reaction shown below. Include the cations when drawing the fatty acid salts.

\[
\begin{align*}
\text{CH}_3(CH_2)_{16}C-O-CH_2 & \text{ (triglyceride)} \\
\text{CH}_3(CH_2)_{12}C-O-CH & + 3 \text{NaOH} \rightleftharpoons \text{CH}_3(CH_2)_{16}C-O^-\text{Na}^+ \\
\text{CH}_3(CH_2)_{14}C-O-CH_2 & \text{ (glycerol)} \\
\end{align*}
\]

**EXPLANATION:**

In the *saponification* reaction, a *triglyceride* reacts with *hydroxide ions* to produce *three long-chain carboxylate ions* and *glycerol*.

- The hydroxide ions in the saponification reaction come from hydroxide-containing ionic compounds, usually sodium hydroxide (NaOH) or potassium hydroxide (KOH). When the cation of the hydroxide-containing compound is specified, it is often written after the long-chain carboxylate ion products as shown in the solution to this problem.
- The compounds formed from the long-chain carboxylate anions and the Na\(^+\) (or K\(^+\)) cations are *ionic* and are called *fatty acid salts*.

For more details: See chapter 12 part 4 video or chapter 12 section 5 in the textbook.
12.20) Identify the following items as being properties of either glycerophospholipids, sphingophospholipids, or both glycerophospholipids AND sphingophospholipids.

a) contain a phosphate residue
b) contain a glycerol residue
c) present in biological membranes
d) amphipathic
e) contain a sphingosine residue
f) contain an alcohol residue
g) can contain two fatty acid residues
12.20) Identify the following items as being properties of either glycerophospholipids, sphingophospholipids, or both glycerophospholipids AND sphingophospholipids.

a) contain a phosphate residue

b) contain a glycerol residue

c) present in biological membranes

d) amphipathic

e) contain a sphingosine residue

f) contain an alcohol residue

g) can contain two fatty acid residues

HINT:
For the items that involve residues, consider the general form of glycerophospholipids and sphingophospholipids.

You can find the correct responses for the items that do not involve residues in the phospholipids section of your lecture notes or the textbook.

For more help: See chapter 12 part 5 video or chapter 12 section 6 in the textbook.
12.20) Identify the following items as being properties of either glycerophospholipids, sphingophospholipids, or both glycerophospholipids AND sphingophospholipids.

a) contain a phosphate residue  both glycerophospholipids AND sphingophospholipids.

b) contain a glycerol residue   glycerophospholipids

c) present in biological membranes  both glycerophospholipids AND sphingophospholipids.

d) amphipathic  both glycerophospholipids AND sphingophospholipids.

e) contain a sphingosine residue   sphingophospholipids.

f) contain an alcohol residue  both glycerophospholipids AND sphingophospholipids.

g) can contain two fatty acid residues   glycerophospholipids

For more details: See chapter 12 part 5 video or chapter 12 section 6 in the textbook.
12.21) The difference between sphingophospholipids and glycerophospholipids is that sphingophospholipids
   a) have three alcohol residues that replace the fatty acid residues.
   b) have one phosphate, but the phosphate is attached to the fatty acid residue, not the glycerol.
   c) have three phosphates, not one, and they are attached to all of the fatty acids.
   d) none of the above.
12.21) The difference between sphingophospholipids and glycerophospholipids is that sphingophospholipids

a) have three alcohol residues that replace the fatty acid residues.
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d) none of the above.

For more help: See chapter 12 part 5 video or chapter 12 section 6 in the textbook.
12.21) The difference between sphingophospholipids and glycerophospholipids is that sphingophospholipids
a) have three alcohol residues that replace the fatty acid residues.
b) have one phosphate, but the phosphate is attached to the fatty acid residue, not the glycerol.
c) have three phosphates, not one, and they are attached to all of the fatty acids.
d) none of the above.

For more details: See chapter 12 part 5 video or chapter 12 section 6 in the textbook.
12.22) The illustration below shows how the fatty acid, glycerol, phosphate, and alcohol residues combine to form a **glycerophospholipid**. Match the box number with the **type of bonding pattern** that is formed.

**Type of bonding pattern choices:**

- a) ester
- b) amide
- c) phosphoester
- d) phosphodiester
- e) peptide
- f) glycosidic

i) **Box #1**: ________________

ii) **Box #2**: ________________

iii) **Box #3**: ________________

iv) **Box #4**: ________________
12.22) The illustration below shows how the fatty acid, glycerol, phosphate, and alcohol residues combine to form a **glycerophospholipid**. Match the box number with the **type of bonding pattern** that is formed.

**Type of bonding pattern choices:**
- a) ester
- b) amide
- c) phosphoester
- d) phosphodiester
- e) peptide
- f) glycosidic

HINT:

i) Box #1: ________________

ii) Box #2: ________________

iii) Box #3: ________________

iv) Box #4: ________________

For more help: See chapter 12 part 5 video or chapter 12 section 6 in the textbook.
12.22) The illustration below shows how the fatty acid, glycerol, phosphate, and alcohol residues combine to form a glycerophospholipid. Match the box number with the type of bonding pattern that is formed.

