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# LIPIDS

BY

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ZOOLOGY: SEM- III, PAPER- C7T: FUNDAMENTALS OF BIOCHEMISTRY, UNIT 1: CARBOHYDRATES



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## **Lipid Definition:**

Lipids are a heterogeneous group of organic compounds that contain hydrogen, carbon, and oxygen atoms, which forms the framework for the structure and function of living cells.

## **Properties of Lipids:**

- Lipids are non-polar molecules, which are insoluble in water i.e. hydrophobic and soluble in non-polar organic solvents like



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alcohol, chloroform, acetone, benzene, etc. because water is a polar molecule.

- Lipids are a family of organic compounds, composed of fats and oils.
- They naturally occur in most plants, animals, microorganisms and are used as cell membrane components, energy storage molecules, insulation, and hormones.
- In the human body, these molecules can be synthesized in the liver and are found in oil, butter, whole milk, cheese, fried foods, and also in some red meats. These molecules yield high



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energy and are responsible for different functions within the human body.

- Lipids are oily or greasy non polar 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.



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- Lipids are significant in biological systems as they form for a mechanical barrier dividing a cell from the external environment known as the cell membrane.
- Lipids may be either liquids or non-crystalline solids at room temperature.
- Pure fats and oils are colorless, odorless, and tasteless.
- They have no ionic charges.
- Solid triglycerols (Fats) have high proportions of saturated fatty acids.



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- Liquid triglycerols (Oils) have high proportions of unsaturated fatty acids.
- Lipids play many roles in cells, including serving as energy storage (fats/oils), constituents of membranes (glycerophospholipids, sphingolipids, cholesterol), hormones (steroids), vitamins (fat soluble), oxygen/ electron carriers (heme), among others.
- For lipids that are very hydrophobic, such as fats/ oils, movement and storage in the aqueous environment of the body requires special structures.



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- Other, amphipathic lipids, such as glycerophospholipids and sphingolipids spontaneously organize themselves into lipid bilayers when placed in water. Majority of the lipids can be derived from acetyl-CoA.
- The functions of lipids include storing energy, signaling, and acting as structural components of cell membranes.
- Lipids also have applications in the cosmetic and food industries as well as in nanotechnology.
- Some of the main properties of Lipids are:



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**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 lipa-ses. Alkaline hydrolysis is termed saponification because one of the products of the hydrolysis is a soap, generally sodium or potassium salts of fatty acids.





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**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.

