Lipids

Lipids are:

- Biomolecules that contain fatty acids or a steroid nucleus.
- Soluble in organic solvents, but not in water.
- Named for the Greek word *lipos*, which means “fat.”
- Extracted from cells using organic solvents.
24.1 Structure and Classification of Lipids
24.2 Fatty Acids and Their Esters

Fatty acids are:
- Long-chain carboxylic acids that have an even number (usually 12-24) of carbon atoms.
- Insoluble in water.
- Saturated or unsaturated.
Fatty Acid Formulas

- The formulas for fatty acids are written as condensed and line-bond formulas. For example, caprylic acid with 8 carbon atoms can be written as:

\[
\text{CH}_3\text{--(CH}_2\text{)}_6\text{--COOH} \\
\text{CH}_3\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--COOH} \\
\text{CH}_3\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--C--OH}
\]

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

\[
\text{CH}_3\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--C--OH}
\]
24.3 Properties of Fats and Oils

Saturated fatty acids have single C–C bonds.

**TABLE 24.1** Structures of Some Common Fatty Acids

<table>
<thead>
<tr>
<th>NAME</th>
<th>TYPICAL SOURCE</th>
<th>NUMBER OF CARBONS</th>
<th>NUMBER OF DOUBLE BONDS</th>
<th>CONDENSED FORMULA</th>
<th>MELTING POINT (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Saturated</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lauric</td>
<td>Coconut oil</td>
<td>12</td>
<td>0</td>
<td>CH₃(CH₂)₁₀COOH</td>
<td>44</td>
</tr>
<tr>
<td>Myristic</td>
<td>Butter fat</td>
<td>14</td>
<td>0</td>
<td>CH₃(CH₂)₁₂COOH</td>
<td>58</td>
</tr>
<tr>
<td>Palmitic</td>
<td>Most fats and oils</td>
<td>16</td>
<td>0</td>
<td>CH₃(CH₂)₁₄COOH</td>
<td>63</td>
</tr>
<tr>
<td>Stearic</td>
<td>Most fats and oils</td>
<td>18</td>
<td>0</td>
<td>CH₃(CH₂)₁₆COOH</td>
<td>70</td>
</tr>
<tr>
<td><strong>Unsaturated</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oleic</td>
<td>Olive oil</td>
<td>18</td>
<td>1</td>
<td>CH₃(CH₂)₇CH=CH(CH₂)₇COOH(cis)</td>
<td>4</td>
</tr>
<tr>
<td>Linoleic</td>
<td>Vegetable oils</td>
<td>18</td>
<td>2</td>
<td>CH₃(CH₂)₄CH=CHCH₂CH=CH(CH₂)₇COOH(all cis)</td>
<td>−5</td>
</tr>
<tr>
<td>Linolenic</td>
<td>Soybean and canola oils</td>
<td>18</td>
<td>3</td>
<td>CH₃CH₂CH=CHCH₂CH=CHCH₂CH=CH(CH₂)₇COOH(all cis)</td>
<td>−11</td>
</tr>
<tr>
<td>Arachidonic</td>
<td>Lard</td>
<td>20</td>
<td>4</td>
<td>CH₃(CH₂)₄(CH=CHCH₂)₄CH₂CH₂COOH(all cis)</td>
<td>−50</td>
</tr>
</tbody>
</table>
Saturated Fatty Acids

Saturated fatty acids have:

- Molecules that fit closely together in a regular pattern.
- Strong attractions between fatty acid chains.
- High melting points that makes them solids at room temperature.
Unsaturated Fatty Acids

Unsaturated fatty acids typically contain *cis* double bonds.
A saturated fatty acid (palmitic acid)

A cis unsaturated fatty acid (linolenic acid)
Stearic acid, an 18-carbon saturated fatty acid

Linoleic acid, an 18-carbon unsaturated fatty acid

cis double bonds
Unsaturated Fatty Acids

Unsaturated fatty acids have cis C=C bonds.

