

CHEMISTRY OF LIPIDS

Lipids are naturally occurring compounds, relatively insoluble in water but freely soluble in non-polar organic solvents like, benzene, chloroform, ether and alcohol.

Found in animals and plants

Formed of long-chain hydrocarbon groups but may also contain oxygen, phosphorus, nitrogen and sulfur.

Functions

- ❑ Triglycerides are the major storage form of energy
- ❑ Provide essential fatty acids; phospholipids, hormones
- ❑ Form important constituents of cell membrane and helps to maintain the membrane structure and integrity
- ❑ Absorption of vitamin A, D, E and K needs lipids in the diet

- ❑ The basic unit of lipids, acetyl CoA (the active form of acetic acid) is used for the synthesis of cholesterol and hence steroid hormones.
- ❑ Its insulating effect has been utilized in the body for protecting internal organs from shock.
- ❑ Help in blood coagulation
- ❑ Dipalmitoyl lecithin, a phospholipid act as surfactant and is required for the normal functioning of the lung alveoli.

Classification

Simple lipids

- Are the esters of fatty acid with glycerol or higher alcohols.
Examples: fats and waxes

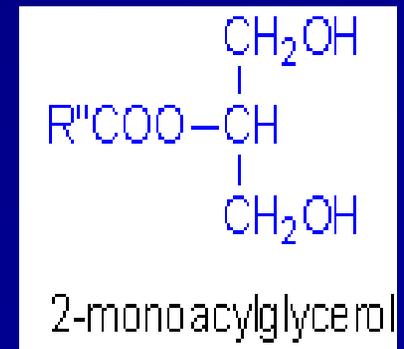
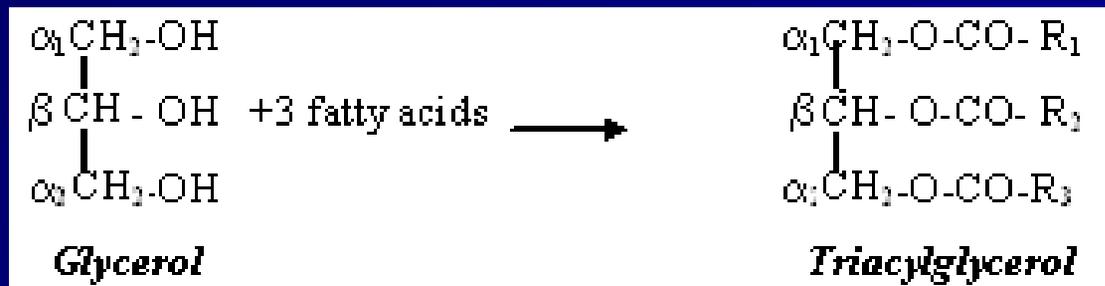
Fats:

Esters of fatty acids with glycerol. A fat in the liquid state is known as oil.

Fat is also called as triglyceride or triacylglycerol

Triacylglycerol :

- All the commercially important fats and oils of animal and plant origin consist exclusively of the simple lipid class triacylglycerols
- Esters of fatty acid with the trihydric alcohol glycerol.
- Glycerol with one molecule of fatty acid is called monoacylglycerol
two molecule of fatty acid is diacylglycerol
three fatty acids is triglyceride



R1, R2 and R3 indicate the fatty acids. The fatty acids may be same or different type. Usually R2 is an unsaturated fatty acid

Waxes: Esters of fatty acids with monohydric long chain alcohols

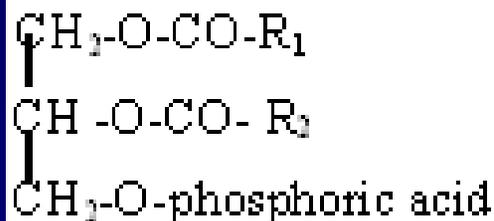
Compound lipids

They are esters of fatty acid with one of the various alcohols and in addition, it contains other groups (non-lipid component).

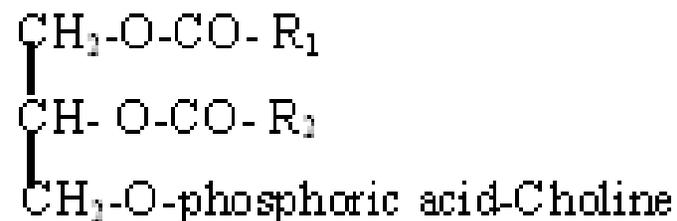
The subclasses are:

a. Phospholipid

compound lipids containing alcohol, fatty acid, phosphoric acid and a nitrogenous base or other alcoholic group.



phosphatidic acid



Lecithin (phosphatidyl choline)

- **Lecithin:** Alcohol + fatty acid + phosphoric acid + choline.
The fatty acid part of R1 is saturated fatty acid and R2 at β position is an unsaturated fatty acid.
Present in brain, nervous tissue, sperm and egg yolk.
Are surface-active agent and help in emulsification of fats.
Dipalmitoyl lecithin is a lung surfactant (lowers surface tension) prevents the collapse of lung alveoli.
Absence of dipalmitoyl lecithin in premature infants may produce respiratory distress syndrome or hyaline membrane disease.
- **Cephalins:** Alcohol+ fatty acid+ phosphoric acid + ethanolamine or serine as a nitrogenous base instead of choline present in lecithin.
- Present in brain, erythrocytes and many other tissues.

