INTRODUCTION

- Lipids are heterogeneous group of compound related to fatty acid, fats, oils, waxes and other related substances.
- The term lipid was first used by German biochemist 'Bloor' in 1943.
- It is derived from a Greek word 'lipos' means fat.
- Lipids are insoluble in water and soluble in organic solvent such as benzene, ether, chloroform, acetone etc.
- They yield fatty acids upon hydrolysis which are utilized by living organisms.
- Lipids is not a polymer as like carbohydrate and proteins.

- It is macromolecules and major component of the diet because of their high energy value.
- The basic component of all lipid is fatty acid.
- The fats or lipids are defined as the esters of glycerol (alcohols) and fatty acids or as triglycerides.
- It is found in most plants and animals.
- In plants, lipids are mainly occur in seeds and fruits, whereas in animal, they are found in adipose tissue, bone marrow and nerve tissue

1. **Food material.** Lipids provide food, highly rich in calorific value. One gram lipid produces 9.3 kilocalories of heat.

2. **Food reserve.** Lipids provide are insoluble in aqueous solutions and hence can be stored readily in the body as a food reserve.

3. **Structural component.** Lipids are an important constituent of the cell membrance.

4. **Heat insulation.** The fats are characterized for their high insulating capacity. Great quantities of fat are deposited in the subcutaneous layers in aquatic mammals such as whale and in animals living in cold climates.

5. **Fatty acid absorption.** Phospholipids play an important role in the absorption and transportation of fatty acids.

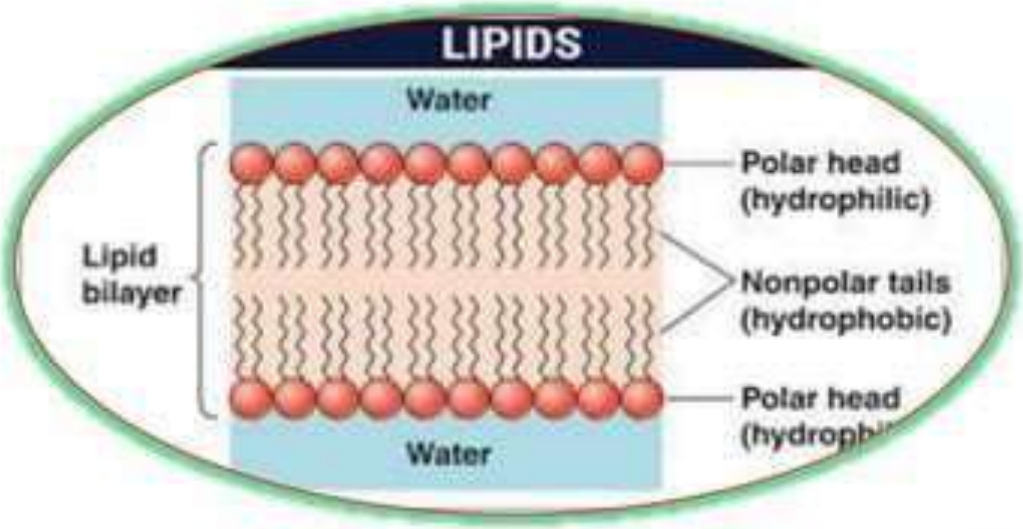
6. **Hormone synthesis.** The sex hormones, adrenocorticoids, cholic acids and also vitamin D are all synthesized from cholesterol, a steroidal lipid.

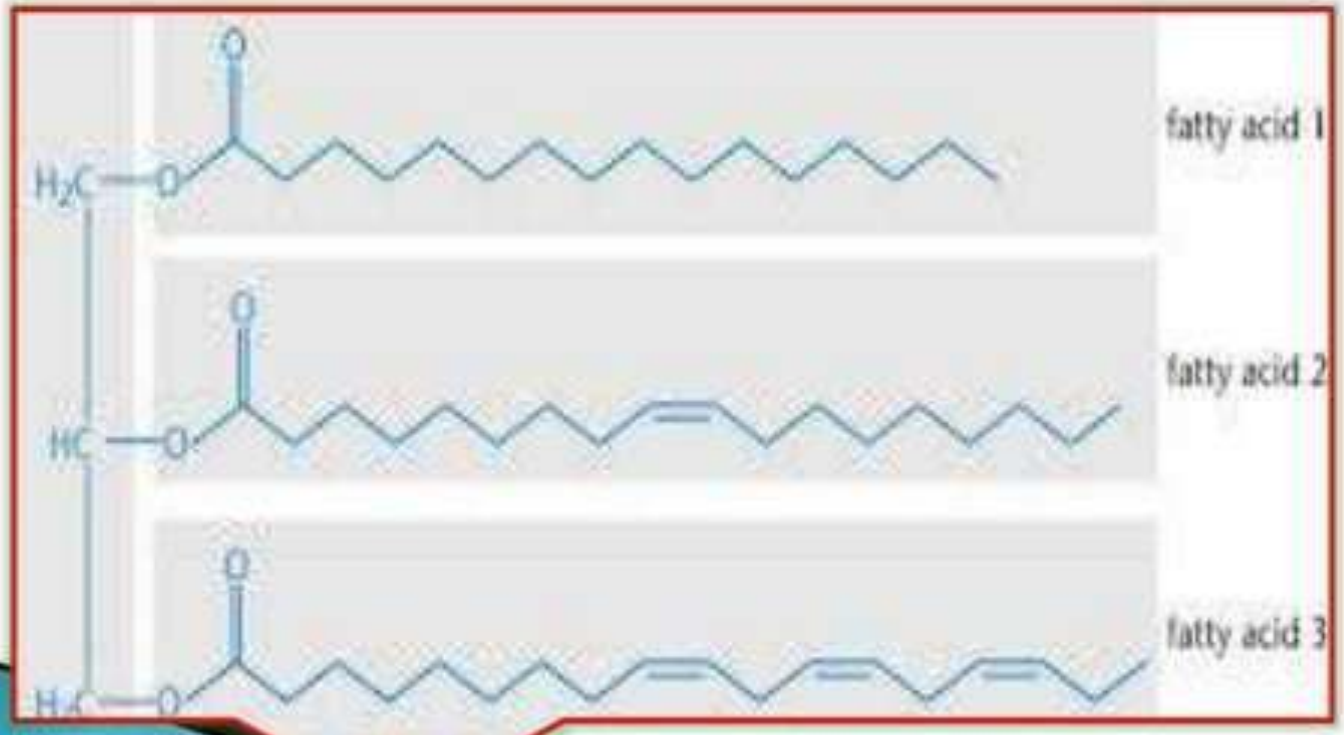
7. **Vitamin carriers.** Lipids act as carriers of natural fat-soluble vitamins such as vitamin A, D and E.

Fig. 12–7. **A cholesterol deposit, (known as atherom) filling almost all the space inside the artery.**

8. **Blood cholesterol lowering.** Chocolates and beef, especially the latter one, were believed to cause many heart diseases as they are rich in saturated fatty acids, which boost cholesterol levels in blood and clog the arterial passage (Fig. 12–7). But researches conducted at the University of Texas by Scott Grundy and Andrea Bonanome (1988) suggest that at least one saturated fatty acid stearic acid, a major component of cocoa butter and beef fat, does not raise blood cholesterol level at all. The researchers placed 11 men on three cholesterol-poor liquid diets for three weeks each in random order. One formula was rich in palmitic acid, a known cholesterol booster; the second in oleic acid; and the third in stearic acid. When compared with the diet rich in palmitic acid, blood cholesterol levels were 14% lower in subjects put on the stearic acid diet and 10% lower in those on the oleic acid diet.

9. **Antibiotic agent.** *Squalamine*, a steroid from the blood of sharks, has been shown to be an antibiotic and antifungal agent of intense activity. This seems to explain why sharks rarely contract infections and almost never get cancer.

