Any Ground Plant or Animal Material which is soluble in a non-polar solvent such as ether, dichloromethane or acetone.

Lipids

- Lipids are a heterogeneous class of naturally occurring organic compounds classified together on the basis of common solubility properties.
- Lipids are insoluble in water, but soluble in organic solvents including diethyl ether, dichloromethane, and acetone.
- Lipids include:
  - fatty acids, triacylglycerols, waxes, sphingolipids, phosphoacylglycerols, and glycolipids.
  - lipid-soluble vitamins.
  - prostaglandins, leukotrienes, and thromboxanes.
  - cholesterol, steroid hormones, and bile acids.

**Triacylglycerols – Fats & Oils**

Physical properties depend on the fatty acid components; all are unbranched & even numbered.
- Melting point increases as the number of carbons in the hydrocarbon chains increases and as the number of double bonds decreases.
- Triglycerides rich in unsaturated fatty acids are generally liquid at room temperature and are called oils.
- Triglycerides rich in saturated fatty acids are generally semisolids or solids at room temperature and are called fats.
Vegetable oils and tallow are triacylglycerols, commonly called triglycerides in the medical profession when dissolved in blood.

Fats & Oils are the long term energy storage molecules in plants and animals.

Fatty Acid Reactions

Enzyme Hydrolysis

Vegetable oils and tallow are triacylglycerols, commonly called triglycerides in the medical profession when dissolved in blood.

Fats & Oils are the long term energy storage molecules in plants and animals.

Fatty acids are unbranched-chain carboxylic acids derived from hydrolysis of animal fats, vegetable oils, or membrane phospholipids.

Nearly all have an even number of carbon atoms, most between 12 and 20, in an unbranched chain.

The three most abundant are palmitic acid (16:0), stearic acid (18:0), and oleic acid (18:1).

In most natural unsaturated fatty acids, the cis isomer predominates; the trans isomer is rare.

Trans fats are formed during partial hydrogenation (hardening) of oils to make shortening & margarine. They are very unhealthy fats and strongly contribute to arteriosclerosis (heart disease)!

Unsaturated fatty acids have lower melting points than their saturated counterparts; the greater the degree of unsaturation, the lower the melting point.

<table>
<thead>
<tr>
<th>Carbon Atoms/Double Bonds*</th>
<th>Common Name</th>
<th>Melting Point (°C)</th>
<th>Which are these?</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:0</td>
<td>Lauric acid</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>14:0</td>
<td>Myristic acid</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>16:0</td>
<td>Palmitic acid</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>18:0</td>
<td>Stearic acid</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>20:0</td>
<td>Arachidic acid</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>16:1</td>
<td>Palmitoleic acid</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>18:1</td>
<td>Oleic acid</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>18:2</td>
<td>Linoleic acid</td>
<td>-5</td>
<td></td>
</tr>
<tr>
<td>18:3</td>
<td>Linolenic acid</td>
<td>-11</td>
<td></td>
</tr>
<tr>
<td>20:4</td>
<td>Arachidonic acid</td>
<td>-49</td>
<td></td>
</tr>
</tbody>
</table>

*Most Common
Saponification of Triacylglycerols
Hydrolysis of Fatty Acid Esters in strong base makes soap!

\[
\begin{align*}
\text{CH}_3\text{O} & \quad \text{(CH}_2\text{n}_n\text{CH}_3) \\
\text{CHO} & \quad \text{(CH}_2\text{n}_n\text{CH}_3) \\
\text{CH}_2\text{O} & \quad \text{(CH}_2\text{n}_n\text{CH}_3)
\end{align*}
\]

\[
\begin{align*}
\text{NaOH} & \\
\text{NaOH} & \\
\text{NaOH}
\end{align*}
\]

glycerol fatty acyl unit glycerol fatty acid salt

Soaps organize themselves in water so that the nonpolar tails point inward and the carboxylate groups face the water. They are thus able to bring oils and greases into aqueous solution by dissolving them in their oily tails. Soaps precipitate as calcium and magnesium salts in hard water and are less effective in cleansing.

Waxes
- Esters of long unbranched chain primary alcohols and fatty acids.

\[
\begin{align*}
\text{CH}_3\text{(CH}_2\text{n}_n\text{C} \quad \text{OH} & \quad \text{HO} \quad \text{CH}_2\text{(CH}_2\text{n}_n\text{CH}_3) \\
\text{O} & \quad \text{n, n'} = \text{even number 26 - 34}
\end{align*}
\]

\[
\begin{align*}
\text{CH}_3\text{(CH}_2\text{n}_n\text{C} \quad \text{O} & \quad \text{CH}_2\text{(CH}_2\text{n}_n\text{CH}_3) + \text{HOH}
\end{align*}
\]

- Waxes are found on the exterior surfaces of leaves of plants, and in some body oils.
- They principally provide protection from environmental conditions.
- Carnuba (Car) Wax is isolated from tropical plant leaves. It is mostly supplanted by synthetic silicones today.

