2.3: Lipids

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Lipids are hydrophobic compounds that are typically present in non-aqueous biological phases. They include fats, oils, certain vitamins and hormones and non-protein membrane components. In bacteria, lipids account for 10-15% of the total dry cell weight. They are however less abundant in eukaryotes, representing, for example, only 1-to-6% of the total dry cell weight in the baker's yeast *Saccharomyces cerevisiae*.

Fatty acids, which have for general formula CH_3–$(CH_2)_n$–COOH, are a major component of most lipids. In general, *n* is greater than 14 and less than 20 and fatty acids that deviate from this range are rare. Unsaturated species contain C=C double bonds. The most abundant fatty acids in plants and animals are palmitic, stearic, oleic and linoleic acids (Fig. 1). More than half of plant and animal fatty acids are unsaturated and many contain more than two double bonds. This does not hold true in bacteria where branching, hydroxylation and inclusion of cyclopropane rings is more common.

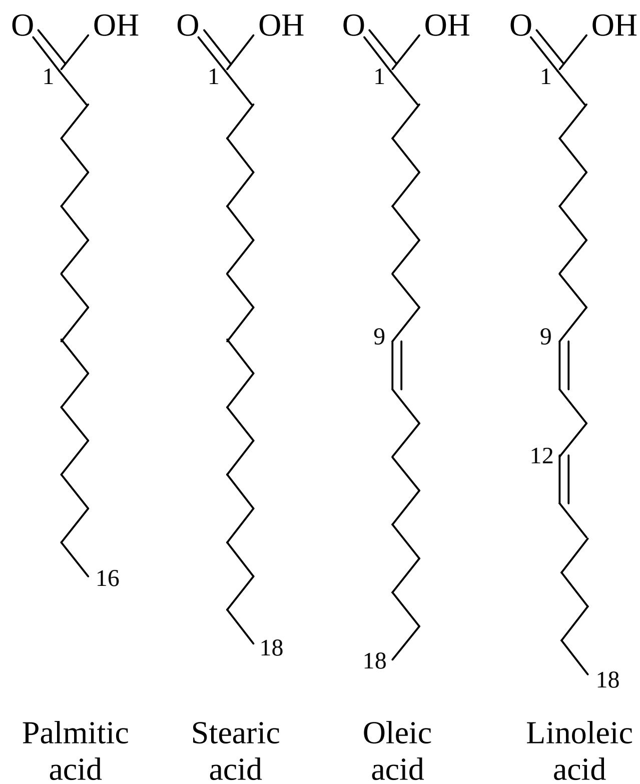


Fig. 1 Structure of the most abundant fatty acids in higher plants and animals.

Saturated fatty acids exhibit a high degree of conformational flexibility due to the possibility of free rotation about each of their C–C bonds. The extended conformation is however the norm since it limits interactions between successive methylene groups leads to the lowest energy structure. Unsaturated fatty acids almost always have their C=C bond in a *cis* conformation, which result in a rigid, 30º kink in the molecule. The melting point of fatty acids decreases with the degree of chain unsaturation and so does lipid fluidity. This property is particularly important because lipid fluidity is key in facilitating lateral diffusion of integral membrane proteins in biological membranes.

Fats and oils largely consist of a mixture of triglycerides that are formed when glycerol reacts with fatty acids (Fig. 2). Triglycerides are the most abundant class of lipids in plants and animals because they provide large amounts of metabolic energy upon oxidation. Unlike glycogen, which functions as a short-term energy source, a normal fat content can support body function for 2-to-3 months. Simple triglycerides are composed of a glycerol molecule and three identical fatty acids chains (e.g., tristearin incorporates three stearic acids). More common complex triglycerides may contain two or three different types of fatty acids residues (Fig. 2).

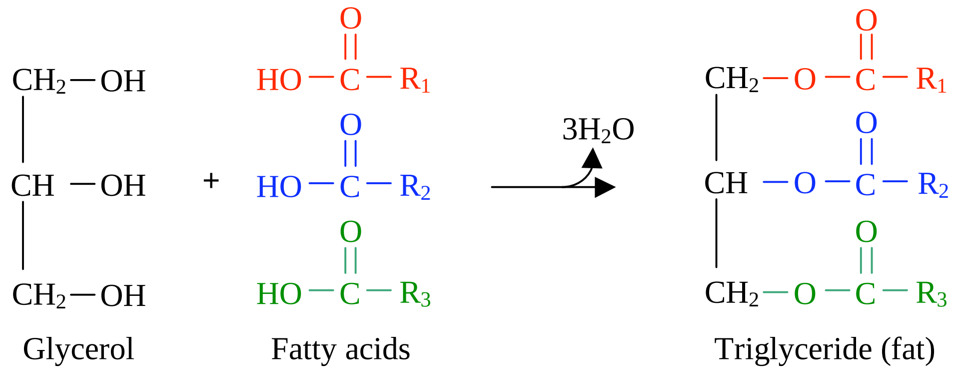


Fig. 2 Triglycerides or fats are formed upon condensation of glycerol and fatty acids. Fatty acids may be identical or differ from each other and may be saturated or unsaturated.

