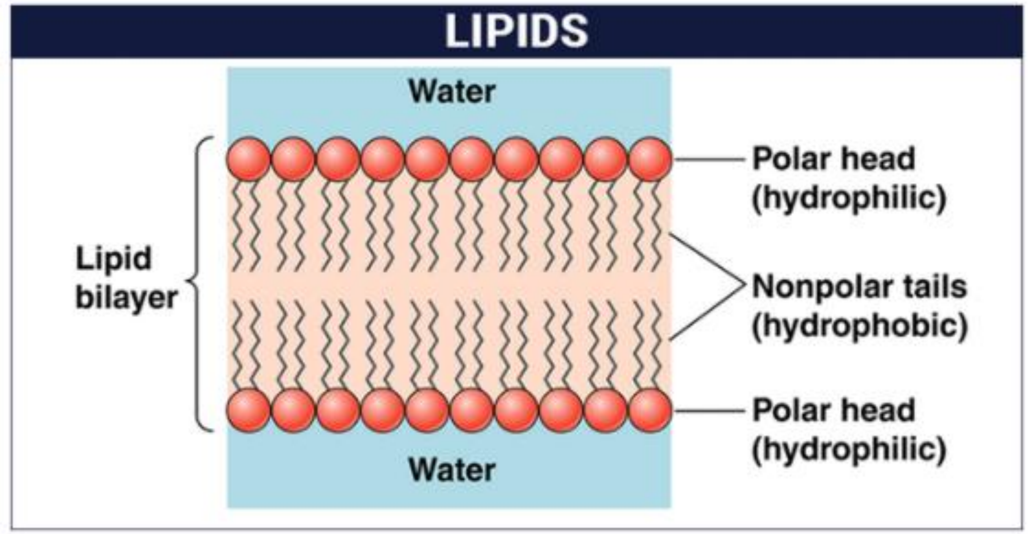
SEC-A2-Analytical clinical biochemistry

Lipids: Classification. Biological importance of triglycerides and phosphoglycerides and cholesterol; Lipid membrane, Liposomes and their biological functions and underlying applications.

Lipids:

The **lipids** are a large and heterogeneous group of substances of biological origin that are easily dissolved in organic solvents such as methanol, acetone, chloroform, and benzene. By contrast, they are either insoluble or only poorly soluble in water. Their low water solubility is due to a lack of polarizing atoms such as O, N, S, and P.

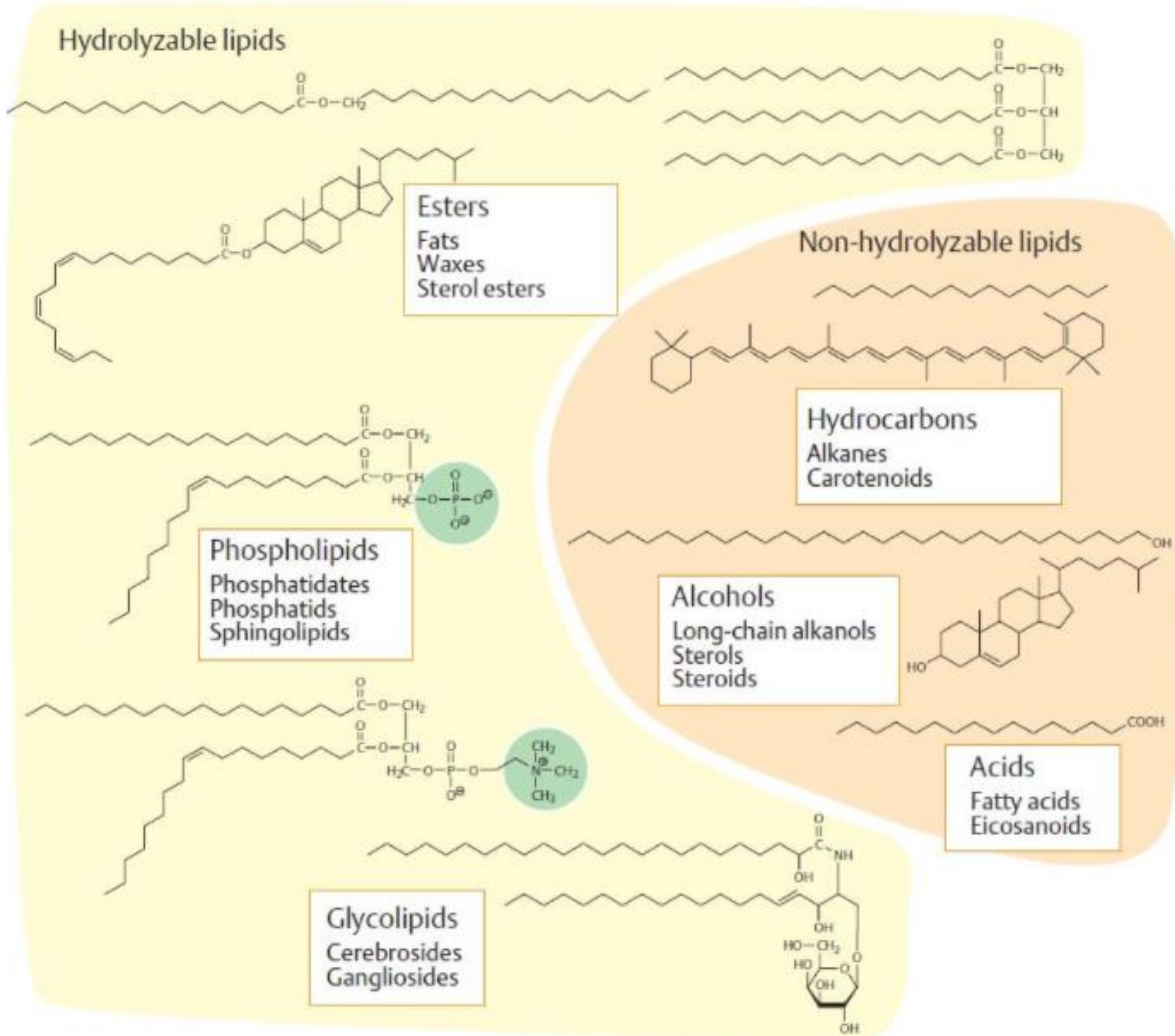


Properties of Lipids:

Lipids are a family of organic compounds, composed of fats and oils. These molecules yield high energy and are responsible for different functions within the human body. Listed below are some important characteristics of Lipids.

- Lipids are oily or greasy nonpolar molecules, stored in the adipose tissue of the body.
- Lipids are a heterogeneous group of compounds, mainly composed of hydrocarbon chains.
- Lipids are energy-rich organic molecules, which provide energy for different life processes.
- Lipids are a class of compounds characterised by their solubility in nonpolar solvents and insolubility in water.
- Lipids are significant in biological systems as they form a mechanical barrier dividing a cell from the external environment known as the cell membrane.

Classification of Lipids: Lipids can be classified into two main classes: i) Nonhydrlyzable and ii) Hydrolyzable.



Nonsaponifiable or non-hydrolyzable Lipids:

A nonsaponifiable lipid cannot be disintegrated into smaller molecules through hydrolysis. Nonsaponifiable lipids include cholesterol, prostaglandins, etc

- The hydrocarbons include the **alkanes** and **carotenoids**.

- The lipid alcohols are also not hydrolyzable. They include long-chained alkanols and cyclic sterols such as cholesterol, and steroids such as estradiol and testosterone. The most important acids among the lipids are fatty acids. The eicosanoids also belong to this group; these are derivatives of the polyunsaturated fatty acid arachidonic acid.

Saponifiable or hydrolyzable Lipids:

A saponifiable lipid comprises one or more ester groups, enabling it to undergo hydrolysis in the presence of a base, acid, or enzymes, including waxes, triglycerides, sphingolipids and phospholipids.