- **Phosphatidyl inositol:** Phosphatidic acid + inositol (alcohol) instead of a nitrogenous base.

They are important component of cell membrane.

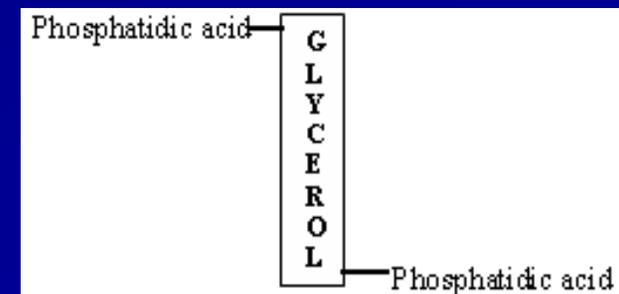
The action of certain hormones (e.g. oxytocin, vasopressin) is mediated through phosphatidyl inositol (PI). In response to hormonal action, PI is cleaved to diacyl glycerol (DAG) and inositol triphosphate (IP3). Both these compounds act as second messenger for hormonal action.

Plasmalogen: They differ from lecithin or cephalin in α 1 position of glycerol where the fatty acid is replaced by a long chain unsaturated aliphatic aldehyde such as palmitic or stearic aldehyde. Plasmalogens are present in large quantities in the skeletal muscle, cardiac muscle and in semen.

- **Cardiolipin:** It is diphosphatidyl glycerol.

Contains two molecules of phosphatidic acid held by glycerol.

Present in the inner mitochondrial membrane and has antigenic properties.



- **Ceramide:** Formed by the esterification of sphingosine with a fatty acid of high molecular weight.

Found in white matter of brain and medullated nerves.

Ceramide is common for all glycolipid and sphingomyelin.

- **Sphingomyelin:** This is a sphingophospholipid.

Does not contain glycerol but a unsaturated amino alcohol, i.e. sphingosine.

They contain a molecule of choline, phosphoric acid and a fatty acid. Sphingomyelin makes up a large part of the myelin sheath. These are also present in brain, lungs, nerve and other tissues.

Deposition of sphingomyelin in liver, lymph nodes, bone marrow and central nervous system results in Neimman-Pick disease. It may be due to the deficiency of sphingomyelinase enzyme in these tissues.

■ **Glycolipids:**

They contain fatty acid, sphingosine (amino alcohol), carbohydrate or carbohydrate derivative.

e.g. Cerebroside, ganglioside

Cerebrosides: Contains fatty acid, sphingosine and a sugar (usually galactose).

Present in white matter of brain and myelin sheath of nerves.

Increased in Gaucher's disease in tissues like reticuloendothelial cells of spleen, liver, lymph node and bone.

Gangliosides: Contains N-acetylneuraminic acid (sialic acid), fatty acid, sphingosine and three molecules of hexoses (glucose or galactose).

Designated as GM1, GM2 etc.

Found in grey matter of the brain

In Tay Sach's disease ganglioside level increases.

Lipoproteins:

The different types of lipoproteins are

- 1] Chylomicron: Transports dietary triglyceride and cholesterol esters from intestine to peripheral tissues and liver
- 2] Very low density lipoprotein (VLDL): Transports endogenous triglyceride from liver to extrahepatic tissues.
- 3] Low density lipoprotein (LDL): Transports cholesterol from liver to extrahepatic tissues
- 4] High density lipoprotein (HDL): Transports cholesterol from extrahepatic tissues back to the liver in an esterified form

Since lipids are water insoluble they are present in the blood in the form of lipoproteins which are water-soluble.

- Composed of triglyceride and cholesterol ester core surrounded by a shell of proteins (also called as Apo proteins), phospholipid and free cholesterol.
- Have an outer polar surface, makes them water-soluble.
- Separated by ultracentrifugation into four distinct groups based on their density (d) and by electrophoresis

Derived lipid:

- Substances derived from above groups by hydrolysis.
E.g. fatty acid, glycerol, alcohol and cholesterol

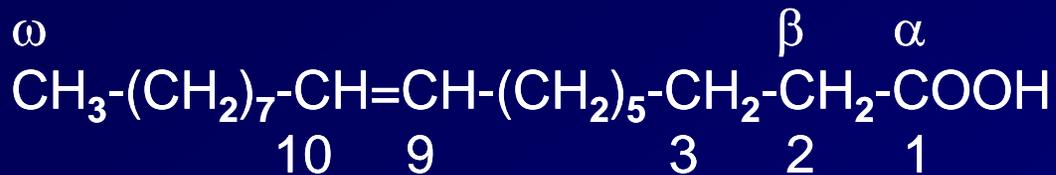
Fatty acids:

- **Definition:** Fatty acids are aliphatic monocarboxylic organic acid with chain length usually ranging from C-4 to C-24 and it is a constituent of lipid. The fatty acids have the general formula R-CO -OH.