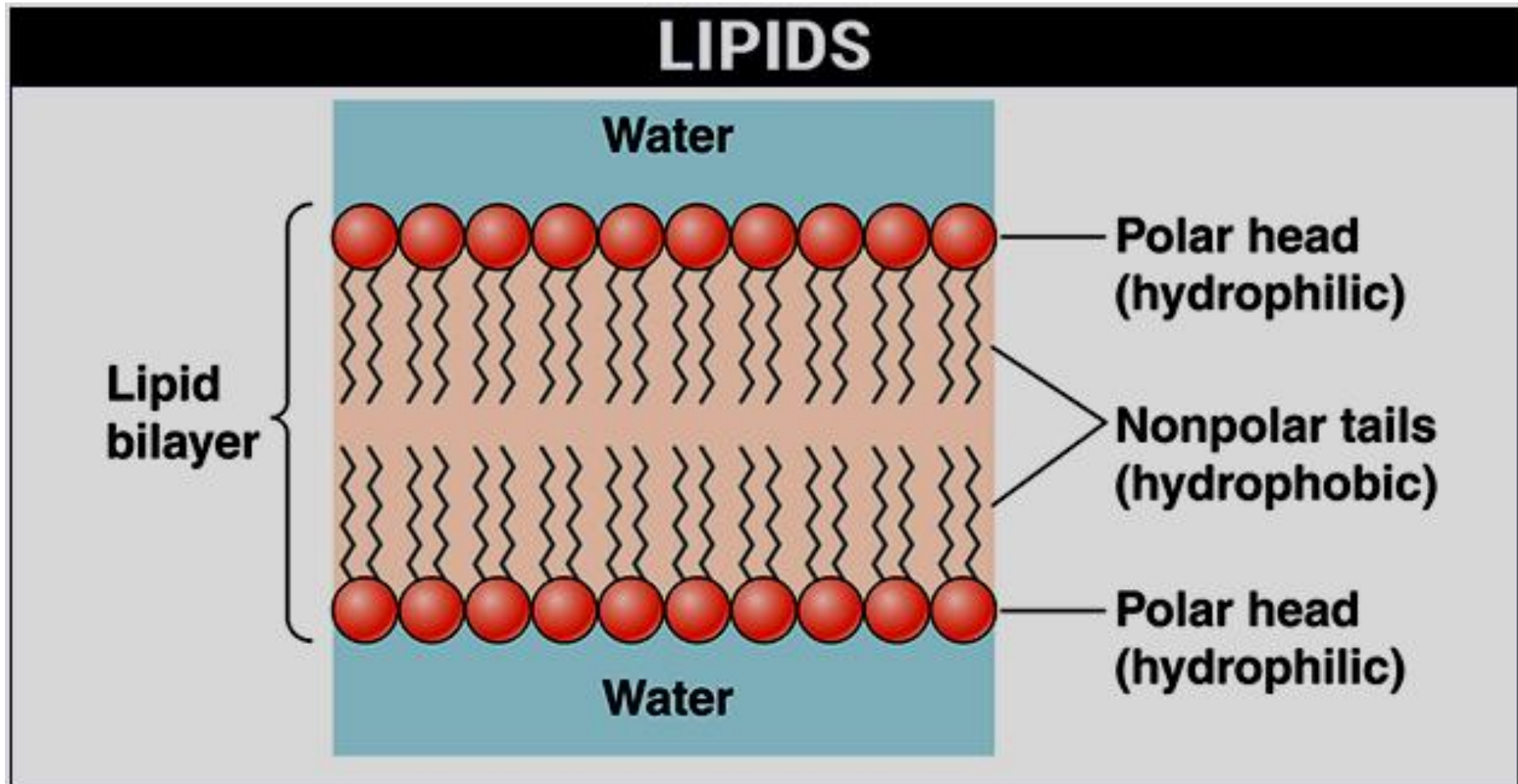


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**5. Rancidity:** The term rancid is applied to any fat or oil that develops a disagreeable odor. Hydrolysis and oxidation reactions are responsible for causing rancidity. Oxidative rancidity occurs in triacylglycerols containing unsaturated fatty acids.

## Structure of Lipids:

- ❖ Lipids are made of the elements Carbon, Hydrogen and Oxygen, but have a much lower proportion of water than other molecules such as carbohydrates.





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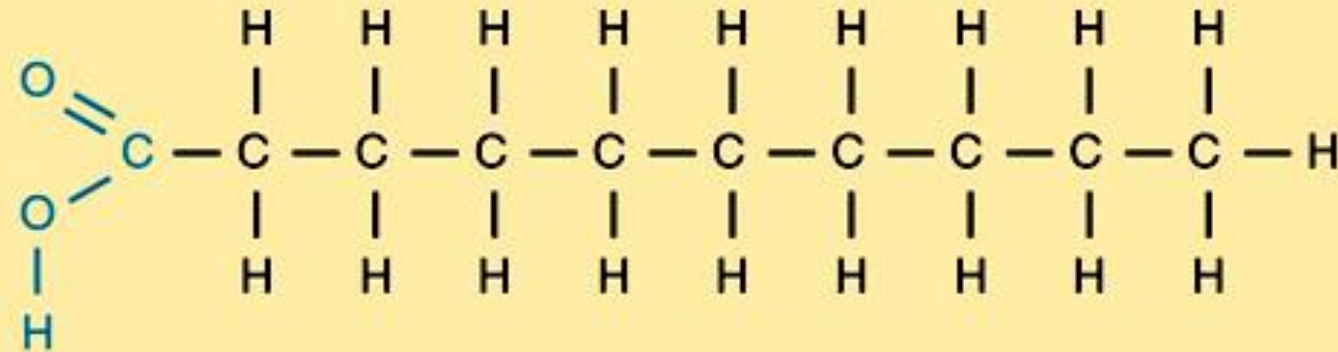
- ❖ Unlike polysaccharides and proteins, lipids are not polymers—they lack a repeating monomeric unit.
- ❖ They are made from two molecules: Glycerol and Fatty Acids.
- ❖ A glycerol molecule is made up of three carbon atoms with a hydroxyl group attached to it and hydrogen atoms occupying the remaining positions.
- ❖ Fatty acids consist of an acid group at one end of the molecule and a hydrocarbon chain, which is usually denoted by the letter 'R'.
- ❖ They may be saturated or unsaturated.



