Johns Hopkins Engineering

Molecular Biology

Richard S. Potember, Ph.D.
Potember@jhu.edu

Module 2 / Lecture 4

Lipids

JOHNS HOPKINS
WHITING SCHOOL
of ENGINEERING

Lipids

Lipids are not formed by the kind of ***stepwise polymerization*** that gives rise to proteins, nucleic acids, and polysaccharides.

They are regarded as **macromolecules** because of their high **molecular weights**.

Lipids resemble one another more in their solubility properties than in their chemical structures.

The distinguishing feature of lipids is their **hydrophobic nature**.

Lipids

They are rich in nonpolar hydrocarbon regions and have relatively few polar groups.

Some lipids are ***amphipathic*** having both a polar and a nonpolar region.

Lipids play at least three main roles in cells:

energy storage

membrane structure

specific biological functions - transmission of chemical signals into and within cells.

The six main classes *of* lipids are *fatty acids, triacylglycerols, phospholipids, glycolipids, steroids,* and *terpenes.*

Fatty Acids Are the Building Blocks of Several Classes of Lipids

Fatty acids are components of several other kinds of lipids.

A fatty acid is a long, unbranched hydrocarbon chain with a carboxyl group at one end

The fatty acid molecule is **amphipathic**; the carboxyl group renders one end (often called the "head") polar, whereas the hydrocarbon "tail" is nonpolar.

Table 3-5 summarizes the nomenclature of fatty acid chain length.