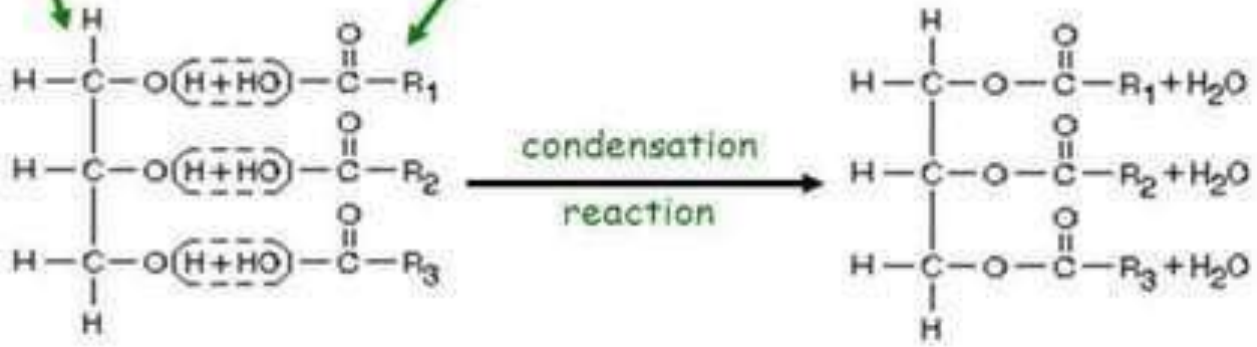

LIPIDS
Water
Polar head
(hydrophilic)
Lipid
bilayer
Nonpolar tails
(hydrophobic)
Polar head
Water


fatty acid 1
fatty acid 2
fatty acid 3

Triglycerides are the esters of Glycerol and Fatty acids

Glycerol "backbone" is a water-soluble alcohol

Fatty Acids are chains of carbon atoms with a methyl ($-CH_3$) group at one end and a carboxylic acid ($-COOH$) group at the other



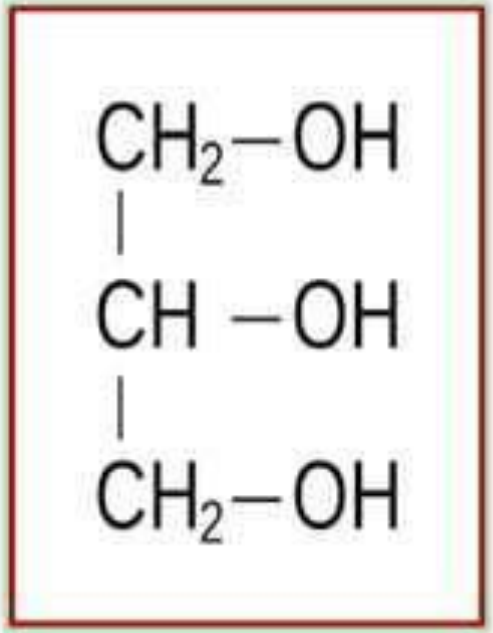
Glycerol + 3 Fatty Acids

Triglyceride + 3 water molecules

Structures linked by ester bonds (R-COOR') and water is released

ALCOHOLS:

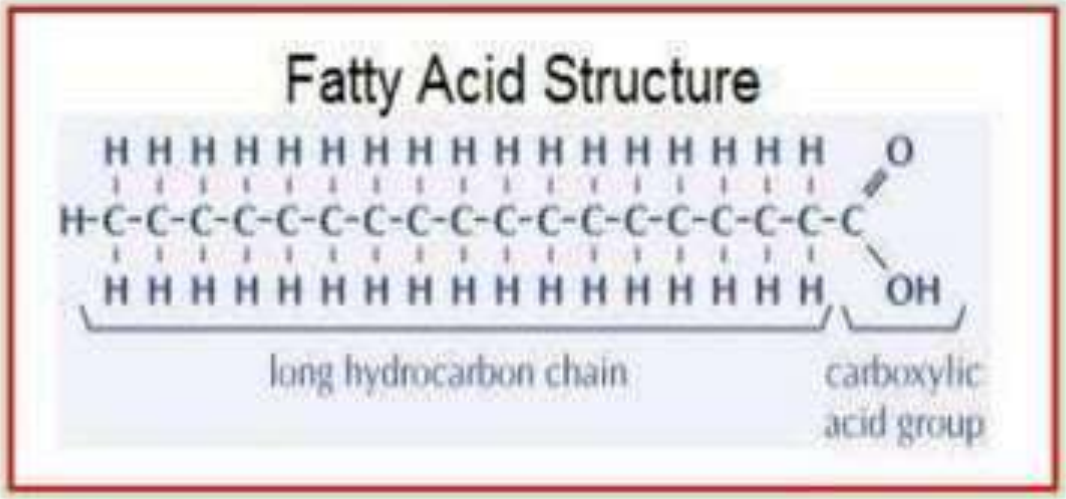
- Alcohols are found in lipid molecule may be saturated. These commonly include glycerol, cholesterol, and higher alcohol.
- In the structure of glycerol, the carbon atom are denoted as 1, 2, 3 from any end.



Glycerol

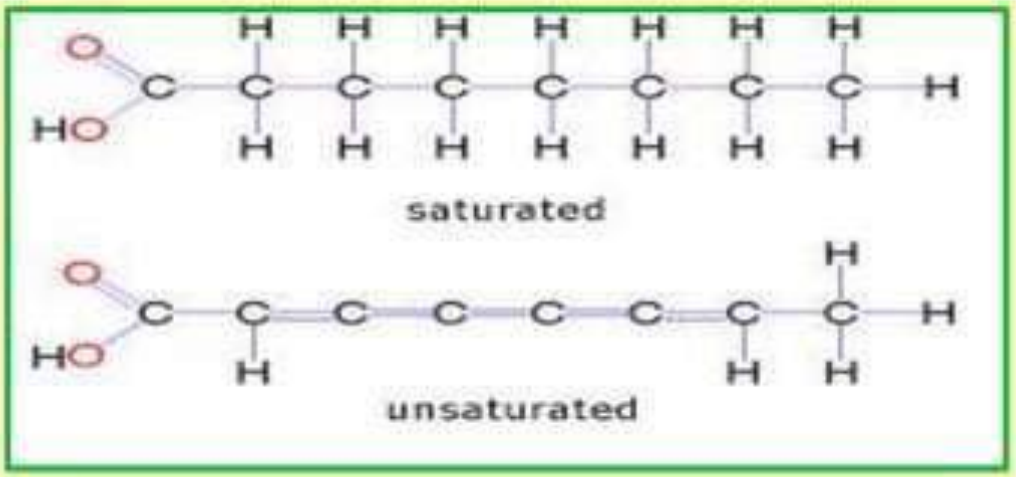
FATTY ACIDS:

- Fatty acids are long chain organic acids having 4 to 30 carbon atoms.
- They have a single carboxyl group and a long, non polar hydrocarbon 'tail', which provide to most lipid their hydrophobic and oily nature.



TYPES OF FATTY ACIDS

- Saturated fatty acids ⟶ having single bond
- Unsaturated fatty acids ⟶ having double bond
- Hydroxy fatty acids ⟶ having hydroxyl group
- Cyclic fatty acids ⟶ having ring structure



Saturated fatty acids:

- The general formula of these acids is $C_nH_{2n+1}COOH$.
- They tend to be solid at room temperature.
- They have single bond.
- It may increase blood cholesterol level and cardiovascular diseases.
- It may be divided in two groups:
- Straight chain fatty acids: found in plants and animals.

  Example: Stearic acid- $CH_3(CH_2)_{16}COOH$

  Palmitic acid- $CH_3(CH_2)_{14}COOH$
- Branched chain fatty acids: minor component of natural fat or oil.

  Example: Isopalmitic acid- $(CH_3)_2CH(CH_2)_{12}COOH$

  Found in wool fat

Unsaturated fatty acids:

- They have usually double bond.
- **Unsaturated fats**, which are liquid at room temperature, are beneficial **fats** because they can decrease blood cholesterol levels, stabilize heart rhythms, and play a number of other beneficial **roles**.

