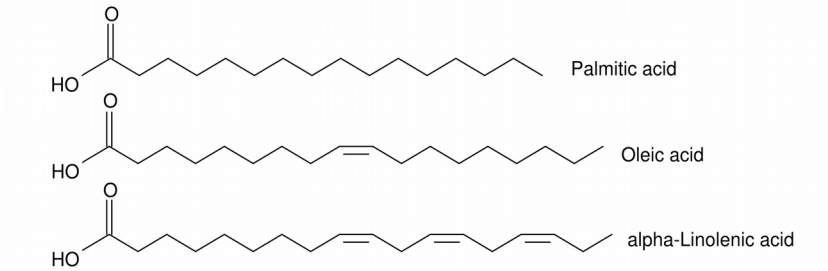
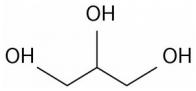
Triglycerides, Fatty Acids, Soap, and Cell Membranes

Animals store energy as fatty acids attached in groups of three as triglycerides. Fatty acids are long hydrocarbon chains that have some double bonds, but with the carbon at one end connected to an OH group and double-bonded to an oxygen.

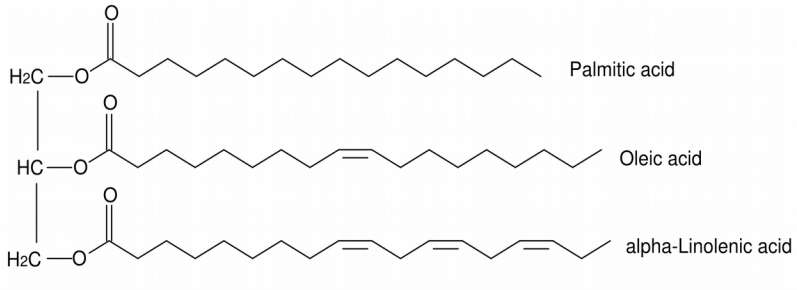
The following diagram on the right shows three fatty acids, a saturated fatty acid with no double bonds, and omega-9 unsaturated fatty acid with a double bond at the 9th carbon from its tail, and an omega-3 polyunsaturated fatty acid with the first of 3 double bonds at the 3rd carbon from its tail.



When a glycerol molecule

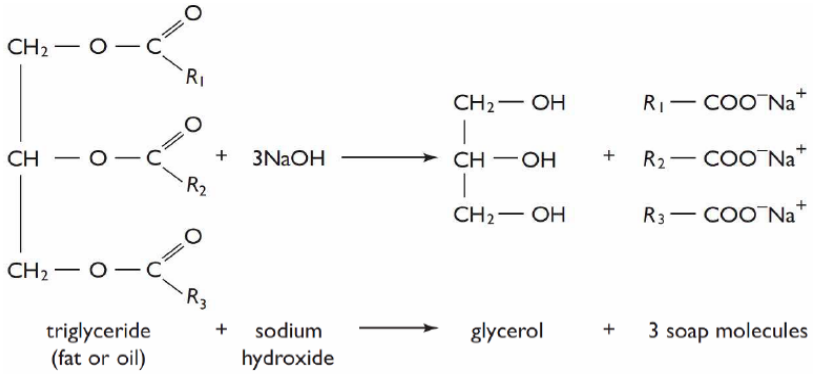


is attached to any 3 fatty acids, three water molecules are released and a triglyceride is formed. For example, the three fatty acids shown above can be connected to produce the triglyceride shown on the right.



Three soap molecules are made by combining triglycerides in lard with sodium and potassium hydroxide found in lye (wood ash + water).

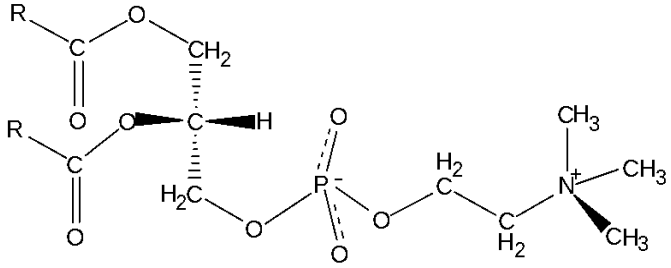
The reaction with sodium hydroxide is shown on the right where the tails of the fatty acids are simply abbreviated by the R symbols. Glycerol is freed, but the fatty acids now have a $Na^{+}O^{-}$ instead of an OH at the head end. The result is a strong electric dipole at the head instead of the neutral covalent bonded OH. This change makes the head of the soap molecules very attractive to water (hydrophilic).



The tail end avoids water (hydrophobic) while being attracted to similar long chains in grease. That allows the water molecules to pull on the head while the tail is stuck to the grease.

There is, however, a problem if the soap is being used in "hard" water that contains Ca^{++} and/or Mg^{++} ions. The double charge of these ions causes them to be attracted to two soap molecules at once in a structure that looks like $R_1—COO^{-}$ Ca++ $^{-}OOC—R_2$. The water molecules now have considerable more difficulty pulling on the hydrophilic ends since access to them is restricted by a second soap molecule.

Fatty acids are also found in phospholipid molecules used to construct cell membranes. Phospholipids have the structure show on the right. The fatty acid tails (represented by letters "R") extend to the left in this diagram.



The phospholipids used to build cell walls have one saturated fatty acid with a straight chain and the other fatty acid with a double bond causing it to bend. The purpose of the bend is to make the cell membrane more fluid so that its shape can change and protein molecules immersed in the cell wall can slide around the cell wall. The detailed structure beyond the phosphate group varies according the membrane needs.

When immersed in water, phospholipids self-assemble into hollow cells, solid balls and sheets as shown below. Their hydrophobic tails are then protected from the surrounding water.