- The simple esters include the **fats** (triacylglycerol; one glycerol + three acyl residues); the **waxes** (one fatty alcohol + one acyl residue); and the **sterol esters** (one sterol + one acyl residue).

- The **phospholipids** are esters with more complex structures. Their characteristic component is a phosphate residue. The phospholipids include the phosphatidic acids (one glycerol + two acyl residues + one phosphate) and the phosphatides (one glycerol + two acyl residues + one phosphate + one amino alcohol).

- In the **sphingolipids**, glycerol and one acyl residue are replaced by sphingosine. Particularly important in this group are the sugar-containing **glycolipids** (one sphingosine + one fatty acid + sugar). The cerebrosides (one sphingosine + one fatty acid + one sugar) and gangliosides (one sphingosine + one fatty acid + several different sugars, including neuraminic acid) are representatives of this group. The components of the hydrolyzable lipids are linked to one another by ester bonds. They are easily broken down either enzymatically or chemically.

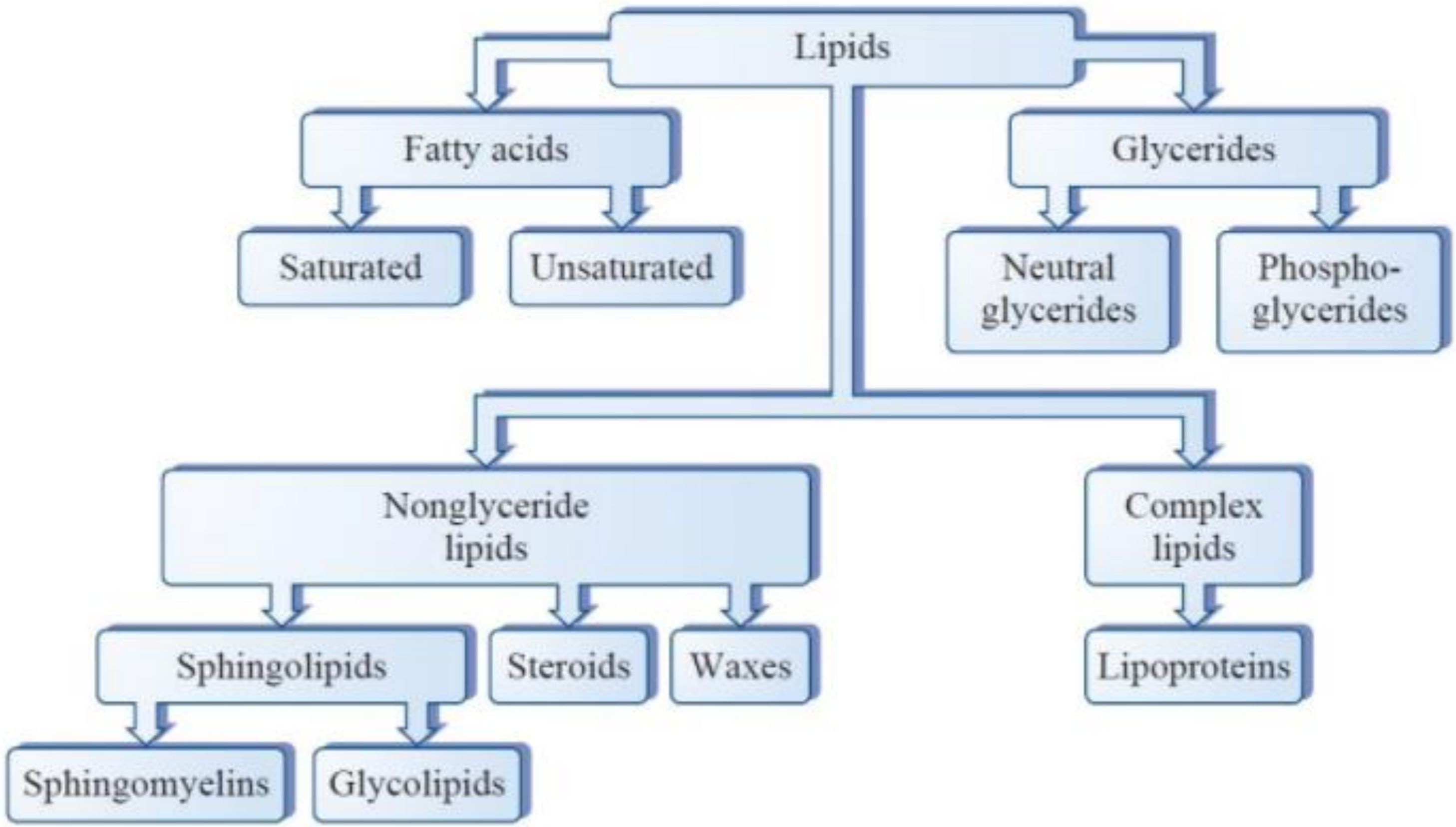
Further, these categories can be divided into non-polar and polar lipids.

- Nonpolar lipids, namely triglycerides, are utilized as fuel and to store energy.
- Polar lipids, that could form a barrier with an external water environment, are utilized in membranes. Polar lipids comprise sphingolipids and glycerophospholipids.
- Fatty acids are pivotal components of all these lipids.

Types of Lipids:

Within these two major classes of lipids, there are numerous specific types of lipids important to live, including fatty acids, triglycerides, glycerophospholipids, sphingolipids and steroids. These are broadly classified as simple lipids and complex lipids.

Lipids are commonly subdivided into four main groups:



Fatty acids (saturated and unsaturated):

- Fatty acids are long-chain monocarboxylic acids. As a consequence of their biosynthesis, fatty acids generally contain an even number of carbon atoms.

- The general formula for a saturated fatty acid is $CH_3(CH_2)_nCOOH$, in which n in biological systems is an even integer.
- An example of an unsaturated fatty acid is the 18-carbon unsaturated fatty acid oleic acid. In the case of unsaturated fatty acids, there is at least one carbon-to-carbon double bond. Because of the double bonds, the carbon atoms involved in these bonds are not "saturated" with hydrogen atoms. The double bonds found in almost all naturally occurring unsaturated fatty acids are in the cis configuration.

Glycerides (glycerol-containing lipids):

- Glycerides are lipid esters that contain the glycerol molecule and fatty acids. They may be subdivided into two classes: neutral glycerides and phosphoglycerides.
- Neutral glycerides are nonionic and nonpolar. Phosphoglyceride molecules have a polar region, the phosphoryl group, in addition to the nonpolar fatty acid tails. The structures of each of these types of glycerides are critical to their function. The esterification of glycerol with a fatty acid produces a neutral glyceride. Esterification may occur at one, two, or all three positions, producing monoglycerides, diglycerides, or triglycerides. Although monoglycerides and diglycerides are present in nature, the most important neutral glycerides are the triglycerides, the major component of fat cells.

- Phospholipids are a group of lipids that are phosphate esters. The presence of the phosphoryl group results in a molecule with a polar head (the phosphoryl group) and a nonpolar tail (the alkyl chain of the fatty acid). Because the phosphoryl group ionizes in solution, a charged lipid results. The most abundant membrane lipids are derived from glycerol-3-phosphate and are known as phosphoglycerides.

Nonglyceride lipids (sphingolipids, steroids, waxes):

- **Sphingolipids** are lipids that are not derived from glycerol. Like phospholipids, sphingolipids are amphipathic, having a polar head group and two nonpolar fatty acid tails, and are structural components of cellular membranes.

- **Steroids** are a naturally occurring family of organic molecules of biochemical and medical interest. The steroids are members of a large, diverse collection of lipids called the isoprenoids. All of these compounds are built from one or more five-carbon units called isoprene.