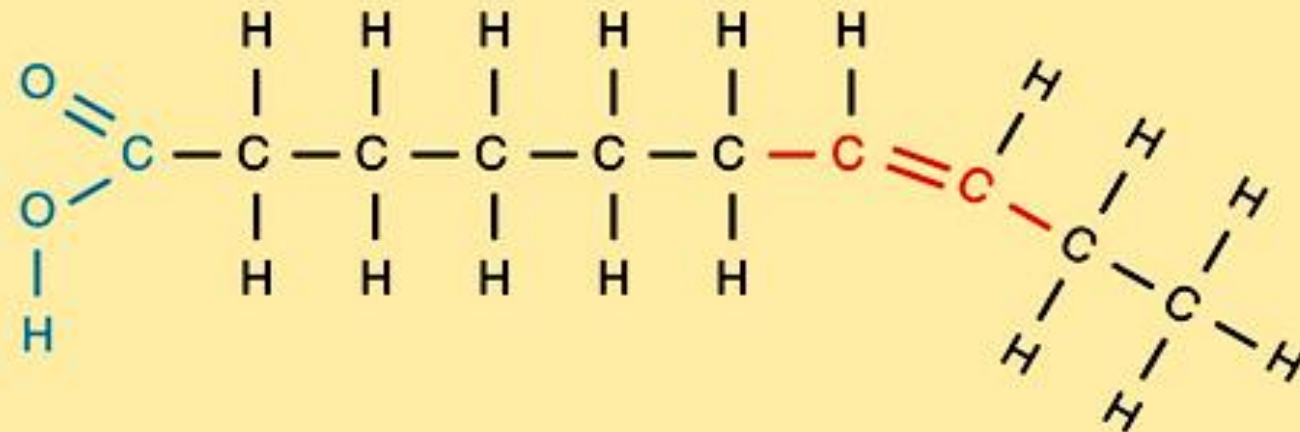
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- ❖ A fatty acid is saturated if every possible bond is made with a Hydrogen atom, such that there exist no C=C bonds.
- ❖ Unsaturated fatty acids, on the other hand, do contain C=C bonds. Monounsaturated fatty acids have one C=C bond, and polyunsaturated have more than one C=C bond.
- ❖ Lipids are the polymers of fatty acids that contain a long, non-polar hydrocarbon chain with a small polar region containing oxygen.
- ❖ The lipid structure is explained in the diagram below:

(a) Saturated



(b) Unsaturated



## Lipid Structure – Saturated and Unsaturated Fatty Acids



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## Structure of Triglycerides:

- ✓ Triglycerides are lipids consisting of one glycerol molecule bonded with three fatty acid molecules.
- ✓ The bonds between the molecules are covalent and are called Ester bonds.
- ✓ They are formed during a condensation reaction.
- ✓ The charges are evenly distributed around the molecule so hydrogen bonds do not form with water molecules making them insoluble in water.



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## Classification of Lipids:

Lipids can be classified into two main classes:

- Non saponifiable lipids, and
- Saponifiable lipids.

