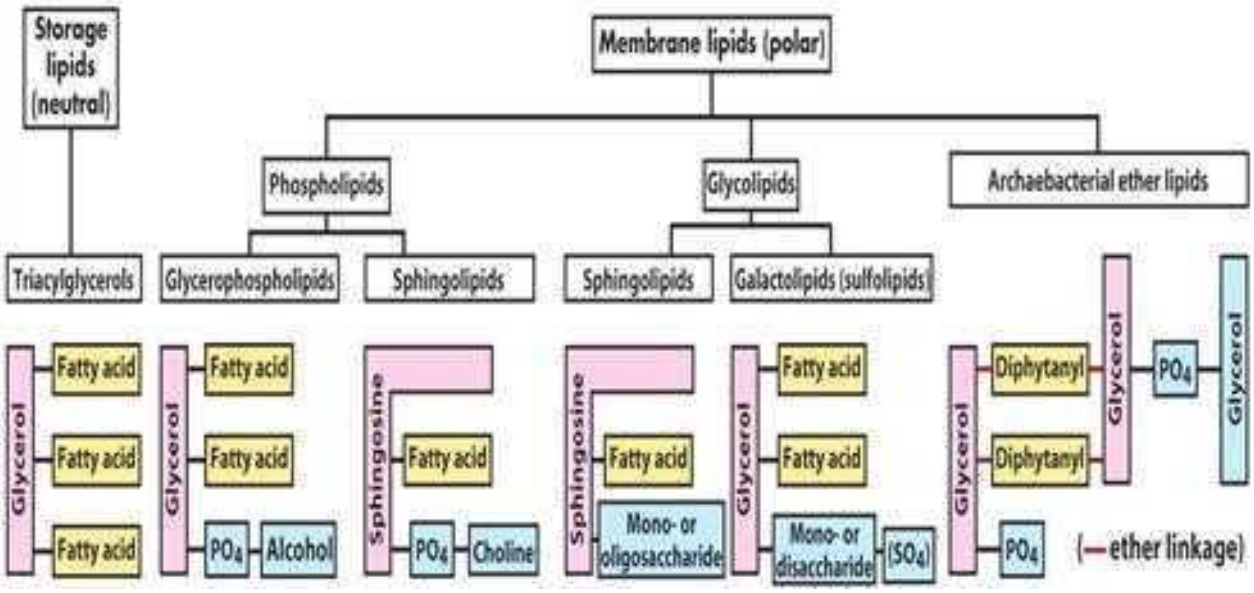
Lipids:

The key feature of lipids is their solubility in non-polar solvents, and cellular environments, and their insolubility in polar solvents such as H2O. They have limited or no water solubility. As a result, they block the movement of polar substances. A wide variety of structures exist. Lipids are classified as follow:-

A-



B-1-Lipids with fatty acids(Fats and oils (triglycerides),Waxes, Phospholipids, Sphingolipids)

2-Lipids without fatty acids(Steroids)

C-

1-Simple lipids (**fats, oils, waxes)**

2-Compound lipids (**phospholipids, spingolipids, glygolipids)**

3-Derived lipids **(hormones, fat-solubility vitamins)**

D-On the basis of whether they undergo hydrolysis reactions in alkaline solution:

1. Saponifiable lipids can be hydrolyzed under alkaline conditions to yield salts of fatty acids.

2. Nonsaponifiable lipids do not undergo hydrolysis reactions in alkaline solution**.**

Structural Variety:

A wide variety of structures exist.

(1) Fats and Oils: esters of Amphipathic alkane and/or alkene chain structures with Cn-length tails.

(2) Cholesterol: an isoprene-derived four-ringed steroid structure.

(3) Eicosanoids: Prostaglandins thromboxanes and leukotrienes. hormone-like molecules.

(4) Waxes: Cn - alcohols; derivatives.

(5) Terpenes: ubiquitous covalent compounds composed of 2 or more isoprene subunits.

(6) Cerebrosides, Gangliosides, Sphingomyelins: all enriched in nerve and brain gray matter.

Functions:-

(1) Lipids are the major structural components of biological membranes.

(2) Energy Storage. Lipids store about 9 kcal per gram. Carbohydrates only store about 4 kcal/gm.

(3) Vitamins. Examples: vitamins A (retinal), D (cholecalciferol), E (α-tocophorol), and K (phylloquinone).

(4) Novel functions. Examples include the pain response (prostaglandins); intracellular "hormones" (signal-transduction, nerve cell membranes (sphingomyelins).

(5) One more important function of dietary lipids is that of supplying the so-called essential fatty acids

(6) Bile acids derived from cholesterol act as an emulsifying agent and facilitate the digestion and absorption of lipids.

(7) Insulation from environment, Low thermal conductivity, And High Heat Capacity .

(8) Mechanical protection (can absorb shocks)

(9) Water repulsive**,** hydrophobic nature:

keeps surface of the organism dry

Prevents excessive wetting (birds)

Prevents loss of water via evaporation

(10) Flexibility control and acoustics in marine mammals

Increased density while diving deep helps sinking.

(11) Cofactors for enzymes

Vitamin K: blood clot formation, ubiquinone coenzyme-Q (CoQ10)

(11) Growth factors, vit.D (hormone precursors)

(12) Pigments, Color of tomatoes, carrots, pumpkins, some birds

(13) Antioxidants, Vitamin E

Fatty Acids

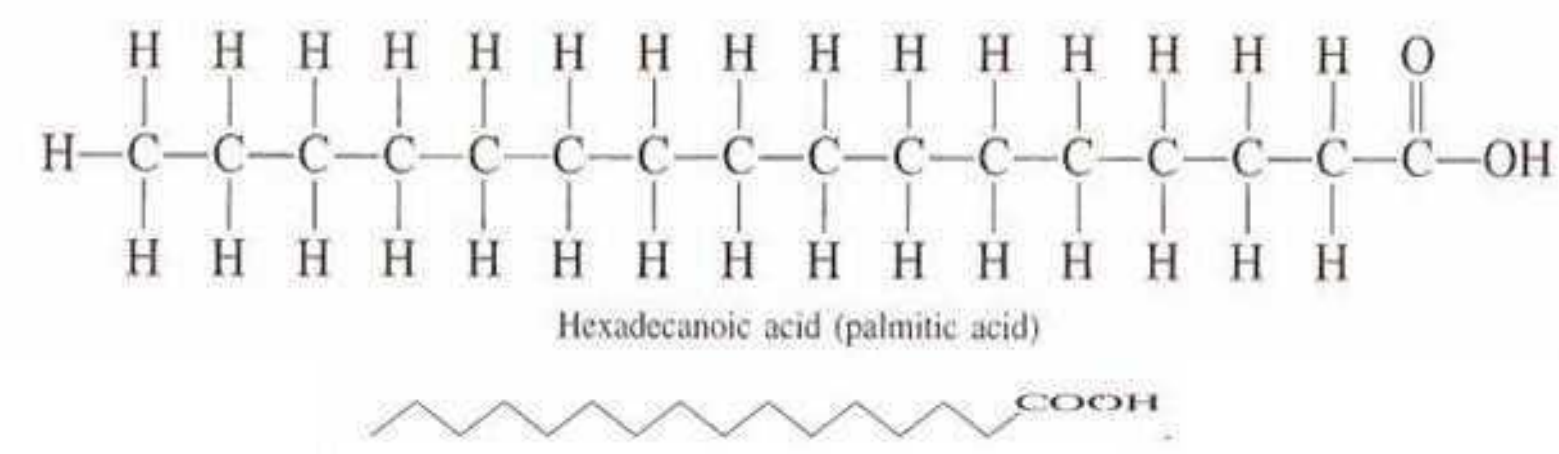
Are saponifiable lipid building blocks. Fatty acids are naturally occurring carboxylic acids with an **unbranched carbon chain** , an **even number of carbon atoms, cis double bond and conjugated form.** Long-chain fatty acids **(12 to 26 carbon atoms)** are found in meats and fish; medium-chain fatty acids **(6 to 10 carbon atoms)** and short-chain fatty acids **(less than 6 carbon atoms)** occur primarily in dairy products.

There are saturated and unsaturated Fatty acids.

Saturated Fatty acids

Fatty acid chains that contain only carbon-carbon single bonds are referred to as saturated.

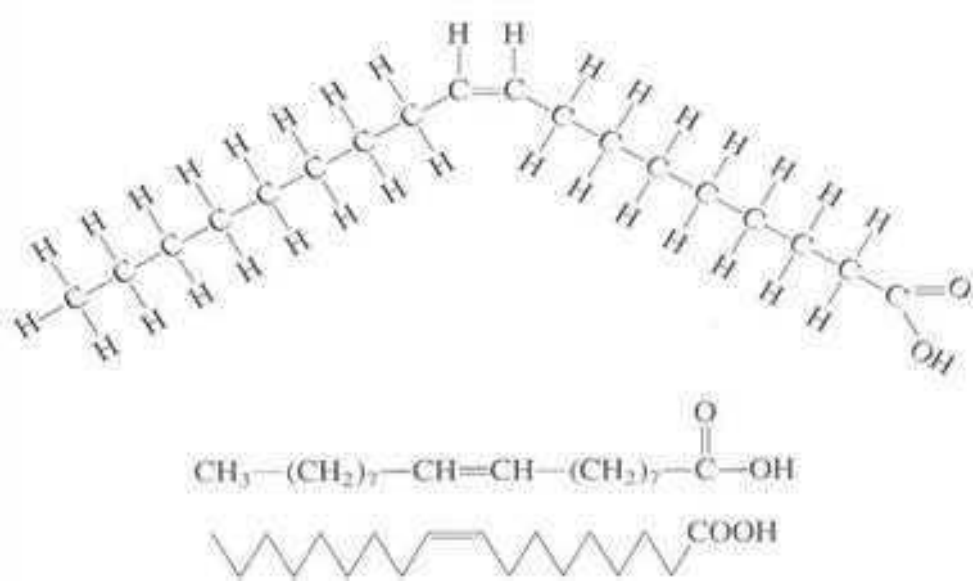
Palmitic acid:



Un-Saturated

Those molecules that contain one(monounsaturated fatty acids) or more double bonds(polyunsaturated fatty acids) are said to be unsaturated.

