Lipids - So far we have come into contact with amino acids and carbohydrates. The next class of bio-molecules is the **lipids**, which are, generally speaking, hydrophobic in nature. These molecules include **fats**, **oils**, **steroids**, and several other specialized molecules. Lipids can be classified as follows:

Fatty Acids and **Triacylglycerols**
Phospholipids and **Sphingolipids**

We will look at each of these groups individually, getting a feel for their properties, structures and functions. Then we will look at some metabolism of lipids.

Fatty Acids: The carboxylic acid group that is present in amino acids is the "active" part of the group of molecules called fatty acids. What makes the "fatty" is that the carboxylic group is attached to a long hydrocarbon chain (generally > 12 carbon atoms). There are two main classifications of fatty acids: **saturated** and **unsaturated**. The difference between them is that the saturated fatty acids are alkane chains (i.e. NO double bonds), while the unsaturated ones are polyenes (several double bonds).

Some common saturated fatty acids are:

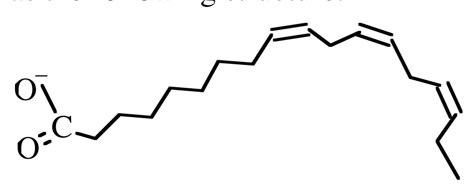
Lauric Acid (12 carbons long)	$CH_3(CH_2)_{10}COOH$
Myristic Acid (14 carbons long)	$CH_3(CH_2)_{12}COOH$
Palmitic Acid (16 carbons long)	$CH_3(CH_2)_{14}COOH$
Stearic Acid (18 carbons long)	$CH_3(CH_2)_{16}COOH$
Arachidic Acid (20 carbons long)	$CH_3(CH_2)_{18}COOH$
Lignoceric Acid (22 carbons long)	$CH_3(CH_2)_{20}COOH$
Cerotic Acid (24 carbons long)	$CH_3(CH_2)_{22}COOH$

All of these are straight chains, have an even number of carbons, and have no branches. This is a common characteristic of natural fatty acids. However, there are some rare fatty acids that do possess rings or branches, but we will not be looking at them here.

The unsaturated fatty acids fall into several categories. They can either be **mono-**unsaturated or **poly**unsaturated. And, since there are double bonds involved, they can be either **cis** or **trans** fatty acids. Here are some common cis-unsaturated fatty acids:

Palmitoleic Acid	$CH_3(CH_2)_5CH{=}CH(CH_2)_7COOH$
Oleic Acid	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$
Linoleic Acid	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$
α-Linolenic Acid	$CH_3(CH_2CH{=}CH)_3(CH_2)_7COOH$
Arachidonic Acid	$CH_3(CH_2)_3(CH_2CH{=}CH)_4(CH_2)_3COOH$

The presence of cis double bonds prevents the molecules from packing tightly. For example α-linolenic acid has the following structure:



Therefore, fats rich in cis fatty acids melt at much lower temperatures. In other words, they tend to be liquid at room temperature. On the other hand, saturated fats and trans fats tend to be solids at room temperature.

As we will see, the body can synthesize (anabolize) fatty acids, except for **linolenic** and **linoleic** acids. These are referred to as **essential** fatty acids (as opposed to nonessential) meaning that the only source of these is through diet.
There are two important **derivatives** of fatty acids. The first are called **waxes**, and they are **esters** of fatty acids and long chain alcohols. The second group, which are more important physiologically, are called the **eicosanoids** and they consist of **hormone**-like molecules (called autocrine regulators). These are fatty acids that have hydroxyl groups, rings, and/or amino groups. The molecules known as **prostoglandins** fall into this category. They typically have a cyclopentyl group as part of the chain. Other molecules that fall into the eicosanoid family are the **thromboxanes** and the **leukotrienes**.

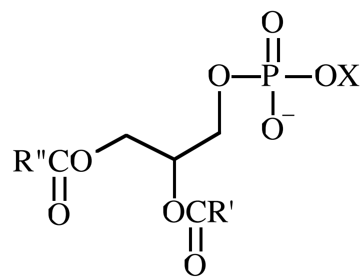
Triacylglycerols: Most fatty acids are not found in their free acid form. Rather, they exist in a form called a **neutral fat**. The neutrality comes from an ester linkage between the fatty acid and **glycerine** (a.k.a. glycerol or 1,2,3 propanetriol). Since the glycerine has three hydroxyl groups, there are 3 positions for esters. If all three are occupied by an ester linkage, the resulting molecule is called a **triacylglycerol**, or, more commonly, **tri-glyceride**. Unlike fatty acids, these molecules are very hydrophobic (the acid group on the free fatty acid is water soluble), groups of these molecules coalesce into compact globules. In fact, **adipocytes** (adipose tissue cells) which store fat use this property to store large amounts of fat in very small volumes.