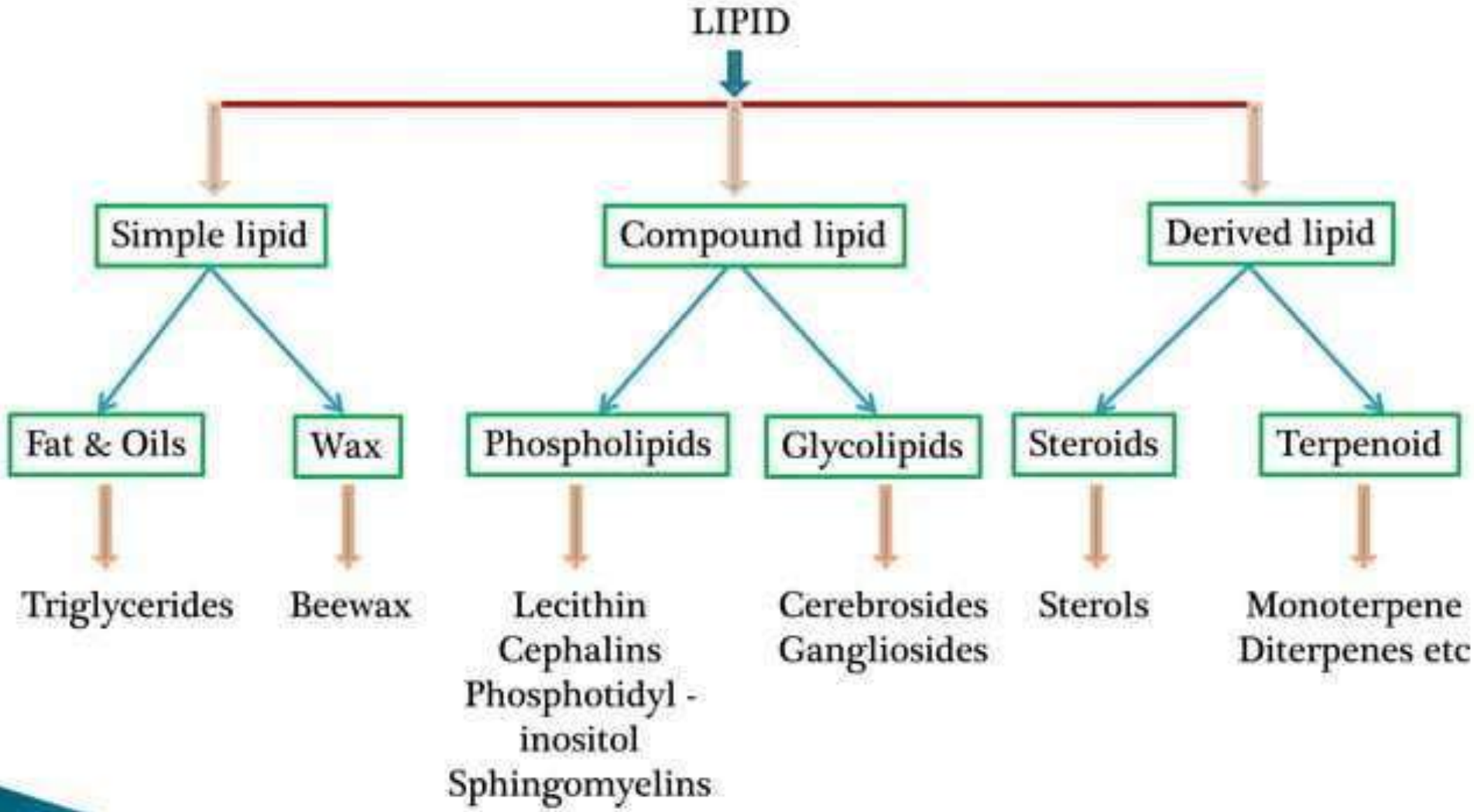
Example:

- Oleic acid ⟶ $C_nH_{2n-1}COOH$ (Contain one double bond)
- Linoleic acid ⟶ $C_nH_{2n-3}COOH$ (Two double bond)
- Linolenic acid ⟶ $C_nH_{2n-5}COOH$ (Three double bond)
- Arachidonic acid ⟶ $C_nH_{2n-7}COOH$ (Four double bond)

Table 12–2. Straight chain saturated fatty acids, commonly found in natural fats

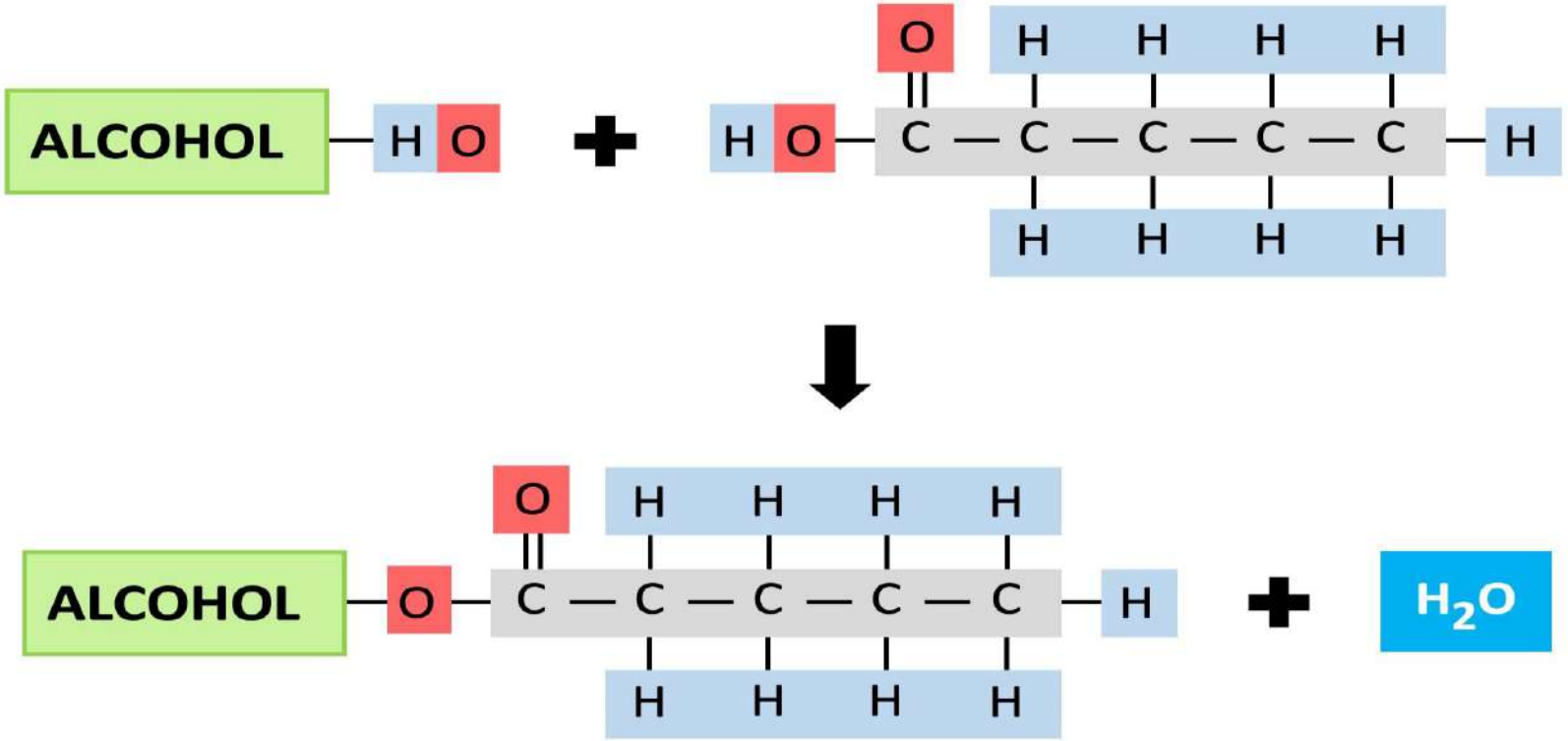
Trivial name	*Systematic name**	*Carbon skeleton*	*Structure†*	*Common source*
Butyric	*n*-Butanoic	4 : 0	$CH_3(CH_2)_2COOH$	Butter
Caproic	*n*-Hexanoic	6 : 0	$CH_3(CH_2)_4COOH$	Coconut and palm oils
Caprylic	*n*-Octanoic	8 : 0	$CH_3(CH_2)_6COOH$	Coconut and palm oils
Capric	*n*-Decanoic	10 : 0	$CH_3(CH_2)_8COOH$	Coconut and palm oils
Lauric (*laurus*^{L} = laurel plant)	n-Dodecanoic	12 : 0	$CH_3(CH_2)_{10}COOH$	Laurel oil, Spermaceti
Myristic (*Myristica*^{L} = nutmeg genus)	*n*-Tetradecanoic	14 : 0	$CH_3(CH_2)_{12}COOH$	Butter and wool fats
Palmitic (*palma*^{G} = palm tree)	*n*-Hexadecanoic	16 : 0	$CH_3(CH_2)_{14}COOH$	Animal and plant fats
Stearic (stear = hard fat)	*n*-Octadecanoic	18 : 0	$CH_3(CH_2)_{16}COOH$	Animal and plant fats
Arachidic (*Arachis*^{L} = legume genus)	*n*-Eicosanoic	20 : 0	$CH_3(CH_2)_{18}COOH$	Groundnut oil
Behenic	*n*-Docosanoic	22 : 0	$CH_3(CH_2)_{20}COOH$	Groundnut oil
Lignoceric (*lignum*^{L} = wood; *cera*^{L} = wax)	*n*-Tetracosanoic	24 : 0	$CH_3(CH_2)_{22}COOH$	Groundnut and Rapeseed oils
Cerotic	*n*-Hexacosanoic	26 : 0	$CH_3(CH_2)_{24}COOH$	Wool fat
Montanic	*n*-Octacosanoic	28 : 0	$CH_3(CH_2)_{26}COOH$	—