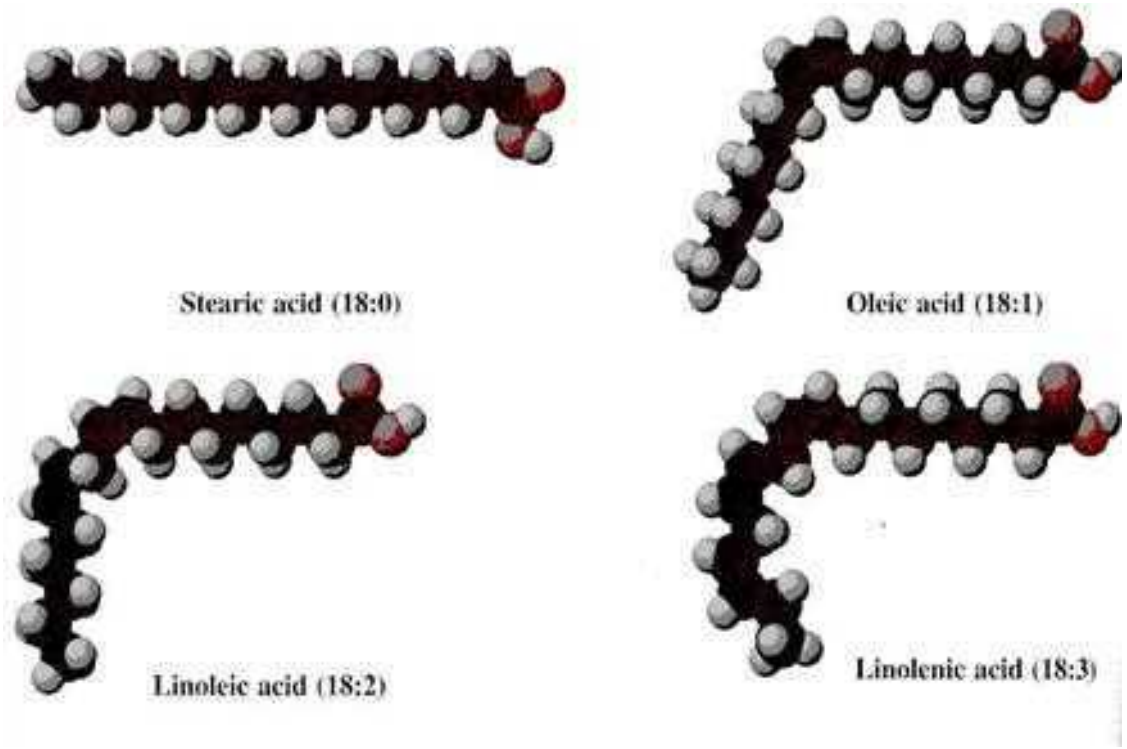
Oleic acid:



There is free rotation about C-C bonds in the fatty acid hydrocarbon, except where there is a double bond. Each cis double bond causes a **kink** in the chain.

Points of unsaturation are important because they are all cis in naturally occurring fatty acids and cause a bend in the aliphatic part of the molecule.

If the unsaturation was trans, the aliphatic part would look like the saturated fatty acid.



A-Saturated fatty acids

Namenvw	Formula	C-No.	Occurance	Melting point
Butyric	C_3H_7COOH	4:0	Butter fat	-6.5
Caproic	$C_5H_{11}COOH$	6:0	Butter fat	-1.5
Caprylic	$C_7H_{15}COOH$	8:0	Coconut oil	16
Capric	$C_9H_{19}COOH$	10:0	Palm kernel oil	31

Lauric	$C_{11}H_{23}COOH$	12:0	Coconut oil	44
Myristic	$C_{13}H_{27}COOH$	14:0	Nutmeg oil “Pistachio”	58
Palmitic	$C_{15}H_{31}COOH$	16:0	Animal and Veg. fats	63
Stearic	$C_{17}H_{35}COOH$	18:0	Animal and Veg. fats	70
Arachidic	$C_{19}H_{39}COOH$	20:0	Peanuts oil	75

unStructure and acids name	# of =	# of C	Melting P.	Occurance
$CH_3(CH_2)_5CH=CH(CH_2)_7COOH$ Palmitolic acid	1	16 16:1cΔ9	-0.5	Butter fat
$CH_3(CH_2)_7CH=CH(CH_2)_7COOH$ Oleic acid	1	18 18:1CΔ9	13	Olive oil
$CH_3(CH_2)_4CH=CHCH_2CH=CH(CH_2)_7COOH$ Linolic acid	2	18 18:2Δ9,12	-5	Linseed oil “cotton”
$CH_3CH_2CH=CHCH_2CH=CHCH_2CH=CH(CH_2)_7COOH$ Linolenic Acid	3	18 18:3Δ9,12,15	-11	Linseed oil
$CH_3(CH_2)_4(CH=CHCH_2)_3CH=CH(CH_2)_3COOH$	4	20	-50	Lecithin

Arachidonic acid		20:4Δ9,12,15, 17		

18:3 all cis $\Delta^{6,9,12}$ γ- Linoleic acid (an omega-6)

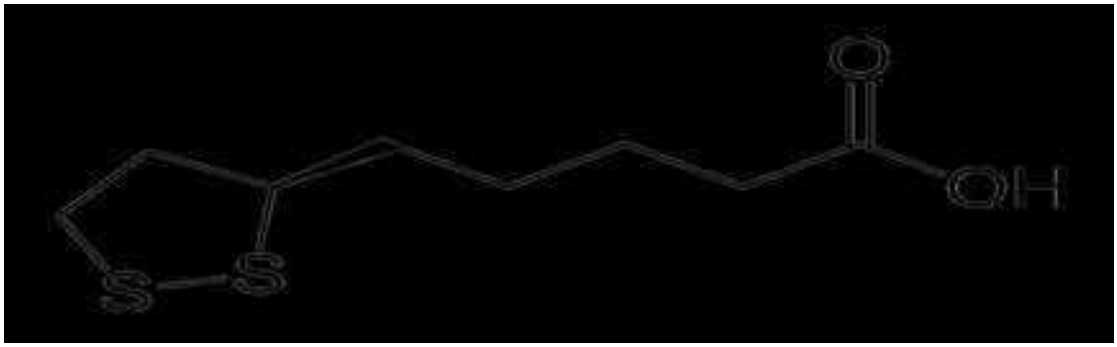
20:5 all cis $\Delta^{5,8,11,14,17}$ Eicosapentaenoic acid (an omega-3)

18:3 all cis $\Delta^{9,11,13}$ Eleostearic acid (conjugated acid)

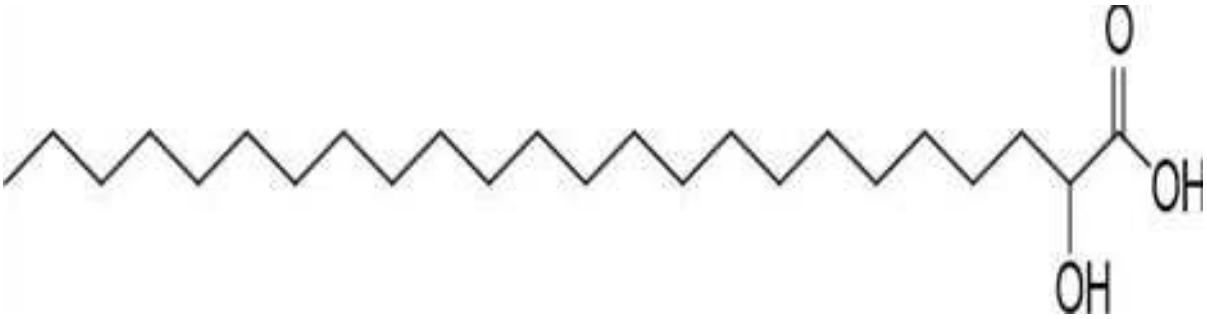
Lipoic acid:

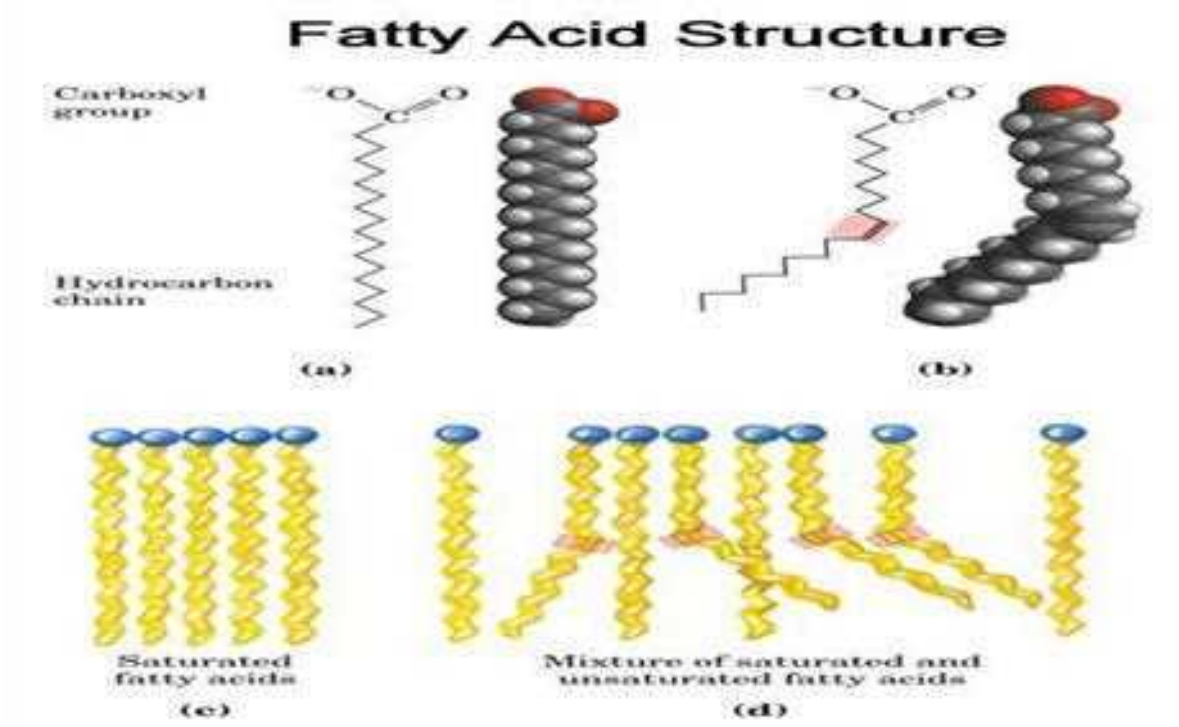
R)-5-(1,2-dithiolan-3-yl) pentanoic acid

is **cofactor** for **enzyme** **systems** such as in the **citric acid cycle** through which many organisms turn nutrients into energy.



