LIPIDS II:
1. TRACYLGLYCEROLS:
   - How are they broken down?
     - Hydrolyzed into 3 fatty acids and 1 glycerol
     - Physiologically in body:
       - Enzyme called a LIPASE present in adipocytes and intestines

   \[
   \text{CH}_2\text{OCR} + 3\text{H}_2\text{O} \xrightarrow{\text{lipases}} \text{CHOH} + \text{RCOOH} + \text{CH}_2\text{OH} + \text{R'}\text{COOH} + \text{CH}_2\text{OH} + \text{R''COOH}
   \]

   - Saponification
     - Treat with base (NaOH) and heat to produce soaps (salts of FAs) and glycerol
     - Used to (and still do!) boil animal fat with lye (NaOH) to make soap!

   \[
   \text{CH}_2\text{OCR} + 3\text{H}_2\text{O} \xrightarrow{\text{NaOH}} \Delta \text{CHOH} + \text{R'}\text{COO}^-\text{Na}^+ + \text{CH}_2\text{OH} + \text{R''COO}^-\text{Na}^+ + \text{Glycerol} \quad \text{Soaps (Na}^+\text{ salts of fatty acids)}
   \]
2. PHOSPHOACYLGlycEROLS (Phospholipids; Phosphoglycerides)

- Very similar in structure to triacylglycerols except one of the alcohols of glycerol is esterified by **phosphoric acid** instead of a fatty acid = **phosphatidic acid (PA)**

- The phosphoric acid group is then esterified by a second alcohol to form the **phosphoacylglycerol**

16-18 FAs most common

Position 1 favors SATURATED FAs

Position 2 favors UNSATURATED FAs

These alcohols give very different properties to the phospholipids due to different structures
Phospholipids are MUCH MORE amphiphilic than triacylglycerols due to CHARGED groups at neutral pH
- Has both hydrophilic and hydrophobic regions
- Therefore we can say that phospholipids have:
  - One POLAR HEAD
  - TWO NON-POLAR TAILS
An amphiphilic lipid

Lipid bilayer

Phosphatidylcholine

Figure 8-9 Concepts in Biochemistry, 3/e
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GLYCEROLIPIDS WITH OTHER HEAD GROUPS:

Phosphatidylethanolamine

Diphosphatidylglycerol (Cardiolipin)

Phosphatidylserine

Phosphatidylglycerol

Phosphatidylinositol
Phospholipids can be degraded to their component parts by a family of enzymes called PHOSPHOLIPASES.

**EXAMPLE: SNAKE VENOM**

- Venoms of poisonous snakes contain (among other things) phospholipases which cause the breakdown of the phospholipids.
  - Western Diamondback Rattlesnake and Indian Cobra contain **Phospholipase A2**
  - **Phospholipase A2** catalyzes the hydrolysis of fatty acids at the C2 Position.

- Remaining compound called **lysolethicin**
  - “one-legged” phospholipids
  - Acts as a detergent
  - Dissolved membranes in red blood cells causing them to rupture

**Phospholipase A2 cleaves at C2**

**LYSOLECITHIN:**

Acts like a detergent that disrupts and dissolves membranes in red blood cells.
3. SPHINGOLIPIDS

- Membrane lipids based on the core structure of SPHINGOSINE, a long chain amino alcohol
  - Glycerol is replaced by sphingosine

**General Form:**

1. Fatty acid linked to sphingosine at an AMINO group at position 2
2. 2\textsuperscript{nd} esterification takes place at the HYDROXYL (-OH) on sphingosine

If X = H \(\rightarrow\) Ceramide
- Sugar \(\rightarrow\) cerebroside
- phosphocholine \(\rightarrow\) sphingomyelin
- complex oligosaccharide \(\rightarrow\) ganglioside

<table>
<thead>
<tr>
<th>Name of X</th>
<th>Structure of X</th>
<th>Name of Sphingolipid</th>
</tr>
</thead>
<tbody>
<tr>
<td>(b) Hydrogen</td>
<td>(-H)</td>
<td>Ceramide</td>
</tr>
<tr>
<td>(c) Phosphocholine</td>
<td>(-PO_3H)</td>
<td>Sphingomyelin</td>
</tr>
<tr>
<td>(d) Glucose</td>
<td>(-CH_2OH)</td>
<td>Glucosylcerebroside</td>
</tr>
<tr>
<td>(c) Complex</td>
<td>galactose-glucose</td>
<td>Ganglioside</td>
</tr>
<tr>
<td>oligosaccharide</td>
<td>Sia</td>
<td></td>
</tr>
</tbody>
</table>
Sphingolipids:
- Much more amphiphilic than triacylglycerols
- **Sphingomyelin**
  - Insulates nerve axons
  - Major lipid of myelin sheaths
- **Cerebrosides and Gangliosides**
  (glycolipids)
  - Abundant in brain and nervous system membranes
  - Improper degradation results in many metabolic diseases
  - **Tay-Sachs Disease**
    - Gangliosides accumulate in nerve cells, brain, and spleen → Death!
  - **Gaucher Disease**
    - Accumulation of glucocerebrosides
      - Enlarged liver and spleen
      - Bone pain
      - Anemia
    - Deficiency in the enzyme glucocerebrosidase
4. **NON-SAPONIFIABLE LIPIDS/STEROIDS**
   - Based on a fused ring system – **RIGID** structure
   - No ester linkages
   - Includes **HORMONES** (testosterone, progesterone, estrogen)

- **Cholesterol**
  - Common membrane lipid
  - Almost exclusive to animal cells
  - Very hydrophobic but amphiphilic
    - Hydrophilic group is the –OH on ring A
  - Serves as the starting point for synthesis of steroid hormones
LIPID VITAMINS

Vitamin D2

Vitamin D3

Phylloquinone (vitamin K)

α-Tocopherol (vitamin E)
BIOLOGICAL MEMBRANES
- Membranes surround all cells and organelles
- Membranes are based on LIPID BILAYERS (double layer of lipid)
  - Made up of phospholipids, glycosphingolipids, sphingolipids and cholesterol (if animal)
  - Non-polar components minimize exposure to water by forming a bilayer
  - Polar head groups face outward and H-bond with water
  - Lipid fatty acid chains face inward and interact via hydrophobic interactions

LIPID BILAYERS

Membranes are:
- Fluid not static
  - Consistency of vegetable oil
  - Nature of the lipids (length, degree of saturation) dictates fluidity and melting temperature
    - Saturated versus non-saturated – saturated higher melting temperature
    - Length of fatty acids – longer generally higher melting temperature
    - Saturated less fluid than unsaturated
- Lipids are constantly moving LATERALLY (side to side)
- Rarely flip from one leaflet to the other
- When does, requires a lot of energy
- Use proteins called **FLIPPASES**
- Because of this, lipid bilayers are **ASYMMETRIC**
- Some lipids on inner leaflet only
- Some lipids on outer leaflet only
- Distribution is NOT random

**LIPID BILAYER**

*C = gray & yellow; O esters = red; Phosphate = green*  
*Choline head groups = magenta; Water = blue spheres*

**LIPID MOVEMENT ANIMATIONS:**

http://www.d.umn.edu/~sdowning/Membranes/animationindx.html