Complex Lipids
- Glycolipids are complex lipids that contain a carbohydrate.
- Phospholipids contain an alcohol, two fatty acids, and a phosphate ester, in glycerophospholipids, the alcohol is glycerol in sphingolipids, the alcohol is sphingosine:

\[
\begin{align*}
\text{CH}_2\text{OH} & \quad \text{glycerol} \\
\text{CHOH} & \quad \text{CH}_3\text{(CH}_2\text{)}_{12}\text{CH} \quad \text{CH} \quad \text{CH} \quad \text{CH} \\
\text{CH}_2\text{OH} & \quad \text{sphingosine} \\
\text{CH}_2\text{OH} & \quad \text{OH} \quad \text{OH}
\end{align*}
\]

- Complex lipids form the membranes around cells and small structures within cells. In aqueous solution, complex lipids spontaneously form into a back-to-back lipid bilayer. Polar head groups are in contact with the aqueous environment. Nonpolar tails are buried within the bilayer. The major force driving the formation of lipid bilayers is hydrophobic interaction. The arrangement of hydrocarbon tails in the interior can be rigid (rich in saturated fatty acids) or fluid (rich in unsaturated fatty acids).
Lipid Components & Cell Membrane Properties

- Both Hydrophilic head groups and Hydrophobic tail groups are necessary to form cell membranes.
- Two hydrophobic tail groups are necessary to facilitate the bilayer structure, instead of a spherical micelle.
- The hydrophobic tail groups intermingle between the membrane surfaces.
- Cholesterol molecules help stabilize the cell membranes from being too fluid, much like clothing stays.
- The lipid bilayer is self-sealing, a puncture by an object seals automatically on removal of the object.
- Molecules cannot breach the cell membrane, but must enter by means of facilitating proteins or delivery systems.

Glycerophospholipids or Phosphoglycerides

- The second most abundant group of naturally occurring lipids are found almost exclusively in plant and animal membranes = 40% - 50% phosphoacylglycerols and 50% - 60% proteins.
- The most abundant phosphoacylglycerols are derived from phosphatidic acid, a molecule in which glycerol is esterified with two molecules of fatty acid and one of phosphoric acid. The three most abundant fatty acids in phosphatidic acids are palmitic (16:0), stearic (18:0), and oleic (18:1).

Phosphatidic Acid:  
**CH_{2}O** — **O** — **CH_{2}CH_{2}CH_{2}CO_{2}H**  
**CHO** — **O** — **CH_{2}CH_{2}CH_{2}CO_{2}H**  
**CH_{2}OH** — **OH**

Phosphatides:

- **R = choline**:  
  \[
  HOCH_{2}CH_{2}CH(CH_{3})_{3}—O—CH_{2}CH_{2}CH(CH_{3})_{3}—O—CH_{2}CH_{2}CH(CH_{3})_{3}
  \]
  **phosphatidylcholine**
  **lecithin**

- **R = ethanolamine**:  
  \[
  HOCH_{2}CH_{2}NH_{2}—O—CH_{2}CH_{2}CH(CH_{3})_{3}—O—CH_{2}CH_{2}CH(CH_{3})_{3}
  \]
  **phosphatidylethanolamine**
  **cephalin**

- **R = serine**:  
  \[
  HOCH_{2}CHCO_{2}NH_{3}—O—CH_{2}CH_{2}CH(CH_{3})_{3}—O—CH_{2}CH_{2}CH(CH_{3})_{3}
  \]
  **phosphatidylserine**
  **cephalin**

A fourth alcohol is inositol (see text) important in membranes.
Phospholipids - Plasmalogens

The plasmalogens occur widely in nerve and muscle tissue.

Sphingolipids

The white matter of the brain and spinal cord are nerve axions wrapped in a myelin sheath. Degradation of this sheath results in Multiple Sclerosis.

Steroids

All steroids, e.g. hormones, cholesterol, vitamins, etc. contain or are derived from this basic structure. Cholesterol is the most common steroid in the body and is an essential component in cell membranes and the synthesis of bile salts and cholesteryl esters.
Steroids - Vitamins

7-dehydrocholesterol → vitamin D₃

UV irradiation

Steroids – The Female Hormones

Cholesterol

estradiol

progesterone

testosterone

Steroids – The Male Hormones

androsterone

testosterone

progesterone
Steroids – Adrenocortical Hormones

This hormone regulates Na+ and K+ levels.

- **Aldosterone**
  - Regulates glucose, glycoen levels.
  - Both are potent anti-inflammatories.

- **Cortisone**
  - Regulates Na+ and K+ levels.

- **Cortisol**
  - Regulates glucose, glycoen levels.

Bile Salts are Detergents for Lipid Digestion

- Sodium cholate
- Glycocholate
- Taurine cholate
- Cholesteryl ester
  - R is a long chain fatty acid
  - Cholesteryl esters are very important in cholesterol transport.