Table 18.1 Structures and Melting Points of Common Fatty Acids (Continued)

<table>
<thead>
<tr>
<th>Name</th>
<th>Carbon Atoms</th>
<th>Structure</th>
<th>Melting Point (°C)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monounsaturated Fatty Acids</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palmitoleic acid</td>
<td>16</td>
<td><img src="structure1.png" alt="Structure" /></td>
<td>0</td>
<td>Butter</td>
</tr>
<tr>
<td>Oleic acid</td>
<td>18</td>
<td><img src="structure2.png" alt="Structure" /></td>
<td>13</td>
<td>Olives, corn</td>
</tr>
<tr>
<td>Polyunsaturated Fatty Acids</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linoleic acid</td>
<td>18</td>
<td><img src="structure3.png" alt="Structure" /></td>
<td>−9</td>
<td>Soybean, safflower, sunflower</td>
</tr>
<tr>
<td>Linolenic acid</td>
<td>18</td>
<td><img src="structure4.png" alt="Structure" /></td>
<td>−17</td>
<td>Corn</td>
</tr>
<tr>
<td>Arachidonic acid</td>
<td>20</td>
<td><img src="structure5.png" alt="Structure" /></td>
<td>−50</td>
<td>Prostaglandins</td>
</tr>
</tbody>
</table>

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Unsaturated Fatty Acids

Unsaturated fatty acids:

- Have nonlinear chains that do not allow molecules to pack closely.
- Have low melting points.
- Are liquids at room temperature.
Learning Check

Assign the melting points –17°C, 13°C, and 69°C to the following 24 C fatty acids. Explain.

Stearic acid  saturated
Oleic acid  one double bond
Linolenic acid  two double bonds
Solution

- Stearic acid: mp 69°C
- Oleic acid: mp 13°C
- Linolenic acid: mp -17°C

Stearic acid is saturated and would have a higher melting point than the unsaturated fatty acids. Because linoleic acid has two double bonds, it would have a lower mp than oleic acid, which has one double bond.
Olive Oil

- Olive oil contains a high percentage of oleic acid.
- Oleic acid is a monounsaturated fatty acid with one cis double bond.

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A fat

An oil
Vegetable oils contain more unsaturated fatty acids, which makes their melting points lower.
Omega-6 and Omega-3 Fatty Acids

The first double bond:
- In vegetable oils is at carbon 6 (omega-6).
- In fish oils is at carbon 3 (omega-3).

Some of the food sources of ω-3 and ω-6 fatty acids are fish and shellfish, flaxseed (linseed), hemp oil, soya oil, canola (rapeseed) oil, chia seeds, pumpkin seeds, sunflower seeds, leafy vegetables, and walnuts.
Learning Check

Write a fatty acid with 10 carbon atoms that is:
A. Saturated

B. Monounsaturated  omega-3

C. Monounsaturated  omega-6
Solution

Write a fatty acid with 10 carbon atoms that is:

A. Saturated
\[ \text{CH}_3\text{—CH}_2\text{—CH}_2\text{—CH}_2\text{—CH}_2\text{—CH}_2\text{—CH}_2\text{—CH}_2\text{—CH}_2\text{—COOH} \]

B. Monounsaturated omega-3
\[ \text{CH}_3\text{—CH}_2\text{—CH=CH—CH}_2\text{—CH}_2\text{—CH}_2\text{—CH}_2\text{—CH}_2\text{—COOH} \]

C. Monounsaturated omega-6
\[ \text{CH}_3\text{—CH}_2\text{—CH}_2\text{—CH}_2\text{—CH}_2\text{—CH=CH—CH}_2\text{—CH}_2\text{—CH}_2\text{—COOH} \]
Waxes

Waxes are:

- Esters of saturated fatty acids and long-chain alcohols.
- Coatings that prevent loss of water by leaves of plants.

<table>
<thead>
<tr>
<th>Table 18.2 Some Typical Waxes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>Beeswax</td>
</tr>
<tr>
<td>Carnauba wax</td>
</tr>
<tr>
<td>Jojoba wax</td>
</tr>
</tbody>
</table>
Triacylglycerols

In a triacylglycerol, glycerol forms ester bonds with three fatty acids.
Learning Check

What are the fatty acids in the following triacylglycerol?

\[
\begin{align*}
\text{CH}_2 & \quad \text{O} \quad \text{C} \quad (\text{CH}_2)_{16}\text{CH}_3 \\
\text{CH} & \quad \text{O} \quad \text{C} \quad (\text{CH}_2)_{7}\text{CH} = \text{CH}(\text{CH}_2)_{7}\text{CH}_3 \\
\text{CH}_2 & \quad \text{O} \quad \text{C} \quad (\text{CH}_2)_{12}\text{CH}_3
\end{align*}
\]
Solution