**Type of bonding pattern choices:**
- a) ester
- b) amide
- c) phosphoester
- d) phosphodiester
- e) peptide
- f) glycosidic

i) Box #1: ________________ ester

ii) Box #2: ________________ phosphodiester

iii) Box #3: ________________ phosphoester

iv) Box #4: ________________ phosphoester

For more details: See chapter 12 part 5 video or chapter 12 section 6 in the textbook.
12.23) The illustration below shows how the fatty acid, sphingosine, phosphate, and alcohol residues combine to form a **sphingophospholipid**. Match the box number with the **type of bonding pattern** that is formed.

**Type of bonding pattern choices:**
- a) ester
- b) amide
- c) phosphoester
- d) phosphodiester
- e) peptide
- f) glycosidic

i) **Box #1:** ______________

ii) **Box #2:** ______________
12.23) The illustration below shows how the fatty acid, sphingosine, phosphate, and alcohol residues combine to form a sphingophospholipid. Match the box number with the type of bonding pattern that is formed.

**Type of bonding pattern choices:**
- a) ester
- b) amide
- c) phosphoester
- d) phosphodiester
- e) peptide
- f) glycosidic

**HINT:**
For more help: See chapter 12 part 5 video or chapter 12 section 6 in the textbook.

i) Box #1: ______________

ii) Box #2: ______________

---

For more help: See chapter 12 part 5 video or chapter 12 section 6 in the textbook.
12.23) The illustration below shows how the fatty acid, sphingosine, phosphate, and alcohol residues combine to form a sphingophospholipid. Match the box number with the type of bonding pattern that is formed.

**Type of bonding pattern choices:**
- a) ester
- b) amide
- c) phosphoester
- d) phosphodiester
- e) peptide
- f) glyosidic

i) **Box #1:** __amide__

ii) **Box #2:** __phosphoester__

For more details: See chapter 12 part 5 video or chapter 12 section 6 in the textbook.
12.24) The subclasses of glycerophospholipids are determined by the identity of their X-group. Phosphatidylethanolamines are a subclass of glycerophospholipids. In humans, phosphatidylethanolamines are found in nervous tissue such as the white matter of brain, nerves, neural tissue, and in spinal cord.

Draw the condensed structure of the phosphatidylethanolamine that contains two stearic acid residues.

<table>
<thead>
<tr>
<th>Organic “X group”</th>
<th>Glycerophospholipid Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>(-\text{CH}_2\text{CH}_2\text{NH}_3^+)</td>
<td>Phosphatidylethanolamine (present in Cephalin)</td>
</tr>
<tr>
<td>(\text{CH}_3)</td>
<td>Phosphatidylcholine (present in Lecithin)</td>
</tr>
<tr>
<td>(-\text{CH}_2\text{CH}_2\text{N}^-\text{CH}_3)</td>
<td>(\text{CH}_3)</td>
</tr>
<tr>
<td></td>
<td>Phosphatidylserine (present in Cephalin)</td>
</tr>
</tbody>
</table>
12.24) The subclasses of glycerophospholipids are determined by the identity of their X-group. Phosphatidylethanolamines are a subclass of glycerophospholipids. In humans, phosphatidylethanolamines are found in nervous tissue such as the white matter of brain, nerves, neural tissue, and in spinal cord.

Draw the condensed structure of the *phosphatidylethanolamine* that contains two stearic acid residues.

**HINT:**

Fatty acid, glycerol, phosphate, and alcohol residues combine to form a *glycerophospholipid* as illustrated below.

---

**Organic “X group”** | **Glycerophospholipid Class**
--- | ---
$\text{CH}_2\text{CH}_2\text{NH}_3^+$ | Phosphatidylethanolamine (present in Cephalin)
$\text{CH}_3$ | Phosphatidylcholine (present in Lecithin)
$\text{CH}_2\text{CH}_3\text{NH}_3^+$ | Phosphatidylserine (present in Cephalin)

---

For more help: See chapter 12 part 5 video or chapter 12 section 6 in the textbook.
The subclasses of glycerophospholipids are determined by the identity of their X-group. Phosphatidylethanolamines are a subclass of glycerophospholipids. In humans, phosphatidylethanolamines are found in nervous tissue such as the white matter of brain, nerves, neural tissue, and in spinal cord.

Draw the condensed structure of the phosphatidylethanolamine that contains two stearic acid residues.

**EXPLANATION:**
Fatty acid, glycerol, phosphate, and alcohol residues combine to form a glycerophospholipid as illustrated below.