### 1. Non saponifiable Lipids:

A non saponifiable lipid cannot be disintegrated into smaller molecules through hydrolysis. Non saponifiable lipids include cholesterol, prostaglandins etc





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## 2. Saponifiable Lipids:

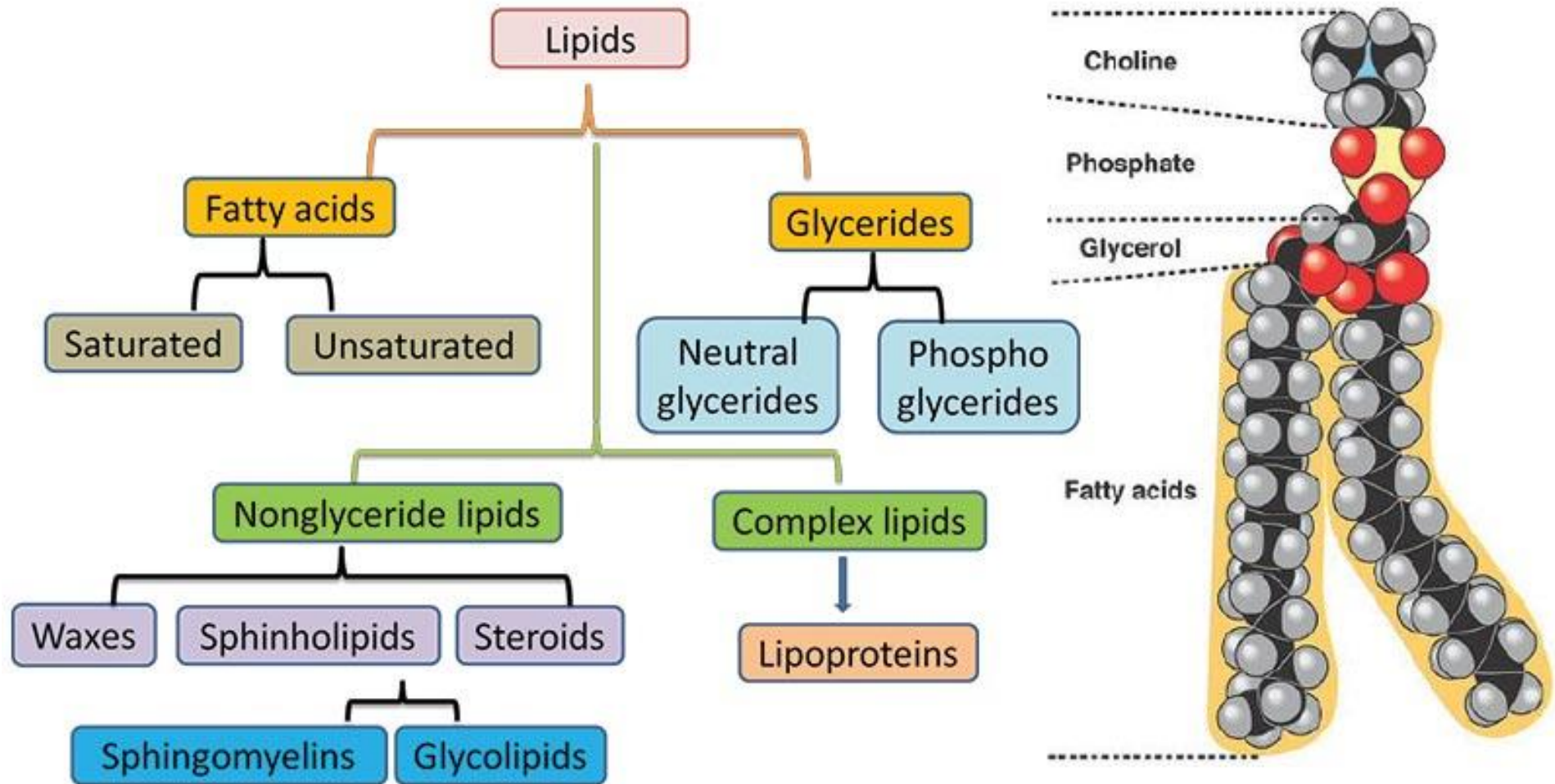
A saponifiable lipid comprises one or more ester groups, enabling it to undergo hydrolysis in the presence of a base, acid, or enzymes, including waxes, triglycerides, sphingolipids, and phospholipids.

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



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-  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.





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## Types of Lipids:

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

### Simple Lipids

Esters of fatty acids with various alcohols.



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1. **Fats:** Esters of fatty acids with glycerol. Oils are fats in the liquid state
2. **Waxes:** Esters of fatty acids with higher molecular weight monohydric alcohols

## Complex Lipids

Esters of fatty acids containing groups in addition to alcohol and a fatty acid.