What are the fatty acids in the following triacylglycerol?

\[
\begin{align*}
\text{CH}_2-O-\text{C}-(\text{CH}_2)_{16}\text{CH}_3 & \quad \text{Stearic acid} \\
\text{CH}-O-\text{C}-(\text{CH}_2)_{7}\text{CH}=\text{CH}(\text{CH}_2)_{7}\text{CH}_3 & \quad \text{Oleic acid} \\
\text{CH}_2-O-\text{C}-(\text{CH}_2)_{12}\text{CH}_3 & \quad \text{Myristic acid}
\end{align*}
\]
Olestra, A Fat Substitute

Olestra is:

- Used in foods as an artificial fat.
- Sucrose linked by ester bonds to several long-chain fatty chains.
- Not broken down in the intestinal tract.
24.4 Chemical Reactions of Triacylglycerols

The chemical reactions of triacylglycerols are similar to those of alkenes and esters.

- In **hydrogenation**, double bonds in unsaturated fatty acids react with $H_2$ in the presence of Ni or Pt catalyst.

- In **hydrolysis**, ester bonds are split by water in the presence of an acid, a base, or an enzyme.
Hydrogenation of Oils

Hydrogenation:

- Adds hydrogen to double bonds in oils to form single bonds.
- Produces solid shortening, margarine, and other products.
Hydrogenation

- Hydrogenation converts double bonds to single bonds.

\[
\begin{align*}
\text{Pt} & \quad \text{O} \\
\text{CH}_2\text{O}C\text{-(CH}_2\text{)}_7\text{CH}=\text{CH(CH}_2\text{)}_7\text{CH}_3 & +3\text{H}_2 \\
\text{CH-OC-(CH}_2\text{)}_7\text{CH}=\text{CH(CH}_2\text{)}_7\text{CH}_3 & \\
\text{CH}_2\text{-O-C-(CH}_2\text{)}_7\text{CH}=\text{CH(CH}_2\text{)}_7\text{CH}_3
\end{align*}
\]
In hydrolysis, triacylglycerols are split into glycerol and three fatty acids.

An acid or enzyme catalyst is required.

\[
\begin{align*}
\text{CH}_2\text{O} & \text{C}-(\text{CH}_2)_{14}\text{CH}_3 \\
\text{CH} & \text{O} \text{C}-(\text{CH}_2)_{14}\text{CH}_3 + 3\text{H}_2\text{O} \xrightarrow{\text{H}^+} \\
\text{CH}_2\text{O} & \text{C}-(\text{CH}_2)_{14}\text{CH}_3 \\
\text{CH} & \text{O} \text{C}-(\text{CH}_2)_{14}\text{CH}_3 \\
\text{CH}_2\text{O} & \text{C}-(\text{CH}_2)_{14}\text{CH}_3
\end{align*}
\]
Soaps are:

- Salts of fatty acids.
- Formed by saponification, a reaction in which a triacylglycerol reacts with a strong base.

\[
\text{CH}_2\text{O} \xrightarrow{- \text{O}} \text{C} \xrightarrow{-(\text{CH}_2)_{16}\text{CH}_3} + 3 \text{NaOH} \quad \xrightarrow{+ 3 \text{Na}^+ \text{O}} \quad \text{C} \xrightarrow{- \text{O}} \text{CH}_2\text{O} \xrightarrow{- \text{OH}} \text{C} \xrightarrow{-(\text{CH}_2)_{16}\text{CH}_3} \quad \text{salts of fatty acids (soaps)}
\]
Learning Check

What products are obtained from the complete hydrogenation of glyceryl trioleate?
1) Glycerol and 3 oleic acids
2) Glyceryl tristearate
3) Glycerol and 3 stearic acids
Solution

What products are obtained from the complete hydrogenation of glyceryl trioleate?