- **Waxes** are derived from many different sources and have a variety of chemical compositions, depending on the source. Paraffin wax, for example, is composed of a mixture of solid hydrocarbons (usually straight-chain compounds). The natural waxes generally are composed of a long-chain fatty acid esterified to a long-chain alcohol. Because the long hydrocarbon tails are extremely hydrophobic, waxes are completely insoluble in water. Waxes are also solid at room temperature, owing to their high molecular weights.

- Two examples of waxes are myricyl palmitate, a major component of beeswax, and whale oil (spermaceti wax), from the head of the sperm whale, which is composed of cetyl palmitate.

Complex lipids (lipoproteins):

- Complex lipids are lipids that are bonded to other types of molecules. The most common and important complex lipids are plasma lipoproteins, which are responsible for the transport of other lipids in the body.

- Lipids are only sparingly soluble in water, and the movement of lipids from one organ to another through the bloodstream requires a transport system that uses plasma lipoproteins. Lipoprotein particles consist of a core of hydrophobic lipids surrounded by amphipathic proteins, phospholipids, and cholesterol.

Fatty Acids: Lipid Building Blocks: They are long, unbranched chain carboxylic acid carboxylic acids with inear(unbranched) carbon chain - Fatty acids are naturally occuring monocarboxylic acids which nearly all have an even number of carbon atoms.

Saturated fatty acids:

- Even number of Carbon atoms: i) Long chain fatty acids: C12 - C26; ii) Medium chain fatty acids: C6 - C11; iii) Short-chain fatty acids: C4 - C5
- **Numbering** starts from the end of -COOH group

Saturated Fatty Acids	
Caproic Acid (6)	$CH_3(CH_2)_4CO_2H$
Caprylic Acid (8)	$CH_3(CH_2)_6CO_2H$
Capric Acid (10)	$CH_3(CH_2)_8CO_2H$
Lauric Acid (12)	$CH_3(CH_2)_{10}CO_2H$
Myristic Acid (14)	$CH_3(CH_2)_{12}CO_2H$
Palmitic Acid (16)	$CH_3(CH_2)_{14}CO_2H$
Stearic Acid (18)	$CH_3(CH_2)_{16}CO_2H$
Arachidic Acid (20)	$CH_3(CH_2)_{18}CO_2H$
Lignoceric Acid (24)	$CH_3(CH_2)_{22}CO_2H$

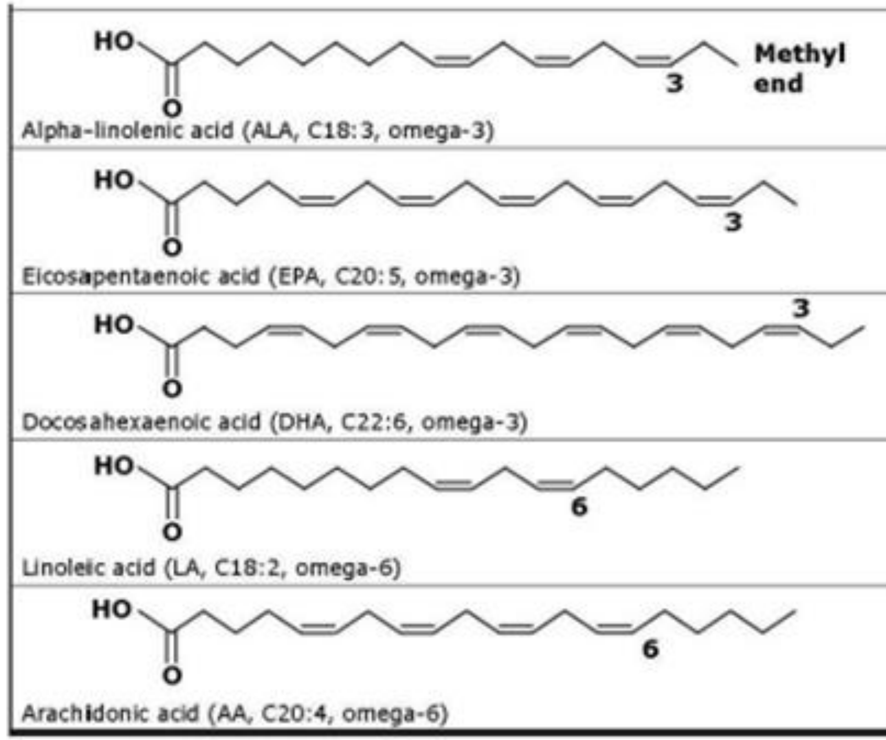
*Occur as major fatty acids in human storage fats.

Unsaturated fatty acids:

Unsaturated Fatty Acids	
Crotonic Acid (4:1)2	$CH_3CH{=}CHCO_2H$
Palmitoleic Acid (16:1)9 OMEGA 7	$CH_3(CH_2)_5CH{=}CH(CH_2)_7CO_2H$
Oleic acid* (18:1)9 OMEGA 9	$CH_3(CH_2)_7CH{=}CH(CH_2)_7CO_2H$

- **Numbering** of unsaturated fatty acids starts from the other end of COOH. See structural notation: it indicates number of C atoms E.g., 18:2 – 18 carbons, 2 double bonds.

- **Monosunsaturated:** one C=C bond. Most abundant is oleic acid (18:1)



- **Polyunsaturated fatty acids**: 2 or more C=C bonds present - up to six double bonds are present in fatty acids. In most unsaturated fatty acids, the cis isomer predominates; the trans isomer is rare and cis configuration imparts lower melting points than their saturated counterparts; the greater the degree of unsaturation, the lower the melting point.

- Scientists differentiate fatty acids by the characteristics of their molecules. The two principal essential fatty acids are Omega-6 (n-6) series and the Omega-3(n-3) series. The number indicates the position of the first double carbon bond when counting from a specified end of the molecule.
- Omega refers to number carbon atoms in the hydrocabon chain at the terminal end of chain after the last double bond.

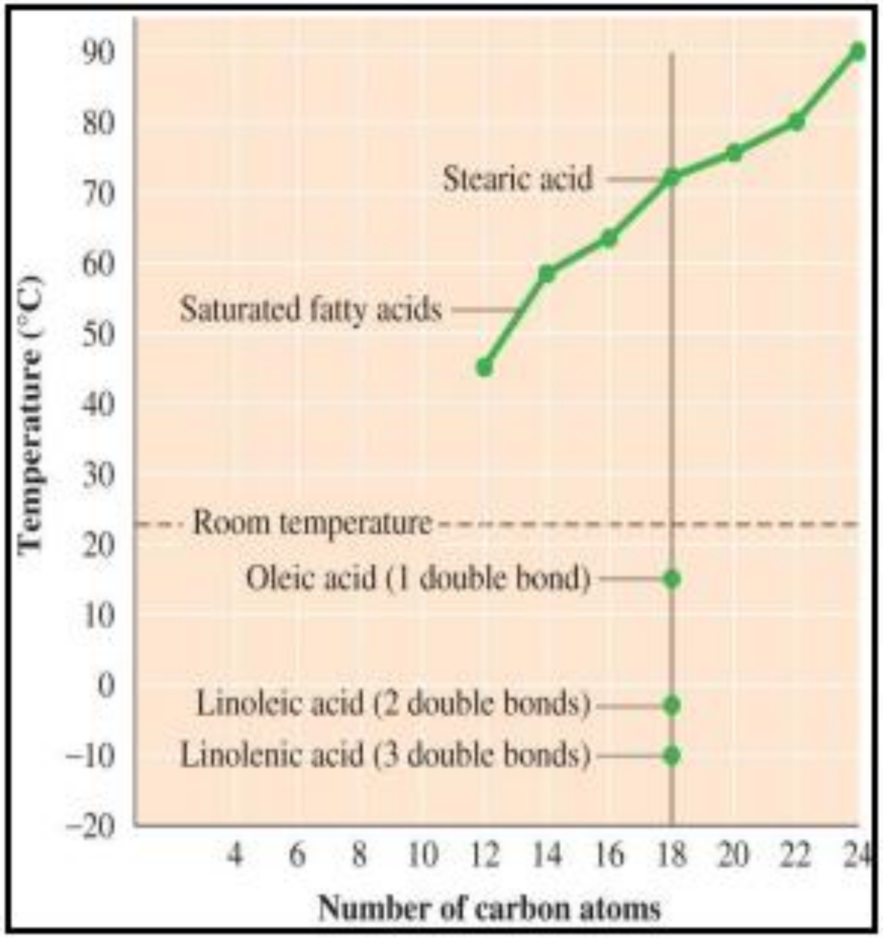
Essential Fatty Acids: Must be part of diet. They are fatty acids that cannot be produced by the body and are necessary for proper metabolism. The OMEGA 6 and OMEGA 3 fatty acids are referred to as Essential Fatty Acids (**EFA**).

- **Omega-6 Series:** Linoleic Acid (LA) -- LA is the essential fatty acid from which Gamma Linolenic Acid (GLA) is derived.
- Gamma linolenic Acid (GLA) -- GLA is found primarily in mother's milk and Evening Primrose seeds. Moderate but variable amounts are found in borage and blackcurrant seeds.
- Dihomogamma linolenic Acid (DGLA) -- DGLA is found in mother's milk and organ meats such as spleens, kidneys and adrenals.
- Arachidonic Acid (AA) -- AA is found in meats, dairy products and seafood such as shrimps and prawns.

- **Omega-3 Series:** Alpha linolenic Acid (ALA) -- ALA is found in green, leafy vegetables and linseed (GLA) oils. Eicosapentaenoic (EPA) -- EPA is found primarily in marine and fish oils. Docosahexaenoic (DHA) -- DHA found primarily in marine and fish oils.

Physical Properties of Fatty Acids:

- **Water solubility**: Short chain fatty acids have some solubility whereas long chain fatty acids are insoluble. Short chain fatty acids are sparingly soluble because of carboxylic acid polar group.
- **Physical properties** such as melting point depends on the number of C atoms and degree unsaturation.
- **Melting Point:** Depends Upon: Length of carbon chain. Also degree of unsaturation (number of double bonds in a molecule.
- Physical properties of triglycerides depend on their fatty acid components Melting point of the triglycerides increases as the number of carbons in their hydrocarbon chains increases and as the number of double bonds decreases.
- Triglycerides rich in unsaturated fatty acids are generally liquid at room temperature and are called oils. Triglycerides rich in saturated fatty acids are generally semisolids or solids at room temperature and are called fats.



Effect of unsaturation on physical properties:

- **Saturated fatty acids:**

Hydrocarbon chains of the saturated fatty acids can lie parallel with strong London dispersion forces between their chains; they pack into well-ordered, compact crystalline forms and melt above room temperature as exemplified in animal facts.

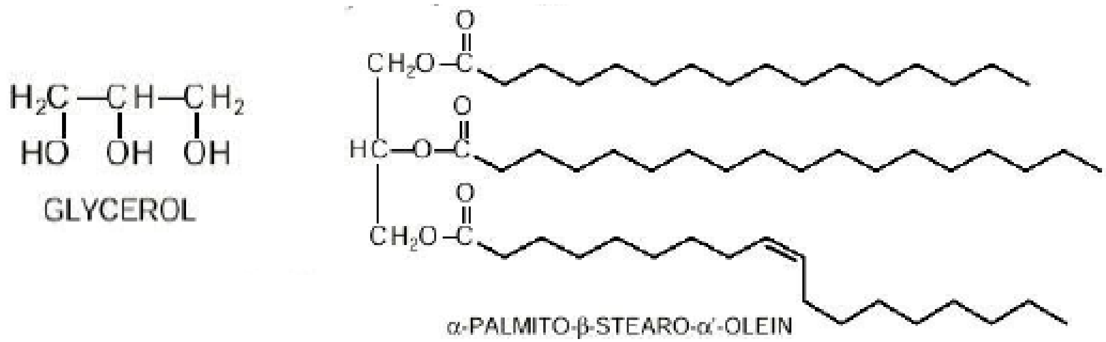
- **Unsaturated fatty acids**

Hydrocarbon chains have a less ordered structure and dispersion forces between them are weaker in unsaturated fatty acids because of the **cis** configuration of the double bonds in unsaturated fatty acids, thei; these triglycerides have melting points below room temperature as exemplified in triglycerides found fish and polar bears.

Energy-Storage Lipids: Triacylglycerols:

- **Simple Triacylglycerols**: Three identical fatty acids are esterified. Naturally occurring simple triacylglycerols are rare.

- **Mixed Triacylglycerols**: A triester formed from the esterification of glycerol with more than one kind of fatty acid. In nature mostly mixed triacylglycerols are found and are different even from the same source depending on the feed, e.g., corn, peanut and wheat -fed cows have different triacylglycerols.



- Triacylglycerols are concentrated primarily in special cells (adipocytes), nearly filled with the material.

- **Dietary Considerations and Triacylglycerols:**

In the past two decades, considerable research has been carried out concerning the role dietary factors as a cause of disease (obesity, diabetes, cancer, hypertension, and atherosclerosis). Numerous studies have shown that, in general, nations whose citizens have hit dietary intakes of triacylglycerols (fats and oils) tend to have higher incidences of her disease and certain types of cancers. This is the reason for concern that the typical Americ; diet contains too much fat and the call for Americans to reduce their total dietary fat intake. According to U.S. Department of Agriculture (USDA) Food Guide or the Dietary Approaches to Stop Hypertension (DASH) Eating Plan, it is recommended for WEIGHT MANAGEMENT a daily diet should have less than 10 percent of calories from saturated fatty acids and less than 300 mg/day of cholesterol, and keep trans fatty acid consumption as low as possible.

Contrary to recommendations, however, there are several areas of the world when high dietary fat intake does not translate into high risks for cardiovascular disease, obesity, and certain types of cancers. These exceptions, which include some Mediterranean; countries and the Inuit people of Greenland, suggest that relationships between direct triglyceride intake and risk factors for disease involve more than simply the total amount of triglycerides taken in.

