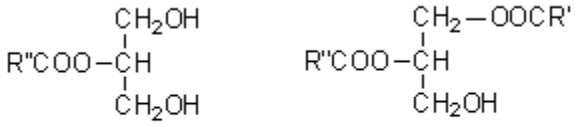
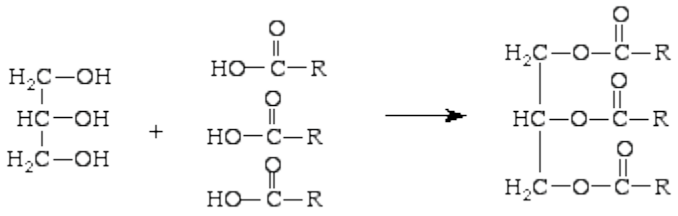
1- Simple lipids:

The simple lipids are esters of fatty acids with various alcohols. These have subdivided into two groups (1) **fats and oils** (2) **waxes.**

(I) **Fats and oils**: fats and oils are fatty acid esters of glycerol e.g. triacylglycerols (also known as triglycerides) diacylglycerols and monoacylglycerols.



2-monoacylglycerol 1,2-/2,3-diacylglycerol



Glycerol fatty acids triglycerides

The triglycerides (TGs) are composed of one glycerol moiety and three molecules of fatty acids and are most **abundant lipids in nature**. The fats and oils are widely distributed as TGs in both plants (in seeds) and animals (in adipose tissues).

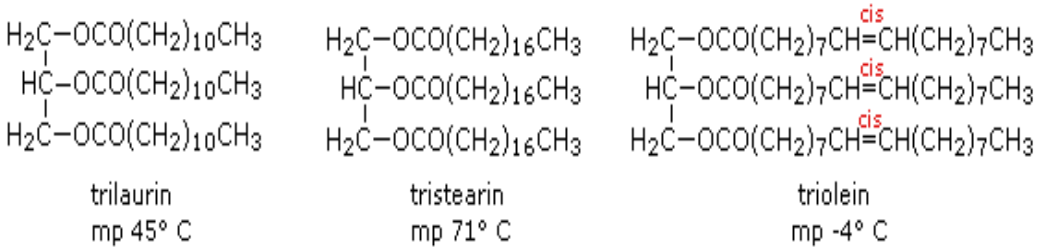
The fats and oils are electrically uncharged (non-polar) and **neutral in reaction**. They are **hydrophobic molecules.** Physically, oils exist as liquids, while fats are solid at room temperature (25C).

The fats and oils contain both **saturated** and **unsaturated** fatty acids, e.g. palmitic acid, palmitoleic acid, oleic acid, linoleic acid, linolenic acid, arachidonic acid, etc.

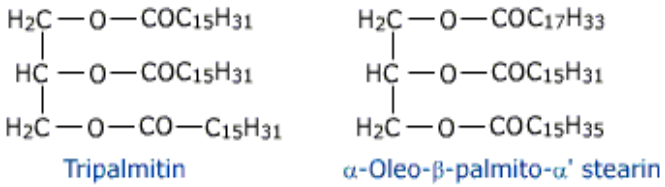
The plant oils contain TGs largely composed of unsaturated fatty acids and are liquid at room temperature, whereas animal's fats contain TGs primarily composed of saturated fatty acid and are solid at room temperature.

TGs are of two types:- (a)Simple TGs (b) Mixed TGs

The simple are composed of glycerol and three identical fatty acids, whereas the mixed TGs contain two or three different fatty acids. **Most natural fats and oils are complex mixtures of simple and mixed TGs.**



(a)Simple TGs



(a)Simple TGs (b) Mixed TGs

Biomedical significance of fats and oils

- **TGs** constitute about 90% of **total dietary lipids**. Remaining 10% includes **other lipids**.
- In human body, fatty acids are stored in the form of neutral TGs. The TGs are stored as 'fat globules' in cytoplasm of specialized cells called **adipocytes** or **fat cells**, under the skin, in the abdominal cavity and mammary glands. The fat stored in adipose tissues serves as "body major fuel storage reservoir". About 15-20 kg of triglycerides are deposited in moderately obese persons, which meet their energy requirements for months. Some of storage triglycerides also occur in cardiac and skeletal muscles, but only for local use. The fat stored subcutaneously also serves as **"thermal insulator"** against low temperature.