2) Glyceryl tristearate
Learning Check

Write the product of the following reaction.

\[
\text{Ni} \quad \text{CH}_2 \text{O} \text{C} \text{(CH}_2\text{)}_5\text{CH=CH(CH}_2\text{)}_7\text{CH}_3 + 3 \text{H}_2 \quad \text{Ni}
\]
Solution

\[
\begin{align*}
\text{CH}_2 & \quad \text{O} \quad \text{C} \quad (\text{CH}_2)_{14}\text{CH}_3 \\
\text{CH} & \quad \text{O} \quad \text{C} \quad (\text{CH}_2)_{14}\text{CH}_3 \\
\text{CH}_2 & \quad \text{O} \quad \text{C} \quad (\text{CH}_2)_{14}\text{CH}_3
\end{align*}
\]
**Phospholipid:** A lipid that has an ester link between phosphoric acid and an alcohol (either glycerol or sphingosine).

Glycerol 3-phosphate (alcohol in glycerophospholipids)

Sphingosine (alcohol in sphingolipids)

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Glycerophospholipids are:

- The most abundant lipids in cell membranes.
- Composed of glycerol, two fatty acids, phosphate and an amino alcohol.
Polarity of Glycerophospholipids

- A glycerophospholipid has polar and nonpolar regions.

(a) Chemical structure of a glycerophospholipid

(b) Simplified way to draw a glycerophospholipid

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Lecithin and Cephalin

Lecithin and cephalin are glycerophospholipids:
- Abundant in brain and nerve tissues.
- Found in egg yolk, wheat germ, and yeast.
Sphingolipids

- Sphingolipids are phospholipids that have an amide bond between a fatty acid and sphingosine, an 18-carbon alcohol.
A sphingomyelin
Glycolipids

- Glycosphingolipids contain monosaccharides bonded to the –OH of sphingosine by a glycosidic bond.
- Cerebrosides contain only one monosaccharide.
Gangliosides

- Gangliosides are similar to cerebrosides, but contain two or more mono-saccharides.
A glycolipid
Learning Check

Identify each as a:

1) Fatty acid  2) Triacylglycerol
3) Amino alcohol  4) Glycerophospholipid
5) Glycosphingolipid
   A. Glyceryl trioleate
   B. Cephalin
   C. Choline
   D. Galactocerebroside
   E. Palmitic acid
Solution

A. Glyceryl trioleate 2) Triacylglycerol
B. Cephalin 4) Glycerophospholipid
C. Choline 3) Amino alcohol
D. Galactocerebroside 5) Glycosphingolipid
E. Palmitic acid 1) Fatty acid
Lipid Diseases (Lipidoses)

In many lipid diseases, the deficiency of an enzyme causes the accumulation of glycolipids.

Fabry's Disease:

- Fabry's disease is a fat storage disorder caused by a deficiency of alpha-galactocidase involved in the biodegradation of lipids.
- Some of the female carriers exhibit signs of the condition, especially cloudiness of the cornea. In addition to the eye manifestations, males characteristically have burning sensations in their hands and feet that is worse with exercise and hot weather. Most of the males have small, raised, reddish-purple blemishes on their skin.
- As the carriers grow older, they may have impaired arterial circulation leading to early heart attacks and strokes. The kidneys become progressively involved, and many patients require kidney transplantation or dialysis.
Gaucher’s Disease

- In 1882, a French physician named Philippe Charles Ernest Gaucher (pronounced: go-SHAY) first described a clinical syndrome in a 32-year-old woman whose liver and spleen were enlarged.
- Caused by a deficiency of beta-glucocidase involved in the biodegradation of lipids.
- The most common symptoms of Gaucher Disease are enlargement of the liver and spleen, anemia, reduced platelets (resulting in easy bruising and long clotting times), bone pain ("bone crises"), bone infarctions often leading to damage to the shoulder or hip joints, and a generalized demineralization of the bones (osteoporosis).
Niemann-Pick Disease

- Niemann-Pick disease (NP) caused by a deficiency of sphingomyelinase refers to a group of inherited metabolic disorders known as the leukodystrophies or lipid storage diseases in which harmful quantities of a fatty substance (lipids) accumulate in the spleen, liver, lungs, bone marrow, and the brain. Symptoms may include lack of muscle coordination, brain degeneration, learning problems, loss of muscle tone, increased sensitivity to touch, feeding and swallowing difficulties, slurred speech, and an enlarged liver and spleen.
Tay-Sachs Disease

Tay-Sachs disease caused by a deficiency of hexoaminidase is a fatal genetic lipid storage disorder in which harmful quantities of a fatty substance called ganglioside GM2 build up in tissues and nerve cells in the brain.