**ANSWER**

For more details: See [chapter 12 part 5 video](#) or [chapter 12 section 6](#) in the textbook.
12.25) Using the phosphatidylethanolamine that you drew in the previous problem (and shown below), label the polar head and nonpolar tail regions of the molecule.

\[
\begin{align*}
\text{CH}_3\text{(CH}_2\text{)}_{16}\text{C} & \text{O} - \text{CH}_2 \\
\text{O} & \\
\text{CH}_3\text{(CH}_2\text{)}_{16}\text{C} & \text{O} - \text{CH} \\
\text{CH}_2\text{O} - \text{P} & \text{O} - \text{CH}_2\text{CH}_2\text{NH}_3^+ \\
\text{O} & \\
\end{align*}
\]
12.25) Using the *phosphatidylethanolamine* that you drew in the previous problem (and shown below), label the polar head and nonpolar tail regions of the molecule.

![Diagram of phosphatidylethanolamine molecule]

**HINT:**

The polar head region is quite **hydrophilic**. This region is attracted to water through **dipole-dipole** interactions because it contains several “highly polar” bonds. It can **hydrogen bond** with water. The polar head is also attracted to water through **ion-dipole interactions** because of the **formal charge** on both an oxygen and a nitrogen.

For more help: See chapter 12 part 5 video or chapter 12 section 6 in the textbook.
12.25) Using the phosphatidylethanolamine that you drew in the previous problem (and shown below), label the polar head and nonpolar tail regions of the molecule.

**ANSWER**

- **Nonpolar “Tails”**
- **Polar “Head”**

**EXPLANATION:**

- The **polar head** region is quite *hydrophilic*. This region is attracted to water through *dipole-dipole* interactions because it contains several “highly polar” bonds. It can *hydrogen bond* with water. The polar head is also attracted to water through *ion-dipole interactions* because of the *formal charge* on both an oxygen and a nitrogen.

- The hydrocarbon chains of the fatty acid residues make up the *nonpolar tails*.

**For more details:** See chapter 12 part 5 video or chapter 12 section 6 in the textbook.
12.26) The subclasses of sphingophospholipids are determined by the identity of their X-group. *Sphingomyelins* are a subclass of sphingophospholipids. They are found in the myelin sheaths of nerve cells.

Draw the condensed structure of the sphingomyelin that is composed from the residues shown below.

<table>
<thead>
<tr>
<th>“X-group”</th>
<th>Sphingophospholipid Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>(-\text{H})</td>
<td>Ceramide</td>
</tr>
<tr>
<td>(-\text{CH}_2\text{CH}_2\text{NH}_3^+) or (-\text{CH}_2\text{CH}_2\text{N}^+\text{CH}_3)</td>
<td>Sphingomyelin</td>
</tr>
</tbody>
</table>

\[
\text{CH}_3\text{CH}_2\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3\text{CH}_2\text{CH}_3 \cong \text{CH} - \text{CH} - \text{OH}
\]

\[
\begin{align*}
\text{O} & \quad \text{H} - \text{N} - \text{CH} \\
\text{CH}_3\text{(CH}_2\text{)}_{14} & \quad \text{C} - \text{OH} \\
\text{palmitic acid} & \\
\text{H} & \quad \text{CH}_2 - \text{O} - \text{H} \\
\text{sphingosine} & \\
\text{O} & \quad \text{HO} - \text{P} - \text{OH} \\
\text{phosphate} & \\
\end{align*}
\]

\[
\text{CH}_3
\]

an alcohol
12.26) The subclasses of sphingophospholipids are determined by the identity of their X-group. Sphingomyelins are a subclass of sphingophospholipids. They are found in the myelin sheaths of nerve cells.

Draw the condensed structure of the Sphingomyelins that is composed from the residues shown below.

A fatty acid, sphingosine, phosphate, and alcohol residues combine to form a sphingomyelin as illustrated above.

For more help: See chapter 12 part 5 video or chapter 12 section 6 in the textbook.
The subclasses of sphingophospholipids are determined by the identity of their X-group. Sphingomyelins are a subclass of sphingophospholipids. They are found in the myelin sheaths of nerve cells.

Draw the condensed structure of the Sphingomyelins that is composed from the residues shown below.

**EXPLANATION:**
A fatty acid, sphingosine, phosphate, and alcohol residues combine to form a **sphingomyelin** as illustrated here.

For more details: See chapter 12 part 5 video or chapter 12 section 6 in the textbook.
Categorized each of these compounds as being either a glycerophospholipid or a sphingophospholipid.
Categorized each of these compounds as being either a glycerophospholipid or a sphingophospholipid.

**HINT:**
The key to differentiating between the two classes of phospholipids is to identify either a **glycerol backbone** (for **glycerophospholipids**) or a **sphingosine backbone** (for **sphingophospholipids**).

- An easy way to do so is to look for the nitrogen in the amide bond between the fatty acid residue and the sphingosine backbone. This **amide bonding pattern is present in sphingophospholipids**, but not in glycerophospholipids.

*For more help:* See chapter 12 part 5 video or chapter 12 section 6 in the textbook.
Categorized each of these compounds as being either a **glycerophospholipid** or a **sphingophospholipid**.

**EXPLANATION:**

The key to differentiating between the two classes of phospholipids is to identify either a **glycerol backbone** (for **glycerophospholipids**) or a **sphingosine backbone** (for **sphingophospholipids**).

- An easy way to do so is to look for the nitrogen in the amide bond between the fatty acid residue and the sphingosine backbone. This **amide bonding pattern is present in sphingophospholipids**, but not in glycerophospholipids.

For more details: See chapter 12 part 5 video or chapter 12 section 6 in the textbook.
12.28)

i) Glycolipids are lipids that contain one or more ________________ residues.
   a) phosphate
   b) monosaccharide
   c) amino acid
   d) all of the above

ii) Glycolipids are easily distinguished from phospholipids by the *absence* of _______________ residues in glycolipids.
   a) phosphate
   b) monosaccharide
   c) amino acid
   d) none of the above

iii) The specific ________________ residues that protrude from red blood cells form the basis of ABO blood typing.
   a) phosphate
   b) monosaccharide
   c) amino acid
   d) all of the above
i) Glycolipids are lipids that contain one or more ________________ residues.  

**HINT:**  
- a) phosphate  
- b) monosaccharide  
- c) amino acid  
- d) all of the above  

Consider the general forms of glycolipids (glyceroglycolipids and sphingoglycolipids).

ii) Glycolipids are easily distinguished from phospholipids by the absence of ________________ residues in glycolipids.  

**HINT:**  
- a) phosphate  
- b) monosaccharide  
- c) amino acid  
- d) none of the above  

Compare the general forms of glycolipids (glyceroglycolipids and sphingoglycolipids) with those of phospholipids (glycerophospholipids and sphingophospholipids).

iii) The specific ________________ residues that protrude from red blood cells form the basis of ABO blood typing.  

**HINT:**  
- a) phosphate  
- b) monosaccharide  
- c) amino acid  
- d) all of the above

*For more help:* See chapter 12 part 6 video or chapter 12 section 6 in the textbook.
i) Glycolipids are lipids that contain one or more ________________ residues.
   a) phosphate  
   b) monosaccharide  
   c) amino acid  
   d) all of the above
   **EXPLANATION:** Consider the general forms of glycolipids (glyceroglycolipids and sphingoglycolipids).

ii) Glycolipids are easily distinguished from phospholipids by the absence of ________________ residues in glycolipids.
   a) phosphate  
   b) monosaccharide  
   c) amino acid  
   d) none of the above
   **EXPLANATION:** Compare the general forms of glycolipids (glyceroglycolipids and sphingoglycolipids) with those of phospholipids (glycerophospholipids and sphingophospholipids).

iii) The specific ________________ residues that protrude from red blood cells form the basis of ABO blood typing.
   a) phosphate  
   b) monosaccharide  
   c) amino acid  
   d) all of the above
   The specific monosaccharide residues that protrude from the membrane serve in maintaining membrane stability, attaching cells to one another to form tissues, and as a “recognition site” for “cell signaling” chemicals. Cell signaling chemicals make it possible for the cells to respond to their environment in order to enable functions such as tissue homeostasis, immunity, and the development of the organism. When signaling systems are not operating correctly to process the communication between cells and their environments, diseases such as cancer, diabetes, and autoimmune disorders occur.

**For more details:** See chapter 12 part 6 video or chapter 12 section 6 in the textbook.
12.29) Glycolipids often have glycerol or sphingosine backbones. Glycolipids with a glycerol backbone are called **glyceroglycolipids**. Glycolipids with a sphingosine backbone are called **sphingoglycolipids**. Draw condensed structure for the general form of a glyceroglycolipid and a sphingoglycolipid.
12.29) Glycolipids often have glycerol or sphingosine backbones. Glycolipids with a glycerol backbone are called glyceroglycolipids. Glycolipids with a sphingosine backbone are called sphingoglycolipids. Draw condensed structure for the general form of a glyceroglycolipid and a sphingoglycolipid.

**HINT:**
The general forms of both types of glycolipids can be found in the glycolipids section of your lecture notes or the textbook.

For more help: See chapter 12 part 6 video or chapter 12 section 6 in the textbook.
12.29) Glycolipids often have glycerol or sphingosine backbones. Glycolipids with a *glycerol backbone* are called **glyceroglycolipids**. Glycolipids with a *sphingosine backbone* are called **sphingoglycolipids**. Draw condensed structure for the general form of a glyceroglycolipid and a sphingoglycolipid.

**For more details:** See chapter 12 part 6 video or chapter 12 section 6 in the textbook.
12.30)  

a) Steroids are lipids that contain a particular fused, four-ring structure. Fused rings are rings that share atoms. Draw the fused four-ring (skeletal) structure, which is common to all steroids.

b) The three types of steroids are:

1) _____________________
2) _____________________
3) _____________________
a) Steroids are lipids that contain a particular fused, four-ring structure. Fused rings are rings that share atoms. Draw the fused four-ring (skeletal) structure, which is common to all steroids.

**HINT:**
The fused four-ring structure, which is common to all steroids, contains three six-member rings and one five-member ring.

b) The **three types of steroids** are:

1) ___________________

2) **steroid hormones**

3) ___________________

**HINT:** Outside of the health and scientific communities, the term “steroid” is often only associated with the performance enhancing drugs (steroid hormones) that are used by some athletes/bodybuilders. Those steroid hormones are just one type of steroid.

**For more help:** See chapter 12 part 7 video or chapter 12 section 7 in the textbook.
a) Steroids are lipids that contain a particular fused, four-ring structure. Fused rings are rings that share atoms. Draw the fused four-ring (skeletal) structure, which is common to all steroids.

![Fused Four-Ring Structure](image)

The fused four-ring structure, which is common to all steroids, contains three six-member rings and one five-member ring, that are fused to each other in the pattern shown here.

b) The three types of steroids are:

1. [ ] **cholesterol**
2. [ ] **steroid hormones**
3. [ ] **bile salts**

Outside of the health and scientific communities, the term “steroid” is often only associated with the performance enhancing drugs (steroid hormones) that are used by some athletes/bodybuilders. Those steroid hormones are just one type of steroid.

For more details: See [chapter 12 part 7](#) video or chapter 12 section 7 in the textbook.
12.31) Identify the following items as being characteristic of either cholesterol, steroid hormones, or bile salts.

a) signaling compounds

b) structural component of animal biological membranes

c) emulsify and transport dietary triglycerides and assist in their metabolism

d) starting material for the biosynthesis of other steroids

e) produced in the liver and stored in the gallbladder

f) the name of the particular molecule

g) a subclass is adrenal corticosteroids
12.31) Identify the following items as being characteristic of either cholesterol, steroid hormones, or bile salts.

a) signaling compounds

b) structural component of animal biological membranes

c) emulsify and transport dietary triglycerides and assist in their metabolism

d) starting material for the biosynthesis of other steroids

e) produced in the liver and stored in the gallbladder

f) the name of the particular molecule

g) a subclass is adrenal corticosteroids

**HINT:**
You can find all of the information needed for this problem in the “steroids” section of your lecture notes or the textbook.

**For more help:** See chapter 12 part 7 video or chapter 12 section 7 in the textbook.
12.31) Identify the following items as being characteristic of either cholesterol, steroid hormones, or bile salts.

a) signaling compounds **steroid hormones**

b) structural component of animal biological membranes **cholesterol**

c) emulsify and transport dietary triglycerides and assist in their metabolism **bile salts**

d) starting material for the biosynthesis of other steroids **cholesterol**

e) produced in the liver and stored in the gallbladder **bile salts**

f) the name of the particular molecule **cholesterol**

g) a subclass is adrenal corticosteroids **steroid hormones**

For more details: See chapter 12 part 7 video or chapter 12 section 7 in the textbook.
12.32) Because blood, lymph, and intercellular fluid are *aqueous mixtures*, cholesterol and triglycerides *do not dissolve* so they must be emulsified in order to be transported throughout the body. This is done by *lipoproteins*.

- *Lipoproteins* are composed of a core that contains emulsified triglycerides and cholesterol, which is surrounded by a micelle monolayer made from proteins, phospholipids, and cholesterol.
- There are five classes of lipoproteins: *chylomicrons*, *very low-density lipoproteins* (VLDL), *intermediate-density lipoproteins* (IDL), *low-density lipoproteins* (LDL), and *high-density lipoproteins* (HDL).

  i) As the ratio of protein to lipid in a lipoprotein increases, the density ______________.
     a) increases
     b) decreases

  ii) A high HDL level is correlated with a ______________ risk of heart disease.
     a) greater
     b) lowered

  iii) A high LDL level is correlated with a ______________ risk of heart disease.
     a) greater
     b) lowered
12.32) Because blood, lymph, and intercellular fluid are *aqueous mixtures*, cholesterol and triglycerides *do not dissolve* so they must be emulsified in order to be transported throughout the body. This is done by *lipoproteins*.

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1. As the ratio of protein to lipid in a lipoprotein increases, the density ______________.
   - a) increases
   - b) decreases
   **HINT**: Protein is more dense than lipid.

2. A high HDL level is correlated with a ____________ risk of heart disease.
   - a) greater
   - b) lowered

3. A high LDL level is correlated with a ____________ risk of heart disease.
   - a) greater
   - b) lowered

**For more help**: See chapter 12 part 7 video or chapter 12 section 7 in the textbook.
12.32) Because blood, lymph, and intercellular fluid are *aqueous mixtures*, cholesterol and triglycerides *do not dissolve* so they must be emulsified in order to be transported throughout the body. This is done by *lipoproteins*.

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- There are five classes of lipoproteins: *chylomicrons*, *very low-density lipoproteins* (VLDL), *intermediate-density lipoproteins* (IDL), *low-density lipoproteins* (LDL), and *high-density lipoproteins* (HDL).

**i)** As the ratio of protein to lipid in a lipoprotein increases, the density ____________.

- a) increases **EXPLANATION:** Since protein is more dense than lipid, the greater the percentage of protein, the higher the density of the lipoprotein.
- b) decreases

**ii)** A high HDL level is correlated with a ____________ risk of heart disease.

- a) greater
- b) lowered

**iii)** A high LDL level is correlated with a ____________ risk of heart disease.

- a) greater
- b) lowered

For more details: See chapter 12 part 7 video or chapter 12 section 7 in the textbook.
12.33) The thickening of the inner layer of the artery is caused by the accumulation of plaque, which is made from living white blood cells and remnants of dead cells, including cholesterol and triglycerides. Lipoproteins contain cholesterol and triglycerides in their micelle monolayers, and in their emulsified cores.

- A high LDL level is correlated with a greater risk of heart disease.
- A high HDL level is correlated with a lowered risk of heart disease.

For these reasons, it is recommended that adults have the lipid levels in their blood tested at least once every five years. The test is called a lipoprotein panel or a lipid panel. Although the concentration of cholesterol is not directly measured in these tests, the terms “total cholesterol,” “bad cholesterol,” and “good cholesterol” are often used by practitioners when describing or discussing the results of lipid panels. Write the meaning of each of these terms when they are used in the context of lipid panels.

a) *total cholesterol:*

b) *bad cholesterol:*

c) *good cholesterol:*
The thickening of the inner layer of the artery is caused by the accumulation of **plaque**, which is made from living white blood cells and remnants of dead cells, including **cholesterol** and **triglycerides**. Lipoproteins contain cholesterol and triglycerides in their micelle monolayers, and in their emulsified cores.

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For these reasons, it is recommended that adults have the lipid levels in their blood tested at least once every five years. The test is called a **lipoprotein panel** or a **lipid panel**. Although the concentration of cholesterol is not directly measured in these tests, the terms “**total cholesterol**,” “**bad cholesterol**,” and “**good cholesterol**” are often used by practitioners when describing or discussing the results of lipid panels. Write the meaning of each of these terms when they are used in the context of lipid panels.

a) **total cholesterol:**

HINT:

Cholesterol is the name of a particular molecule, however, in lipid panels, the term “**total cholesterol**” is used for something else.

b) **bad cholesterol:**

You can find all of these definitions in the “**Transport of Cholesterol and Triglycerides**” section of your lecture notes or the textbook.

c) **good cholesterol:**

For more help: See chapter 12 part 7 video or chapter 12 section 7 in the textbook.
The term "good cholesterol" is given to HDL since it transports cholesterol back to the liver (the liver can remove cholesterol from the body) and lowers the risk of heart disease.

Cholesterol is the name of a particular molecule, however, in lipid panels, the term "total cholesterol" is used for the concentration of HDL + LDL + 20% of the triglycerides.

The term "bad cholesterol" is used for the concentration of LDL.

For these reasons, it is recommended that adults have the lipid levels in their blood tested at least once every five years. The test is called a lipoprotein panel or a lipid panel. Although the concentration of cholesterol is not directly measured in these tests, the terms “total cholesterol,” “bad cholesterol,” and “good cholesterol” are often used by practitioners when describing or discussing the results of lipid panels. Write the meaning of each of these terms when they are used in the context of lipid panels.

a) total cholesterol: Cholesterol is the name of a particular molecule, however, in lipid panels, the term “total cholesterol” is used for the concentration of HDL + LDL + 20% of the triglycerides.

b) bad cholesterol: The term “bad cholesterol” is used for the concentration of LDL.

c) good cholesterol: The term “good cholesterol” is given to HDL since it transports cholesterol back to the liver (the liver can remove cholesterol from the body) and lowers the risk of heart disease.
Arachidonic acid, eicosapentaenoic acid, or dihomo-gamma-linolenic acid undergo *reactions* that transform them into the various classes of **eicosanoids** - such as *prostaglandins, thromboxanes, leukotrienes,* and *prostacyclin*.

- **Prostaglandins** have a wide range of biological effects, including causing pain, causing inflammation, causing fever, affecting blood pressure, inducing sleep, regulating blood flow to particular organs, controlling ion transport across membranes, and inducing labor.

**QUESTION:** Using complete sentences, explain how **Nonsteroidal Anti-inflammatory Drugs (NSAIDs)** are able to reduce pain, fever, and inflammation.
12.34) Arachidonic acid, eicosapentaenoic acid, or dihomo-gamma-linolenic acid undergo reactions that transform them into the various classes of eicosanoids - such as prostaglandins, thromboxanes, leukotrienes, and prostacyclin.

- **Prostaglandins** have a wide range of biological effects, including causing pain, causing inflammation, causing fever, affecting blood pressure, inducing sleep, regulating blood flow to particular organs, controlling ion transport across membranes, and inducing labor.

QUESTION: Using complete sentences, explain how Nonsteroidal Anti-inflammatory Drugs (NSAIDs) are able to reduce pain, fever, and inflammation.