CLASSIFICATION OF LIPID



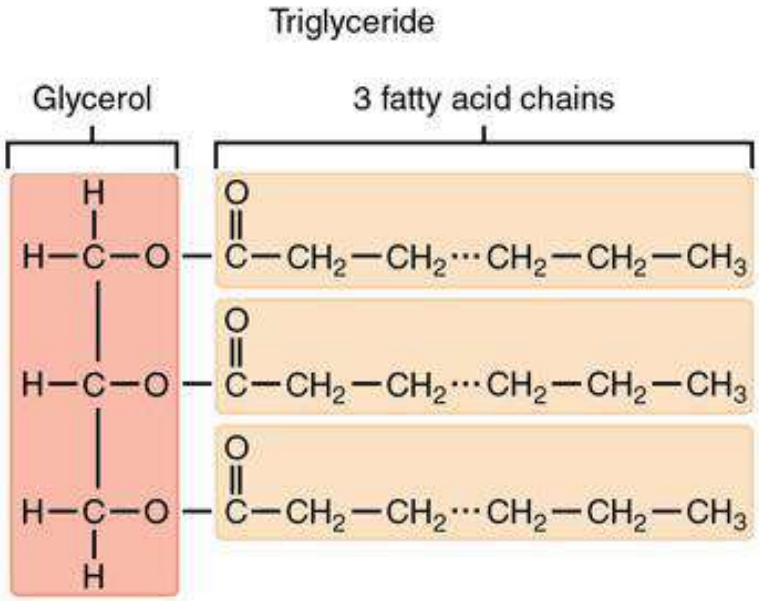
1. Simple lipid

- These are esters of fatty acids and alcohols.
- They are formed by the condensation of alcohols and acids.



Fat and Oils

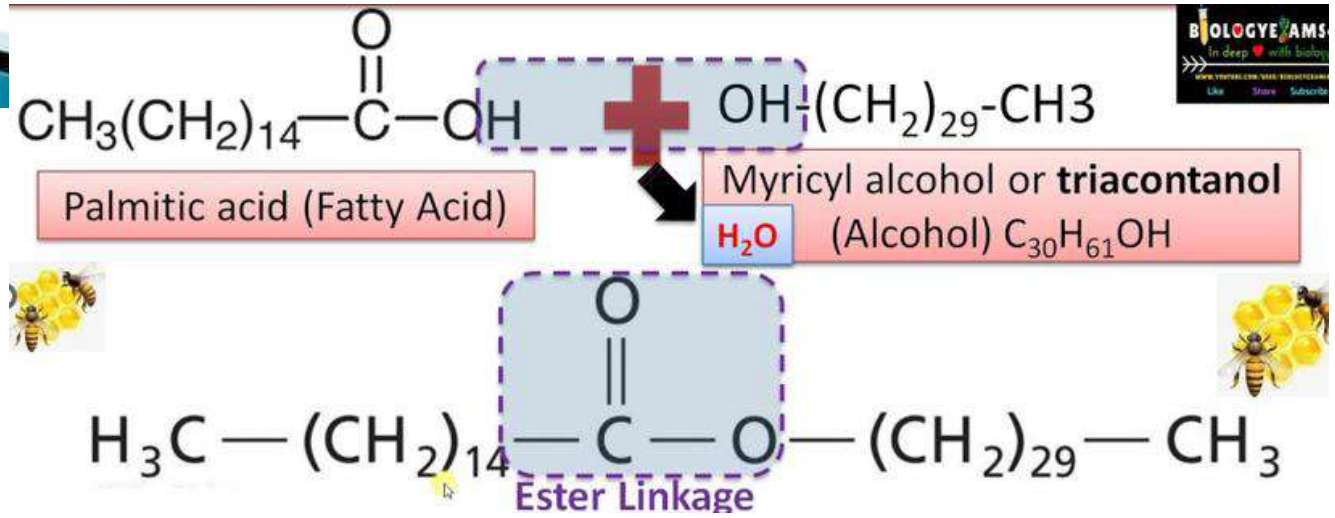
- Fats are found in all living cells.
- They are formed from carbon, hydrogen and oxygen, but they are poor in oxygen in compare to carbohydrates.
- They are insoluble in water and soluble in organic solvent.
- The fats, which are liquid at room temperature, are called oils.
- Lipids are high molecular weight compounds.
- The glycerol is trihydric alcohols, in which one, two or three –OH group react with fatty acids to form mono, di or triglycerides.



- In all fats, glycerol is present, but the composition of fatty acids may be different.
- The fatty acids may be saturated or unsaturated.
- In living cells, fat or its derivatives are present as main constituents of protoplasm.
- They serve as source of energy and enters in the composition of various cell components.
- Double energy is released from a lipid molecule than oxidation of glucose molecule.
- Most animal fat such as milk, meet, eggs are rich in saturated fatty acids.
- Plant cells contain a large portion of unsaturated fatty acids.

Waxes

- These are the esters of long chain saturated and unsaturated fatty acids with monohydroxy alcohols.
- In vertebrates, waxes are secreted by cutaneous glands as a protective coating to keep the skin lubricated and water proof.
- Hair, wool and fur also coated with wax.
- The leaves of many plants are shiny because of the deposition of protective coating.
- Waxes also serve as the storage form of fuel in planktons.
- Waxes act as major food and storage lipid in marine organisms (whale, salmon), because they consume planktons in large amount.
- They are widely used in making varnishes, wax coated paper, lotion, oinments etc.

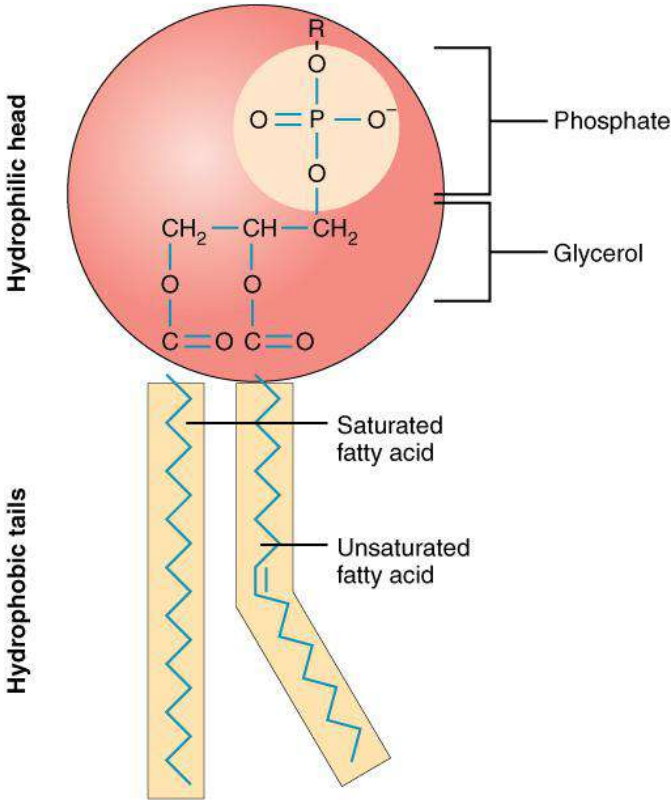


2. Compound lipid

- Compound lipid are those molecule which consist of glycerol and fatty acid join with other organic molecule such as carbohydrate, protein, amino acids etc.
- Compound lipid can be categorized in to two types:
- Phospholipid
- Glycolipid

PHOSPHOLIPIDS

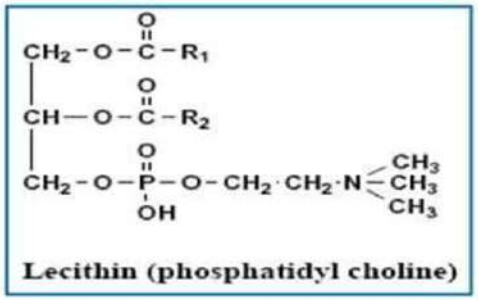
- Phospholipids are a class of lipids whose molecule has a hydrophilic "head" containing a phosphate group, and two hydrophobic "tails" derived from fatty acids, joined by an alcohol residue.
- The phosphate group can be modified with simple organic molecules such as choline, ethanolamine or serine.
- Phospholipids are a key component of all cell membranes.
- They can form lipid bilayers.
- The phospholipids are amphiphilic.
- The hydrophilic end usually contains a negatively charged phosphate group, and the hydrophobic end usually consists of two "tails" that are long fatty acid residues.