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1. **Phospholipids:** These are lipids containing, in addition to fatty acids and alcohol, a phosphoric acid residue. They frequently have nitrogen-containing bases and other substituents, eg, in glycerophospholipids the alcohol is glycerol and in sphingophospholipids the alcohol is sphingosine.
2. **Glycolipids (glycosphingolipids):** Lipids containing a fatty acid, sphingosine, and carbohydrate.
3. **Other complex lipids:** Lipids such as sulfolipids and amino lipids. Lipoproteins may also be placed in this category



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## Precursor and Derived Lipids

These include fatty acids, glycerol, steroids, other alcohols, fatty aldehydes, and ketone bodies, hydrocarbons, lipid-soluble vitamins, and hormones. Because they are uncharged, acylglycerols (glycerides), cholesterol, and cholesteryl esters are termed neutral lipids. These compounds are produced by the hydrolysis of simple and complex lipids.

Some of the different types of lipids are described below in detail.



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## Fatty Acids

Fatty acids are carboxylic acids (or organic acid), usually with long aliphatic tails (long chains), either unsaturated or saturated.

### . Saturated fatty acids

Lack of carbon-carbon double bonds indicates that the fatty acid is saturated. The saturated fatty acids have higher melting points compared to unsaturated acids of the corresponding size due to their ability to pack their molecules together thus leading to a straight rod-like shape.





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## . Unsaturated fatty acids

Unsaturated fatty acid is indicated when a fatty acid has more than one double bond.

“Often, naturally occurring fatty acids possesses an even number of carbon atoms and are unbranched.”

On the other hand, unsaturated fatty acids contain a cis-double bond(s) which create a structural kink that disables them to group their molecules in straight rod-like shape.



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## Role of Fats

Fats play several major roles in our body. Some of the important roles of fats are mentioned below:

- Fats in the correct amounts are necessary for the proper functioning of our body.
- Many fat-soluble vitamins need to be associated with fats in order to be effectively absorbed by the body.
- They also provide insulation to the body.
- They are an efficient way to store energy for longer periods.



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## Waxes

Waxes are “esters” (an organic compound made by replacing the hydrogen with acid by an alkyl or another organic group) formed from long-alcohols and long-chain carboxylic acids.

Waxes are found almost everywhere. Fruits and leaves of many plants possess waxy coatings, that can safeguard them from small predators and dehydration.

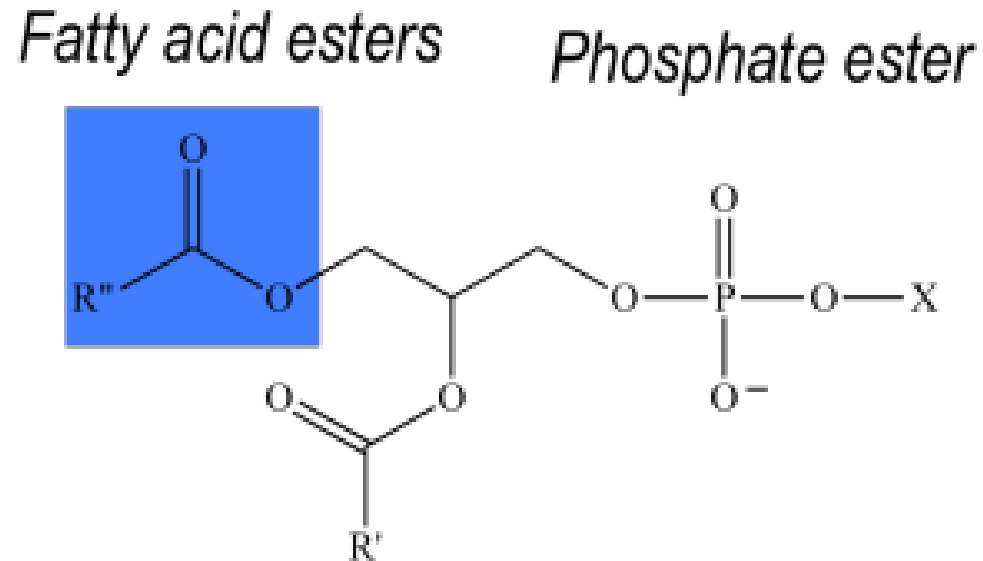
Fur of a few animals and the feathers of birds possess same coatings serving as water repellants.