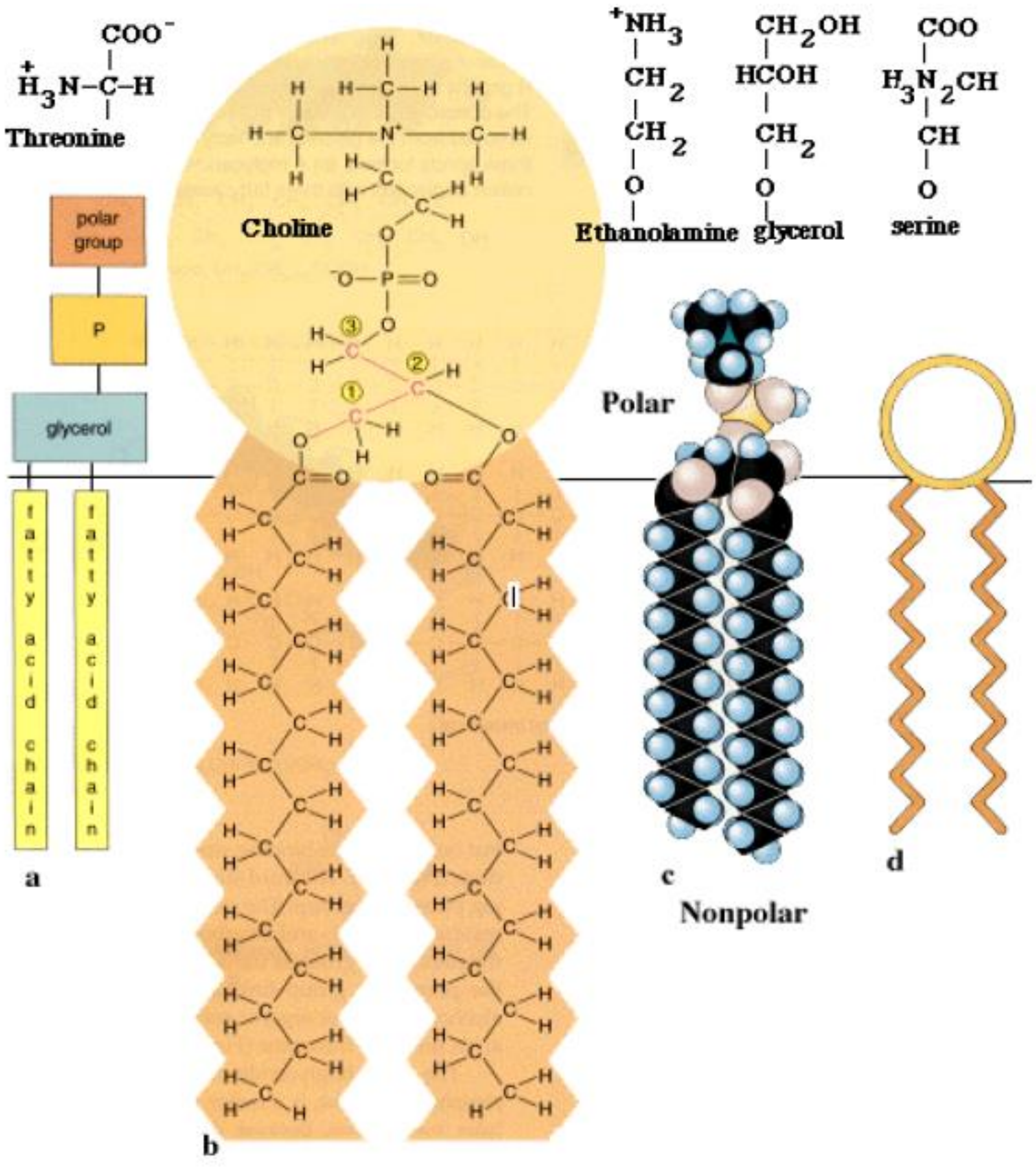
- **Effect of high Fructose Corn Syrup (HFCS) on the Obesity and LDL bad fats in the blood stream:**

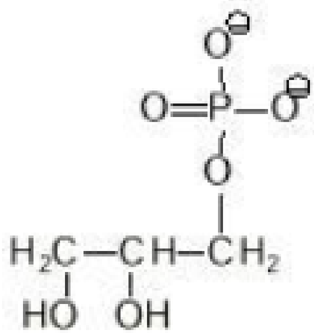
Recent studies indicate Obesity and type 2 diabetes are occurring at epidemic rates in the United States and many parts of the world are could also come from the high fructose levels in the diets. The "obesity epidemic" appears to have emerged largely from changes in our diet to reduce dietary fats and reduced physical activity. An important but not well-appreciated dietary change has been the substantial increase in the amount of dietary fructose consumption from high intake of sucrose and high fructose corn syrup, a common sweetener used in the food industry. A high flux of fructose to the liver, the main organ capable of metabolizing this simple carbohydrate, perturbs glucose metabolism and glucose uptake pathways, and leads to a significantly enhanced rate of triglyceride (TG) in the form of HDL, driven by the high flux of glycerol and acyl portions of TG molecules from fructose breakdown. These metabolic disturbances appear to underlie the induction of insulin resistance commonly observed with high fructose feeding in both humans and animal models. The emerging evidence from recent epidemiological and biochemical studies clearly suggests that the high dietary intake of fructose has rapidly become an important causative factor in the development of the metabolic disorders leading to obesity. **There is an urgent need for increased public awareness** of the risks associated with high fructose consumption and greater efforts should be made to curb the supplementation of packaged foods with high fructose additives.

Membrane Lipids: Phospholipids:

The Primary lipids of biological membranes are Phospholipids, a group of phosphate-containing molecules with structures related to the triglycerides. In most common phospholipids, called phosphoglycerides, glycerol forms the backbone of the molecule but only two of its binding sites link to fatty acid residues. The third site links instead to a bridging phosphate group. The carbon linked to the phosphate group is called the 3-carbon; the carbons attached to fatty acid residues are the 1 and 2 carbons. The other end of the phosphate bridge links to another organic subunit, most commonly a nitrogen-containing alcohol. Other organic subunits that may link at this position include the amino acids serine and threonine and a sugar, inositol.

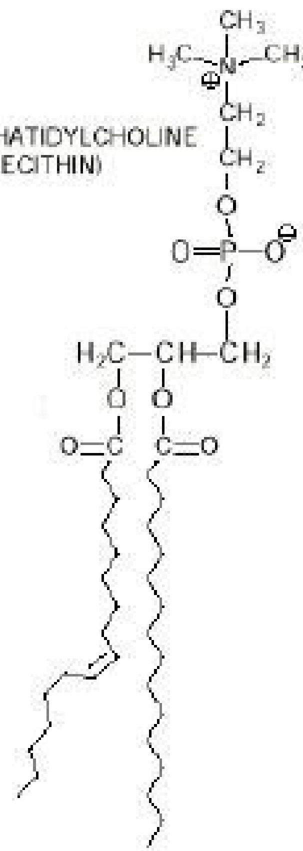
Phosphatidycholine (lecithin) is a major lipid component of cellular membranes. Because different fatty acids may bind at the 1 and 2 carbons of the glycerol residue in phosplipids of this type, phosphatidyl choline is actually a family of closely relate molecules differing in the particular fatty acids present. The colored blocks represents the arrangement of subunits in phospholipids (a). Structure (b) represents the formula for phosphatidy choline, a common membrane phospholipid. (c) is the space-filling model of phosphatidyl choline and (d) is a diagram widely used to depict a phopholipid molecule. The circle represents the polar end of the molecule and the zigzag lines the nompolar carbon chains of the fatty acid residues.

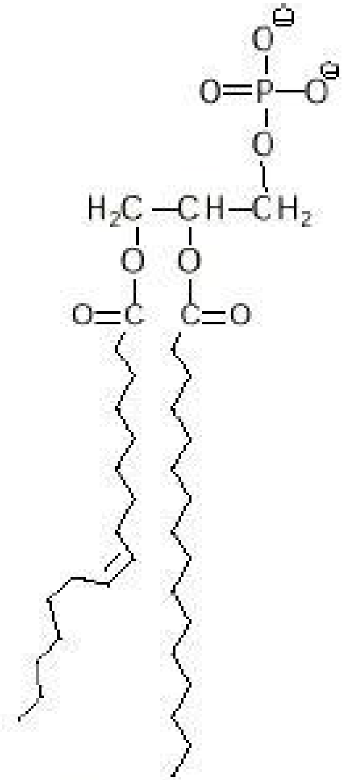

Threonine
Choline
Ethanolamine
glycerol
serine
polar group
P
glycerol
fatty acid chain
fatty acid chain
Polar
Nonpolar
a
b
c
d



GLYCEROL-3-PHOSPHATE

PHOSPHATIDYLCHOLINE
(LECITHIN)