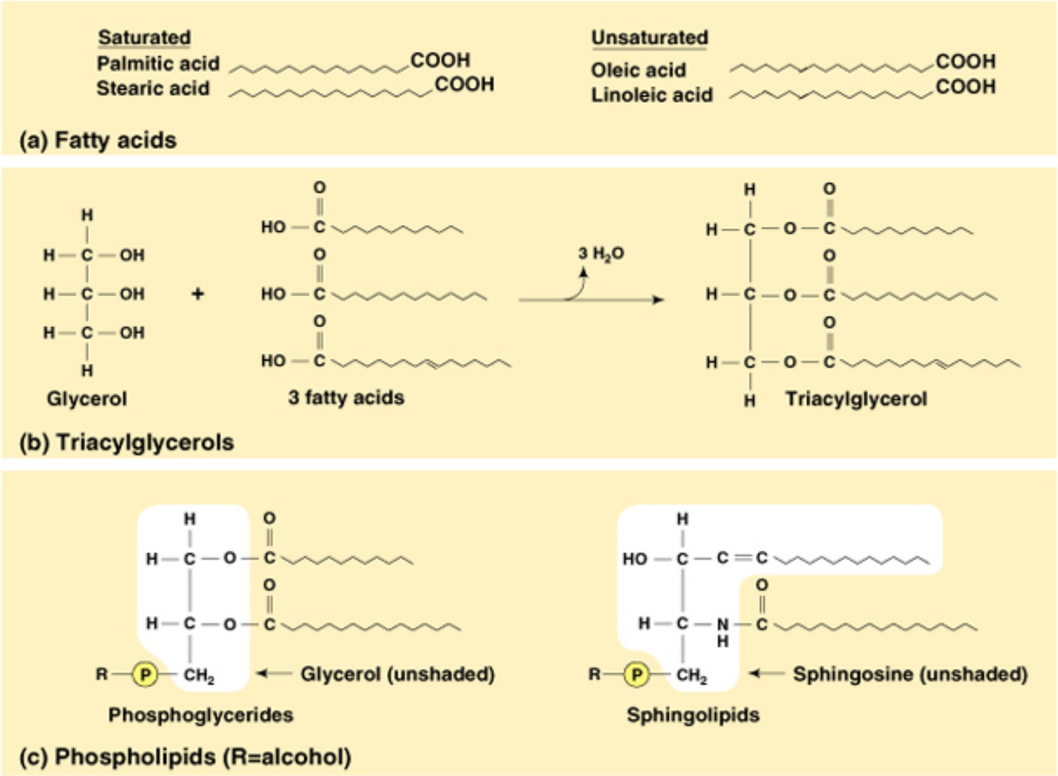
Nomenclature of the Fatty Acids

Table 3-5 Nomenclature of the Fatty Acids*

Number of Carbons	Number of Double Bonds	Common Name	Systematic Name	Formula
12	0	Laurate	*n*-dodecanoate	$CH_3(CH_2)_{10}COO^-$
14	0	Myristate	*n*-tetradecanoate	$CH_3(CH_2)_{12}COO^-$
16	0	Palmitate	*n*-hexadecanoate	$CH_3(CH_2)_{14}COO^-$
18	0	Stearate	*n*-octadecanoate	$CH_3(CH_2)_{16}COO^-$
20	0	Arachidate	*n*-eicosanoate	$CH_3(CH_2)_{18}COO^-$
16	1	Palmitoleate	*cis*-Δ^9-hexadecenoate	$CH_3(CH_2)_5CH{=}CH(CH_2)_7COO^-$
18	1	Oleate	*cis*-Δ^9-octadecenoate	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COO^-$
18	2	Linoleate	*cis, cis*-Δ^9, Δ^{12}-octadecadienoate	$CH_3(CH_2)_4(CH{=}CHCH_2)_2(CH_2)_6COO^-$
18	3	Linolenate	All *cis*-Δ^9, Δ^{12}, Δ^{15}-octadecatrienoate	$CH_3CH_2(CH{=}CHCH_2)_3(CH_2)_6COO^-$
20	4	Arachidonate	All *cis*-Δ^5, Δ^8, Δ^{11}, Δ^{14}-eicosatetraenoate	$CH_3(CH_2)_4(CH{=}CHCH_2)_4(CH_2)_2COO^-$

*The common names, systematic names, and formulas are for the ionized (anionic) forms of the fatty acids, because fatty acids exist primarily in the anionic form at the near-neutral pH of most cells. For the names and structures of the free fatty acids, simply replace the "-ate" ending with "-ic acid" and substitute a hydrogen atom (H) for the negative charge in each case.

The Main Classes of Lipids



Fatty Acids are the Building Blocks of Several Classes of Lipids

Fatty acids yield a great deal of energy upon oxidation.

One gram of fat contains >2x as much usable energy as a gram of sugar or polysaccharide.

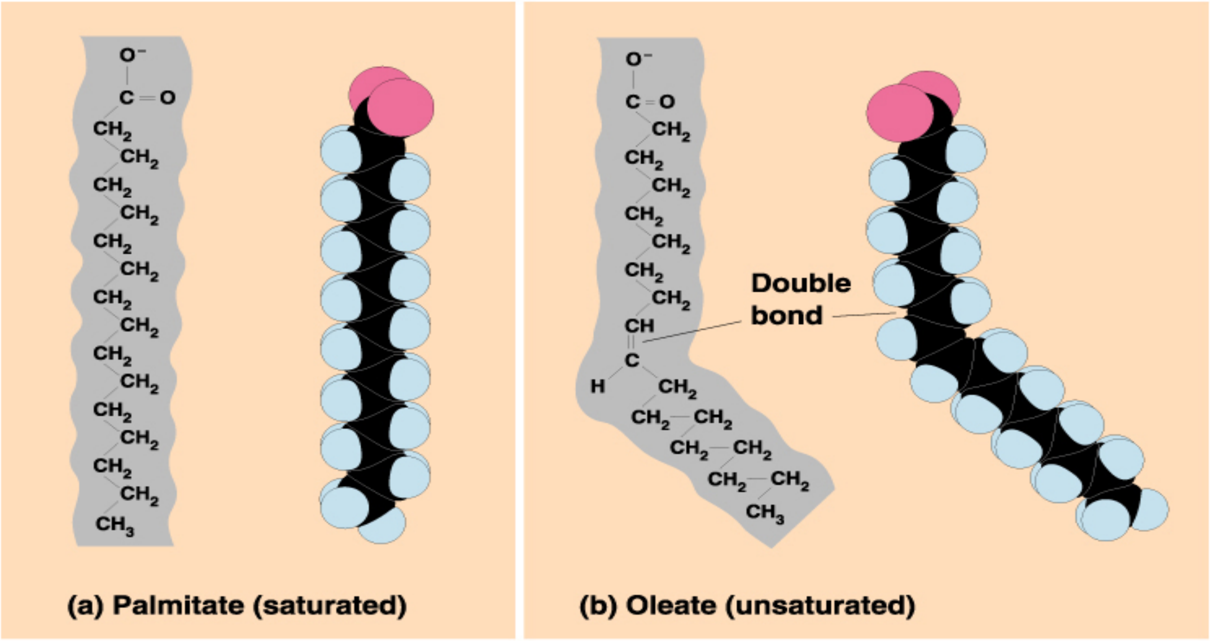
Fatty acids without double bonds are **saturated fatty acids** because every carbon atom in the chain has the maximum number of hydrogen atoms attached to it.

The general formula for a saturated fatty acid with n carbon atoms is CH_2O_2.

Unsaturated fatty acids contain one or a few **double bonds**.

The presence of **unsaturation** affects the shape of the molecule and therefore the kinds of structures of which it can be a part.

Structures of Saturated and Unsaturated Fatty Acids



Structures of Saturated and Unsaturated Fatty Acids. (a) The saturated 16-carbon fatty acid palmitate. (b) The unsaturated 18-carbon fatty acid oleate. The space-filling models are intended to emphasize the overall shape of the molecules. Notice the kink that the double bond creates in the oleate molecule.

Triacyiglycerols Are Storage Lipids

Triacylglycerols (***triglycerides)*** consist of a **glycerol** molecule with three fatty acids linked to it.

Glycerol is a three-carbon alcohol with a hydroxyl group on each carbon.

Fatty acids are linked to glycerol by ***ester bonds****,* formed by the removal of **water**.

Triglycerides are synthesized stepwise, with one fatty acid added at a time.

Monoglycerides contain a single esterified fatty acid, ***diglycerides*** have two, and ***triglycerides*** *have three.*

The three fatty acids of a given triacylglycerol need not he identical.

Triacyiglycerols Are Storage Lipids

The main function of ***triglycerides*** is to **store energy.**

In some animals, ***triglycerides*** also provide **insulation against cold temperatures**. Animals such as walruses, seals, and penguins that live in very cold climates store triacylglycerols under their skin and depend on the insulating properties of this fat for survival in harsh environments.

Triglycerides are usually solid or semi-solid at room temperature and are called fats.

In plants, **most *triglycerides*** are **liquid** at room temperature, - *vegetable oils.*

Fatty acids that are oils have kinks that prevent an orderly packing of the molecules.

As a result, vegetable oils have lower melting temperatures than most animal fats. Soybean oil and corn **oil are two** familiar vegetable oils.

Phospholipids Are Important in Membrane Structure

Phospholipids make up a third class of lipids.

They are similar to ***triglycerides*** in some chemical details but differ strikingly in their properties and their role in the cell.

Phospholipids are important in membrane structure.

They are critical to the bilayer structure found in all membranes.

In terms of chemistry, phospholipids are ***phosphoglycerides*** or ***sphingolipids***.

Steroids Are Lipids with a Variety of Functions

Steroids constitute yet another distinctive class of lipids.

Steroids are derivatives of a four-membered ring compound called ***phenanthrenes*** which makes them structurally distinct from other lipids.

The only property that links them to the other classes of lipids is that they are relatively **nonpolar** and therefore **hydrophobic**.

Steroids differ from one another in the number and positions of double bonds and functional groups.

The most common steroid in animal cells is **cholesterol.**

Steroids Are Lipids with a Variety of Functions

Cholesterol is an amphipathic molecule, with a polar head group and a nonpolar hydrocarbon body and tail.

Cholesterol is found primarily in **membranes**.