(II)Waxes: The term ′wax‘ is derived from the old English word ‘weax‘ that means ‘the material of the honeycomb‘.

CH_3 $(CH2)_{14}$-COO-$(CH2)_{28}CH_3$

Myricyl palmitate

- Waxes are esters of long chain fatty acids with high molecular weight monohydroxy aliphatic alcohols.
- In contrast to fats and oils, the waxes are composed of one molecule of fatty acid and one molecule of alcohol(other than glycerol), e.g. myricyl palmitate ,which is the major component of bees wax, is ester of myricyl alcohol (C_{30} $H_{61}OH$) and palmitic acid ($C_{15}H_{31}COOH$).

Biomedical Significance of Waxes

- Waxes are chemically inert and are not hydrolyzed by intestinal lipases.
- Waxes are present as protective coatings of the skin, wool fibers, fur, leaves, etc. and serve as water repellents to keep them waterproof.

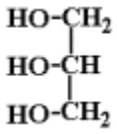
2- Compound or complex lipids

- These are esters of fatty acids and alcohols with some groups such as phosphoric acid, nitrogenous bases, protein residue, sugar residues and sulphate.
- The compound lipids have been subdivided into the following major groups:
- **(I) Phospholipids (II) Glycolipids (III) lipoprotein** .

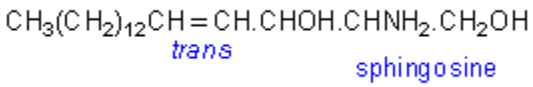
(I) Phospholipids:

Phospholipids are composed of fatty acids, an alcohol (either glycerol or sphingosine), phosphoric acid residue and nitrogenous base.
Depending on the type of alcohol, phospholipids have been further classified into two types:

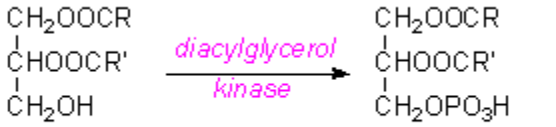
a. **Glycerophospholipids** containing glycerol as an alcohol.
b. **Sphingophospholipids** (sphingomyelins) containing sphingosine (also known as sphingol) as an alcohol. Phospholipids are **polar lipids**.



Glycerol



- Phospholipids are the major lipids present in biomembranes. The other membrane lipids are ' non-polar lipids ' such as cholesterols and triacylglycerol (TGs).
- The most abundant membrane phospholipids are glycerophospho-lipids, which include phosphatidylcholine (lecithin), phosphatidyl-ethanolamine (cephalin), phosphatidylserine and phosphatidyl-inositol.
- Lecithin is most abundant glycerophospholipid of the cell membrane and represents the storage form of **body's choline.**
- Membrane phospholipids also include a small proportion of **sphingophospholipids**.



(i) Glycerophospholipids

- The **fatty acids in phosphoglycerides** may be any of a wide variety of **saturated and unsaturated** fatty acids. The **phosphoglycerides** are derived from **phosphatidic acid** by addition of **a nitrogenous base** to the **phosphatidic acid**, and are named on the basis of the type **nitrogenous base** present**;** e.g. phosphoglyceride containing nitrogenous base

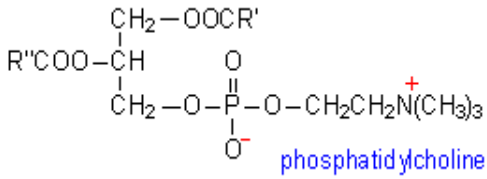
choline and **ethanolamine** are called **phosphatidylcholine** and **phosphatidylethanolamine**, respectively.

- The **three chief nitrogenous bases present in glycerophspholipid are choline, ethanolamine and serine.**

(CH3)3N-CH2-CH2-OH NH3-CH2-CH2-OH HO-CH2-CH (NH2)-COOH
Choline Ethanolamine Serine

- Each phosphoglyceride molecule at one end has a hydrophilic ' polar or ionic ' head (glycerol phosphate - N. base) and at other end it has hydrophobic 'non-polar' hydrocarbon chains(of fatty acids)
- The phosphatidylcholine and phosphtidylethanolamine have choline and ethanolamine as nitrogen base in their polar head, respectively.