Phosphoglycerides (*aka* glycerophospholipids or phospholipids) are major components of biological membranes. These amphiphilic molecules are built from a phosphorylated derivative of glycerol (glycerol-3-phosphate) esterified at its carbons 1 and 2 by fatty acids and at its phosphoryl group by a polar molecule that is often an alcohol (Fig. 3). The most common phospholipids in biological membranes are phosphatidylcholine, phosphatidylserine, phosphatidyl glycerol and phosphatidyl inositol.

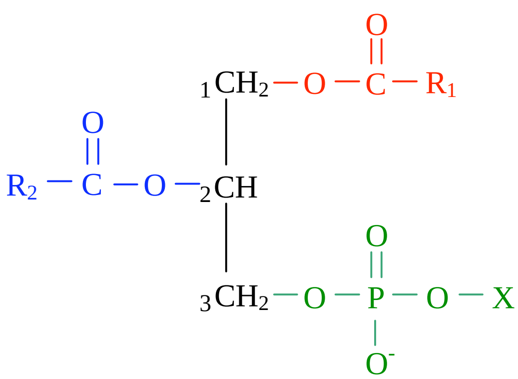
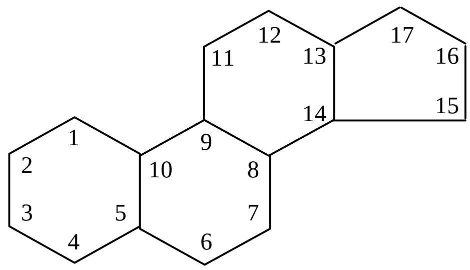


Fig. 3 General structure of a phosphoglyceride. Fatty acids at position C1 (red) are usually saturated and have a chain length of C_{16}-to-C_{18}. Fatty acids at position C2 (blue) are often unsaturated and C_{16} to C_{20}. The substituent X on the phosphoryl group (green) is typically a polar alcohol such as ethanolamine, choline, serine or glycerol.

In addition to phospholipids, sphingolipids are another major lipid component of membranes. These molecules are derived from the C_{18} amino alcohols sphingosine and dihydrosphingosine, as well as from their C_{16}, C_{17}, C_{19} and C_{20} homologs. Sphingolipids include sphingomyelins, cerebrosides and gangliosides.

Steroids, which are mostly found in eukaryotes, are derivatives of cyclopentano-perhydrophenanthrene (Fig. 4a). Theses hormones regulate animal development and metabolism at very low concentrations. Cholesterol (Fig. 4b) is perhaps one of the best-known steroids. Although it is abundant in membranes where its rigid character decreases lipid fluidity, cholesterol is also found in blood plasma lipoproteins and serves as the metabolic precursor of a number of a number of steroid hormones. These include cortisone (which exhibits anti-inflammatory properties), progesterone (whose derivatives are used as contraceptives) and the male sex hormone testosterone.

a



b

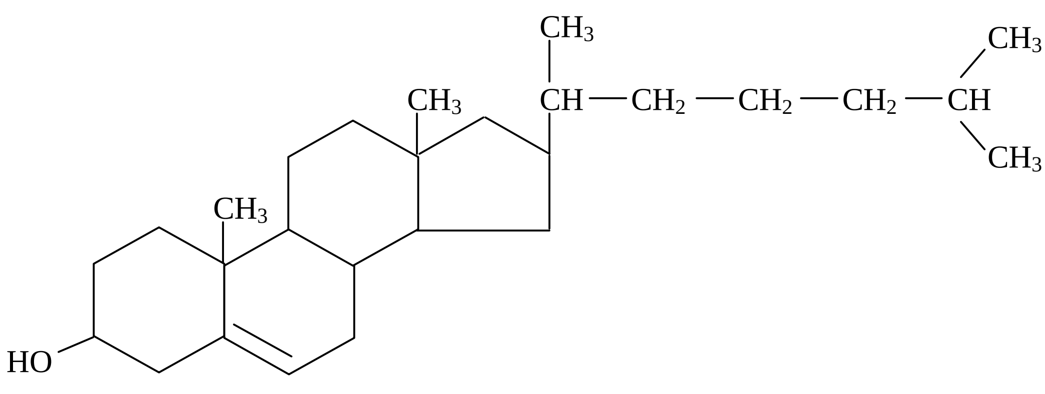


Fig. 4 Chemical structures of cyclopentanoperhydrophenanthrene (a) and its derivative, cholesterol (b). Panel (a) shows the basic numbering scheme of carbon atoms.