- Infants with Tay-Sachs disease appear to develop normally for the first few months of life. Then, as nerve cells become distended with fatty material, a relentless deterioration of mental and physical abilities occurs. The child becomes blind, deaf, and unable to swallow.

- Other neurological symptoms include dementia, seizures, and an increased startle reflex to noise. A much rarer form of the disorder occurs in patients in their twenties and early thirties and is characterized by an unsteady neurological deterioration.
Lipid Diseases (Lipidoses)

- In many lipid diseases, the deficiency of an enzyme causes the accumulation of glycolipids.

<table>
<thead>
<tr>
<th>Names of Disease</th>
<th>Lipid Stored</th>
<th>Type</th>
<th>Enzyme Absent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabry’s</td>
<td>Gal-gal-glucosylceramide</td>
<td>Ganglioside</td>
<td>α-Galactosidase</td>
</tr>
<tr>
<td>Gaucher’s</td>
<td>Glucosylceramide</td>
<td>Cerebroside</td>
<td>β-Glucosidase</td>
</tr>
<tr>
<td>Niemann–Pick</td>
<td>Sphingomyelin</td>
<td>Sphingolipid</td>
<td>Sphingomyelinase</td>
</tr>
<tr>
<td>Tay–Sachs</td>
<td>GM₂ ganglioside</td>
<td>Ganglioside</td>
<td>Hexosaminidase A</td>
</tr>
</tbody>
</table>

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Steroids

Steroids are:

- Lipids containing the steroid nucleus, which is a fused structure of four rings.
- Found in cholesterol, bile salts, hormones, and vitamin D.
Cholesterol is:

- The most abundant steroid in the body.
- Composed of the steroid nucleus with methyl \( \text{CH}_3 \) groups, an alkyl chain, and a hydroxyl group –\( \text{OH} \) attached.
Cholesterol in Foods

**Cholesterol:**

- Is considered elevated if plasma cholesterol exceeds 200-220 mg/dL.
- Is synthesized in the liver and obtained from foods.

<table>
<thead>
<tr>
<th>Food</th>
<th>Serving Size</th>
<th>Cholesterol (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liver (beef)</td>
<td>3 oz</td>
<td>370</td>
</tr>
<tr>
<td>Egg</td>
<td>1</td>
<td>250</td>
</tr>
<tr>
<td>Lobster</td>
<td>3 oz</td>
<td>175</td>
</tr>
<tr>
<td>Fried chicken</td>
<td>3½ oz</td>
<td>130</td>
</tr>
<tr>
<td>Hamburger</td>
<td>3 oz</td>
<td>85</td>
</tr>
<tr>
<td>Chicken (no skin)</td>
<td>3 oz</td>
<td>75</td>
</tr>
<tr>
<td>Fish (salmon)</td>
<td>3 oz</td>
<td>40</td>
</tr>
<tr>
<td>Butter</td>
<td>1 tablespoon</td>
<td>30</td>
</tr>
<tr>
<td>Whole milk</td>
<td>1 cup</td>
<td>35</td>
</tr>
<tr>
<td>Skim milk</td>
<td>1 cup</td>
<td>5</td>
</tr>
<tr>
<td>Margarine</td>
<td>1 tablespoon</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 18.4  Cholesterol Content of Some Foods

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Lipoproteins

Lipoproteins are the "packages" in which cholesterol and triglycerides travel throughout the body.
Types of Lipoproteins

Lipoproteins:
- Differ in density, composition, and function.
- Include low-density lipoprotein (LDLs) and high-density lipoprotein (HDLs).

<table>
<thead>
<tr>
<th>Table 18.5 Composition and Properties of Plasma Lipoproteins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (g/mL)</td>
</tr>
<tr>
<td>----------------------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Composition (% by mass)</td>
</tr>
<tr>
<td>Triacylglycerol</td>
</tr>
<tr>
<td>Phospholipids</td>
</tr>
<tr>
<td>Cholesterol</td>
</tr>
<tr>
<td>Cholesteryl esters</td>
</tr>
<tr>
<td>Protein</td>
</tr>
</tbody>
</table>
Lipoproteins

Lipoproteins play an important role in our health by carrying lipids, or fats, through the bloodstream. Special proteins, called apoproteins, wrap around the lipids to form lipoproteins. These lipoproteins transport the lipids to all of the cells in the body.

