Fatty Acids

- **Fatty acids** $\rightarrow$ R-COOH (R is a long hydrocarbon chain) are the major components of triacylglycerols, glycerophospholipids, and sphingolipids

- Fatty acids differ from one another in:
  1. Length of the hydrocarbon chain
  2. Degree of unsaturation (# of double bonds)
  3. Position of double bond(s) in the chain

### Nomenclature of fatty acids

a. Most fatty acids have 12 to 20 carbons
b. Most chains have an **even number** of carbons
c. IUPAC nomenclature: carboxyl carbon is C-1
d. Common nomenclature: $\alpha$, $\beta$, $\gamma$, $\delta$, $\varepsilon$ etc. after C-1
e. Carbon farthest from carboxyl carbon is $\omega$ no matter the length of chain

![Diagram of a fatty acid molecule with labeled carbon atoms and bonds.]
Some naturally occurring fatty acids in animals

<table>
<thead>
<tr>
<th>Number of carbon atoms</th>
<th>Number of double bonds</th>
<th>Common name</th>
<th>Systematic name</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>0</td>
<td>Laurate</td>
<td><em>n</em>-Dodecanoate</td>
<td>CH₃(CH₂)₁₀ COO⁻</td>
</tr>
<tr>
<td>14</td>
<td>0</td>
<td>Myristate</td>
<td><em>n</em>-Tetradecanoate</td>
<td>CH₃(CH₂)₁₂ COO⁻</td>
</tr>
<tr>
<td>16</td>
<td>0</td>
<td>Palmitate</td>
<td><em>n</em>-Hexadecanoate</td>
<td>CH₃(CH₂)₁₄ COO⁻</td>
</tr>
<tr>
<td>18</td>
<td>0</td>
<td>Stearate</td>
<td><em>n</em>-Octadecanoate</td>
<td>CH₃(CH₂)₁₆ COO⁻</td>
</tr>
<tr>
<td>20</td>
<td>0</td>
<td>Arachidate</td>
<td><em>n</em>-Eicosanoate</td>
<td>CH₃(CH₂)₁₈ COO⁻</td>
</tr>
<tr>
<td>22</td>
<td>0</td>
<td>Behenate</td>
<td><em>n</em>-Docosanoate</td>
<td>CH₃(CH₂)₂₀ COO⁻</td>
</tr>
<tr>
<td>24</td>
<td>0</td>
<td>Lignocerate</td>
<td><em>n</em>-Tetracosanoate</td>
<td>CH₃(CH₂)₂₂ COO⁻</td>
</tr>
<tr>
<td>16</td>
<td>1</td>
<td>Palmitoleate</td>
<td>cis-Δ⁹-Hexadecenoate</td>
<td>CH₃(CH₂)₅ CH=CH(CH₂)₇ COO⁻</td>
</tr>
<tr>
<td>18</td>
<td>1</td>
<td>Oleate</td>
<td>cis-Δ⁹-Octadecenoate</td>
<td>CH₃(CH₂)₇ CH=CH(CH₂)₇ COO⁻</td>
</tr>
<tr>
<td>18</td>
<td>2</td>
<td>Linoleate</td>
<td>cis, cis-Δ⁹, Δ¹²-Octadecadienoate</td>
<td>CH₃(CH₂)₄(CH=CHCH₂)₂(CH₆) COO⁻</td>
</tr>
<tr>
<td>18</td>
<td>3</td>
<td>Linolenate</td>
<td>all-cis-Δ⁹, Δ¹², Δ¹⁵-Octadecatrienoate</td>
<td>CH₃(CH₂)₅(CH=CHCH₂)₃(CH₂)₆ COO⁻</td>
</tr>
<tr>
<td>20</td>
<td>4</td>
<td>Arachidonate</td>
<td>all-cis Δ⁵, Δ⁸, Δ¹¹, Δ¹⁴-Eicosatetraenoate</td>
<td>CH₃(CH₂)₄(CH=CHCH₂)₄(CH₂)₂ COO⁻</td>
</tr>
</tbody>
</table>

- **Saturated or unsaturated** (monounsaturated or polyunsaturated)
  - Double bonds are generally *cis*
  - Position of double bonds (DB) indicated by Δⁿ, where n indicates lower numbered carbon of each (DB) pair
- **Shorthand notation example:** 20:4Δ⁵,8,11,14 (# carbons : #double bonds, ΔDB positions)
Figure 11.1 - Saturated and monounsaturated fatty acids

The cis double bonds produce kinks in the tails of unsaturated fatty acids.
Figure 11.1- Saturated and monounsaturated lipids

Lipids in the **trans** form will line up or “pack” better than **cis** form.