Cerebronic acid(C24:0: OH) found in plants and in animal wool waxes, skin lipids and specialized tissues, mainly in brain.





Structure of saturated (a) and unsaturated (b) fatty acids. The lower part shows the packing of saturated (c) and unsaturated (d) fatty acids within membranes

The melting points of fatty acids and lipids containing them are also determined by the **length and degree of unsaturation of the hydrocarbon chain**. At room temperature, saturated fatty acids from 12:0 to 24:0 are solid , whereas unsaturated fatty acids of corresponding lengths are liquids like oils. This difference in melting point is because of **lower compaction**, or **lower packing**, of the hydrocarbon chains which have a kink at every C=C double bond in cis configuration. This leads to a reduction in van der Waals interaction that accounts for lower melting point. The melting point decreases with increase in the degree of unsaturation. Similarly, the fluidity of membranes containing high proportions of lipids with unsaturated fatty acyl residues is higher than their counterparts containing saturated fatty acyl residues. This phenomenon has significant bearing on the activity and functions of biological membranes and the proteins embedded in them.

-Trans fatty acids can pack more regularly and show higher melting points than cis forms

-Consuming trans fats increases risk of cardiovascular disease

-Avoid deep-frying partially hydrogenated vegetable oils

Melting Point

Longer chain fatty acids pack better than shorter chains

– M.P.long > M.P.short

Saturated fatty acids pack better than unsaturated

– M.Psat'd > M.P.unsat'd

Trans fatty acids pack better than *cis*

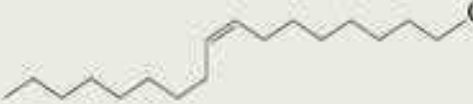
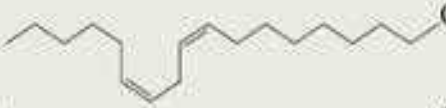
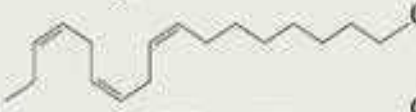
– M.Ptrans > M.P.cis

– hydrogenation increases M.P.

Essential fatty acids

The fatty acids that can not be biosynthesized in suitable amounts by the organisms are considered as nutritionally essential fatty acids. Palmitoleic and oleic acids are not essential in the diet because the tissues can introduce a double bond at Δ9 position of saturated fatty acids.

The first double bond introduced into a saturated fatty acid is nearly always in the Δ9 position by an enzyme system Δ9 desaturase in the endoplasmic reticulum. only linoleic and linolenic acids are known to be essential for complete nutrition of many species of animals, including humans. They are known as nutritionally essential fatty acids. Other polyenoic acids such as C20, C22 and C24, are derived from oleic, linoleic and linolenic acids by chain elongation by elongase and desaturase enzyme systems.

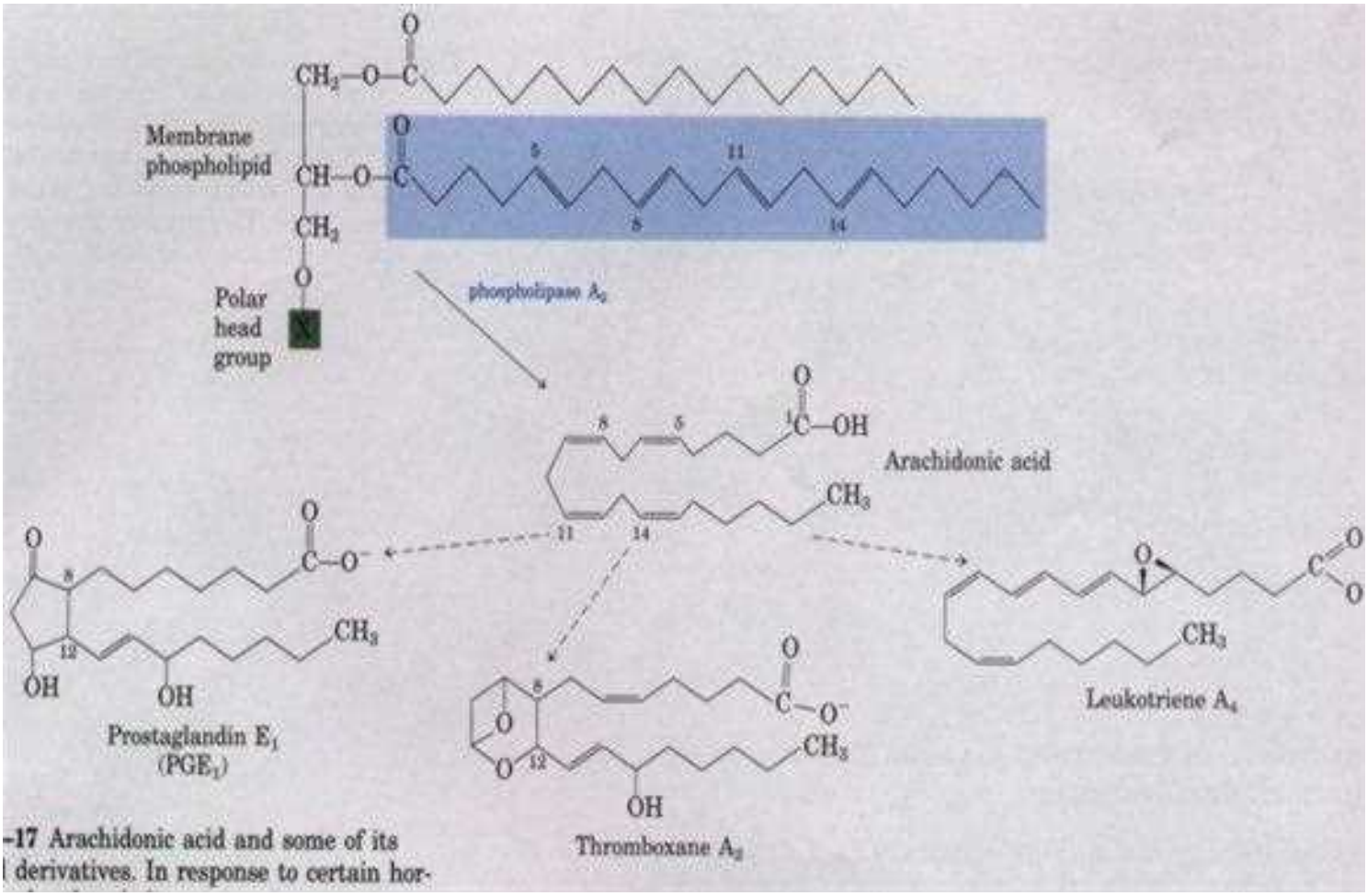
Number of carbons	Common name	Systematic name	Structure	Melting point °C
Saturated				
12	lauric acid	dodecanoic acid		44
14	myristic acid	tetradecanoic acid		58
16	palmitic acid	hexadecanoic acid		63
18	stearic acid	octadecanoic acid		69
20	arachidic acid	eicosanoic acid		77
Unsaturated				
16	palmitoleic acid	(9Z)-hexadecenoic acid		0
18	oleic acid	(9Z)-octadecenoic acid		13
18	linoleic acid	(9Z,12Z)-octadecadienoic acid		−5
18	linolenic acid	(9Z,12Z,15Z)-octadecatrienoic acid		−11
20	arachidonic acid	(5Z,8Z,11Z,14Z)-eicosatetraenoic acid		−50
20	EPA	(5Z,8Z,11Z,14Z,17Z)-eicosapentaenoic acid		−50

Eicosanoids: These molecules (a class of hormone like molecules) regulate:

1-inflammation, 2- pain, 3- sensitivity, 4-blood clotting, 5-reproductive processes

Activation of phospholipase A2 may release arachidonic acid from the membrane phospholipids that contain them. This free arachidonic acid may serve as the precursor molecule for synthesis of different classes of eicosanoids such as prostaglandins, thromboxanes and leukotrienes. The precursor fatty acid **Arachidonic acid** is converted into a prostaglandin by a cyclization reaction. Arachidonic acid is oxidized to form prostaglandin (PGE1) by Prostaglandin E synthase cyclooxygenase activity, and by Prostaglandin E synthase hydroperoxidase activity. The Prostaglandin E1 Synthase Cyclooxygenase (COX)

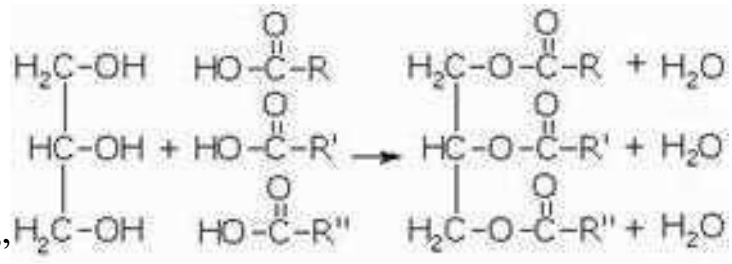
step is inhibited by aspirin. Such pharmaceuticals are called COX inhibitors or NSAIDS.

