Lipids

Benjamin Caballero, MD, PhD
Johns Hopkins University
Section A

Definitions
Some Definitions

- **Lipids** — Generic name, may include lipoproteins, phospholipids, etc.
- **Fats** — Also a generic name, but applied mostly to fats that are solid at room temperature
- **Oils** — Liquid at room temperature
- **Fatty Acids** — Basic building blocks for fats
- **Triglycerides** — Esters of fatty acids with glycerol (may also be mono- or di-glyceride)
Fatty Acids

\[
\text{COOH} \quad [ \text{CH}_2 ]_n \quad \text{CH}_2 \quad \text{CH}_2 \quad \text{CH}_2 \quad \text{CH}_3
\]
Fatty Acids

Carboxyl end
$\Delta$ numbering system

Methyl end
$n (\omega)$ numbering system
Glycerides

Glycerol

Triglyceride
Other Lipids

- **Phospholipids**
  - Phosphatidylcholine
  - Phosphatidylethanolamine
- **Sphingolipids, glycolipids**
- **Sterols**
  - Sex hormones
  - Cholesterol
  - Bile acids
Unsaturated Fatty Acids

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

\[\text{[CH}_2 \text{]}^n\]

Methyl end

\[n (\omega)\] numbering system
Structural Notation

**Palmitic acid, 16:0**

**Oleic acid, 18:1, n-9**
Functions

- Energy storage, mobilization, and utilization
- Prostaglandin, cytokine synthesis
- Cell differentiation and growth
- Cell membrane structure, myelination
- Signal transmission
- Hormone synthesis
- Bile acid synthesis
Essential Fatty Acids

- Humans cannot synthesize double bonds within the last nine carbons of the methyl end (n) of any fatty acid chain.
- Fatty acids with double bonds in those locations must therefore come from the diet—and are considered essential.
- Thus, EFA are (poly)unsaturated.
  - There are no essential saturated fats.
Essential Fatty Acids

- Only two fatty acids are essential:
  - Linoleic and alpha-linolenic acids (ALA)
- Both are (poly)unsaturated
- Therefore, absolute requirements for fat in the diet applies only to unsaturated fat
Linoleic Acid: Cottonseed, Sunflower, Soybean, Corn

C18:2, \( n-6,9 \)
Alpha-Linolenic Acid: Soybean, Mustard, Linseed, Walnut

C18:3,  \textit{n-3,6,9}
Each EFA Heads a Powerful Family

- 18:3, n-3 (ALA)
- 20:5, n-3
- Eicosapentaenoic (EPA)
- 22:5, n-3
- Docosapentaenoic (DPA)
- 22:6, n-3
- Docosahexaenoic (DHA)
Each EFA Heads a Powerful Family

- **18:3, n-3 (ALA)**
  - 20:5, n-3
  - Eicosapentaenoic (EPA)
  - 22:5, n-3
  - Docosapentaenoic (DPA)
  - 22:6, n-3
  - Docosahexaenoic (DHA)

- **18:2, n-6 (Linoleic)**
  - 20:4, n-6
  - Arachidonic acid (AA)
  - Prostaglandins
  - Leukotrienes
**Trans- Fatty Acids**

Oleic acid (C18:1n-9 cis)

Elaidic acid (C18:1n-9 trans)
Trans- Fatty Acids

- Naturally present in small amounts (<1% of total calories) in animal food sources, including human milk
- Mainly introduced in the food chain by the industrial process of hydrogenation
- This process is used to make oils solid at room temperature
## Composition of Some Edible Oils

<table>
<thead>
<tr>
<th></th>
<th>16:0</th>
<th>18:0</th>
<th>18:1</th>
<th>18:2n6</th>
<th>18:3n3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olive</td>
<td>12</td>
<td>2</td>
<td>72</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>Palm</td>
<td>42</td>
<td>4</td>
<td>43</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Canola</td>
<td>5</td>
<td>1</td>
<td>56</td>
<td>24</td>
<td>10</td>
</tr>
<tr>
<td>Sunflower</td>
<td>6</td>
<td>6</td>
<td>33</td>
<td>53</td>
<td>0</td>
</tr>
<tr>
<td>Butter</td>
<td>28</td>
<td>16</td>
<td>26</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Beef</td>
<td>28</td>
<td>13</td>
<td>43</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Chicken</td>
<td>27</td>
<td>7</td>
<td>41</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Salmon*</td>
<td>19</td>
<td>4</td>
<td>23</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

*EPA=8%, DHA=11%
Section B

Fat Metabolism
Overview of Fat Metabolism

Muscle: CO₂, TG ↔ FFA

Other Tissues: FFA turnover 70-300g/24 hr

Adipose Tissue: Lipoprotein lipase, FFA ↔ TG

Albumin-bound FFA

Liver: FFA, CO₂, ketones, TG ↔ TG

VLDL

Dietary triglyceride 25-125g/24 hr

Small Intestine: Endogenous triglyceride 20-30g/24 hr

Chylomicrons & VLDL
**Key Lipid Molecules 1**

- **Chylomicrons**
  - Formed in the intestine to carry fatty acids into the circulation after a meal is consumed
  - Disappear from the blood in the fasting state, degraded in the liver

- **VLD**
  - TG-rich lipoprotein made in the liver
  - Releases TG to tissues and give origin to LDL
Key Lipid Molecules 2

- **LDL**
  - Cholesterol-rich lipoprotein made from remnant VLDL, carries about 70% of blood cholesterol

- **HDL**
  - Made both in liver and intestine, carries cholesterol from the periphery to the liver

- All lipoproteins are eventually captured and degraded in the liver via a receptor system
Section C

Recommendations and Guidelines
Fat in the Human Diet

- Fat is an efficient way to pack more calories in less volume and, thus, fat is important for feeding infants and young children.
- After the first year of life, there is no particular advantage in using fat to provide calories.
- However, flavor and texture of foods are highly dependent on their fat content.
Total Fat: Infants and Children

- Infants fed breast milk consume 50% fat
- After weaning, they should progressively reach the recommended fat intake level for adults, by age 8-10
From 20% to 35% of total calories can be derived from fat
Total Fat: Adults

- From 20% to 35% of total calories can be derived from fat
- Lower limit is set by altered blood lipids (↑ TG, LDL)
Total Fat: Adults

- From 20% to 35% of total calories can be derived from fat
- Lower limit is set by altered blood lipids (↑ TG, LDL)
- Upper limit is determined by increasing risk of excess energy intake and obesity
Recommended Intake: Saturated Fat

- There is no physiological need for saturated fat; however, it is virtually impossible to create a healthy saturated fat-free diet.
- Thus, the recommendation is to consume no more than 10% of total calories from saturated fat.
- Also, some fat in the diet is needed to allow absorption of fat-soluble vitamins.
**Recommended Intake: Unsaturated Fat**

**Essential Fatty Acids**
- Linoleic acid—5-10% of total calories
- Alpha-Linolenic acid—0.2-1.2% of total calories
- Diet should contain certain amount of preformed PUFAs (DHA, EPA)
  - This can be achieved by consuming fatty fish twice a week
EFA Deficiency

- Clinical
  - Dermatitis
  - Thrombocytopenia
  - Increased susceptibility to infections
  - Failure to thrive
  - History of low fat intake

- Laboratory
  - Serum Triene:Tetraene ratio > 0.4