**cis** enhance the fluidity of these lipids.
Polyunsaturated lipids

- all-cis-$\Delta^{9,12,15}$-octadecatrienoate
- $\omega$-3 fatty acid

- $\alpha$-Linolenate
- Eicosapentaenoate (EPA)
- Docosahexaenoate (DHA)
Melting Point of Fatty Acids

<table>
<thead>
<tr>
<th>Common name</th>
<th>Melting point, °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laurate</td>
<td>44</td>
</tr>
<tr>
<td>Myristate</td>
<td>52</td>
</tr>
<tr>
<td>Palmitate</td>
<td>63</td>
</tr>
<tr>
<td>Stearate</td>
<td>70</td>
</tr>
<tr>
<td>Arachidate</td>
<td>75</td>
</tr>
<tr>
<td>Behenate</td>
<td>81</td>
</tr>
<tr>
<td>Lignocerate</td>
<td>84</td>
</tr>
<tr>
<td>Palmitoleate</td>
<td>−0.5</td>
</tr>
<tr>
<td>Oleate</td>
<td>13</td>
</tr>
<tr>
<td>Linoleate</td>
<td>−9</td>
</tr>
<tr>
<td>Linolenate</td>
<td>−17</td>
</tr>
<tr>
<td>Arachidonate</td>
<td>−49</td>
</tr>
</tbody>
</table>

What factors affect melting point?

The number of Van der Waals interactions is important to the melting point temperature.
Triacylglycerols—how fatty acids are stored

- C-2 of glycerol backbone can be chiral if $R_1$ and $R_3$ are different.
- TGs that have 3 saturated fatty acid groups are solid at room temp.
- TGs with unsaturated groups tend to be liquids at room temp.

Olive oil (triolein) → 3 oleates
Figure 11.3 adipose cell electron micrograph

- Lipid is largely triacylglycerol
- Energy source and insulation
Phospholipids

- The most abundant lipid in most membranes

- A phosphate group is located on C-3 of glycerol backbone

- The phosphate group is esterified to glycerol and another compound.

- These lipids are amphipathic molecules

- Families of Phospholipids vary due to different fatty acyl chains
Common Phospholipids

Phosphatidylserine

Phosphatidylcholine

Phosphatidylethanolamine

Phosphatidylinositol

Diphosphatidylglycerol (cardiolipin)
Phospholipases hydrolyze phospholipids

- These can be used to determine the position of fatty acids ($A_1$ and $A_2$)

- $A_2$ is found in pancreatic juice and is found in bee and snake venom (lysis of red blood cells)
Sphingolipids

- Sphingosine is the backbone:
  - *trans* double bond (C-4 – C-5)
  - Amino group (C-2)
  - Hydroxyl groups (C-1 and C-3)

- Sphingomyelins contain a phosphocholine attached to carbon-1 and are abundant in tissues of the central nervous system.
Glycolipids: Sugar containing lipid

**Cerebrosides:**
Glycosphingolipids with one sugar residue attached to the C1 hydroxyl group

![Cerebroside structure](image)

**Galactocerebroside** – a single galactose sugar as the polar head group

**Gangliosides:** more complex glycolipids with branched chain of multiple sugars

Sugar residue is almost always on the extracellular side of the membrane. Often needed for cellular recognition.
Proteins can be anchored to the extracellular side of the plasma membrane using a GPI anchor.

**Clinical Insight:** premature aging
Proteins can be anchored to the intracellular side of the plasma membrane using palmitoyl or farnesyl anchors.

**Figure 11.10: Membrane anchors**

- Protein anchored with a palmitoyl group: 
  - S-Palmitoylcysteine

- Protein anchored with a farnesyl group: 
  - C-terminal S-farnesylcysteine methyl ester
Steroids

- Classified as **isoprenoids** – related to 5-carbon isoprene unit (found in membranes of eukaryotes, but rarely in bacteria)

- **Steroids** contain four fused ring systems: 3-six carbon rings (A, B, C) and a 5-carbon D ring

- Ring system is nearly planar

![Isoprene](image1)

![Steroid nucleus](image2)
Cholesterol

- Cholesterol modulates the fluidity of mammalian cell membranes due to it being less flexible than most other lipids

- It is a precursor of the steroid hormones and bile salts

- It is a sterol (has a hydroxyl group at C-3) (still very hydrophobic)
Structures of several steroids Derived from cholesterol

Estrogen (Estradiol)

Testosterone

Steroid Hormones
Bile steroid derived from cholesterol

Sodium Cholate

Used in the emulsification of fats for the absorption in the intestine.
Cholesterol esters

- Cholesterol is converted to cholesteryl esters for cell storage or transport in blood.

- Fatty acid is esterified to C-3 OH of Cholesterol

- Cholesterol esters are very hydrophobic and must be complexed with phospholipids or amphipathic proteins found in lipoproteins (e.g. HDL and LDL) for transport
Eicosanoids

- Eicosanoids are oxygenated derivatives of C\textsubscript{20} polyunsaturated fatty acids (e.g. arachidonic acid)- mediate many pathological responses

\[
\text{Arachidonic acid} \quad \begin{array}{c}
\text{CH}_3 \\
20:4\Delta^{5,8,11,14}
\end{array}
\]

Prostaglandin E\textsubscript{2} – can cause constriction of blood vessels
Eicosanoids

**Thromboxane A\(_2\)** – involved in blood clot formation

**Leukotriene D\(_4\)** – mediator of smooth-muscle contraction and provokes bronchial constriction seen in asthmatics.

**Aspirin** alleviates pain, fever, and inflammation by inhibiting cyclooxygenase (COX), an enzyme critical for the synthesis of Prostaglandins. (NSAID family of compounds)
Assignment

Read Chapter 11
Read Chapter 12

Topics not covered:
Extremophile Ether Lipids