HINT:

NSAIDs such as aspirin, acetaminophen, and ibuprofen are able to reduce pain, fever, and inflammation by blocking the action of one of the enzymes responsible for eicosanoid formation. See the diagram on the left.

For more help: See chapter 12 part 8 video or chapter 12 section 8 in the textbook.
Arachidonic acid, eicosapentaenoic acid, or dihomo-gamma-linolenic acid undergo reactions that transform them into the various classes of eicosanoids - such as prostaglandins, thromboxanes, leukotrienes, and prostacyclin.

- **Prostaglandins** have a wide range of biological effects, including causing pain, causing inflammation, causing fever, affecting blood pressure, inducing sleep, regulating blood flow to particular organs, controlling ion transport across membranes, and inducing labor.

QUESTION: Using complete sentences, explain how Nonsteroidal Anti-inflammatory Drugs (NSAIDs) are able to reduce pain, fever, and inflammation.

**ANSWER:**

NSAIDs such as aspirin, acetaminophen, and ibuprofen are able to reduce pain, fever, and inflammation by blocking the action of the cyclooxygenase enzyme (COX) that catalyzes the conversion of arachidonic acid into prostaglandins (see the eicosanoids formation diagram on the left).

For more details: See chapter 12 part 8 video or chapter 12 section 8 in the textbook.
12.35) Determine whether each of the following items are characteristic of either simple diffusion, facilitated diffusion, both simple diffusion and facilitated diffusion, or neither simple diffusion nor facilitated diffusion.

a) movement through a membrane

b) a net transport of a species from the side of the membrane where its concentration is less, to the side where its concentration is greater

c) a net transport of a species from the side of the membrane where its concentration is greater, to the side where its concentration is less

d) a form of passive transport

e) a form of active transport

f) require an energetic input from sources other than the concentration gradient of the transported species

g) facilitated by protein channels that pass through the cell membrane
12.35) Determine whether each of the following items are characteristic of either simple diffusion, facilitated diffusion, both simple diffusion and facilitated diffusion, or neither simple diffusion nor facilitated diffusion.

a) movement through a membrane

b) a net transport of a species from the side of the membrane where its concentration is less, to the side where its concentration is greater

c) a net transport of a species from the side of the membrane where its concentration is greater, to the side where its concentration is less

d) a form of passive transport

e) a form of active transport

f) require an energetic input from sources other than the concentration gradient of the transported species

g) facilitated by protein channels that pass through the cell membrane

HINT: Some nonpolar and amphipathic compounds (lipophilic compounds) can pass through a membrane because of their attraction to the phospholipids in the membrane. This diffusive movement of lipophilic compounds through a membrane is called simple diffusion. Diffusion of small ions and polar molecules, which are not lipophilic, through membranes is facilitated by protein channels that pass through the cell membrane. This diffusion of species though protein channels is called facilitated diffusion. Both simple diffusion and facilitated diffusion are called passive transport because they do not require an energetic input from sources other than the concentration gradient of the transported species.

For more help: See chapter 12 part 9 video or chapter 12 section 9 in the textbook.
12.35) Determine whether each of the following items are characteristic of either simple diffusion, facilitated diffusion, both simple diffusion and facilitated diffusion, or neither simple diffusion nor facilitated diffusion.

a) movement through a membrane both simple diffusion and facilitated diffusion

b) a net transport of a species from the side of the membrane where its concentration is less, to the side where its concentration is greater neither simple diffusion nor facilitated diffusion

c) a net transport of a species from the side of the membrane where its concentration is greater, to the side where its concentration is less both simple diffusion and facilitated diffusion

d) a form of passive transport both simple diffusion and facilitated diffusion

e) a form of active transport neither simple diffusion nor facilitated diffusion

f) require an energetic input from sources other than the concentration gradient of the transported species neither simple diffusion nor facilitated diffusion

g) facilitated by protein channels that pass through the cell membrane facilitated diffusion

EXPLANATION: Some nonpolar and amphipathic compounds (lipophilic compounds) can pass through a membrane because of their attraction to the phospholipids in the membrane. This diffusive movement of lipophilic compounds through a membrane is called simple diffusion. Diffusion of small ions and polar molecules, which are not lipophilic, through membranes is facilitated by protein channels that pass through the cell membrane. This diffusion of species through protein channels is called facilitated diffusion. Both simple diffusion and facilitated diffusion are called passive transport because they do not require an energetic input from sources other than the concentration gradient of the transported species.