These fats are stored in the body for two reasons. The first seems to be for insulation. The second, more importantly, is for storage of energy. When fats are catabolized (as we will see later), ATP is produced. Since fats contain much fewer oxygen atoms than carbohydrates, more oxidation must occur (i.e. more NAD will be reduced to NADH). Thus, overall, more energy is released. However, the body generally goes for the sugars first, then fats, when it needs energy.

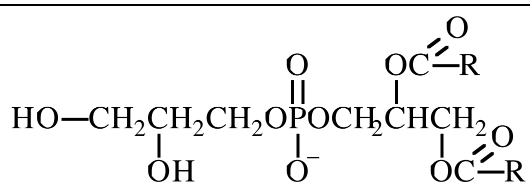
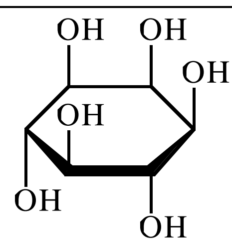
When the triglyceride is solid at room temperature it is called a **fat**; when it is a liquid, it is called an **oil**.

Phospholipids: Glycerol, as we have already stated, has 3 hydroxyl groups, but all three do not have to be linked to fatty acids. **Phosphoglycerides** have 2 fatty acids and a phosphate (as well as an alcohol, amino acid, sugar, or amine). The two fatty acids can and do vary, depending on the "purpose" of the molecule.

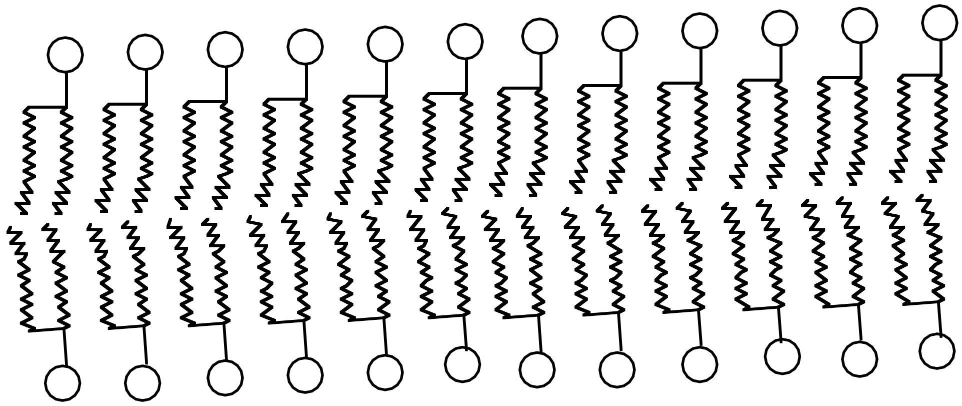
The general appearance of phosphoglycerides is as follows:



R' and R" are two hydrocrabon chains, and X can be one of the following molecules (Note: Each of the molecules loses an OH when it forms a bond to the phosphate moiety; this bond is called a **phosphate ester**, except in the case of water):

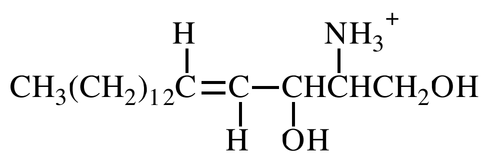
molecule	**(name)**	**type of lipid**
HO—H	water	Phosphatidic Acid
$HO—CH_2CH(NH_3^+)CO_2^-$	serine	Phosphatidylserine
$HO—CH_2CH_2N(CH_3)_3^+$	choline	Phophatidylcholine
$HO—CH_2CH_2NH_3^+$	ethanol-amine	Phophatidylethanolamine
$HO—CH_2CH(OH)CH_2OH$	glycerol	Phosphatidylglycerol
	phophatidyl-glycerol	Diphosphatidylglycerol
	inositol	Diphosphatidylinositol

The phosphatidyl choline molecules are also known as **lecithin**. These phopholipids are present in **cell membranes**. The phophate end of the molecule is water soluble, while the fatty side is not. When phospholipids form a membrane, two layers (a so-called **double-layer**) come together, fatty side to fatty side. The hydrophilic end forms the interface between the membrane and the cell. This is represented pictorially by:



The circles correspond to the hydrophilic end. Adding lecithin to water forms a **micelle**, kind of a mini-cell. If it is added to an oil, it **emulsifies** the oil, i.e. it makes the hydrophobic molecule hydrophilic.

Sphingolipids: Similar to phospholipids, sphingolipids are made from phosphate, fatty acids, and **sphingosine** (instead of glycerine):



The fatty acid forms an amide bond to the amino group, and the phosphate binds to the terminal -OH. These lipids are found in the **myelin sheaths** of nerve cells (the fatty cells that surround the axons of the nerve cells).

There are several diseases that are caused by build up of certain sphingolipids. Most of them manifest themselves as a form of mental retardation. These include Tay-Sachs, Gaucher's, Krabbe's, and Niemann-Pick diseases.

Related to the sphingolipids are the **glycolipids**, which have monosaccharides instead of phosphates. These molecules are not well understood, though they are involved in binding of bacterial toxins (e.g. botulism, tetanus, and cholera).