(a) Phosphatidylcholine: Phosphatidylcholine **is choline derivative of phosphatidic acid,** and is commonly known as **lecithin.**

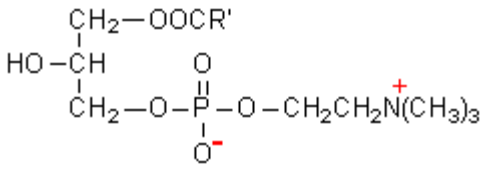


phosphatidylcholine

1. 0n hydrolysis, a lecithin molecule yields two fatty acids, glycerol, phosphoric acid and choline.
2. Various combinations of saturated and unsaturated fatty acids (palmitic acid, stearic acid, oleic acid, linoleic acid, arachidonic acid, etc.) occur in lecithin. The **variations in fatty acids give rise to different in lecithins.**
3. Lecithins are widely distributed in animal tissues (cardiac muscles, liver, brain, nerves, etc.) and are most **abundant glycerophospholipid of the cell membranes.**

Biomedical significance of lecithin

- Lecithin **represents the storage of body's choline.** The choline is required for synthesis of neurotransmitter, acetyl choline, which plays an important role in nerve impulse transmission. The choline also **serves as lipotropic agent and prevents the formation of fatty liver**.
- Lecithinase, (a kind of phospholipase) present in certain snake venoms, hydrolyzes ester bond in position 2 in lecithin to yield lysolecithin. The lysolecithin acts as hemolytic agent and causes intravascular hemolysis, which becomes the cause of death in case of snake bite.

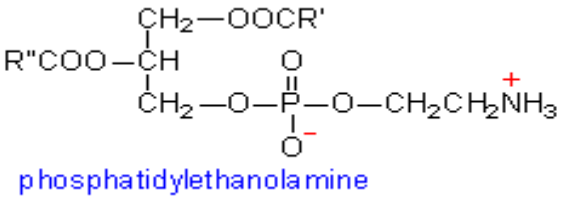


(Lysolecithin)

- Lecithins are also found in plant particularly in seeds. Soybean lecithins are used as emulsifying and smoothing agents in food industries.

(b) Phosphatidylethanolamine

- **Phosphatidylethanolamine** is ethanolamine derivative of phosphatidic acid and is commonly known as **cephalin**. Thus lecithin and cephalin differ in their nitrogenous bases.



(Cephalin)

- On hydrolysis, cephalin molecule yields two fatty acids, glycerol, phosphoric acid and a nitrogenous base, ethanol-amine.
- Cephalins are distributed in animal tissues along with lecithins and phosphatidylserine.
- Like lecithins, cephalins are also found in plants. Lecithinase from certain snake venoms also hydrolyzes ester bond in position 2 of cephalin to yield **lysocephalin**.
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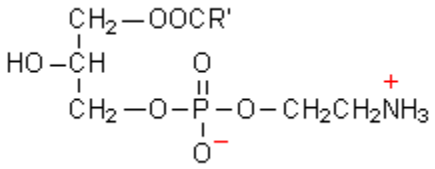
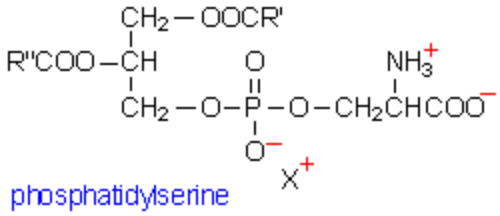


(Lysocephalin)

(c) Phosphatidylserine

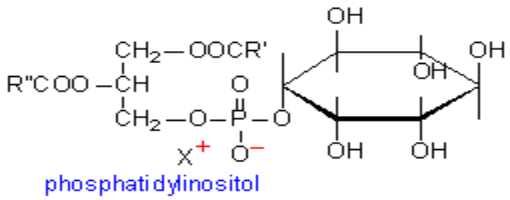
- **Lecithin** and **cephalin** are **major glycerophospholipids** present in animal tissues, e.g. in liver they represent about 55% and 27% of the total phospholipids, respectively.
- The other glycerophospholipids include **phosphatidyserine, phosphatidylinositol, plasmalogens, cardiolipin**, etc.



- The phosphatidylserine is **serine (amino acid) derivative of phosphatidic acid.**
- The phosphatidylserine is found more in brain and nervous tissues as compared to other tissues. In human brain, it represents about 16% of the total phospholipids.