For more details: See chapter 12 part 9 video or chapter 12 section 9 in the textbook.
12.36) Determine whether each of the following items are characteristic of either facilitated diffusion, active transport, or both facilitated diffusion and active transport.

a) movement through a membrane

b) a net transport of a species from the side of the membrane where its concentration is less, to the side where its concentration is greater

c) a net transport of a species from the side of the membrane where its concentration is greater, to the side where its concentration is less

d) a form of passive transport

e) require an energetic input from sources other than the concentration gradient of the transported species

f) facilitated by proteins that pass through the cell membrane
12.36) Determine whether each of the following items are characteristic of either facilitated diffusion, active transport, or both facilitated diffusion and active transport.

a) movement through a membrane

b) a net transport of a species from the side of the membrane where its concentration is less, to the side where its concentration is greater

c) a net transport of a species from the side of the membrane where its concentration is greater, to the side where its concentration is less

d) a form of passive transport

e) require an energetic input from sources other than the concentration gradient of the transported species

f) facilitated by proteins that pass through the cell membrane

**HINT:**

In active transport, where molecules or ions are transported in the direction “against the concentration gradient” - from the side of the membrane where their concentration is less to the side where their concentration is greater - *energy must be supplied*. In the active transport process, the ions or molecules cross the membrane with assistance from a transporter protein.

**For more help:** See chapter 12 part 9 video or chapter 12 section 9 in the textbook.
12.36) Determine whether each of the following items are characteristic of either facilitated diffusion, active transport, or both facilitated diffusion and active transport.

a) movement through a membrane  **both facilitated diffusion and active transport**

b) a net transport of a species from the side of the membrane where its concentration is less, to the side where its concentration is greater  **active transport**

c) a net transport of a species from the side of the membrane where its concentration is greater, to the side where its concentration is less  **facilitated diffusion**

d) a form of passive transport **facilitated diffusion**

e) require an energetic input from sources other than the concentration gradient of the transported species **active transport**

f) facilitated by proteins that pass through the cell membrane  **both facilitated diffusion and active transport**

**EXPLANATION:** Diffusion of small ions and polar molecules, which are not lipophilic, through membranes is facilitated by protein channels that pass through the cell membrane. This diffusion of species through protein channels is called **facilitated diffusion.** Both simple diffusion and facilitated diffusion are called **passive transport** because they do not require an energetic input from sources other than the concentration gradient of the transported species.

In active transport, where molecules or ions are transported in the direction “against the concentration gradient” - from the side of the membrane where their concentration is less to the side where their concentration is greater - **energy must be supplied.** In the active transport process, the ions or molecules cross the membrane with assistance from a **transporter protein.**

**For more details:** See chapter 12 part 9 video or chapter 12 section 9 in the textbook.
12.37) The following statements describe different types of lipids. Match each statement with one of the lipid types shown below.

i) formed from a fatty acid residue, a phosphate residue, and a sphingosine residue

ii) lipids that contain a fused four-ring structure

iii) residues of these lipids are contained in other lipids; they have an even number of carbon atoms

iv) formed from a carbohydrate residue, one or two fatty acid residues, and a glycerol residue

v) formed from three fatty acid residues and a glycerol residue

vi) formed from a carboxylic acid residue and an alcohol residue

vii) formed from a carbohydrate residue, a fatty acid residue, and a sphingosine residue

viii) formed from one or more fatty acid residues, a phosphate residue, and a glycerol residue

Type of lipids choices:

a) triglycerides
b) sphingoglycolipids
c) glyceroglycolipids
d) sphingophospholipids
e) glycerophospholipids
f) fatty acids
g) waxes
h) steroids

This is the last question.
12.37) The following statements describe different types of lipids. Match each statement with one of the lipid types shown below.

i) formed from a fatty acid residue, a phosphate residue, and a sphingosine residue

ii) lipids that contain a fused four-ring structure

iii) residues of these lipids are contained in other lipids; they have an even number of carbon atoms

iv) formed from a carbohydrate residue, one or two fatty acid residues, and a glycerol residue

v) formed from three fatty acid residues and a glycerol residue

vi) formed from a carboxylic acid residue and an alcohol residue

vii) formed from a carbohydrate residue, a fatty acid residue, and a sphingosine residue

viii) formed from one or more fatty acid residues, a phosphate residue, and a glycerol residue

**Type of lipids choices:**

a) triglycerides
b) sphingoglycolipids
c) glyceroglycolipids
d) sphingophospholipids
e) glycerophospholipids
f) fatty acids
g) waxes
h) steroids

**HINT:**
Review and compare the general forms of the lipids discussed in chapter 12.
12.37) The following statements describe different types of lipids. Match each statement with one of the lipid types shown below.

i) formed from a fatty acid residue, a phosphate residue, and a sphingosine residue
   - sphingophospholipids

ii) lipids that contain a fused four-ring structure
    - steroids

iii) residues of these lipids are contained in other lipids; they have an even number of carbon atoms
    - fatty acids

iv) formed from a carbohydrate residue, one or two fatty acid residues, and a glycerol residue
    - glyceroglycolipids

v) formed from three fatty acid residues and a glycerol residue
    - triglycerides

vi) formed from a carboxylic acid residue and an alcohol residue
    - waxes

vii) formed from a carbohydrate residue, a fatty acid residue, and a sphingosine residue
    - sphingoglycolipids

viii) formed from one or more fatty acid residues, a phosphate residue, and a glycerol residue
    - glycerophospholipids

**EXPLANATION:**

The solution to this problem is obtained by considering and comparing the general forms of the lipids discussed in chapter 12.