Lipids

Lipids are a heterogeneous group of compounds, including fats, oils, steroids, waxes, and related compounds. They have the common property of being:

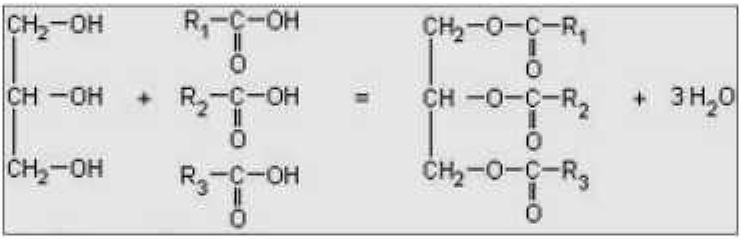
(1) Relatively insoluble in water

(2) Soluble in no polar solvents such as ether and chloroform.

They are important dietary constituents not only because of their high energy value but also because of the fat-soluble vitamins, hormone and the essential fatty acids contained in the fat of natural foods. Fat is stored in adipose tissue, where it also serves as a thermal insulator in the subcutaneous tissues and around certain organs. Combinations of lipid and protein (lipoproteins) serving as the means of transporting lipids in the blood.

Lipid classification

1. **Simple lipids**: Esters of fatty acids with various alcohols like Triglyceride (TG):



Glycerol **Fatty acids** **Triglyceride**

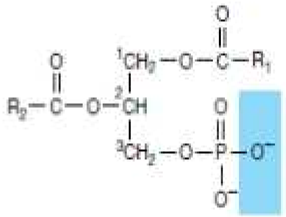
Simple lipid can be divided to:

a. Fats: Esters of fatty acids with glycerol.

b. Waxes: Esters of fatty acids with higher molecular weight of alcohols.

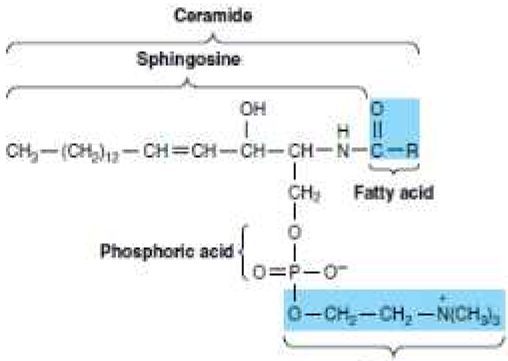
2. Complex lipids: Esters of fatty acids containing groups in addition to an alcohol and a fatty acid can be divided to:

a- phospholipids: Lipids containing, in addition to fatty acids and an alcohol, a phosphoric acid residue. They frequently have nitrogen containing bases and other substituent's:

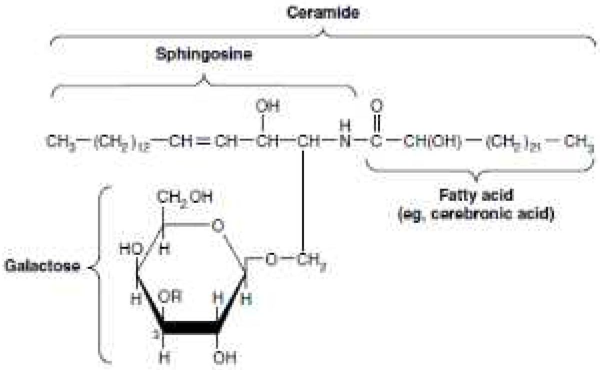


Phosphatidic acid

b- Glycolipids or Sphingolipids: Lipids containing ceramide with other substituent's like choline or carbohydrate:



Sphingomyelin.



Galactocerebroside

3-Derived lipids: These include steroids, lipid-soluble vitamins, and hormones, cholesterol, and cholesteryl esters

Fatty acids

Plasma fatty acids liberated from adipose tissue by lipase activity are transported to the liver and muscle mainly bound to albumin. Triglycerides are transported from the intestine to various tissues, including the liver and adipose tissue, as lipoproteins. Following hydrolysis, fatty acids are taken up, re-esterified and stored as triglycerides. Fatty acids are carboxylic acids with hydrocarbon chains ranging from 4 to 36 carbons long (C4 to C36). a transport form found in the plasma. Fatty acids that occur in natural fats are usually straight-chain derivatives containing an even number of carbon atoms. The chain may be saturated (containing no double bonds) or unsaturated (containing one or more double bonds).

A simplified nomenclature for these compounds specifies the chain length and number of double bonds, separated by a colon; for example, the 16-carbon saturated palmitic acid is abbreviated 16:0, and the 18-carbon oleic acid, with one double bond, is 18:1. The positions of any double bonds are specified by superscript numbers following Δ (delta) (if C-1 being the carboxyl groups) for example: 20-carbon fatty acid with one double bond between C-9 and C-10 (C-1 being the carboxyl carbon) and another between C-12 and C-13 is designated 20:2($\Delta^{9,12}$).

If the (C-1 being the terminal methyl carbon) is known as the ω or n-carbon. The carbon atoms adjacent to the carboxyl carbon (Nots. 2, 3, and 4) are also known as the α, β, and γ carbons, respectively.

Table: structures of saturated fatty acids

Carbon skeleton	*Structure**	*Systematic name†*	*Common name (derivation)*
12:0	$CH_3(CH_2)_{10}COOH$	*n*-Dodecanoic acid	Lauric acid (Latin *laurus*, "laurel plant")
14:0	$CH_3(CH_2)_{12}COOH$	*n*-Tetradecanoic acid	Myristic acid (Latin *Myristica*, nutmeg genus)
16:0	$CH_3(CH_2)_{14}COOH$	*n*-Hexadecanoic acid	Palmitic acid (Latin *palma*, "palm tree")
18:0	$CH_3(CH_2)_{16}COOH$	*n*-Octadecanoic acid	Stearic acid (Greek *stear*, "hard fat")
20:0	$CH_3(CH_2)_{18}COOH$	*n*-Eicosanoic acid	Arachidic acid (Latin *Arachis*, legume genus)

Table: structures of unsaturated fatty acids

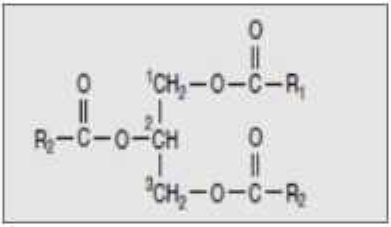
16:1(Δ^9)	$CH_3(CH_2)_5CH{=}CH(CH_2)_7COOH$	*cis*-9-Hexadecenoic acid	Palmitoleic acid
18:1(Δ^9)	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$	*cis*-9-Octadecenoic acid	Oleic acid (Latin *oleum*, "oil")
18:2($\Delta^{9,12}$)	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$	*cis*-,*cis*-9,12-Octadecadienoic acid	Linoleic acid (Greek *linon*, "flax")
18:3($\Delta^{9,12,15}$)	$CH_3CH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$	*cis*-,*cis*-,*cis*-9,12,15-Octadecatrienoic acid	α-Linolenic acid
20:4($\Delta^{5,8,11,14}$)	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_3COOH$	*cis*-,*cis*-,*cis*-,*cis*-5,8,11,14-Icosatetraenoic acid	Arachidonic acid

Physical and Physiologic Properties of Fatty acid

The melting points of even-numbered-carbon fatty acids increase with chain length. A triacylglycerol containing three saturated fatty acids of 12 carbons or more is solid at body temperature, whereas if the fatty acid residues are 18:2, it is liquid to below 0 °C.

Triacylglycerols (Triglyceride) is the main lipid for storage

The triacylglycerols are esters of the glycerol and fatty acids, mono- and diacylglycerols where in one or two fatty acids are esterified with glycerol are also found in the tissues the structure of Triglyceride is:



Triglyceride

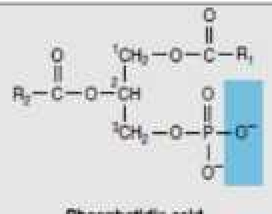
Structural lipid in membrane

Membrane lipids are amphipathic: one end of the molecule is hydrophobic, the other hydrophilic. Their hydrophobic interactions with each other and their hydrophilic interactions with water direct their packing into sheets called membrane bilayers. Phospholipids and some sphingolipids, a polar head group is joined to the hydrophobic moiety by a phosphodiester linkage.

The inositol is present in Phosphatidylinositol is an important constituent of cell membrane phospholipids; upon stimulation by a suitable hormone agonist. These compounds constitute as much as 10% of the phospholipids of brain and muscle.