Lecithins

- Lecithin is a fat that is essential in the cells of the body.
- It can be found in many foods, including soybeans and egg yolks.
- Lecithin is taken as a medicine and is also used in the manufacturing of medicines.
- Lecithin is used for treating memory disorders such as dementia and Alzheimer's disease.
- Lecithin is a any group of yellow-brownish fatty substances occurring in animal and plant tissues which are amphiphilic – they attract both water and fatty substances, and are used for smoothing food textures.

- In addition to glycerol and 2 mol of fatty acids, lecithin also contain phosphoric acid and a nitrogen base choline.
- On hydrolysis, lecithin yields choline, phosphoric acid, glycerol and 2 mol of fatty acids.

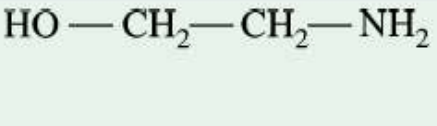


Lecithin (phosphatidyl choline)

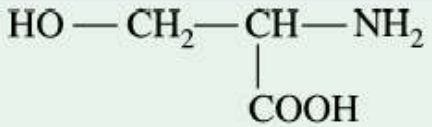
Cephalins

- Cephalins are phosphoglycerides that contain ehtanolamine or the amino acid serine attached to the phosphate group through phosphate ester bonds.
- **Cephalins** are found in most cell membranes, particularly in brain tissues.
- They have role in blood coagulation and accelerate blood clotting.

2. *Cephalins* – The cephalins (*kephalus*^{G} = head) are closely associated with lecithins in animal tissues. These have also been identified from soybean oil. These are similar in structure to the lecithins except that the choline is replaced by either ethanolamine or serine. Serine is the biochemical precursor of ethanolamine.

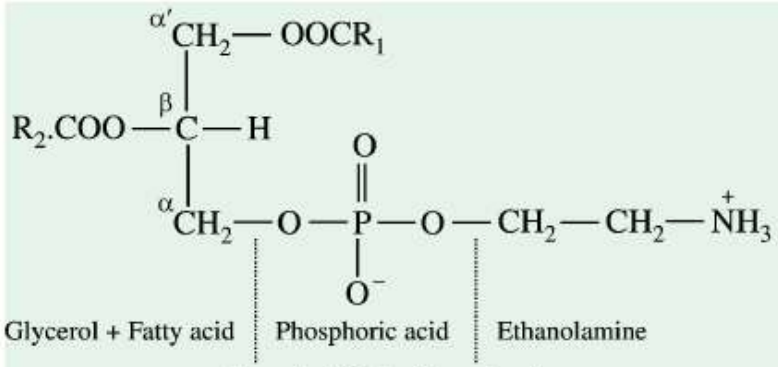


Ethanolamine

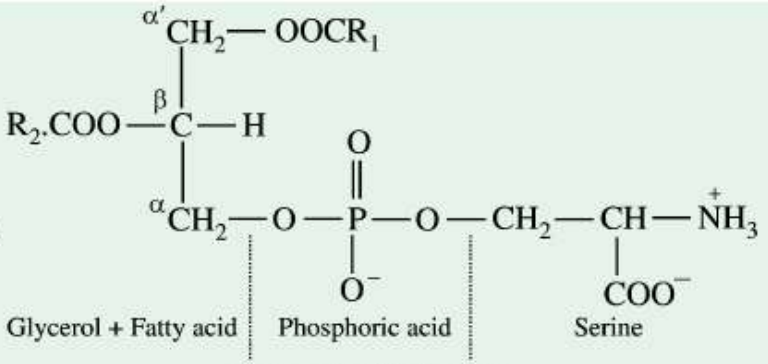


Serine

Accordingly, two types of cephalins are recognized, phosphatidyl ethanolamine and phosphatidyl serine. Like lecithins, the cephalins (Fig. 13–10) also exist in 2 forms, α and β, depending upon the relative positions of the two substituent fatty acids.



α-phosphatidyl ethanolamine



α-phosphatidyl serine

Plasmalogen

3. *Plasmalogens* (=*Phosphoglyceracetals*) – Plasmalogens constitute about 10% of the phospholipids of the brain and muscle. These are apparently not found in significant quantities in plant tissues. Structurally, these resemble lecithins and cephalins but have one of the fatty acids replaced by an unsaturated ether. Since the nitrogen base can be choline, ethanolamine or serine, three types of plasmalogens (Fig. 13–11) are accordingly distinguished : phosphatidal choline, phosphatidal ethanolamine and phosphatidal serine.

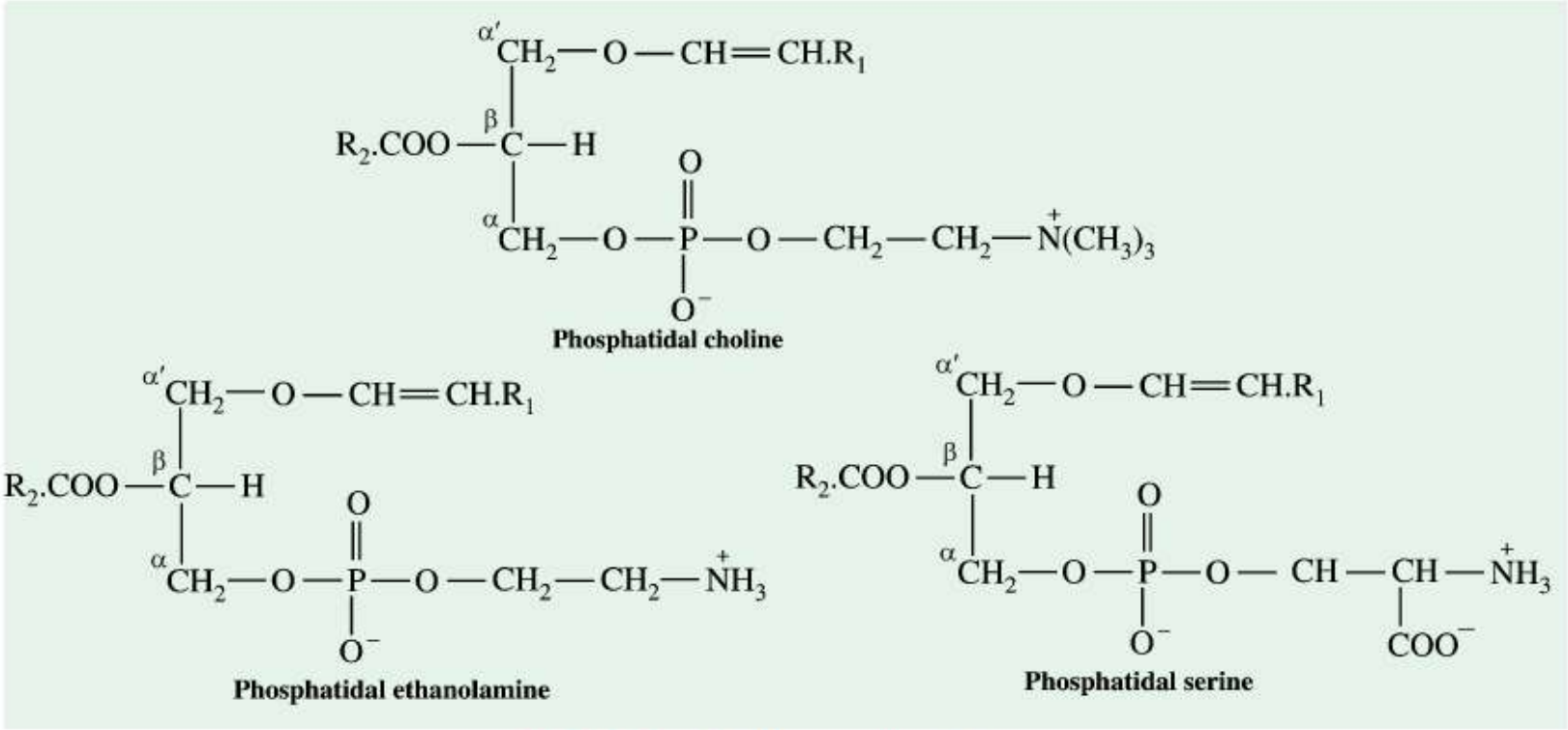
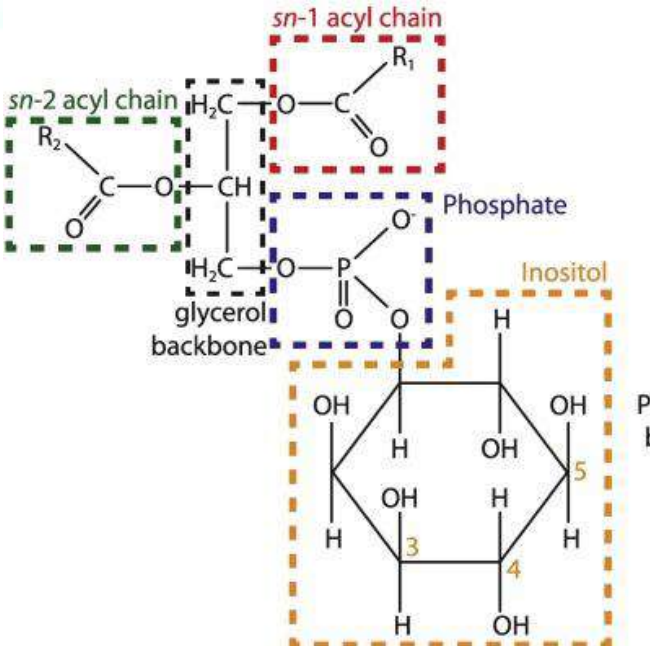