Cholesterol is also the starting point for the synthesis of all the steroid hormones, which include the male and female ***sex hormones***, the ***glucocorticoids***, and the ***mineralocorticoids***.

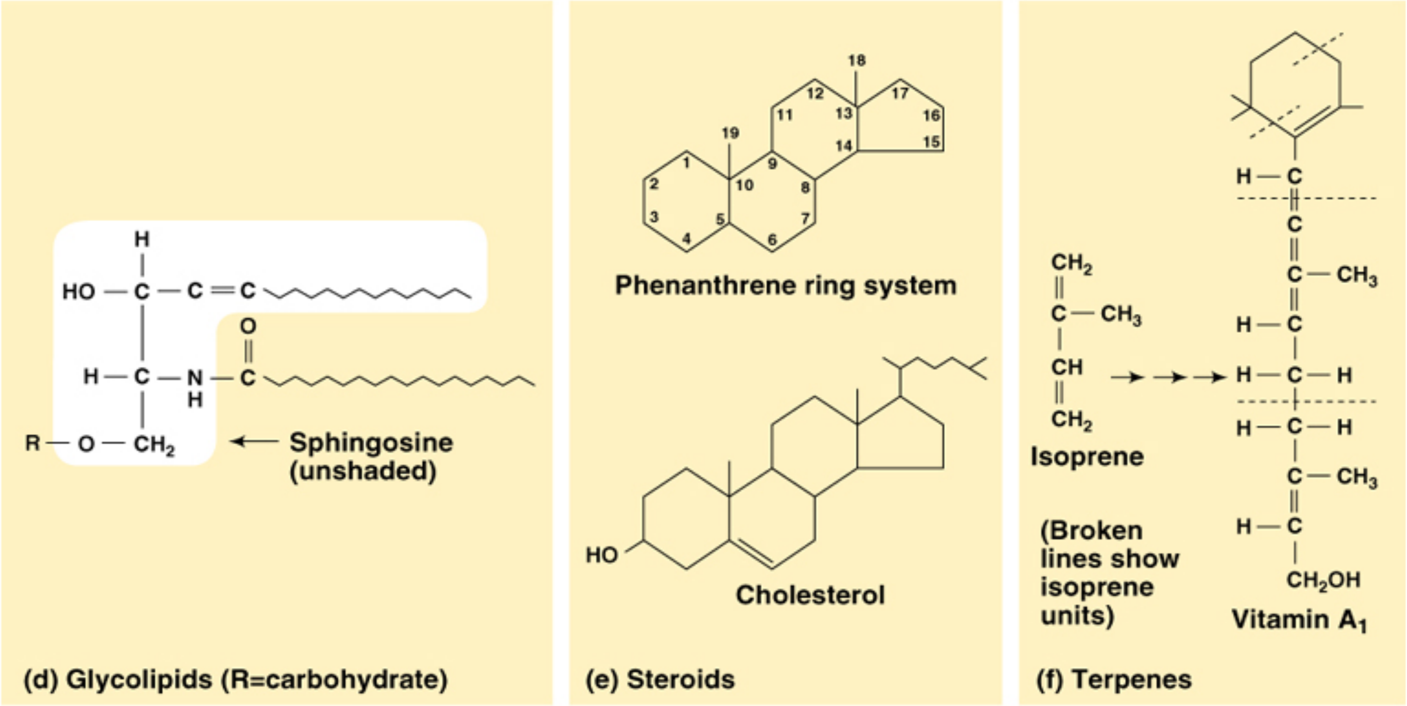
Terpenes are Formed from Isoprene

The final class of lipids consists of the **terpenes**.

Terpenes, synthesized from the five-carbon compound ***isoprene***, are also called ***isoprenoids***.

Isoprene and its derivatives are joined together in various combinations to produce such substances as *vitamin* A1, ***carotenoid pigments***.

Summary: The Main Classes of Lipids



JOHNS HOPKINS
WHITING SCHOOL
of ENGINEERING