Phospholipids

Phospholipids, also called phosphoglycerides, are membrane lipids in which two fatty acids are attached in ester linkage to the first and second carbons of glycerol, and a highly polar or charged group is attached through a phosphodiester linkage to the third carbon:


Phosphatidic acid

Replaced For example:

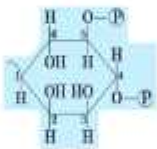
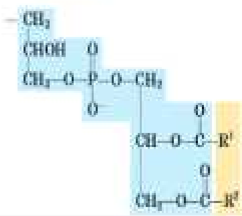
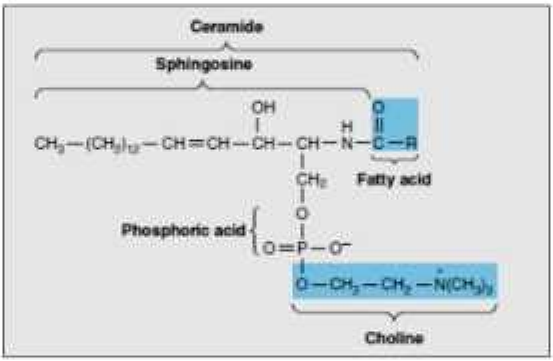
Name of glycerophospholipid	Name of X	Formula of X	Net charge (at pH 7)
Phosphatidic acid	—	$-H$	−1
Phosphatidylethanolamine	Ethanolamine	$-CH_2-CH_2-\overset{+}{N}H_3$	0
Phosphatidylcholine	Choline	$-CH_2-CH_2-\overset{+}{N}(CH_3)_3$	0
Phosphatidylserine	Serine	$-CH_2-CH(COO^-)-\overset{+}{N}H_3$	−1
Phosphatidylglycerol	Glycerol	$-CH_2-CH(OH)-CH_2-OH$	−1
Phosphatidylinositol 4,5-bisphosphate	myo-Inositol 4,5-bisphosphate		−4
Cardiolipin	Phosphatidyl-glycerol		−2

Figure: Glycerophospholipids.

Glycolipid or Sphingolipids

Glycolipids are widely distributed in every tissue of the body, particularly in nervous tissue such as brain. The major glycolipids found in animal tissues are glycosphingolipids. They contain ceramide and one or more sugars. Sphingomyelins are found in large quantities in brain and nerve tissue. The combination of sphingosine plus fatty acid is known as ceramide, a structure also found in the glycosphingolipids



Sphingomyelin

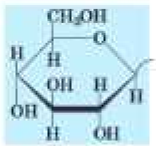
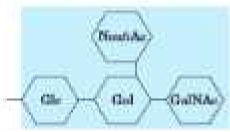
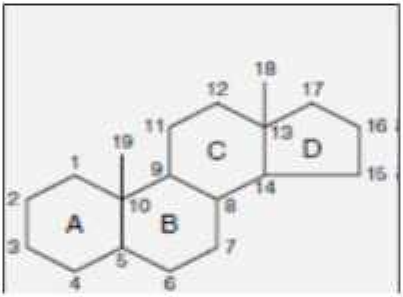
Name of sphingolipid	Name of X	Formula of X
Ceramide	—	—H
Sphingomyelin	Phosphocholine	$-P(=O)(O^-)-O-CH_2-CH_2-\overset{+}{N}(CH_3)_3$
Neutral glycolipids Glucosylcerebroside	Glucose	
Lactosylceramide (a globoside)	Di-, tri-, or tetrasaccharide	
Ganglioside GM2	Complex oligosaccharide	

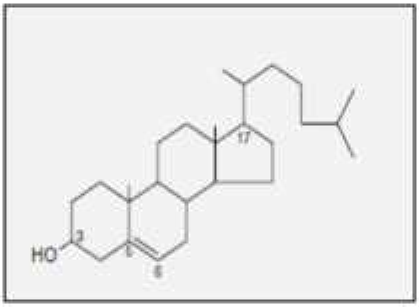
Figure: Glycolipids or Sphingolipids

Steroids

Cholesterol is probably the best known steroid because of its association with atherosclerosis. However, biochemically it is also of significance because it is the precursor of a large number of equally important steroids that include the bile acids, adrenocortical hormones, sex hormones, D vitamins. The liver plays a central role in the regulation of the body's cholesterol homeostasis. For example, cholesterol enters the liver's cholesterol pool from a number of sources including dietary cholesterol as well as that synthesized de novo by extrahepatic tissues and by the liver itself. Cholesterol is eliminated from the liver as unmodified cholesterol in the bile, or it can be converted to bile salts that are secreted into the intestinal lumen. occurrence when the lipid deposition leads to plaque formation, causing the narrowing of blood vessels (atherosclerosis) and increased risk of cardio-, cerebro-, and peripheral vascular disease. The ring structure of cholesterol cannot be metabolized to CO_2 and H_2O in humans. Rather, the intact sterol nucleus is eliminated from the body by conversion to bile acids and bile salts, a small percentage of which is excreted in the feces, and by secretion of cholesterol into the bile, which transports it to the intestine for elimination. Cholesterol is a hydrophobic compound, with a single hydroxyl group located at carbon 3 of the A ring, to which a fatty acid can be attached, producing an even more hydrophobic cholesteryl ester.