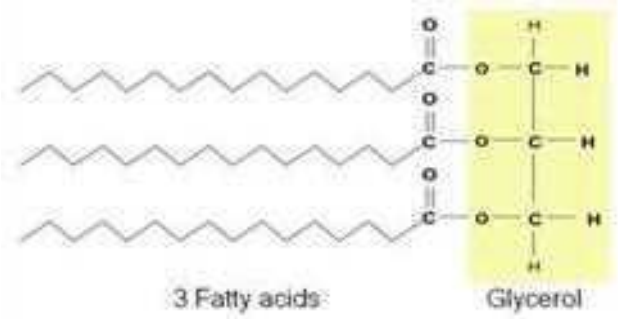


-17 Arachidonic acid and some of its derivatives. In response to certain hor-

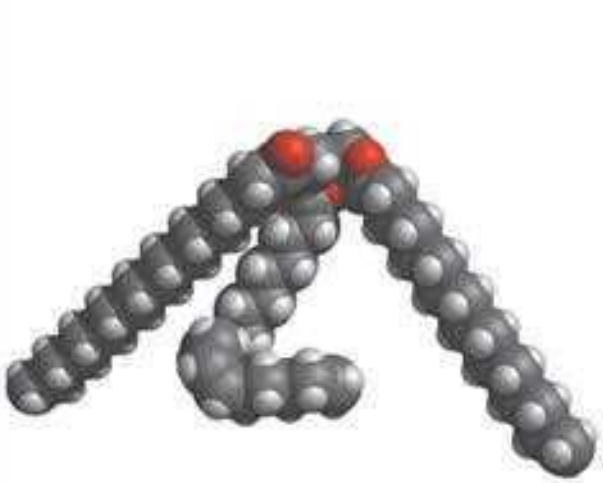
Fats & Oils:-(Glycerides)

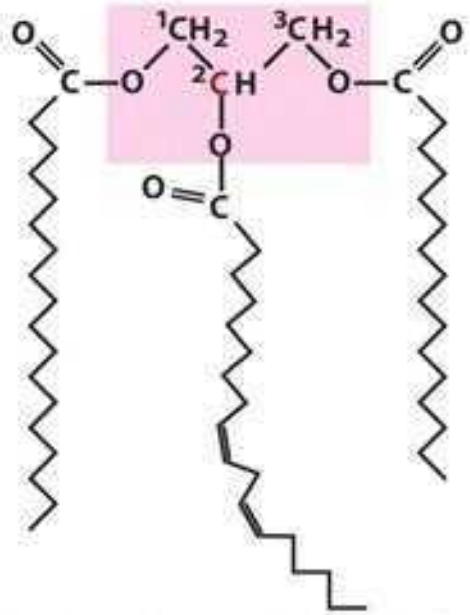
Fatty acid esters of the alcohol – glycerol are called triacylglycerol or triglicerides; "neutral lipids"





Glycerol Fatty acids **Triacylglycerol** **Triacylglycerol**





1-Stearoyl, 2-linoleoyl, 3-palmitoyl glycerol, a mixed triacylglycerol

Beta oxidation:

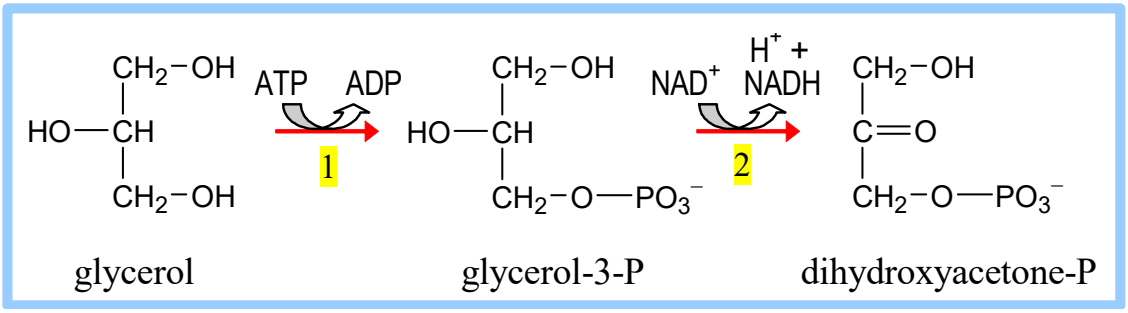
Triacylglycerols (triglycerides) are the most abundant dietary lipids. They are the form in which we store reduced C for energy.

Each triacylglycerol has a **glycerol** backbone to which are esterified **3 fatty acids**

Most triacylglycerols are "**mixed**." The 3 fatty acids differ in chain length & number of double bonds.

Lipid digestion, absorption, transport will be covered separately.

Lipases hydrolyze triacylglycerols, releasing 1 fatty acid at a time, yielding diacylglycerols, & eventually glycerol.



Glycerol, arising from hydrolysis of triacylglycerols, is converted to the Glycolysis intermediate **dihydroxyacetone phosphate**, by reactions catalyzed by:

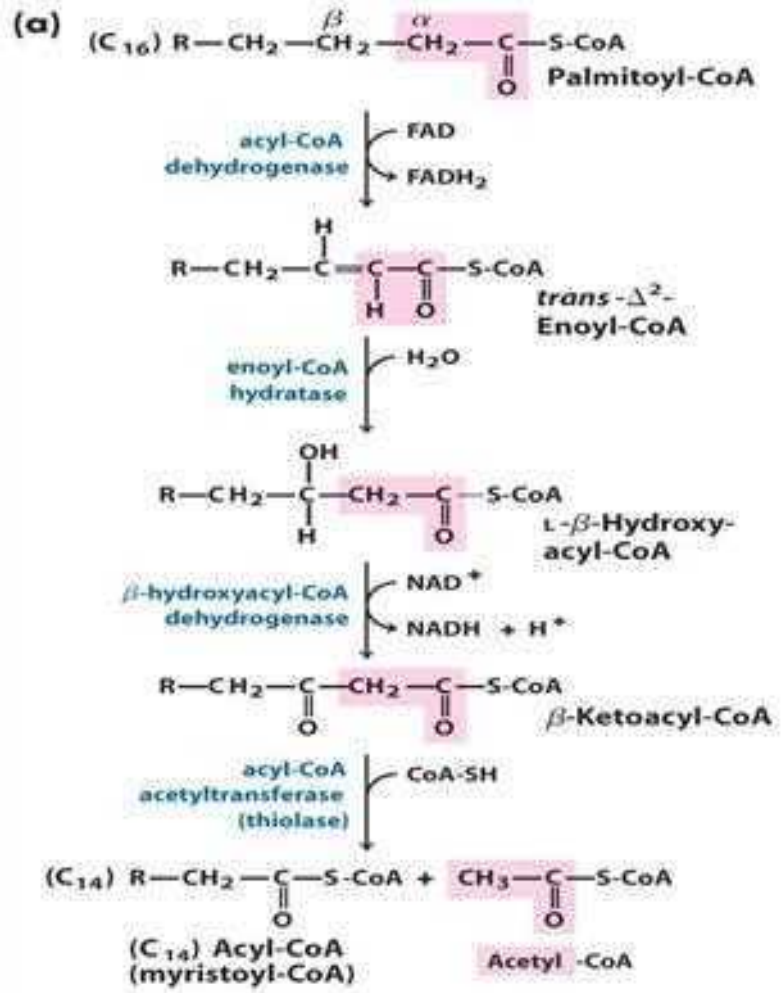
1 Glycerol Kinase

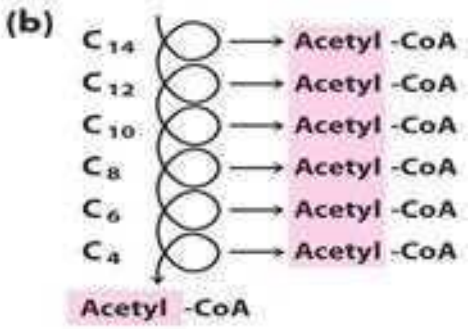
2 Glycerol Phosphate Dehydrogenase.

Free **fatty acids**, which in solution have detergent properties, are transported in the blood bound to **albumin**, a serum protein produced by the liver.

Several proteins have been identified that facilitate **transport** of long chain fatty acids **into cells**, including the plasma membrane protein **CD36** or oxidized during beta oxidation path way

Beta Oxidation Pathway:

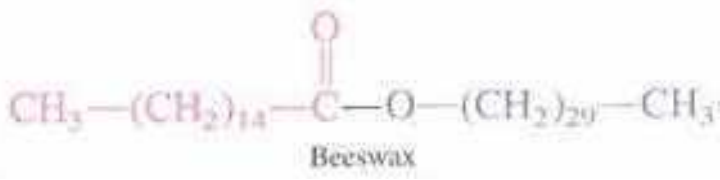




Waxes

wax is a monoester formed from the reaction of a long-chain monohydroxy alcohol with long-chain fatty acid molecule.

Example



Wax	Formula	Source	Use	Melting Point
Beeswax	$CH_3(CH_2)_{14}COOCH_2(CH_2)_{28}CH_3$	**Honeycomb**	**Polishes, candles, lipsticks**	**60-70**
Lanolin	$CH_3(CH_2)_{14}COO(CH_2)_{11}CH_3$	**Lamb's wool**	**ointments, cosmetics, soaps**	**36-43**
Carnauba	$CH_3(CH_2)_{14}COO(CH_2)_{29}CH_3$	**Carnauba palm**	**Polishes, floor waxes, car wax**	**82-85**
Spermaceti	$CH_3(CH_2)_{14}COO(CH_2)_{15}CH_3$	**Head oil of sperm whale**	**Candles, cosmetics, lubricant**	**42-50**

Chemical properties : Uncreative, and hydrophobic .Not easily hydrolysed, therefore they:

-Protective function in animals:

- waterproof of birds
- Earwax → delicate coating of inner ear.

-In Whales, fishes large quantities of waxes are present which act as the insulator.

Complex or Compound lipids:

These are esters of fatty acid with alcohol containing additional (prosthetic) groups. These are sub classified according to the type of prosthetic group present in the lipid:

1- Phospholipids

2- Glycolipids

3- Lipoproteins

1-Phospholipids:

Lipids contain fatty acids, alcohol, and phosphoric acid residue as additional groups. They frequently have nitrogen containing base and other substituents.

Phospholipids may be classified on the basis of the type of alcohol present in them as:

a- Glycerophospholipids.

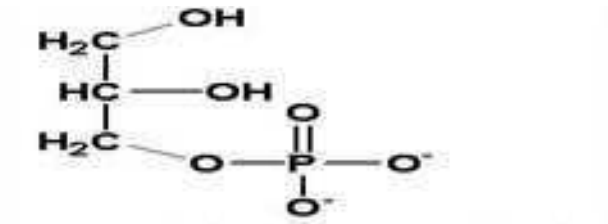
b- Sphingophospholipids.

A- Glycerophospholipids:

Glycerophospholipids, also called phosphoglycerides (phosphoacylglycerols), are 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.

Glycerophospholipids are the most abundant phospholipid molecules found in cell membranes.

The simplest glycerophospholipid, phosphatidic acid, is the precursor for all other glycerophospholipid. Phosphatidic acid is composed of glycerol-3-phosphate that is esterified with two molecules of fatty acids at C-1 and C-2. Glycerophospholipid are classified according to which alcohol becomes esterified to the phosphate group.



Glycerol-3-phosphate (Gly3P)

Glycerolphospholipids contain both a polar and non polar end and therefore are amphipathic.