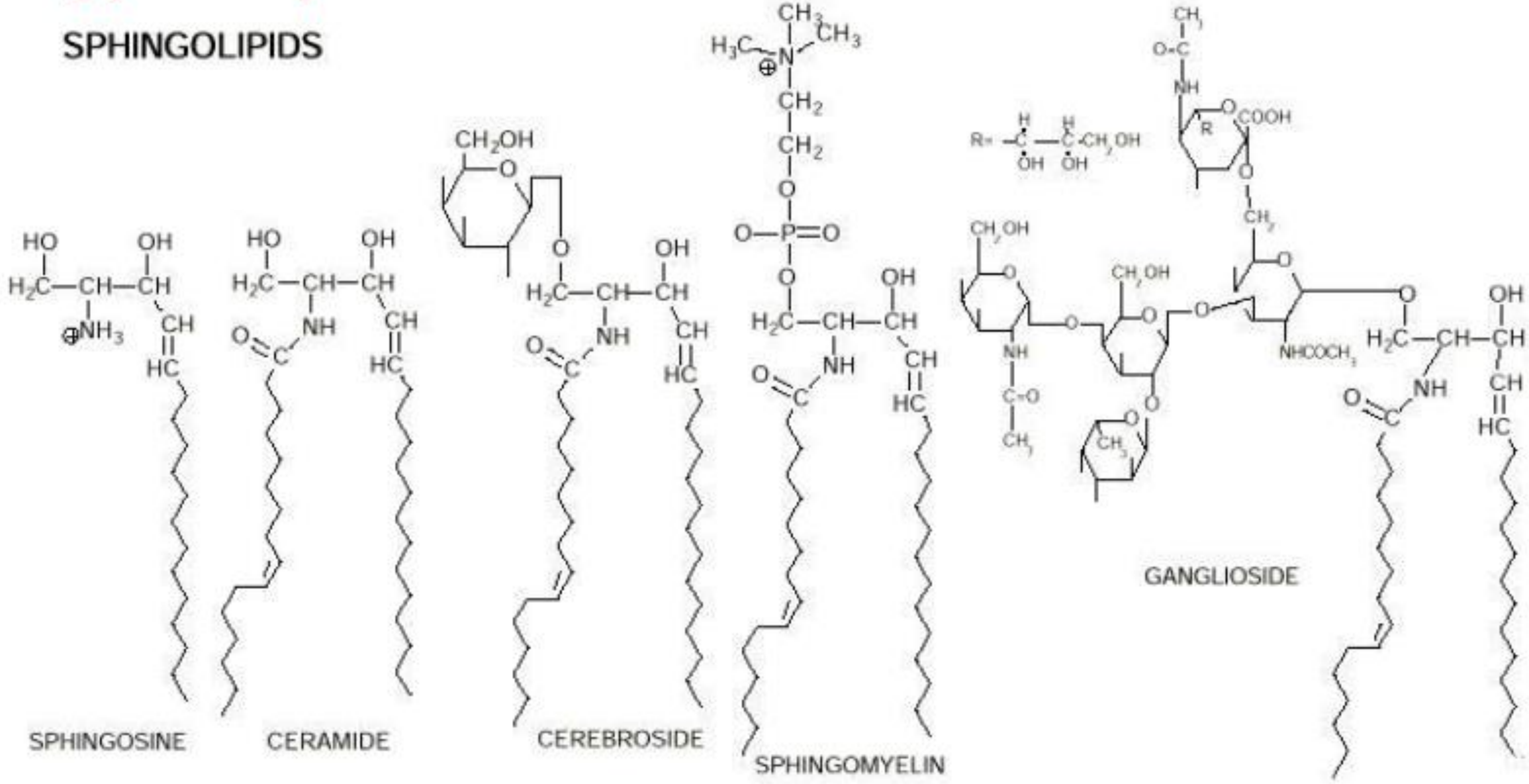


PHOSPHATIDATE

Membrane Lipids: Sphingoglycolipids

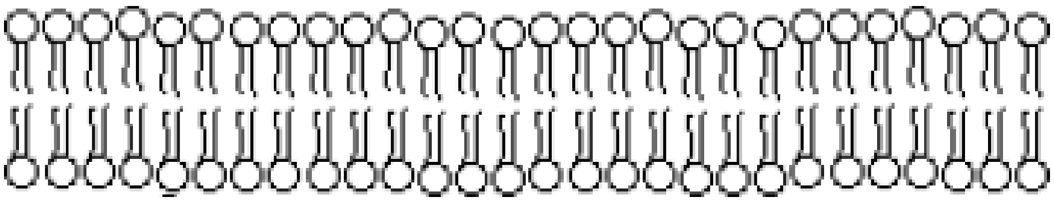
Nonglyceride Lipids

SPHINGOLIPIDS



Membrane Lipids: Planar lipid bilayers:

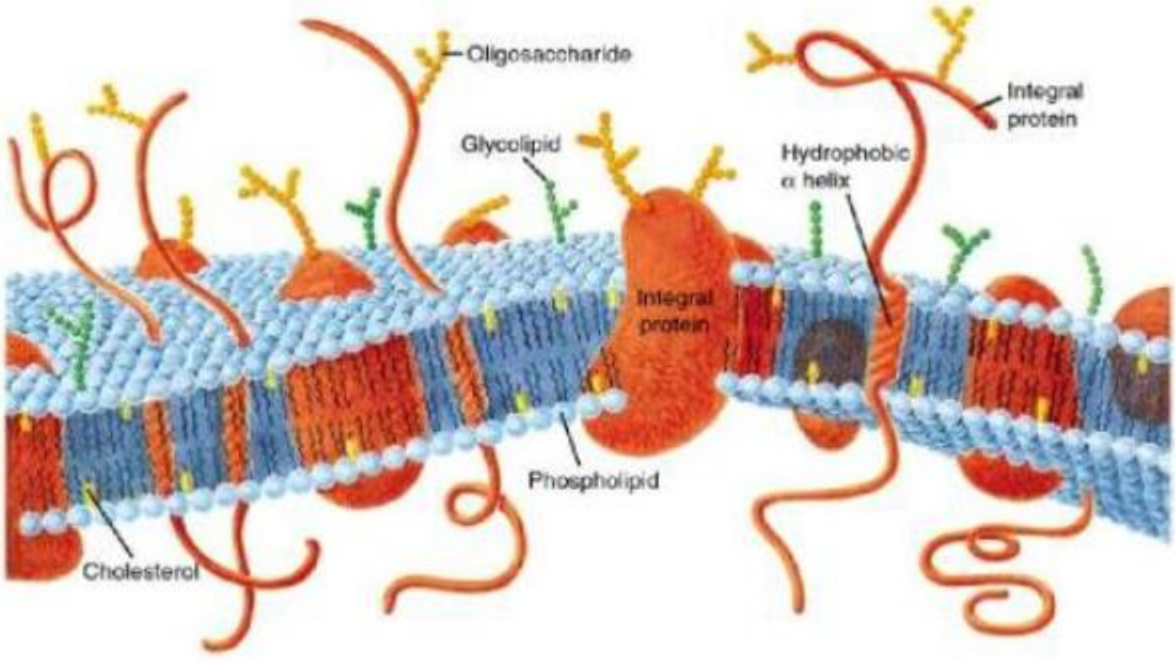
- Biological membranes are bilipid layers . In a real cell the membrane phospholipids create a spherical three dimensional lipid bilayer shell around the cell. However, they are often represented two-dimensionally as:



- Each represents a phospholipid. The circle, or head, is the negatively charged phosphate group and the two tails are the two highly hydrophobic hydrocarbon chains of the phospholipid. The tails of the phospholipids orient towards each other creating a hydrophobic environment within the membrane. This leaves the charged phosphate groups facing out into the hydrophilic environment. The membrane is approximately 5 nm thick. This bilipid layer is semipermeable, meaning that some molecules are allowed to pass freely (diffuse) through the membrane. The lipid bilayer is virtually impermeable to large molecules, relatively impermeable to molecules as small as charged ions, and quite permeable to lipid soluble low molecular weight molecules. Its substantial permeability to water molecules is not well understood. Molecules that can diffuse through the membrane due so at differing rates depending upon their ability to enter the hydrophobic interior of the membrane bilayer.

The Fluid Mosaic Model :

Lipid bilayers are fluid, and individual phospholipids diffuse rapidly throughout the two dimensional surface of the membrane. This is known as the fluid mosaic model of biological membranes (mosaic because it includes proteins, cholesterol, and other types of molecules besides phospholipids). The phospholipids can move to the opposite side of a bacterial cell membrane in a few minutes at room temperature. That's is a distance several thousand times the size of the phospholipid. Membrane proteins diffuse throughout the membrane in the same fashion, though at a slower pace because of their massive size (a phospholipid may be 650 d (daltons, or MW), and a medium sized protein can be 100,000 d). From time to time a given phospholipid will "flip-flop" through the membrane to the opposite side, but this is uncommon. To do so required the hydrophilic head of the phospholipid to pass fully through the highly hydrophobic interior of the membrane, and for the hydrophobic tails to be exposed to the aqueous environment.



Emulsification Lipids: Bile Acids:
Emulsification, Hydrolysis and Micelle Formation:

- Bile salts play their first critical role in lipid assimilation by promoting emulsification. As derivatives of cholesterol, bile salts have both hydrophilic and hydrophobic domains (i.e. they are amphipathic).
- On exposure to a large aggregate of triglyceride, the hydrophobic portions of bile salts intercalate into the lipid, with the hydrophilic domains remaining at the surface. Such coating with bile salts aids in breakdown of large aggregates or droplets into smaller and smaller droplets.
- Hydrolysis of triglyceride into monoglyceride and free fatty acids is accomplished predominantly by pancreatic lipase. The activity of this enzyme is to clip the fatty acids at positions 1 and 3 of the triglyceride, leaving two free fatty acids and a 2-monoglyceride.
- Lipase is a water-soluble enzyme, and with a little imagination, it's easy to understand why emulsification is a necessary prelude to its efficient activity.
- Shortly after a meal, lipase is present within the small intestine in rather huge quantities, but can act only on the surface of triglyeride droplets. For a given volume of lipid, the smaller the droplet size, the greater the surface area, which means more lipase molecules can get to work.
- As monoglycerides and fatty acids are liberated through the action of lipase, they retain their association with bile salts and complex with other lipids to form structures called micelles.

- Micelles are essentially small aggregates of mixed lipids and bile salts suspended within the ingesta. As the ingesta is mixed, micelles bump into the brush border and the lipids, including monoglyceride and fatty acids, are absorbed.
- Lipids are absorbed by a mechanism distinctly different from what we've seen for monosaccharides and amino acids. The major products of lipid digestion - fatty acids and 2-monoglycerides - enter the enterocyte by simply diffusing across the plasma membrane.
- Once inside the enterocyte, fatty acids and monoglyceride are transported into the endoplasmic reticulum, where they are used to synthesize triglyeride! Beginning in the endoplasmic reticulum and continuing in the Golgi, triglyceride is packagedwith cholesterol, lipoproteins and other lipids into particles called chylomicrons.

Cholesterol:

- Cholesterol is a waxy steroid metabolite found in the cell membranes and transported in the blood plasma of all animals. It is an essential structural component of mammalian cell membranes, where it is required to establish proper membrane permeability and fluidity. In addition, cholesterol is an important component for the manufacture of bile acids, steroid hormones, and several fat-soluble vitamins. Cholesterol is the principal sterol synthesized by animals, but small quantities are synthesized in other eukaryotes, such as plants and fungi. It is almost completely absent among prokaryotes, which include bacteria.

- **Atherosclerosis:**

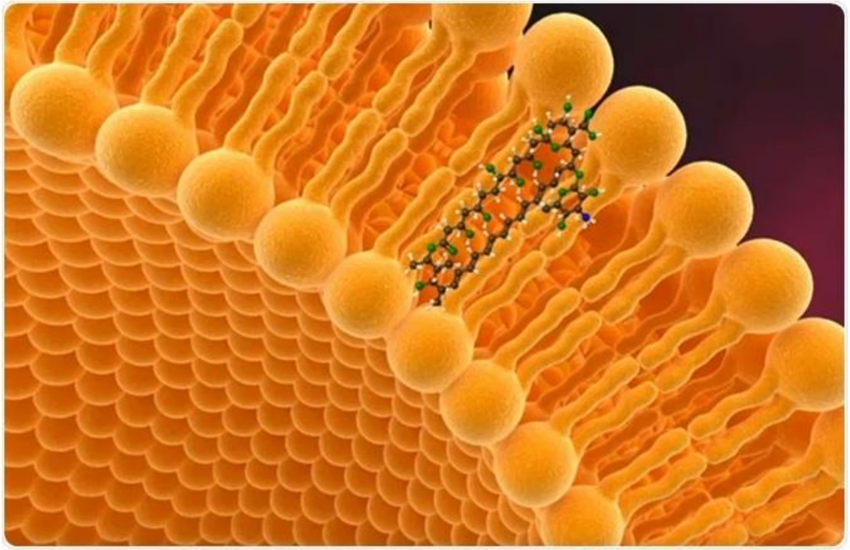
Atherosclerosis is a condition in which patchy deposits of fatty material (atheromas or atherosclerotic plaques) develop in the walls of medium-sized and large arteries, leading to reduced or blocked blood flow. The LDL-cholesterol complex is small and dense compared to chylomicrons and VLDL, and when it is present in high concentrations it tends to deposit inside the blood vessel wall. This contributes to **atherosclerosis** (the build-up of fatty plaque in the arteries; "hardening of the arteries").

- **Bile acids:**

- Bile acids are tri- or dihydroxy cholesterol derivatives. The carbon 17 side chain of cholesterol has been oxidized to a carboxylic acid.

- The oxidized acid side chain is bonded to an amino acid (either glycine or taurine) through an amide linkage. Bile is a fluid containing emulsifying agents (Bile acids) secreted by the liver, stored in the gallbladder, and released into the small intestine during digestion.

Liposome:



A liposome is a spherical-shaped vesicle that is composed of one or more phospholipid bilayers, which closely resembles the structure of cell membranes. The ability of liposomes to encapsulate hydrophilic or lipophilic drugs have allowed these vesicles to become useful drug delivery systems.

The composition of liposomes:

Liposomes can be composed of naturally-derived phospholipids with mixed lipid chains, such as egg phosphatidylethanolamine, or of pure surfactant components like dioleoylphosphatidylethanolamine (DOP). It is common for liposomes to also contain a core aqueous solution that is trapped by one or more bilayers. The phospholipid bilayers of a liposome can originate from natural sources, which are biologically inert, immunogenic and exhibit a lower inherent toxicity.

Classification of liposomes:

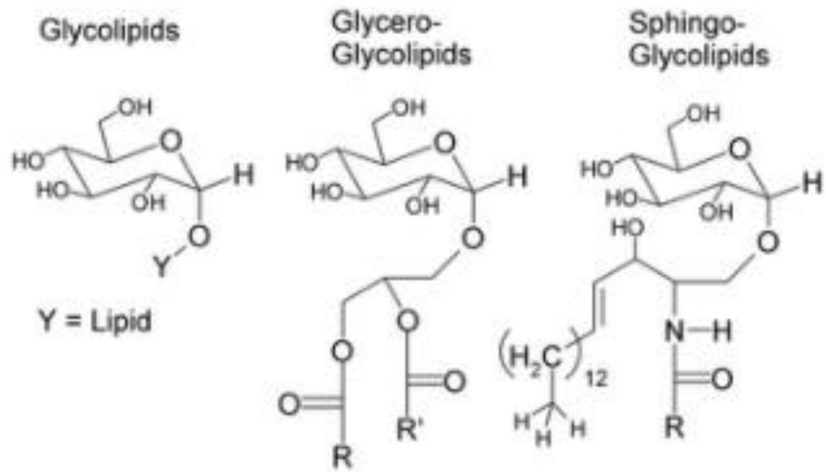
The name liposome is derived from the two Greek words 'lipos,' meaning fat, and 'soma,' meaning body. Liposomes can vary in size from 0.025 micrometers (μm) up to 2.5 μm vesicles. In order to determine the half-life of liposomes, researchers must consider both the size and number of bilayers present within the liposome, as both of these properties play a role in determining the drug encapsulation volume of liposomes.

- Liposomes can be classified as multilamellar vesicles or unilamellar vesicles, which can be further classified as large unilamellar vesicles (LUV) or small unilamellar vesicles (SUV). Unilamellar vesicles contain a single phospholipid bilayer sphere that encloses the aqueous solution, whereas multilamellar liposomes will exhibit multiple phospholipid bilayers.

Glycolipids:

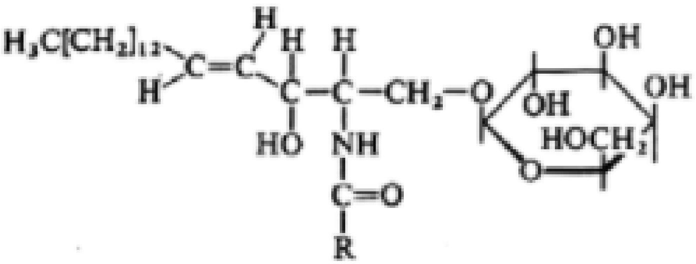
- Glycolipids are components of cellular membranes comprised of a hydrophobic lipid tail and one or more hydrophilic sugar groups linked by a glycosidic bond. Generally, glycolipids are found on the outer leaflet of cellular membranes where it plays not only a structural role to maintain membrane stability but also facilitates cell-cell communication acting as receptors, anchors for proteins and regulators of signal transduction. Glycolipids are found widely distributed throughout all cells and primarily localized, but not exclusively, to the plasma membrane.

- **Structure:** The basic structure of a glycolipid consists of a mono- or oligosaccharide group attached to a sphingolipid or a glycerol group (can be acetylated or alkylated) with one or two fatty acids. These make up the classes of glycosphingolipids and glycoglycerolipids, respectively. Glycolipids interact and bind to the lipid-bilayer through the hydrophobic nature of the lipid tail which anchors it to the surface of the plasma membrane.



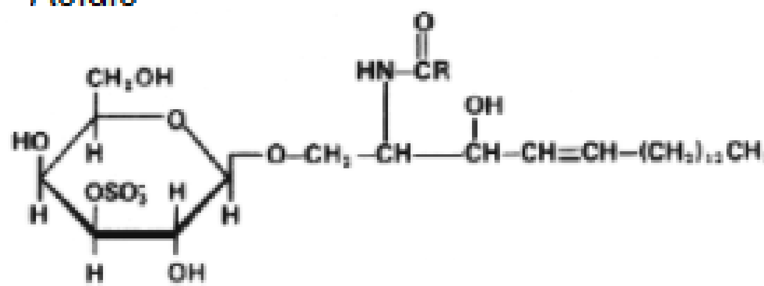
- **Synthesis:** Synthesis of glycolipids proceed by a series of enzymes that sequentially add sugars to the lipid. Glycosphingolipids are derived from lactosylceramide.
- **Degradation:** Degradation of glycosphingolipids are mediated by internalization by endocytosis. They are transported to the lysosomes where enzymes degrade the glycosphingolipids through hydrolytically and irreversible cleavage of bonds. Sphingolipidoses, which are present in the membrane, also mediate the degradation of these class of glycolipids.
- **Location:** The majority of glycolipids are located in membrane structures in the cell. Two-thirds of total glycolipids are distributed in intracellular membranes such as the golgi-apparatus, endosomes, lysosomes, nuclear membrane, and mitochondria.
- **Function:** Carbohydrates on glycolipids are the most exposed structures on the extracellular surface of cells and are flexible with numerous binding sites which make them optimal for cell signaling. Since the lipid moiety is usually buried within the membrane, carbohydrate-carbohydrate interactions are the predominant interactions that may occur between glycolipids. Glycolipids play an important role in several biological functions such as i) **Signal Transduction**; ii) **Cell Proliferation;** iii) **Calcium Signaling.**

- **Types of Glycolipids: Glycosphingolipids:**
- Glycosphingolipids are a class of glycolipids which contain ceramide as the lipid complex. The glycophingolipids can be subdivided into the following groups:
- **Neutral glycosphingolipids**:
- **Acidic glycosphingolipids**:
- **Basic glycosphingolipids**:
- **Amphoteric glycosphingolipids:**

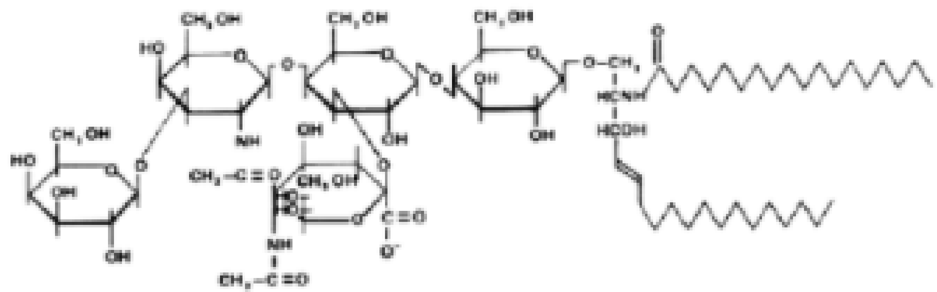


Neutral Glycosphingolipid
(monoglycosylceramide)

Acidic



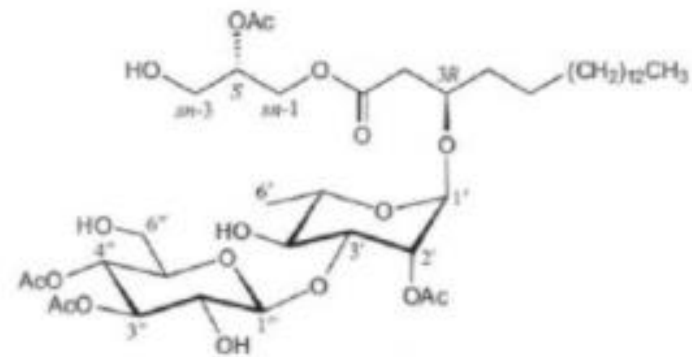
Sulfatide



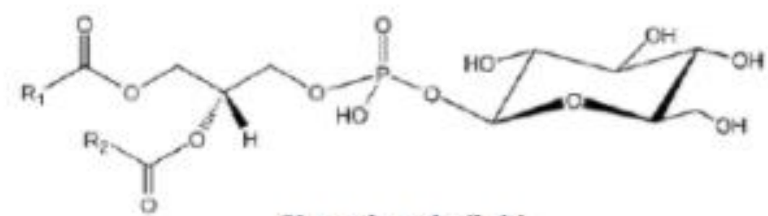
Ganglioside

Glycoglycerolipids: It can be subdivided into the following groups:

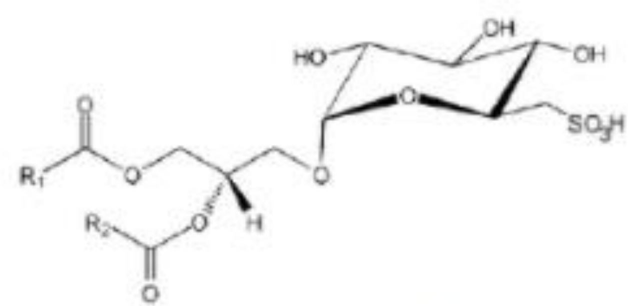
Neutral glycoglycerolipids:
Glycophospholipids:
Sulfoglycoglycerolipids:



Neutral glycoglycerolipid
(2-Acetoxy-1-(3-glycosyloxyoctadecanoyl)glycerol)



Glycophospholipid



Sulfoglycoglycerolipids