- There are several types of lipoproteins, including:
  - chylomicrons
  - very low-density lipoproteins, or VLDL
  - low-density lipoproteins, or LDL
  - and high-density lipoproteins, or HDL

- Combine lipids with proteins and phospholipids, are soluble in water because the surface consists of polar lipids.
Transport of Lipoproteins in the Body

- **Stomach**: Dietary lipids
- **Intestine**: Elimination of cholesterol
- **Liver**: Synthesis of cholesterol and bile salts
- **Fat storage cells**: Stored triacylglycerols
- **Heart and muscles**: Oxidation
- **HDLs** and **LDLs**: carry triacylglycerols from liver to fat storage cells and muscle
- **LDLs**: carry cholesterol to cells and deposit excess cholesterol in arteries
- **HDLs**: move cholesterol to liver
- **VLDLs**

Chemical structures:
- **Glycine**, an amino acid
- **Cholic acid**, a bile acid
- **Sodium glycocholate**, a bile salt

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Bile Salts

**Bile salts:**
- Are synthesized from cholesterol and stored in the gall bladder.
- Emulsify fats and oils to give a greater surface area for lipid digesting enzymes.

![Bile Salts Diagram]

- Cholic acid, a bile acid
- Glycine, an amino acid
- Sodium glycocholate, a bile salt
Steroid Hormones

**Steroid hormones:**
- Are produced from cholesterol.
- Include sex hormones such as androgens (testosterone) in males and estrogens (estradiol) in females.
Adrenal Corticosteroids

Steroid hormones called **adrenal corticosteroids**:  
- Are produced by the adrenal glands located on the top of each kidney.  
- Include *aldosterone*, which regulates electrolytes and water balance by the kidneys.  
- Include *cortisone*, which increases blood glucose level and stimulates the synthesis of glycogen in the liver.
## Adrenal Corticosteroids

<table>
<thead>
<tr>
<th>Corticosteroids</th>
<th>Biological Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cortisone (produced in adrenal gland)</td>
<td>Increases the blood glucose and glycogen levels from fatty acids and amino acids</td>
</tr>
<tr>
<td>Aldosterone (mineralocorticoid) (produced in adrenal gland)</td>
<td>Increases the reabsorption of Na(^+) in kidneys; retention of water</td>
</tr>
<tr>
<td>Prednisone (synthetic corticoid)</td>
<td>Reduces inflammation; treatment of asthma and rheumatoid arthritis</td>
</tr>
</tbody>
</table>

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Anabolic Steroids

Anabolic steroids:
- Are derivatives of testosterone.
- Are used illegally to increase muscle mass.
- Have side effects including fluid retention, hair growth, sleep disturbance, and liver damage.
Cell Membranes

- **Cell membranes:**
- Separate cellular contents from the external environment.
- Consist of a lipid bilayer made of two rows of phospholipids.
- Have an inner portion made of the nonpolar tails of phospholipids with the polar heads at the outer and inner surfaces.
24.7 Structure of Cell Membranes

- The **lipid bilayer** contains proteins, carbohydrates, and cholesterol.
- The unsaturated fatty acids make cell membranes fluid-like rather than rigid.
- Proteins and carbohydrates on the outer surface communicate with hormones and neurotransmitters.
The Fluid-Mosaic Model

- Fluid-mosaic model describes the fluid nature of the membrane and its composition
- Fluid Portion
  - Membrane behaves like a fluid
    - Due to the phospholipids
    - Consistency ranges from oil to a gel like semi-solid
    - animation
An Integral Membrane Protein
Fluid-Mosaic-Model
Cholesterol forms part of the membrane, proteins are embedded in the lipid bilayer, and the carbohydrate chains of glycoproteins and glycolipids extend into the extracellular space, where they act as receptors. Integral proteins form channels to the outside of the cell and also participate in transporting large molecules across the membrane.
Fluid-Mosaic-Model