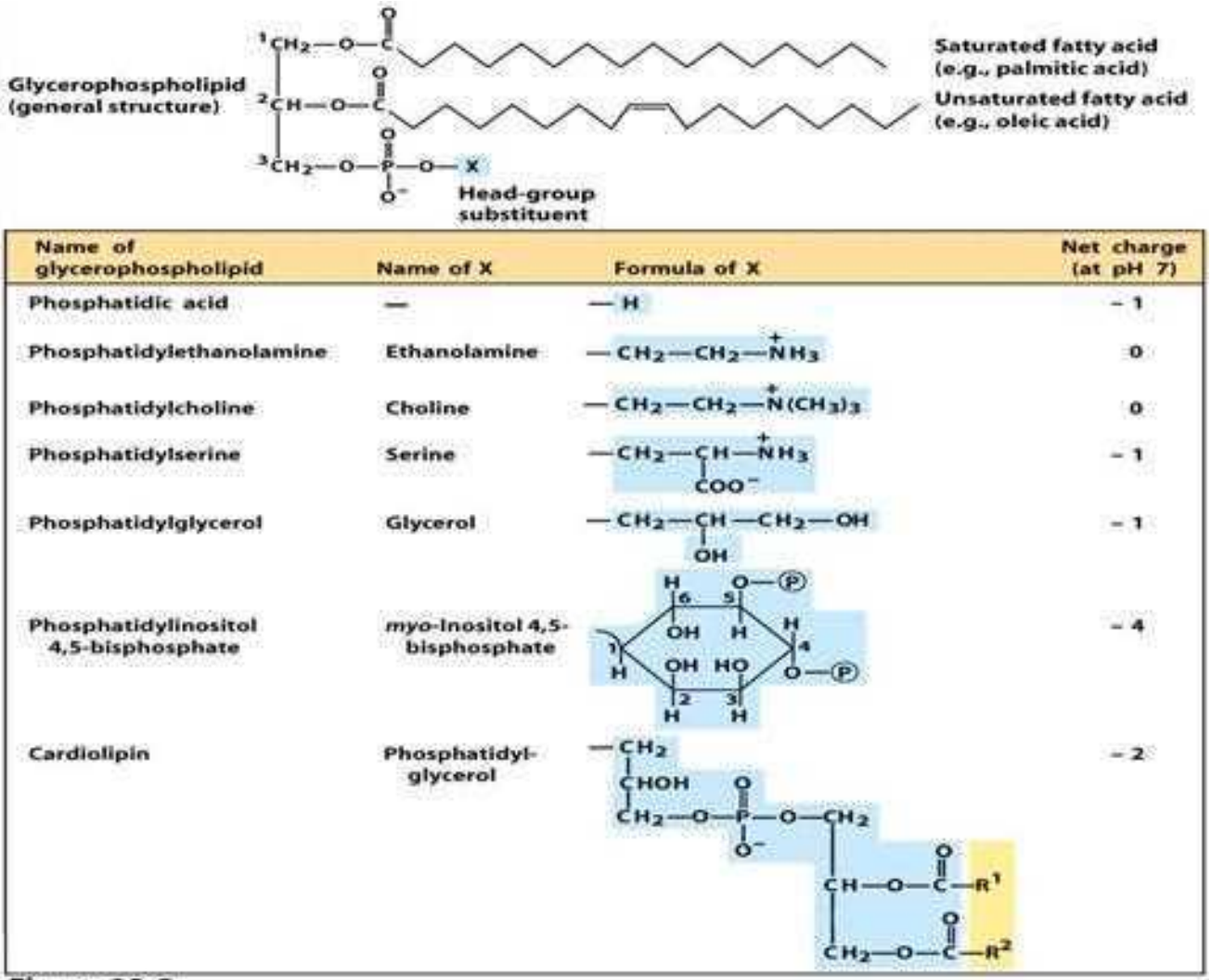
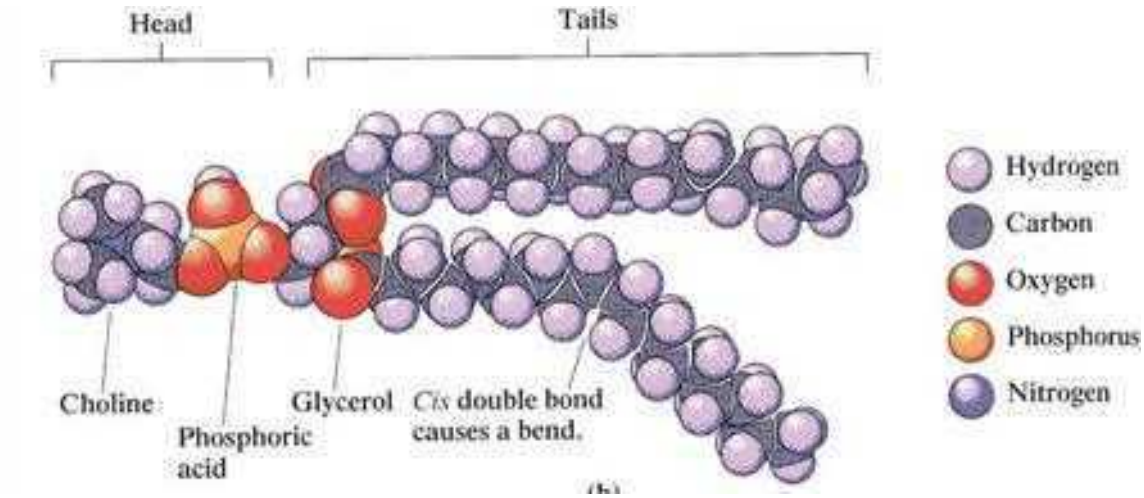


Figure 10-9
Lehninger Principles of Biochemistry, Fifth Edition

Examples on glycerophospholipids:

Phosphotidyl cholin (Lecithin):

These are glycerophospholipids (phosphoacylglycerols) containing glycerol, fatty acids, choline. These are most abundant phospholipids of the cell membrane having both structural and metabolic functions. They occur in the liver, brain and in plasma as part of the lipoproteins, red blood cells and extracellular lipid layer lining the lung alveoli. Lecithin contains both a polar head and non-polar tails therefore are amphipathic.



On complete hydrolysis, lecithin yields cholin, phosphoric acid, glycerol and two molecules of fatty acids. But partial hydrolysis of lecithin by lecithinase (enzymes found in snake venous) causes removal of one fatty acid to yield lysolecithins, when subjected into bloodstream by sting the lysolecithins cause rapid rupture (hemolytic) of the red blood cells.

Phosphatidyl ethanol amine (Cephalin):

Cephalin differs from lecithin in that the nitrogen base ethanol amine is present instead of cholin. Cephalin is also found in bio membranes and possesses amphipathic properties.

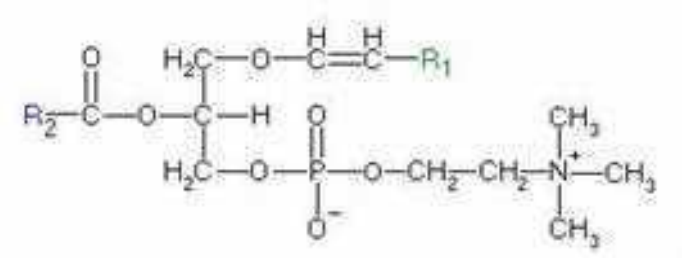
Phosphatidylinositol

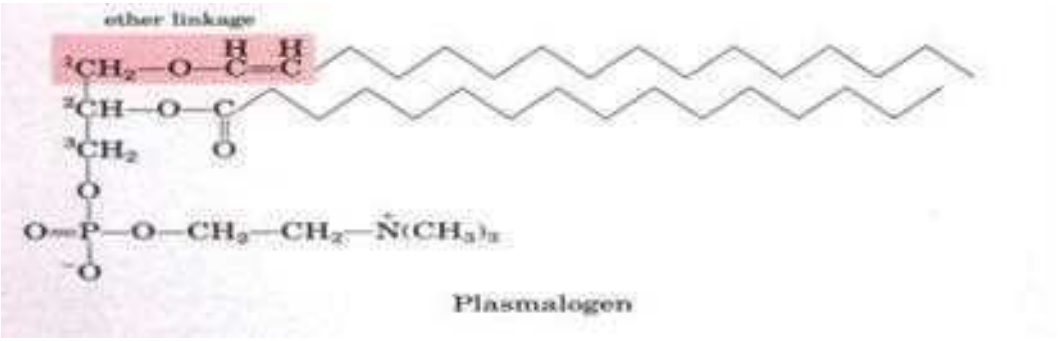
These molecules almost exclusively contain stearic acid at C1 and arachidonic acid at C2. Phosphatidylinositols composed of non-phosphorylated inositol exhibit a net negative charge at physiological pH. They exist in membranes with various levels of phosphate esterified to the hydroxyls of the inositol. Phosphatidyl inositol bisphosphate (PIP2) is present in cell membranes. This compound plays a vital role in the medication of hormone action on cell membranes.

Molecules with phosphorylated inositol are termed polyphosphoinositides.
Inositol phospholipids also serve as points of nucleation for assembly of certain supramolecular complexes involved in signaling and exocytosis. Specific proteins are known to bind phosphatidylinositols in membranes with high specificity and affinity and initiate the formation of multienzyme complexes at the cytosolic surface.

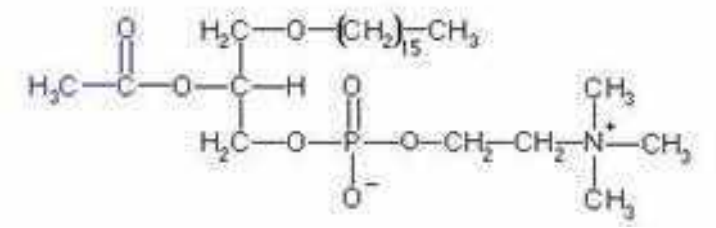
Phosphatidyl glyceracetals (Plasmalogens):

These are phospholipids which have an aliphatic long chain unsaturated either in C-1. The OH group in C-2 is esterified to a fatty acid. The phosphoric acid in C-3 is attached to cholin, ethanol amine or serine. Ethanolamine plasmalogen is prevalent in myelin. Choline plasmalogen is abundant in cardiac tissue. Ether lipids are also abundant in membranes of halophilic bacteria and certain invertebrates.





One of the choline plasmalogens, 1-alkyl, 2-acetyl phosphatidylcholine has been identified as an extremely effective biological mediator, capable of inducing cellular responses at subnanomolar concentrations. This molecule is called platelet activating factor (PAF). It functions as a mediator of hypersensitivity, acute inflammatory reactions and anaphylactic shock. It is released from WBC and stimulates platelet aggregation and the release of serotonin from platelets. It uses a variety of effects on liver, smooth muscle, heart, uterine and lung tissue and plays important role in inflammation and allergic response.