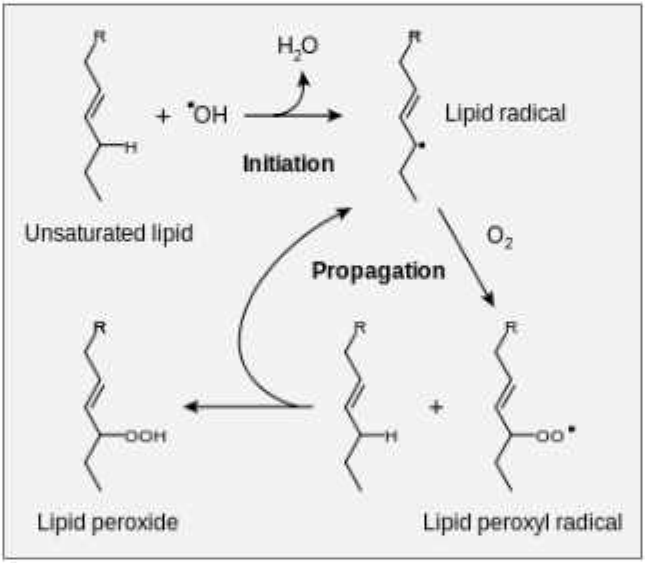
Steroid



Cholesterol, (3-hydroxy-5,6- cholestene)

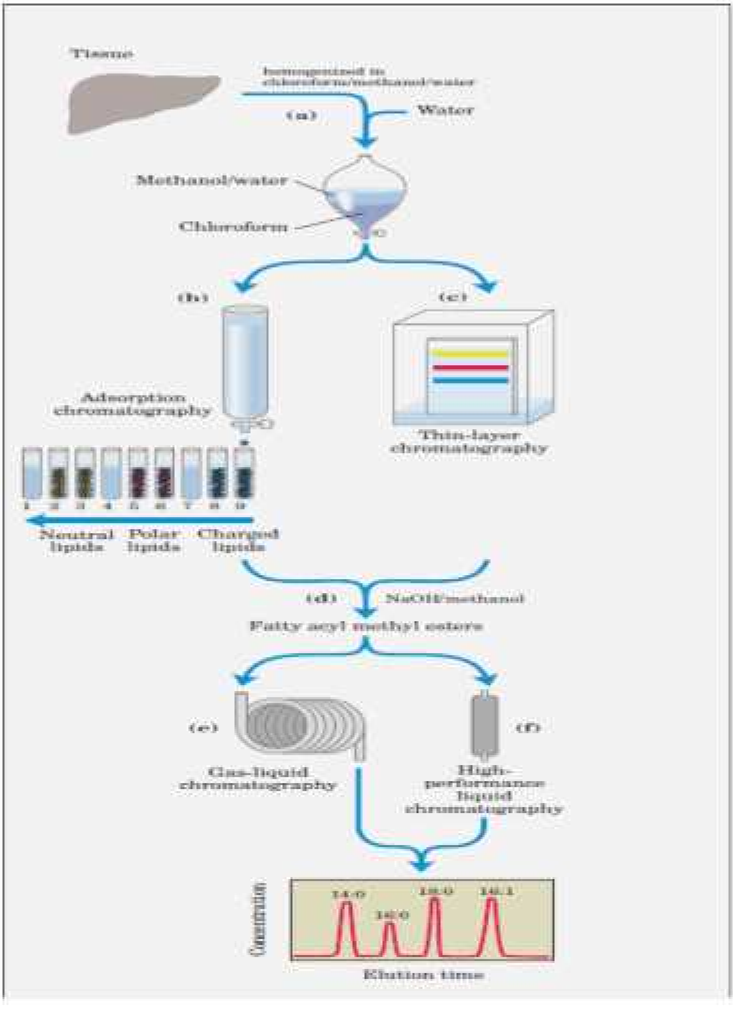
Lipid peroxidation is source of free radical