Nomenclature: Fatty acids are named after the name of the hydrocarbon with the same number of carbon atoms, with suffix -oic acid for saturated fatty acid and the suffix -enoic acid for the unsaturated fatty acid.

Numbering of a fatty acid

- The Carbon atoms of the fatty acids are numbered from the -COOH group.
- Carboxyl group carbon is C1, and then next carbon atom is C2. The carbon atom adjacent to the -COOH group is also called as α -carbon atom, next carbon atom is β and so on. The last carbon atom or CH₃ group is designated as ω carbon. For example oleic acid is written as 18:1;9 or Δ^9 , 18:1

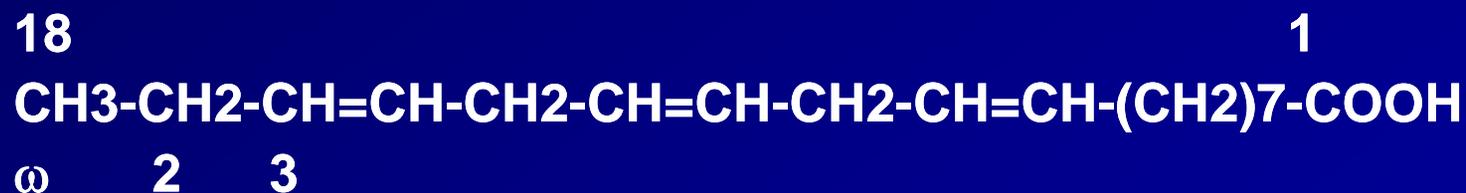


Oleic acid (18:1; 9) or Δ^9 , 18:1 indicates fatty acid having 18 carbon with one double bond at carbon atom 9. The position of the double can also be indicated by the symbol Δ followed by the position of the double bond in superscript.

The linoleic acid is called ω 6 series because of the presence of first double bond from ω 6 carbon at the 6th carbon



Linolenic acid is ω - 3 series



Arachidonic acid is ω - 6 series



Classification of fatty acids:

Saturated Fatty acid

No double bond.

e.g. Acetic acid (2 carbon atoms), butyric acid (C4)

Palmitic acid (C16), stearic acid (C18) & lignoceric acid (C24)

Unsaturated fatty acids:

Have double bonds

They are further classified into

Monounsaturated fatty acid [MUFA] : Contains one double bond e.g. Palmitoleic acid (C16, Δ^9), Oleic acid (C18, Δ^9)

Polyunsaturated fatty acids [PUFA] : Contains more than one double bond

e.g. Linoleic acid (C18, $\Delta^{9,12}$), linolenic acid (C18, $\Delta^{9,12,15}$) and arachidonic acid (C20, $\Delta^{5,8,11,14}$)

Essential fatty acids or PUFA:

- ❖ Not synthesized in the body and should be supplied through diet.
- ❖ Contain more than one double bond.
- ❖ Eg: Linoleic acid, linolenic acid and arachidonic acid.
- ❖ These are not synthesised in human body due to lack of the desaturase enzyme, which introduces double bonds beyond 9th and 10th carbon atoms.

Glycerol

- It is a trihydric alcohol [three hydroxyl groups].
- It is a gluconeogenic substance.

Steroids

- Found in association with lipids.
- Having special ring, cyclopentano perhydrophenanthrene nucleus
- Eg. Steroid hormone, bile acid, vitamin D.

Cholesterol

- One of the important steroids present in the body.
- Has 27 carbon, an -OH group, a double bond, two methyl groups at C10 and C13 and a side chain at C17
- Precursor of various compounds such as vitamin D3, bile acids and adrenocortical and sex hormones.
- Cholesterol is widely distributed in all cells of the body but nervous tissue is rich in cholesterol.
- Steroids containing one or more -OH groups are known as sterols.

- Normal fasting serum cholesterol level is 150-200 mg/dl.
- It is synthesised in our body using acetyl CoA as precursor
- Cholesterol exists in free and ester form. Cholesterol gets esterified through esterase enzymes.
- Excess is harmful to body, it gets deposited in the intima of the arteries producing atherosclerosis. This can narrow the lumen of blood vessel impeding blood flow, which cause thrombosis.

Functions of cholesterol

- Cholesterol if maintained in normal level it has number of good effects. They are,
- It is a precursor for the synthesis of bile acids in liver.
- The steroid hormone in adrenal cortex and sex hormones in gonads are mainly synthesized from cholesterol.

- Cholesterol form 7 dehydrocholesterol in skin, it is converted to vitamin D3 by UV rays.
- It is a poor conductor of heat and hence acts as an insulator
- Cholesterol is abundant in brain and nervous tissue where it functions as an insulating covering for structure, which generates and transmits electrical impulse.

Properties of lipids:

- Oils and fats (lipids) are similar in nature. Oils and lipids are different only in their physical property. Triglycerides, which contain a higher proportion of unsaturated fatty acid or short chain fatty acid, are liquid at 20°C and are usually called as oils, e.g. vegetable oils.
- Fats on the other hand are solid at room temperature and contain saturated long chain fatty acid e.g. animal fat

Reference: Essentials of Biochemistry

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