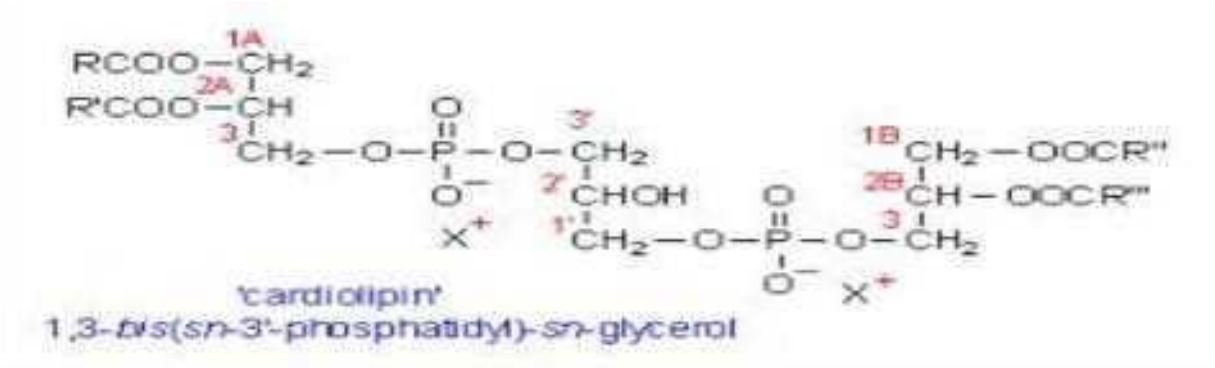
Platelet activating factor

Phosphatidylglycerol

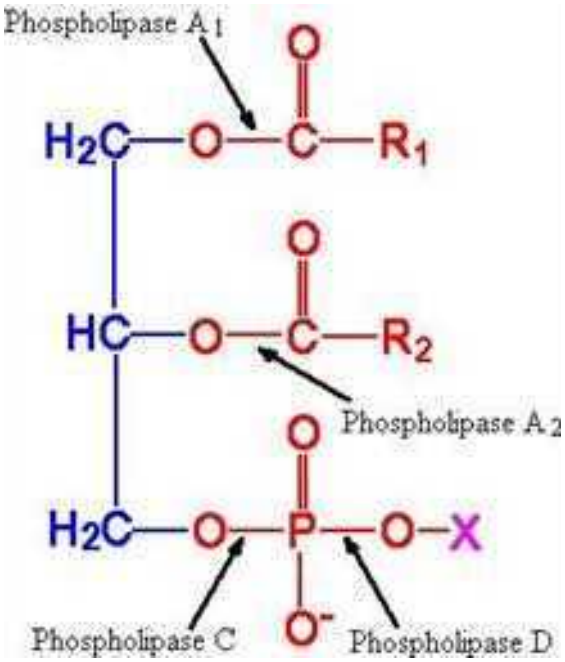
Phosphatidylglycerols exhibit a net negative charge at physiological pH. They are abundant in mitochondrial membranes and as components of lung surfactant. An important role of phosphatidylglycerol is that it acts as a precursor for the synthesis of cardiolipin.

Diphosphatidylglycerols

When phosphatidic acid is erterified in C-3 the diphosphatidyl glycerol or cardiolipin is formed, these molecules are very acidic, exhibiting a net charge of -2 at physiological pH. They are found primarily in the inner mitochondrial membrane, myocardum and also as components of lung surfactant and are important intracellular transducers of signals emanating from the plasma membrane(hormone action on cell membranes).the structure of cardiolipin is shown below.



The membrane phospholipids of most cells are continuously degraded and replaced. The hydrolytic enzymes responsible for degradation of membrane phospholipids are called phospholipases. There are four different type of phospholipases A1, A2, C and D which are specific for specific bonds in the glycerophospholipids. Phospholipases of the A type remove one of the two fatty acids producing a lysophospholipid. These are esterases that do not attack the ether link in plasmalogens. The remaining fatty acid of the lysophospholipid can be removed by lysophospholipases.

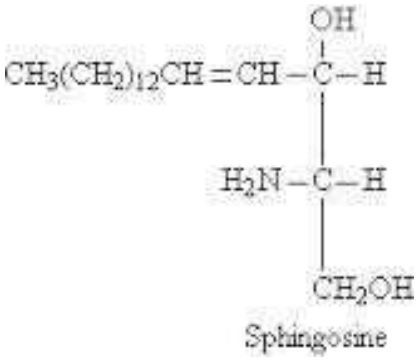


Site of action of phospholipases Site of action of phospholipases

B- Sphingophospholipids:

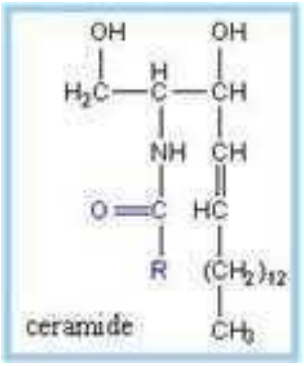
Phospholipids derived from alcohol sphingosine instead of glycerol are called sphingophospholipids.

Sphingosine has a long hydrocarbon tail, and a polar domain that includes an amino group.



The amino group of sphingosine can form an amide bond with a **fatty acid** carboxyl, to yield a **ceramide**. Ceramides occur in small amounts in plants and animals but are the parent

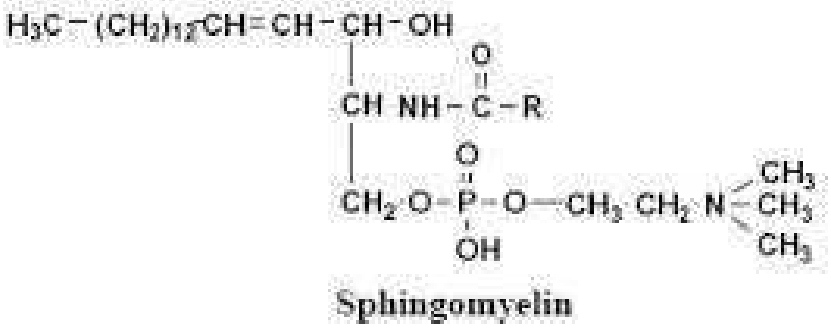
compound for more abundant sphingolipids such as sphingomyelins, cerebrosides and gangliosides



Sphingomyelins:

Sphingomyelins are phospholipids which contain sphingosine , one molecule of fatty acid, phosphoric acid and cholin.

Sphingo myelin is found in most animal cell membranes. They are found in abundance in the myelin sheath that surrounds and insulates cells of the central nervous system.

1. 

Sphingomyelin

Sphingophospholipids are amphipathic, having a polar head group and two non polar fatty acid tails, and are structural components of cell membrane.

Phospholipids are Structural Components of Biological Membrane

Polar lipids are major components of biological membranes. Among the lipids of the membranes, glycerophospholipids are the most abundant. The lipids that constitute the plasma membrane are also termed as the structural lipids. The membrane may additionally have other polar lipids such as sphingolipids, glycolipids, sulfolipids, cholesterol and ether lipids. Membrane lipids make up 5 to 10 percent of the dry mass of most cells. With some important exceptions, these lipids play a passive role in the cell forming impermeable or semipermeable barriers around cells and cellular compartments.

Micelle.s Monolayer spherical complex composed of 20 to 100 lipids. A hydrophobic molecule, for example, greasy dirt, can be trapped inside the central hydrophobic core. This is the concept behind soap and detergent action.

Bilayers. These elements are the basis of membrane structure.

Vesicles. These spherical structures can sequester solutes or solvents within the central cavity.

Structure of a glycerophospholipid molecule (phosphatidylcholine) showing the polar (hydrophilic) head and nonpolar (hydrophobic) tail. The right part shows the orderly aggregation of amphipathic glycerophospholipids in aqueous medium to form micelles, bilayer membrane and liposomes

2-Glycolipids:

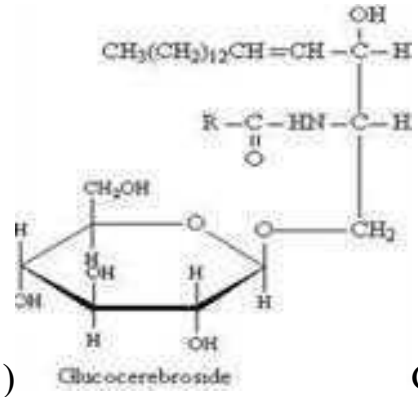
Glycolipids are molecules that contain carbohydrate and lipid and occur largely in the outer face of plasma membrane. They contain one to six, sometimes more, sugar units in their head group connected directly to the -OH at C1 of the ceramide moiety. They do not contain phosphorous. The most commonly found sugars are D-glucose, D-galactose and N-acetyl-galactosamine.

All glycolipids are derivatives of ceramides in which a long chain fatty acid is attached to the amino alcohol sphingosine. They are, therefore called glycosphingolipids.

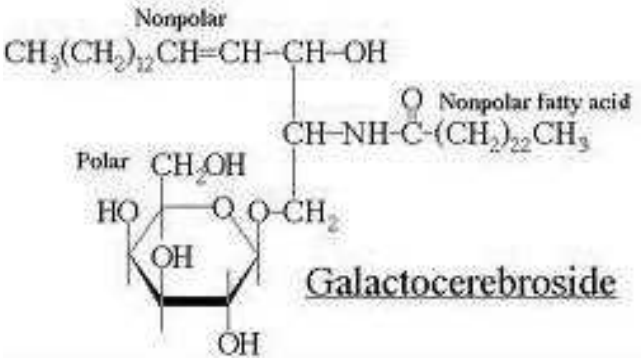
Glycosphingolipids are essential components of all membranes in the body, but they are found in greatest amounts in nerve tissue.

The simplest glycosphingolipids are the cerebrosides.

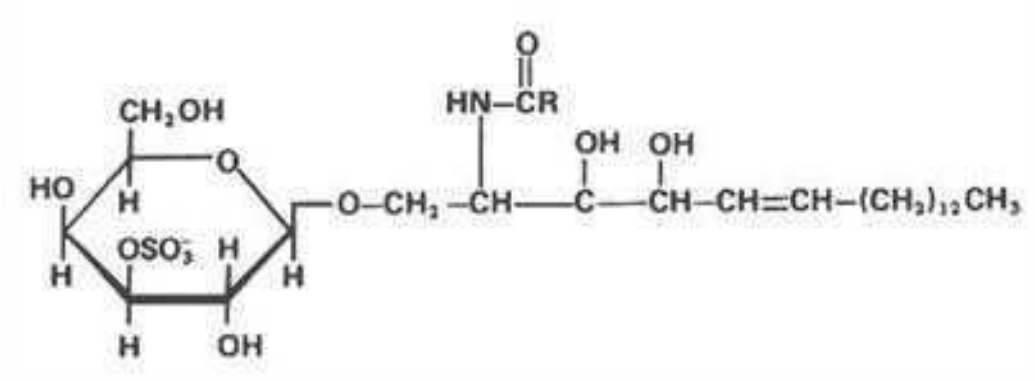
Cerebrosides are cereamide monosaccharide that contain either a galactose (galactocerebroside- the most common cerebroside found in membranes of brain cells), or glucose (glucocerebroside found in the membranes of macrophages {cells that protect the body ingesting and destroying foreign microorganisms})



GIu- Cerebroside

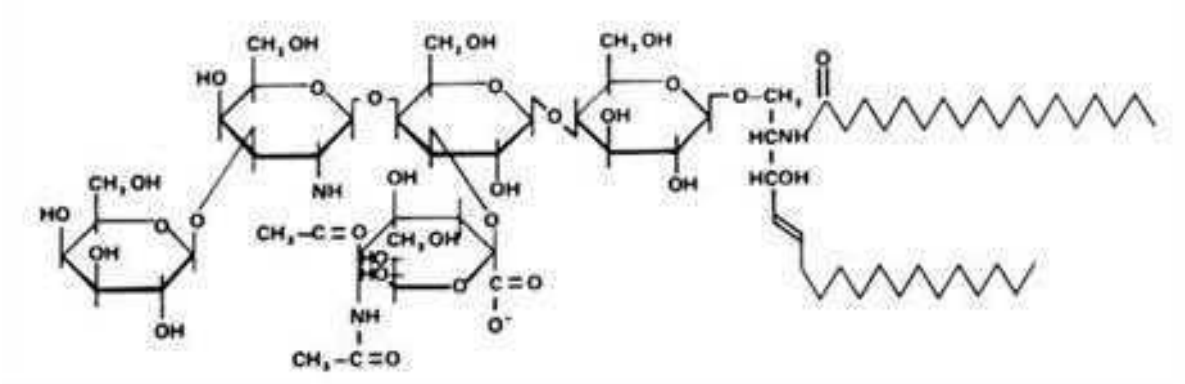


In some cases, β-D-galactose of galactocerebrosides is sulfated at C_3 position to form ionic compounds called sulfatides. Cerebrosides with β-D-glucose are called glucocerebrosides which are present in plasma membrane of the cells in non-neuronal tissue. More complex cerebrosides occur largely in the outer layer of cell membranes and constitute important components of cell surface.



Gangliosides:

Gangliosides are glycolipids that possess oligosaccharide groups, including one or more molecules of N-aceylneuraminic acid (Sialic acid). Gangliosides are mainly components of cell surface membranes and constitute a significant fraction (6%) of brain lipid. Other tissues contain gangliosides but in lesser amounts. They are also the determinants of cell-cell recognition and play important roles in growth and differentiation. Glycosphingolipids are also the determinants of the ABO human blood groups



3-Lipoproteins:

The most common and important complex lipids are plasma lipoproteins. Lipoproteins are responsible for the transport lipid molecules (tri acyl glycerol, phospholipids and cholesterol) through the bloodstream from one organ to another.

Lipoprotein particles consist of a core of hydrophobic lipids surrounded by amphipathic proteins, phospholipis and cholesterol.

Lipoproteins are classified according to their density to:

1-Chylomicrons:

Which are large lipoproteins of extremely low density, transport dietary triacyglycerol (triglyceride) and cholesterol ester from intestine to the tissues (especially muscle and adipose tissues).

2-Very low density lipoproteins (VLDL):

VLDL synthesized in the liver, are responsible for the transport of lipids to the tissues. As VLDL, are transported through the body, they became depleted of triglycerides, as well as some apoproteins and phospholipids. Eventually VLDL is converted to low density of lipoproteins (LDL).

3-Low density lipoproteins (LDL):

LDL carries cholesterol from the liver to tissues.

4-High density lipoproteins (HDL):

HDL transport cholesterol (ester) from the tissues to the liver.

Derived lipids:

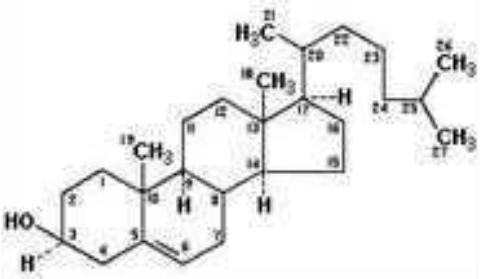
Sterols:

Sterols are a class of steroids. Sterols are structural lipids present in the membranes of most cells. Cholesterol is the major sterol in animal tissues.

Cholesterol is amphipathic, with a polar head the OH group at C-3 and a non polar, the steroid nucleus (cyclopentano per hydrophenanthrene) and hydrocarbon side chain at C-17.

Most of the cholesterol in the body exist as a cholesterol ester, with a fatty acid attached the OH at C-3.

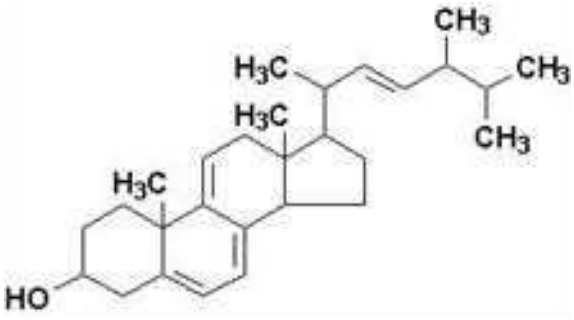
Cholesterol is a major structural constituent of the cell membranes and plasma lipoproteins. Cholesterol is a precursor in the biosynthesis of all steroid hormones (likeTestosterone), vitamin D and bile salts.



Cholesterol Testosterone

Ergosterol

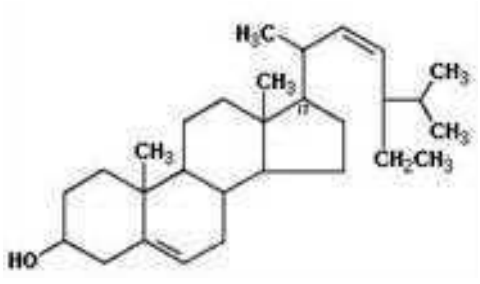
Ergosterol, is the principle sterol of fungi and yeast. It has been named after the ergot bodies, which form on rye plants infected with ergot fungi, from which it was first isolated. Its properties are similar to those of cholesterol. Ergosterol is also important since it serves as the precursor molecule for vitamin D biosynthesis.



Ergosterol

Stigmasterol

Stigmasterol, the structure of which is also very similar to that of cholesterol, is found in the cell membranes of higher plants. It differs from cholesterol only in having a double bond between C22 and C23.

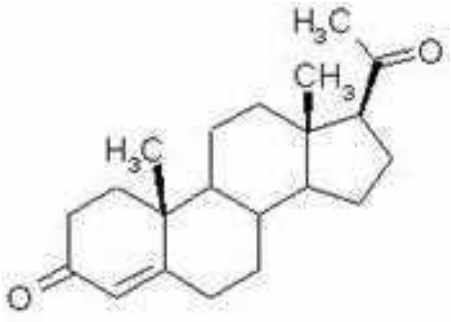


Stigmasterol

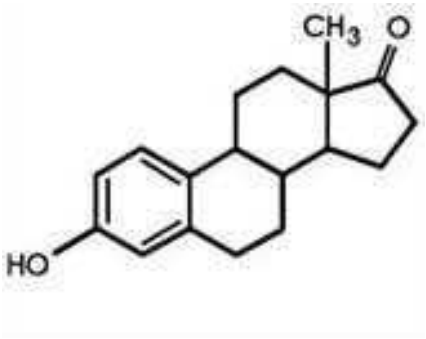
Cholesterol derivatives

The sterols are also used in biological system as precursors for a large number of molecules with specific biological activity. Most important among them are the steroid hormones such as

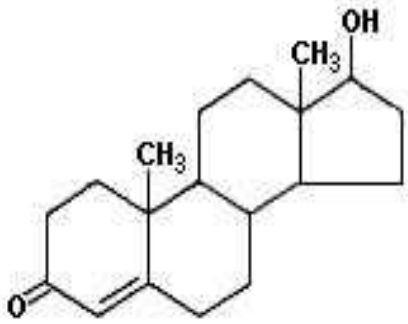
testosterone, estrogen, progesterone and corticosteroids which bring about specific biological effects by regulating the expression of a number of target genes.



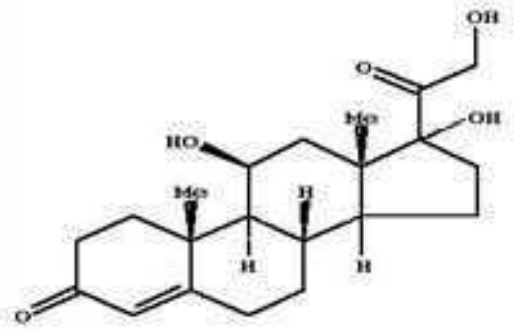
Testosterone



Estrogen

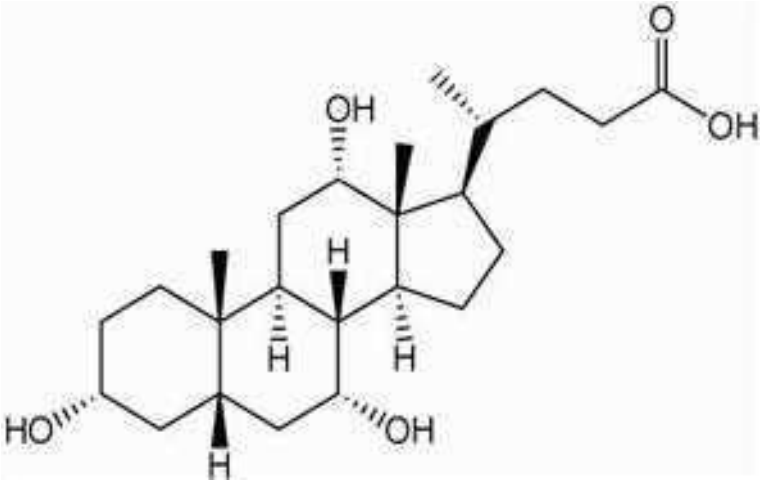


Progesterone



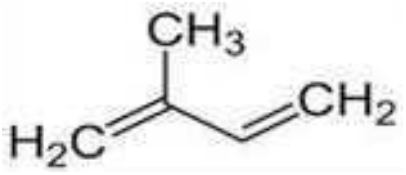
Cortisol

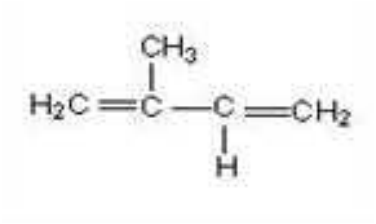
Bile acids, that are polar derivatives of cholesterol, are known to act as detergents in the intestine to emulsify the dietary fat for allowing them to be digested easily by digestive lipases.



Terpenes:

Terpenes are a class of lipids formed from combination of two or more molecules of isoprene units. **Isoprenoids**



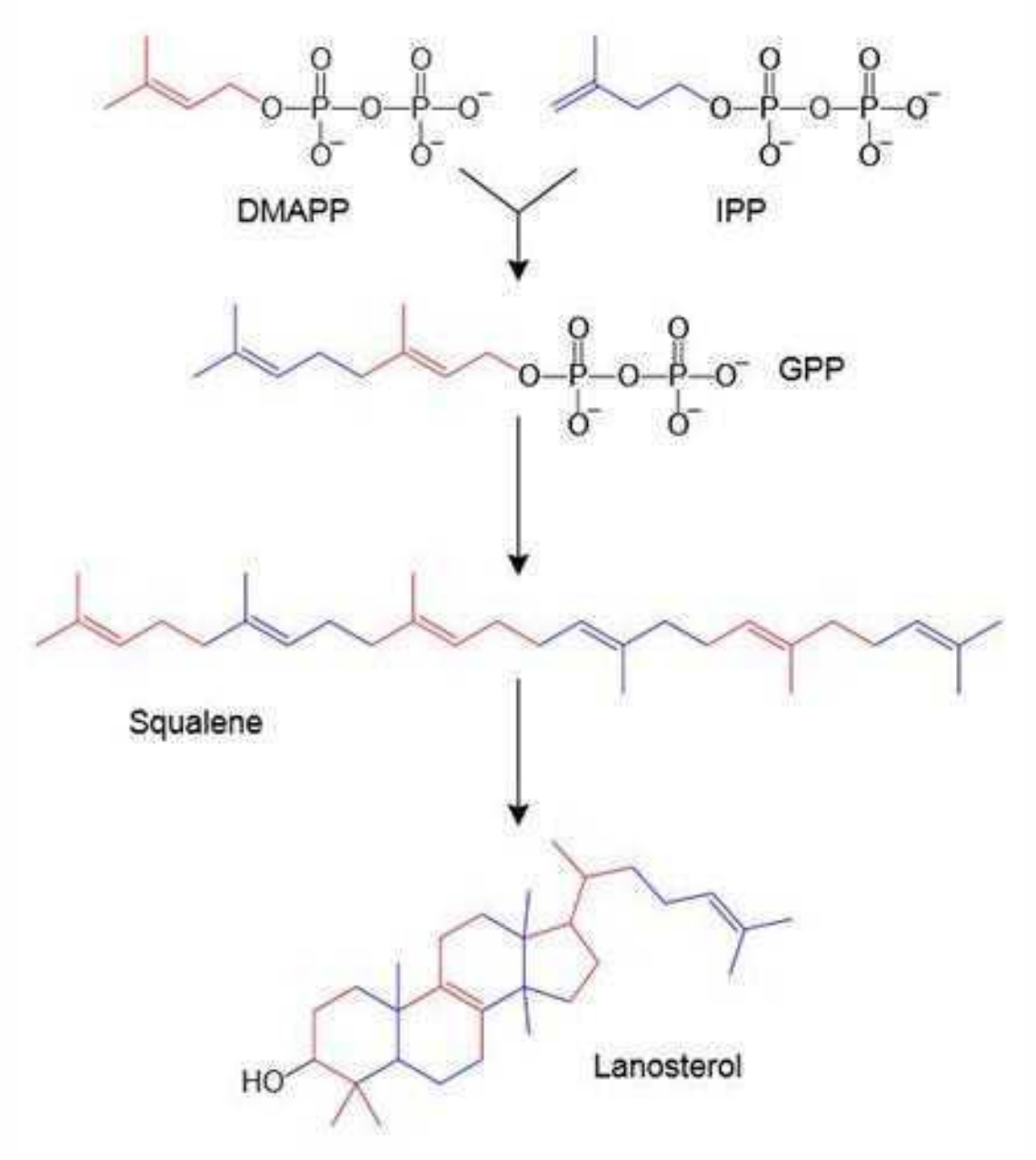


isoprene

The isoprenoids include fat-soluble vitamins A, D, E and K and many biological pigments.

A monoterpenes consist of two isoprene units, as esquiterpens consist of three isoprene units, and a diterpenes consist of four isoprene units and so on. Monoterpenes occur in all high plants,

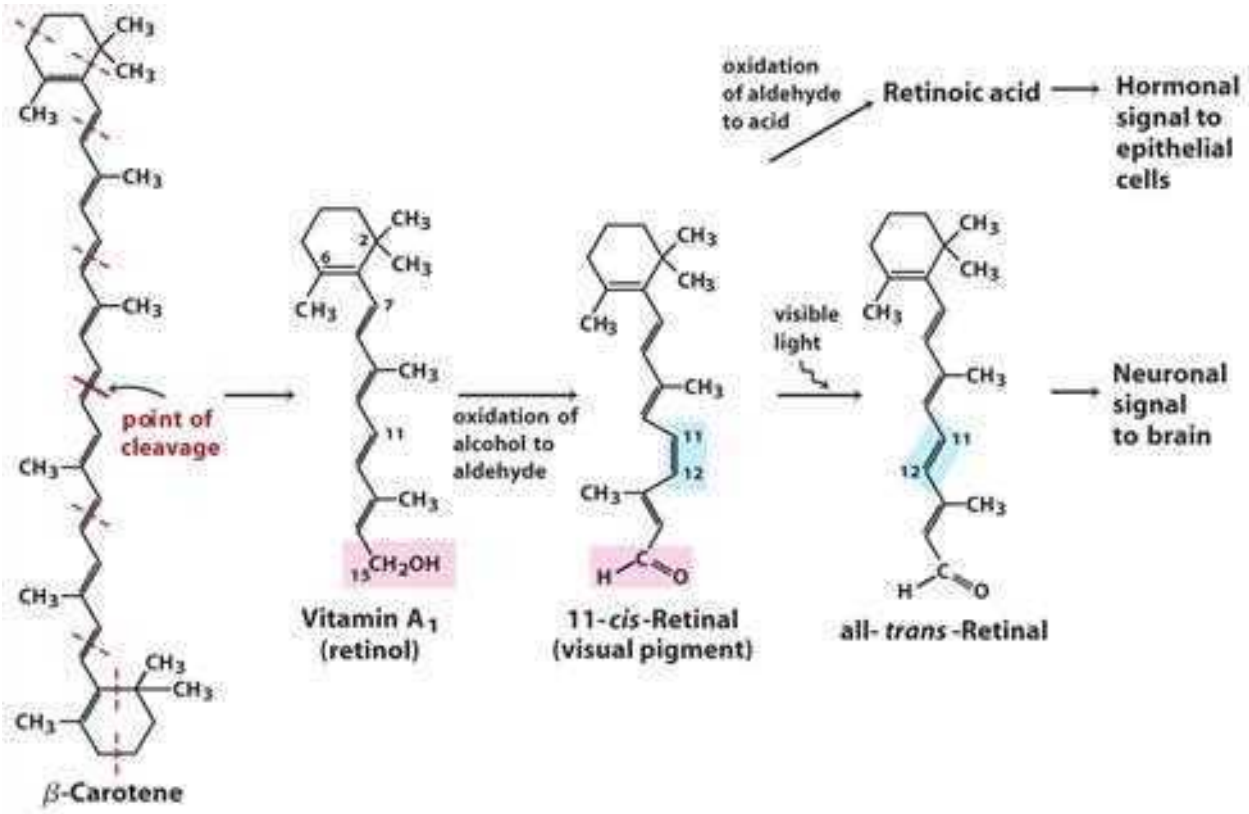
where as sesquiterpenes and diterpenes are less known. The triterpenes are containing 30 carbon atoms and include squaline and lanosterol,



two of the precursors of cholesterol and other steroids.

Tetraterpenes contain 40 carbon atoms include carotenes, a class of colourful photosynthesis, pigments.

β-carotene is the precursor of vitamin A.



Role of Vit. A in vision

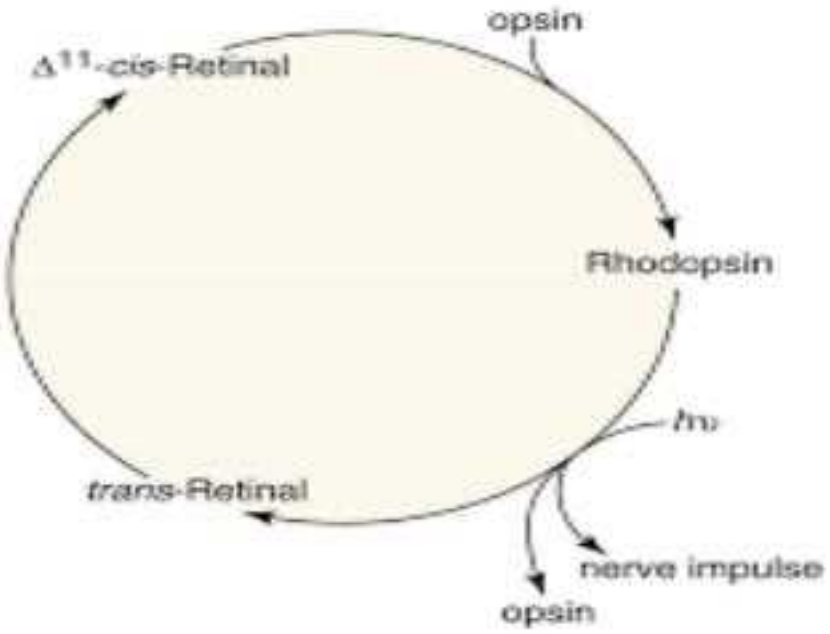


Figure 28.4 Role of vitamin A in vision.