(d) Phosphatidylinositol

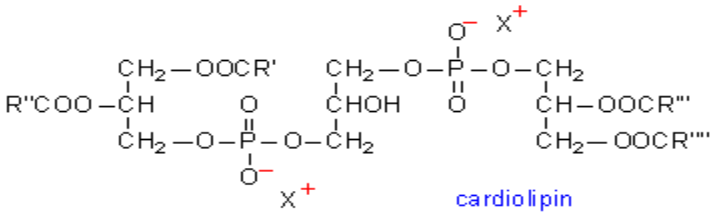
Phosphatidylinositol is inositol (hexa hydroxy cyclohexane) derivative of phosphatidic acid, and is commonly known as **lipositol.**



(Lipositol)

(e) Cardiolipin

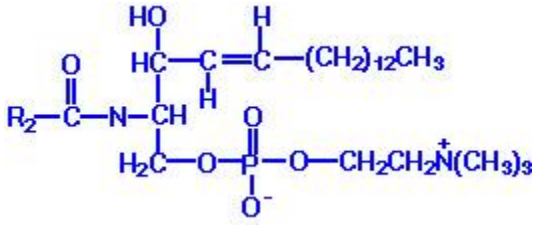
- **Cardiolipin** is major **phospholipids of inner mitochondrial membranes** and was first isolated from **cardiac muscles**.
- **It is a phosphatidyl-glycerol derivative of phosphatidic acid.** In place of a nitrogenous base phosphatidyl-glycerol is present in cardiolipin.
- **On hydrolysis, cardiolipin** yields two molecules of phosphatidic acid and one molecule of glycerol.



Diphosphatidylglycerol

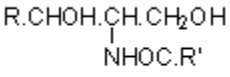
(ii) Sphingophospholipids

- The sphingophospholipids (also known as **sphingomyelins)** are found in most membrane of animal cells but present in **large quantity in brain and nervous tissue.**



Sphingomyelin

- The sphingophospholipids differ from glycerol-phospholipids**.** In place of glycerol, which presents in glycerol-phospholipids, the sphingomyelins contain an **unsaturated 18 carbon amino alcohol** known as **sphingosine**.
- On hydrolysis, one molecule of sphingomyelin yields one molecule of sphingosine, fatty acid, phosphoric acid residue and nitrogenous bases (choline or ethanolamine).
- The sphingomyelins contain phosphocholine and phosphoethanolamine as their 'polar head' groups
- In a sphingomyelin, the amino group of sphingosine is linked through amide linkage to fatty acid to form **ceramide** and -OH group is bound to phosphocholine (or phospho-ethanolamine) to yield finally sphingophospholipids**.**



ceramide

- **In Niemann-Pick disease**, large amount of sphingomyelins occurs in brain, liver and spleen. It is a lysosomal storage disease that results from inherited deficiency of lysosomal enzyme **sphingomyelinase**.

Phspholipases

Enzymes responsible for hydrolysis of phospholipids are called phospholipases. Many types of phospholipases are distributed in animals and plants.

Phspholipase A: Phospholipase A hydrolyzes one of the two ester bonds of a phospholipid to yield a lysophospholipid and one molecule of fatty acid, e.g. lecithinase (phospholipase A) present in certain snake venoms hydrolyzes lecithin to yield lysolecithin.

Phospholipase A is also present in human pancreatic juice. The phospholipase A is of two types, **phospholipase A1 and phospholipase A2, which hydrolyze the ester bond at position 1 and 2 of phospholipids, respectively.**

Lecithin $\xrightarrow{\text{PhspholiPase A1}}$ **lysolecithin +fatty acid.**

Phspholipase B:

Phspholipase B acts on **lysolecithin** to yield glycerylphos-phocholine and one molecule of fatty acid. Phspholipase B is found in association with Phospholipase A in mammals.

Lysolecithin $\xrightarrow{\text{PhspholiPase B}}$ glycrophosphocholine + fatty acid

Phspholipase C:

Phspholipase C cleaves the lecithin into 1, 2-diacylglycerol and phosphocholine. Membrane bound phospholipase C present in brain, smooth muscle, GI system, etc. It is also cleave **phosphatidylinositol 4, 5 biphosphate into 1, 2 diacylglycerol and inositol 1, 4, 5 triphosphate**.

Lecithin $\xrightarrow{\text{PhspholiPase C}}$ 1, 2-diacylglycerol + phosphocholine