**Fatty Acids**

Fatty Acids are carboxylic acids with long-chain hydrocarbon tails

- They are not frequently free in nature, and are mostly found as esters in other lipids
- The most predominant fatty acids in plants and animals are palmitic, oleic, linoleic, and stearic acids (C\textsubscript{16} and C\textsubscript{18})
- Over half of the fatty acids in plants and animals are unsaturated (contain double bonds), often polyunsaturated
- **Fats** are solid at room temp.
- **Oils** are liquid at room temp.

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**Physical Properties of Saturated Fatty Acids**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Common Name</th>
<th>Systematic Name</th>
<th>Structure</th>
<th>mp (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:0</td>
<td>Lauric acid</td>
<td>Dodecanoic acid</td>
<td>CH\textsubscript{3}(CH\textsubscript{2})\textsubscript{11}COOH</td>
<td>44.2</td>
</tr>
<tr>
<td>14:0</td>
<td>Myristic acid</td>
<td>Tetradecanoic acid</td>
<td>CH\textsubscript{3}(CH\textsubscript{2})\textsubscript{13}COOH</td>
<td>52</td>
</tr>
<tr>
<td>16:0</td>
<td>Palmitic acid</td>
<td>Hexadecanoic acid</td>
<td>CH\textsubscript{3}(CH\textsubscript{2})\textsubscript{15}COOH</td>
<td>63.1</td>
</tr>
<tr>
<td>18:0</td>
<td>Stearic acid</td>
<td>Octadecanoic acid</td>
<td>CH\textsubscript{3}(CH\textsubscript{2})\textsubscript{17}COOH</td>
<td>69.6</td>
</tr>
<tr>
<td>20:0</td>
<td>Arachidic acid</td>
<td>Eicosanoic acid</td>
<td>CH\textsubscript{3}(CH\textsubscript{2})\textsubscript{19}COOH</td>
<td>75.4</td>
</tr>
<tr>
<td>22:0</td>
<td>Behenic acid</td>
<td>Docosanoic acid</td>
<td>CH\textsubscript{3}(CH\textsubscript{2})\textsubscript{21}COOH</td>
<td>81</td>
</tr>
<tr>
<td>24:0</td>
<td>Lignoceric acid</td>
<td>Tetracontanoic acid</td>
<td>CH\textsubscript{3}(CH\textsubscript{2})\textsubscript{23}COOH</td>
<td>84.2</td>
</tr>
</tbody>
</table>

*Number of carbon atoms : number of double bonds. For unsaturated fatty acids, \( n \) is the number of carbon atoms, \( s \) is the double-bonded carbon atom, and \( x \) is the number of that carbon atom counting from the methyl terminal (\( s \)) end of the chain.  


- Saturated fatty acids are highly flexible molecules that can assume a wide range of conformations
  - there is relatively free rotation about each C—C bond
  - the extended conformation is still the lowest energy because it minimizes unfavorable steric interactions
- The melting points of saturated fatty acids increases regularly with the number of carbons  
  - i.e. longer saturated fatty acids remain solid at increasingly higher temperatures as chain length increases
Physical Properties of Unsaturated Fatty Acids

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Common Name</th>
<th>Systematic Name</th>
<th>Structure</th>
<th>mp (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16:1n</td>
<td>Palmitoleic acid</td>
<td>9-Hexadecenoic acid</td>
<td>CH₂(CH₃)CH=CH(CH₂)₇COOH</td>
<td>−0.5</td>
</tr>
<tr>
<td>18:1n</td>
<td>Oleic acid</td>
<td>9-Octadecenoic acid</td>
<td>CH₂(CH₃)CH=CH(CH₂)₉COOH</td>
<td>13.4</td>
</tr>
<tr>
<td>18:2n</td>
<td>Linoleic acid</td>
<td>9,12-Octadecadienoic acid</td>
<td>CH₂(CH₃)CH=CH(CH₂)₉(CH₂)COOH</td>
<td>−9</td>
</tr>
<tr>
<td>18:3n</td>
<td>α-Linolenic acid</td>
<td>9,12,15-Octadecatrienoic acid</td>
<td>CH₂(CH₃)CH=CH(CH₂)₉(CH₂)₉(CH₂)COOH</td>
<td>−17</td>
</tr>
<tr>
<td>18:5n</td>
<td>γ-Linolenic acid</td>
<td>6,9,12-Septadecatrienoic acid</td>
<td>CH₂(CH₃)CH=CH(CH₂)₆(CH₂)₉(CH₂)COOH</td>
<td>−49.5</td>
</tr>
<tr>
<td>20:4n</td>
<td>Arachidonic acid</td>
<td>5,8,11,14-Eicosatetraenoic acid</td>
<td>CH₂(CH₃)CH=CH(CH₂)₁₀(CH₂)₈(CH₂)COOH</td>
<td>−54</td>
</tr>
<tr>
<td>20:5n</td>
<td>EPA</td>
<td>5,8,11,14,17-Eicosapentaenoic acid</td>
<td>CH₂(CH₃)CH=CH(CH₂)₁₀(CH₂)₉(CH₂)COOH</td>
<td>39</td>
</tr>
<tr>
<td>22:6n</td>
<td>DHA</td>
<td>4,7,10,13,16,19-Docosahexaenoic acid</td>
<td>CH₂(CH₃)CH=CH(CH₂)₁₃(CH₂)₉(CH₂)COOH</td>
<td></td>
</tr>
</tbody>
</table>

*Number of carbon atoms: number of double bonds. For unsaturated fatty acids, n is the number of carbon atoms, α is the double-bonded carbon atom, and ω is the number of that carbon atom counting from the methyl terminal (ω) end of the chain.


- **Unsaturated fatty acids**
  - the double bonds of biologically produced unsaturated fatty acids are almost always *cis*
  - unsaturated fatty acids generally have much lower melting points than saturated fatty acids
    - saturated stearic acid (18 carbons) has a melting point of 69.6 °C
    - unsaturated oleic acid (18 carbons, 1 double bond) has a melting point of 13.4 °C
  - increasing the number of *cis* double bonds decreases melting points

- **Lower melting points of unsaturated fatty acids**

  - The *cis* double bonds of unsaturated fatty acids alter their chemical properties
    - a *cis* double bond puts a 30° bend in the hydrocarbon chain that interferes with efficient packing, causing unsaturated fatty acid melting points to be much lower than similar saturated fatty acid melting points
Trans fatty acids and margarine

- Liquid vegetable oils are partially hydrogenated to make them semisolid like butter for margarine production
  - heating in the presence of a metal catalyst under H₂ pressure reduces double bonds and isomerizes some during partial hydrogenation
  - the more complete the hydrogenation the firmer the oil and the longer the shelf-life (air oxidation of double bonds turns fat rancid)
- Margarine from vegetable oils contains no cholesterol, though trans fatty acids have been implicated in raising LDL (bad) cholesterol and lowering HDL (good) cholesterol levels

Triacylglycerols

- Fats and oils that occur in plants and animals are largely mixtures of triacylglycerols
  - Nonpolar, water insoluble substances
  - Fatty acid triesters of glycerol
  - Function as energy reservoirs in animals, and are therefore the most abundant class of lipid
  - Triacylglycerols in adipose tissues also serve as thermal insulation

Fats are a highly efficient form in which to store metabolic energy. Fats are less oxidized than carbohydrates, and stored in anhydrous form. (fats provide 6 times the energy of an equal amount of hydrated glycogen, an energy storage polysaccharide)