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Carnauba wax is known for its water resistance and toughness (significant for car wax).

## Phospholipids





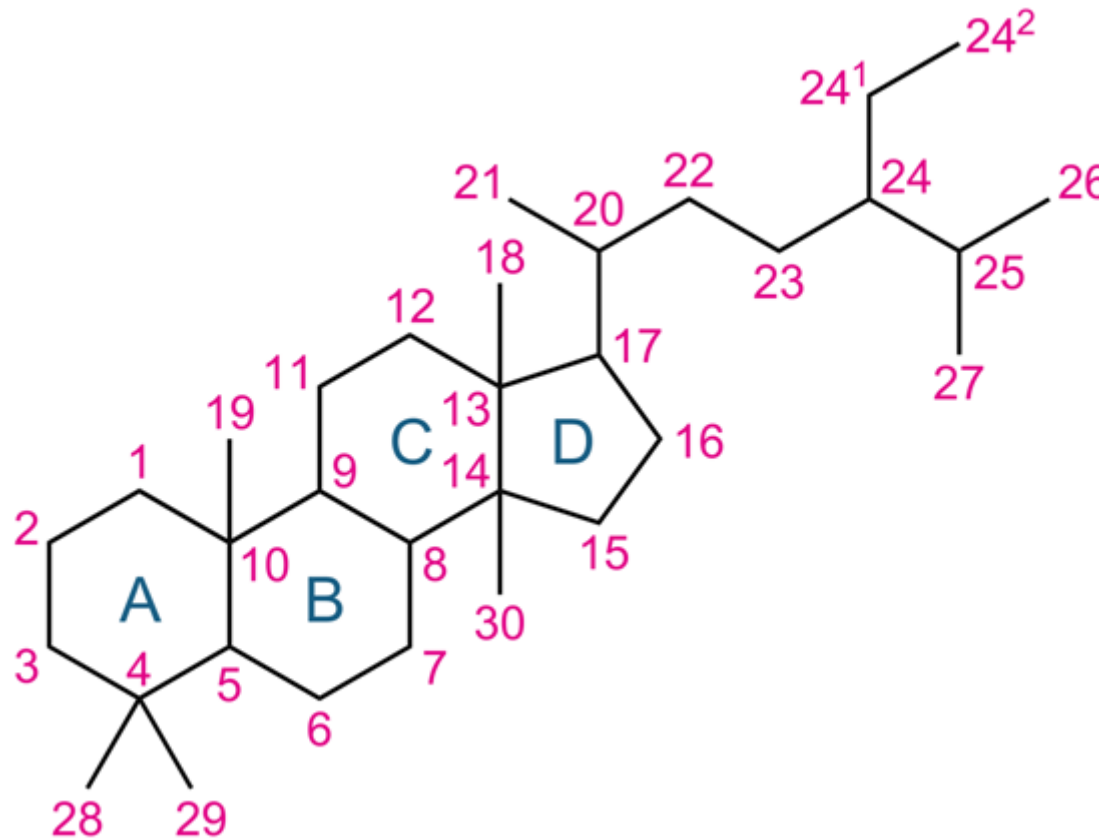
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Membranes are primarily composed of phospholipids that are Phosphoacylglycerols.

Triacylglycerols and phosphoacylglycerols are the same, but, the terminal OH group of the phosphoacylglycerol is esterified with phosphoric acid in place of fatty acid which results in the formation of phosphatidic acid.

The name phospholipid is derived from the fact that phosphoacylglycerols are lipids containing a phosphate group.

## Steroids





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Our bodies possess chemical messengers known as **hormones**, that are basically organic compounds synthesized in glands and transported by the bloodstream to various tissues in order to trigger or hinder the desired process.

Steroids are a kind of hormone that is typically recognized by their tetracyclic skeleton, composed of three fused six-membered and one five-membered ring, as seen above. The four rings are assigned as A, B, C & D as observed in the shade blue, while the numbers in red indicate the carbons.



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## