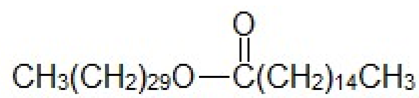
Waxes:

A second group of neutral lipids that are of physiological importance are waxes. Essentially, waxes consist of a long-chain fatty acid linked through an ester linkage to a long-chain alcohol. These molecules are completely water-insoluble and generally solid at room temperatures. Their strongly hydrophobic nature allows them to function as water repellents on the leaves of some plants, on feathers of birds, and on the cuticles of certain insects. Waxes also serve as energy-storage substances in plankton. Whales and many fishes also store large quantities of waxes. The most commonly known animal wax is beeswax, but other insects secrete (release) waxes. A major component of the beeswax used in constructing honeycombs is the ester myricyl palmitate which is an ester of triacontanol and palmitic acid.



Myricyl palmitate

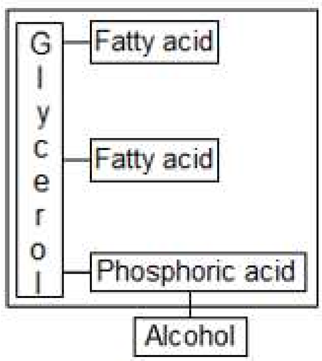
Waxes are mainly consumed industrially as components of complex formulations, often for coatings. They are used to make candles, which used for lighting and decoration. Also, waxes are used as finishes and coatings for wood products. Biological waxes find a variety of applications in the pharmaceutical, cosmetic, and other industries. Lanolin (from lamb's wool), beeswax, carnauba wax are widely used in the manufacture of lotions, ointments, and polishes.

Phosphoglycerides or Phospholipids:

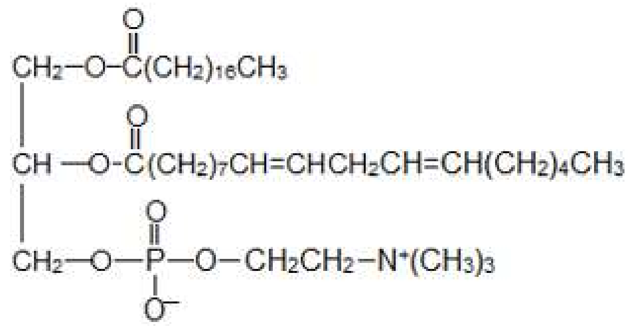
Phosphoglycerides are glycerol-based phospholipids. They are the main component in the lipid bilayers of cell membranes. Phospholipids are similar to the triglycerides with a couple of exceptions. Phospholglycerides are esters of only two fatty acids, phosphoric acid and a trifunctional alcohol - glycerol. The fatty acids are attached to the glycerol at the 1 and 2 positions on glycerol through ester bonds. There may be a variety of fatty acids, both saturated and unsaturated, in the phospholipids. The third oxygen on glycerol is bonded to phosphoric acid through a phosphate ester bond (oxygen-phosphorus double bond oxygen). In addition, there is usually a complex amino alcohol also attached to the phosphate through a second phosphate ester bond. The complex amino alcohols include choline, ethanolamine, and the amino acid-serine.

In phosphoglycerides, the hydroxyl groups at C-1 and C-2 of glycerol are esterified to the carboxyl groups of the two fatty acid chains. The C-3 hydroxyl group of the glycerol backbone is esterified to phosphoric acid. When no further additions are made, the resulting compound is phosphatidic acid (diacylglycerol 3-phosphate). The major phosphoglycerides are named as derivatives of the parent compound phosphatidic acid according to the polar alcohol in the head group. Phosphatidyl serine, phosphatidylcholine and phosphatidylethanolamine have the amino acid serine, choline and ethanolamine in their polar head groups, respectively.

The properties of a phospholipid are characterized by the properties of their fatty acid chain and the phosphate/amino alcohol. The long hydrocarbon chains of the fatty acids are of course non-polar. The phosphate group has a negatively charged oxygen and a positively charged nitrogen to make this group ionic. In addition there are other oxygen of the ester groups, which make on whole end of the molecule strongly ionic and polar.



General structure of a phosphglycerides



Phosphotidyl choline (Lecithin)

There are two common phospholipids:

Lecithin, which contains the amino alcohol, choline.

Cephalins, which contain the amino alcohols serine or ethanolamine.

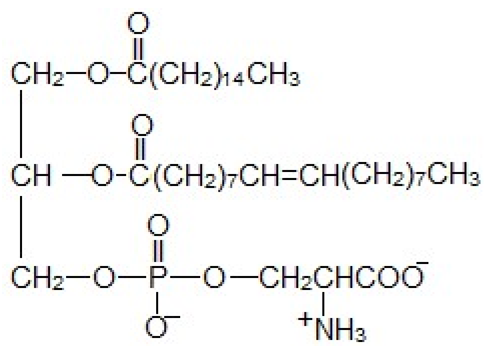
Lecithin:

Lecithin is probably the most common phospholipid. It is found in egg yolks, wheat germ, and soybeans. Lecithin is extracted from soy beans for use as an emulsifying agent in foods. Lecithin is an emulsifier because it has both polar and non-polar properties, which enable it to cause the mixing of other fats and oils with water components. Lecithin is also a major component in the lipid bilayers of cell membranes.

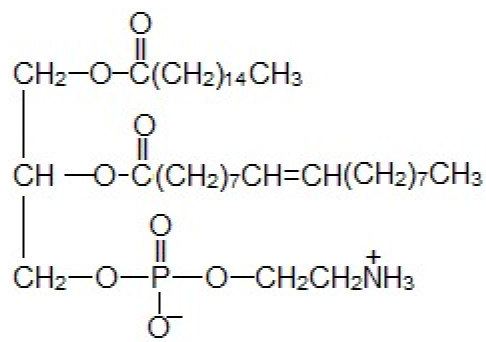
Lecithin contains the ammonium salt of choline joined to the phosphate by an ester linkage. The nitrogen has a positive charge, just as in the ammonium ion. In choline, the nitrogen has the positive charge and has four methyl groups attached.

Cephalins:

Cephalins are phosphoglycerides that contain ehtanolamine or the amino acid serine attached to the phosphate group through phosphate ester bonds. A variety of fatty acids make up the rest of the molecule. Cephalins are found in most cell membranes, particularly in brain tissues. They also important in the blood clotting process as they are found in blood platelets.



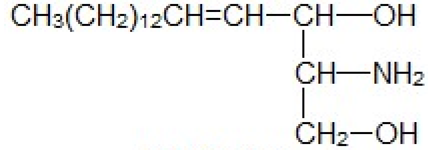
Phosphotidyl serine (Cephalin)



Phosphotidyl ethanoamine (Cephalin)

Sphingolipids:

Sphingolipids are a class of lipids containing a backbone of sphingoid bases, a set of aliphatic amino alcohols that includes sphingosine. Sphingolipids are composed of one molecule of the long-chain amino alcohol sphingosine or one of its derivatives, one molecule of a long-chain fatty acid, and a polar head group that is joined by a glycosidic linkage in some cases and by a phosphodiester in others. Sphingolipids play important roles in signal transmission and cell recognition. Sphingolipidoses, or disorders of sphingolipid metabolism, have particular impact on neural tissue.



Sphingosine

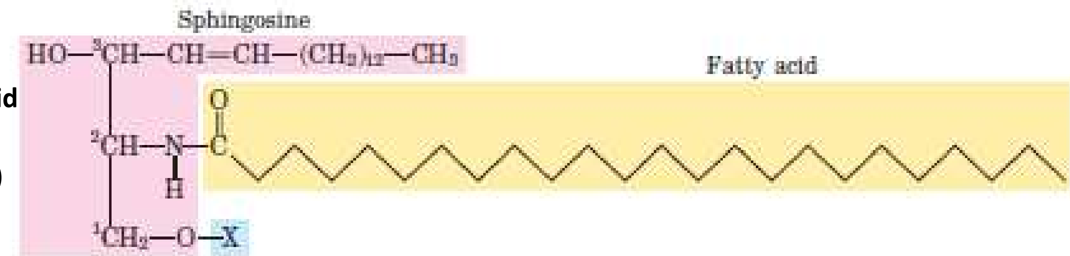
Carbons C-1, C-2, and C-3 of the sphingosine molecule are structurally analogous to the three carbons of glycerol in glycerophospholipids. When a fatty acid is attached in amide linkage to the NH_2 on C-2, the resulting compound is a ceramide, which is structurally similar to a diacylglycerol. Ceramide is the structural parent of all sphingolipids. There are three subclasses of sphingolipids, all derivatives of ceramide but differing in their head groups: sphingomyelins, neutral glycosphingolipids (cerebrosides and globosides), and gangliosides.

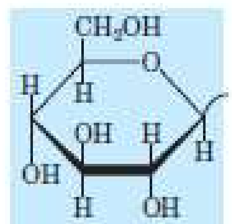
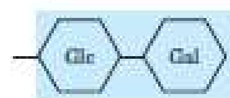
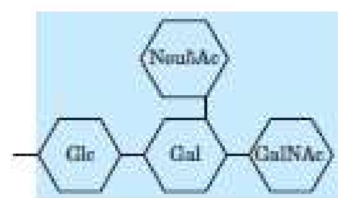
Sphingomyelins contain phosphocholine or phosphoethanolamine as their polar head group. Indeed, sphingomyelins resemble phosphatidylcholines in their general properties and three-dimensional structure, and in having no net charge on their head groups. Sphingomyelins are present in the plasma membranes of animal cells and are especially prominent in myelin, a membranous sheath that surrounds and insulates the axons of some neurons.

Glycosphingolipids, which occur largely in the outer face of plasma membranes, have head groups with one or more sugars connected directly to the OH at C-1 of the ceramide moiety; they do not contain phosphate. Cerebrosides have a single sugar linked to ceramide; those with galactose are characteristically found in the plasma membranes of cells in neural tissue, and those with glucose in the plasma membranes of cells in non-neural tissues. Globosides are neutral (uncharged) glycosphingolipids with two or more sugars, usually D-glucose, D-galactose, or N-acetyl-D-galactosamine. Cerebrosides and globosides are sometimes called neutral glycolipids, as they have no charge at pH 7.

Gangliosides, the most complex sphingolipids, have oligosaccharides as their polar head groups and one or more residues of *N*-acetylneuraminic acid (Neu5Ac), often simply called sialic acid, at the termini. Sialic acid gives gangliosides the negative charge at pH 7 that distinguishes them from globosides. Gangliosides with one sialic acid residue are in the GM (M for mono-) series, those with two are in the GD (D for di-) series, and so on (GT, three sialic acid residues; GQ, four).

Sphingolipid (general structure)



Name of sphingolipid	Name of X	Formula of X
Ceramide	—	$-H$
Sphingomyelin	Phosphocholine	$-\overset{O}{\overset{\parallel}{P}}(O^-)-O-CH_2-CH_2-\overset{+}{N}(CH_3)_3$
Neutral glycolipids Glucosylcerebroside	Glucose	
Lactosylceramide (a globoside)	Di-, tri-, or tetrasaccharide	
Ganglioside GM2	Complex oligosaccharide	

Steroids:

The terpenoids, sometimes called isoprenoids, are a large and diverse class of naturally occurring organic chemicals similar to terpenes, derived from five-carbon isoprene units assembled and modified in thousands of ways. Most are multicyclic structures that differ from one another not only in functional groups but also in their basic carbon skeletons. These lipids can be found in all classes of living things, and are the largest group of natural products. About 60% of known natural products are terpenoids.