Peroxidation of lipids exposed to oxygen is responsible for damage to tissues in vivo, where it may be a cause of cancer, inflammatory diseases, atherosclerosis, and aging. The deleterious effects are considered to be caused by free radicals (ROO•, RO•, OH•) produced during peroxide formation from fatty acids. Lipid peroxidation is a chain reaction providing a continuous supply of free radicals that initiate further peroxidation. The whole process can be depicted as follows:



Separation and identification of lipid

Common procedures in the extraction, separation, and identification of cellular lipids shown in the figure:

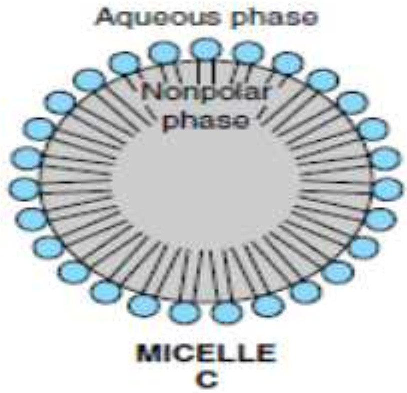


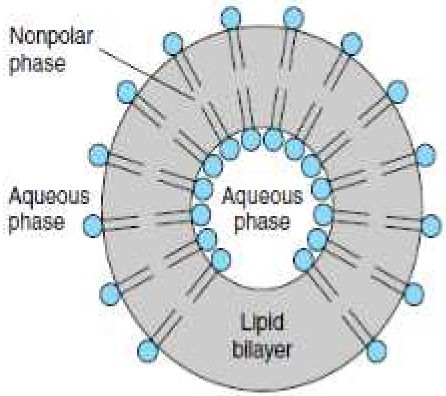
(a) Tissue is homogenized in a chloroform/methanol/water mixture, yields two phases. Lipids in the chloroform phase may be separated by **(b)** Adsorption chromatography on a column of silica gel **(c)** thin layer chromatography (TLC), in which lipids are carried up a silica gel coated plate by a rising solvent front, less polar lipids traveling farther than more polar or charged lipids. **(d)** lipid fraction containing ester-linked fatty acids is esterified in a warm aqueous solution of NaOH and methanol producing a mixture of fatty acyl methyl esters. **(e)** These methyl esters are then separated by gas-liquid chromatography (GLC) or **(f)** high-performance liquid chromatography (HPLC). Precise determination of molecular mass by mass spectrometry allows unambiguous identification of individual lipids.

Amphipathic lipids

In general, lipids are insoluble in water since they contain a predominance of no polar (hydrocarbon) groups. However, fatty acids, phospholipids, sphingolipids, bile salts, cholesterol contain polar groups. Therefore, part of the molecule is **hydrophobic,** or water-insoluble; and part is **hydrophilic,** or water-soluble. Such molecules are described as **amphipathic** .

They become oriented at oil : water interfaces with the polar group in the water phase and the non-polar group in the oil phase. A bilayer of such amphipathic lipids has been regarded as a basic structure in biologic membranes. When a critical concentration of these lipids is present in an aqueous medium, they form **micelles.** Aggregations of bile salts into micelles and liposomes (formation of mixed micelles) with the products of fat digestion are important in facilitating absorption of lipids from the intestine.

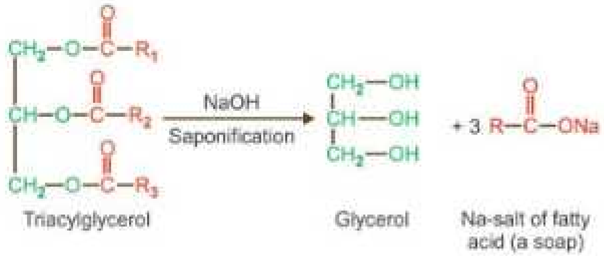




LIPOSOME

Saponification

Hydrolysis of a fat by alkali is called saponification. The products are glycerol and the alkali salts of the fatty acids, which are called soaps. Acid hydrolysis of a fat yields the free fatty acids and glycerol.



Saponification Number

It is defined as, number of mgs of NaOH or KOH required to saponify one gm of fat. It is inversely proportional to the molecular weight of fat. This value is high in fats containing a short chain fatty acids.

Pathways for the catabolism of dietary carbohydrate, protein, and fat