Oil floating on water, an analogy for the fluid-mosaic cell membrane model. When the oil layer is disturbed, it soon flows back together.
24.8 Transport Across Cell Membranes

- **Diffusion** (passive transport) moves particles from a higher to a lower concentration.
- **Facilitated transport** uses protein channels to increase the rate of diffusion.
- **Active transport** moves ions against a concentration gradient
- By using energy.
Modes of transport across cell membranes:

- **Simple diffusion**
- **Facilitated diffusion**
- **Active transport**
An example of active transport. A protein known as the sodium-potassium ATPase uses energy from ATP to move sodium and potassium ions across cell membranes against their concentration gradients.
Learning Check

Identify each lipid as a: 1) glycerophospholipid  
2) steroid      3) triacylglycerol      4) sphingolipid  
A  Cholesterol  
B. Contains glycerol, 2 fatty acids, phosphate, and choline  
C. Glyceryl tristearate  
D. Contains sphingosine, fatty acid, phosphate, and choline  
E. Estradiol  
F. Bile salts
Solution

A. 2 steroid
B. 1 glycerophospholipid
C. 3 triacylglycerol
D. 4 sphingolipid
E. 2 steroid
F. 2 steroid
Eicosanoids: Prostaglandins and Leukotrienes

\[
\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH} = \text{CHCH}_2\text{CH} = \text{CHCH}_2\text{CH} = \text{CHCH}_2\text{CH} = \text{CHCH}_2\text{CH}_2\text{CH}_2\text{COOH}
\]

Arachidonic acid

\[
\text{Arachidonic acid (bent)}
\]

Multistep enzyme-catalyzed synthesis

\[
\text{PGE}_1, \text{ a prostaglandin}
\]

Leukotriene D\textsubscript{4}

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24.9 Eicosanoids: Prostaglandins and Leukotrienes

- The prostaglandins (named for their discovery in prostate cells) and the leukotrienes (named for their discovery in leukocytes) are two classes of eicosanoids that differ somewhat in their structure.

- lower blood pressure, influence platelet aggregation during blood clotting, stimulate uterine contractions, and lower the extent of gastric secretions. In addition, they are responsible for some of the pain and swelling that accompany inflammation.
Functions of Prostaglandins:

- Blood clots form when a blood vessel is damaged. A type of prostaglandin called thromboxane stimulates constriction and clotting of platelets. Conversely, PGI2, is produced to have the opposite effect on the walls of blood vessels where clots should not be forming.

- 3. Certain prostaglandins are involved with the induction of labor and other reproductive processes. PGE2 causes uterine contractions and has been used to induce labor.
Prostaglandins are not produced when anti-inflammatory drugs such as aspirin inhibit their synthesis.
Aspirin (Acetylsalicylic acid) + HOCH$_2$ Enzyme $\rightarrow$ Salicylic acid + CH$_3$-C-O-CH$_2$ Enzyme
Chapter Summary

- Fatty acids are carboxylic acids with long straight hydrocarbon chains.
- Fatty acids may be saturated or unsaturated.
- Fats and oils are triglycerols – triesters of glycerol with fatty acids.
- In fats, the fatty acid chains are mostly saturated and in oils they have varying degree of unsaturation.
- Principal reactions of triglycerols are catalytic hydrogenation and hydrolysis.
Chapter Summary Contd.

- The membrane lipids include phospholipids and glycolipids, and cholesterol.
- The basic structure of cell membranes is a bilayer of lipids.
- Small molecules and lipid-soluble substances can cross the lipid bilayer by simply diffusing through it.
- Ions and hydrophilic substances can move through aqueous fluid-filled channels in membrane proteins.
- Eicosanoids are a group of compounds derived from 20-member unsaturated fatty acids.
Chapter 24 Animations

- 24.1.1:
- 24.1:
  - http://www.bbc.co.uk/education/asguru/biology/01cellbiology/05pathways/05membrane/index.shtml
  - http://telstar.ote.cmu.edu/Hughes/tutorial/ornella_tutorial/bil.swf
  - http://www.bbc.co.uk/education/asguru/biology/01cellbiology/05pathways/05membrane/index.shtml
  - http://www.bbc.co.uk/education/asguru/biology/01cellbiology/05pathways/index.shtml
End Of Chapter 24