Fig. 13–11. The three plasmalogens

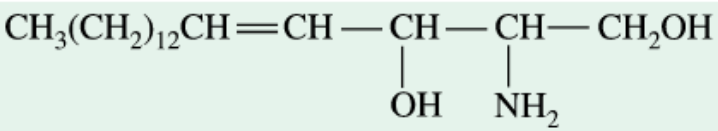
Phosphatidyl Inositol (PI)

- PI is classified as a glycerophospholipid that contains a glycerol backbone, two non-polar fatty acid tails, a phosphate group substituted with an inositol polar head group.
- The most common fatty acids of phosphoinositides are stearic acid, and arachidonic acid.
- Hydrolysis of phosphoinositides yield one mole of glycerol, two moles of fatty acids, one mole of inositol and one, two, or three moles of phosphoric acids, depending on the number of phosphates on the inositol rings.
- It is regarded as the most acidic phospholipids.
- It play important roles in lipid signaling, cell signaling and membrane trafficking.

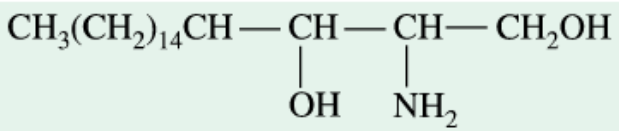


Sphingomyelin

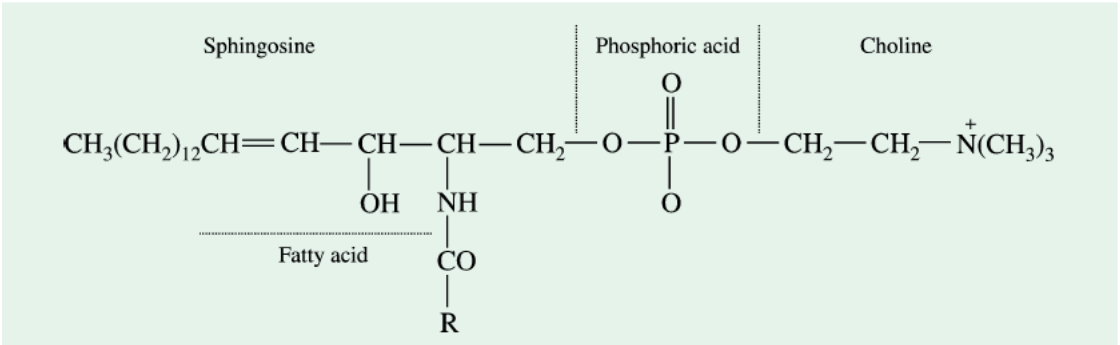
- It is also known as phosphosphingosides.
- These are commonly found in nerve tissue (myelin sheath).
- They are lack in plant and microorganisms.
- Sphingomyelin consists of a phosphocholine head group, a sphingosine, and a fatty acid.
- It is one of the few membrane phospholipids not synthesized from glycerol.
- The sphingosine and fatty acid can collectively be categorized as a ceramide.
- This composition allows sphingomyelin to play significant roles in signaling pathways: the degradation and synthesis of sphingomyelin produce important second messengers for signal transduction.



Sphingosine or **4-sphingenine**
(1, 3-dihydroxy-2-amino-*trans*-octadec-4-ene)



Dihydrosphingosine or **sphinganine**



GLYCOLIPIDS

- Glycolipids are lipids with a carbohydrate attached by a glycosidic (covalent) bond.
- Their role is to maintain the stability of the cell membrane and to facilitate cellular recognition.
- It is essential to the immune response and allow cells to connect to one another to form tissues.
- Glycolipids are found on the surface of all eukaryotic cell membranes.
- The essential feature of a glycolipid is the presence of a monosaccharide or oligosaccharide bound to a lipid moiety.
- The most common lipids in cellular membranes are glycerolipids and sphingolipids, which have glycerol or a sphingosine backbones, respectively.

Cerebrosides

- Cerebrosides is the common name for a group of glycosphingolipids called monoglycosylceramides which are important components in animal muscle and nerve cell membranes.
- They consist of a ceramide with a single sugar residue at the 1-hydroxyl moiety.
- The sugar residue can be either glucose or galactose.
- Therefore the two major types are called glucocerebrosides and galactocerebrosides (galactosylceramides).
- Galactocerebrosides are typically found in neural tissue, while glucocerebrosides are found in other tissues.
- Glucosylceramide is a major constituent of skin lipids, it is the only glycosphingolipid common to plants, fungi and animals.
- Galactosylceramides have not been found in plants.

Gangliosides

- A ganglioside is a molecule composed of a glycosphingolipid (ceramide and oligosaccharide) with one or more sialic acids (e.g. n-acetylneuraminic acid, NANA) linked on the sugar chain.
- The name ganglioside was first applied by the German scientist Ernst Klenk in 1942 to lipids newly isolated from ganglion cells of the brain.
- More than 60 gangliosides are known, which differ from each other mainly in the position and number of NANA residues.
- It is a component of the plasma membrane that modulates cell signal transduction pathways, growth and differentiation of tissues.

3. Derived lipids

- Hydrolysis product of simple and compound lipids is called derived lipids.
- They include fatty acid, glycerol, sphingosine and steroid derivatives.
- Steroid derivatives are phenanthrene structures that are quite different from lipids made up of fatty acids.

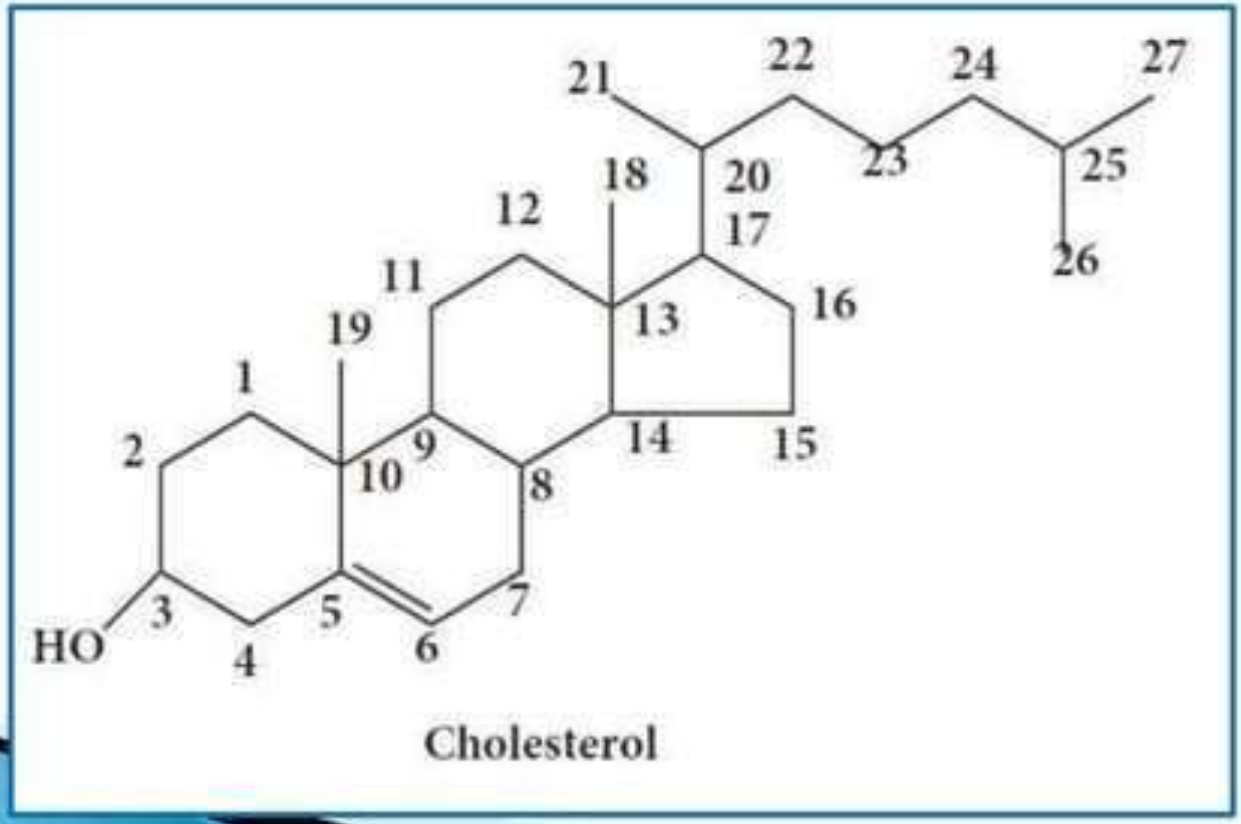
Steroids

- Steroids are derived lipids because they are hydrophobic and insoluble in water, but they do not resemble lipids since they have a structure composed of four fused rings.
- Sterols such as cholesterol and ergosterols is the most common steroid and is the precursor to vitamin D, estrogen, progesterone, aldosterone, cortisol, and bile salts.
- Sterols also known as steroid alcohols.
- Sterols of plants are called phytosterols and sterols of animal are called zoosterols.
- Cholesterol is common zoosterols and stigmasterol is phytosterols.
- Ergosterols is present in cell membrane of fungi and protozoa.

Cholesterols

- Cholesterol is widely distributed in all cells and is a major component of cell membrane and lipoproteins.
- Cholesterol is a C_{27} compound with molecular formula $C_{27}H_{46}O$. With a hydroxyl group at C_3 and a double bond between C_5 and C_6.
- An aliphatic side chain is attached at C_{17} and 5 methyl groups.
- Cholesterol exists as crystals that are white, shiny. It has a high melting point of 150°C.
- It is insoluble in water and soluble in fat solvents.
- Cholesterol oxidized under suitable conditions and to form a ketone called cholestenone.
- The hydroxyl group of cholesterol readily forms ester with fatty acids like stearic acid.

- It helps in maintenance of our body temperature and protects our internal organs.
- In pharmaceutical industries, cholesterol is used in the manufacture of steroid hormones and vitamin D.



Cholesterol

Terpenoids

- The terpenoids, sometimes called isoprenoids, are a large and diverse class of naturally occurring organic chemicals derived from the 5-carbon compound isoprene, and the isoprene polymers called terpenes.
- Most are multicyclic structures with oxygen-containing functional groups.
- Terpenoids mostly occur in natural products and can be found in all classes of living things.
- Several terpenoids are biologically active and are exploited in the fight against cancer, malaria, inflammation, and a variety of infectious diseases.
- Terpenoids can be classify as monoterpene, diterpene, and polyterpene etc.
- Most common example are carotenoids, lycopene pigment etc.

PROPERTIES OF LIPIDS

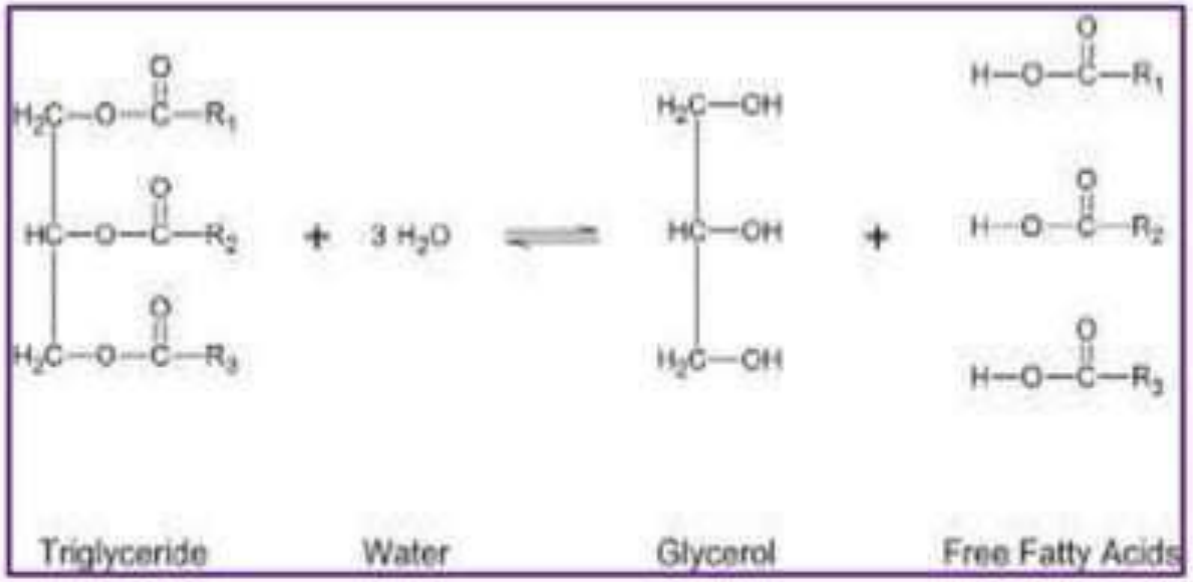
Physical property:

- Lipids may be either liquids or non-crystalline solids at room temperature.
- Pure fats and oils are colorless, odorless, and tasteless.
- They are energy-rich organic molecules.
- Insoluble in water.
- Soluble in organic solvents like alcohol, chloroform, acetone, benzene, etc.
- No ionic charges.
- Solid triglycerols (Fats) have high proportions of saturated fatty acids.
- Liquid triglycerols (Oils) have high proportions of unsaturated fatty acids.

Chemical property:

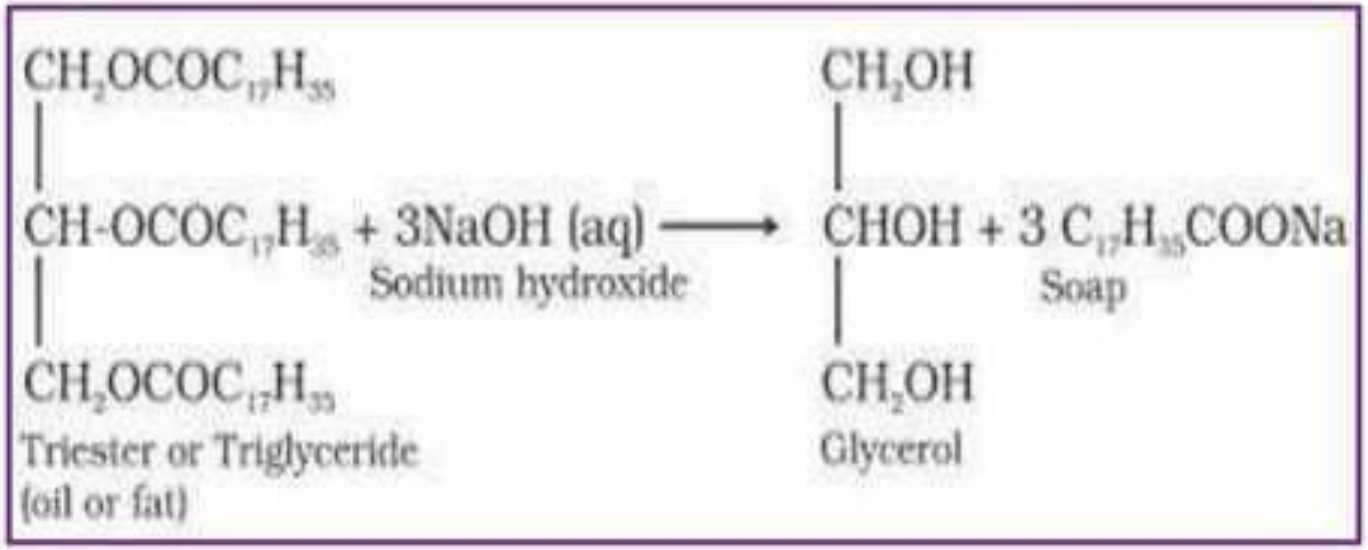
1. Hydrolysis of triglycerols:

- Triglycerols like any other esters react with water to form their carboxylic acid and alcohol a process known as hydrolysis.



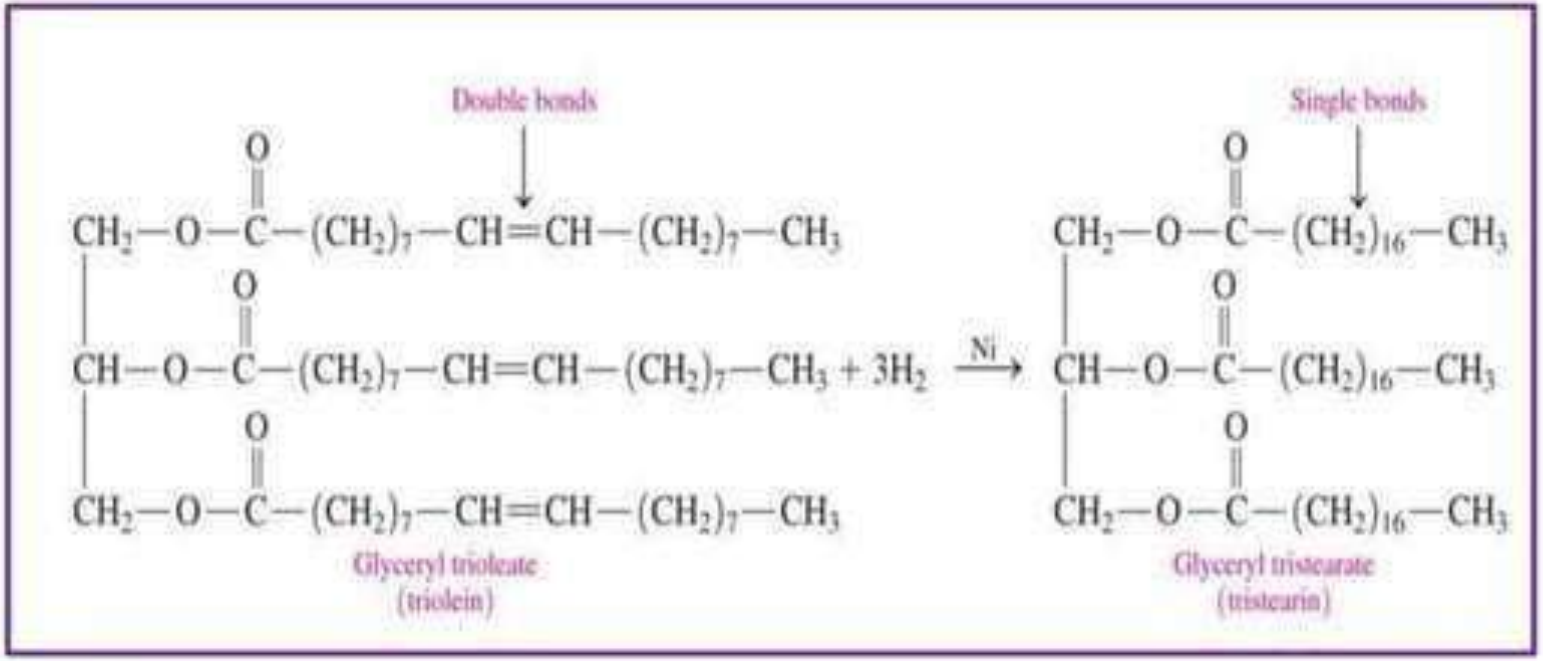
2. Saponification:

- Triacylglycerols may be hydrolyzed by several procedures, the most common of which utilizes alkali or enzymes called lipases. Alkaline hydrolysis is termed saponification because one of the products of the hydrolysis is a soap, generally sodium or potassium salts of fatty acids.



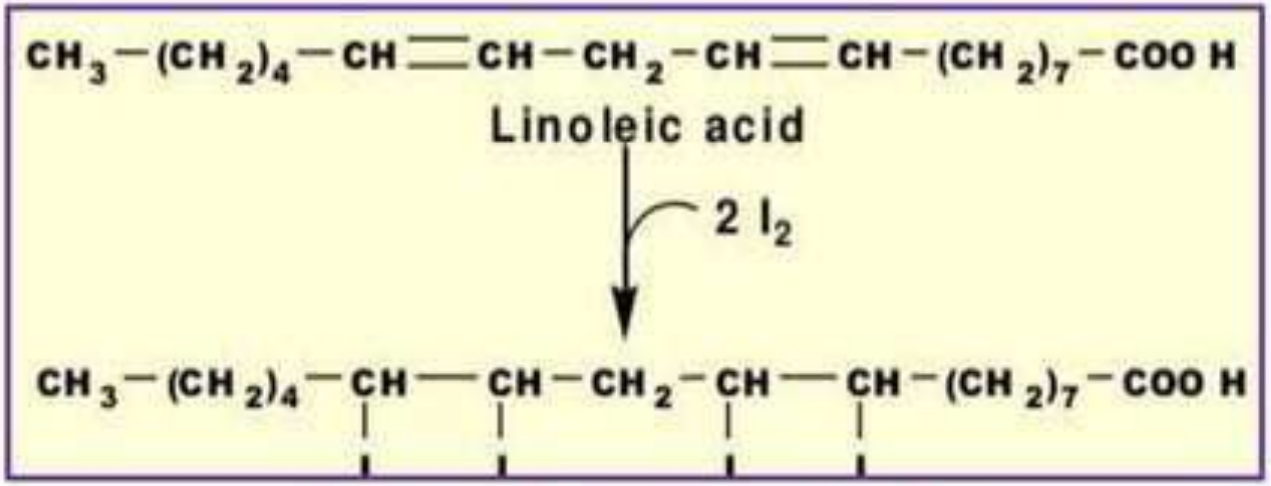
3. Hydrogenation:

- The carbon-carbon double bonds in unsaturated fatty acids can be hydrogenated by reacting with hydrogen to produce saturated fatty acids.



4. Halogenation:

- Unsaturated fatty acids, whether they are free or combined as esters in fats and oils, react with halogens by addition at the double bond(s). The reaction results in the decolorization of the halogen solution.



Stearate tetra iodinate

Function of lipids

- Lipids play extremely important roles in the normal functions and structure of a cell membrane.
- It is used as energy storage and work as insulator.
- Used as a protective coating in plant leaves from drying up.
- Lipid act as hormones.
- Act as the structural component of the body and provide the hydrophobic barrier.
- Lipids are major sources of energy in animals and high lipid containing seeds.
- Lipid act as chemical messengers between cells.
- Layers of subcutaneous fat under the skin also help in insulation and protection from cold.

THANK YOU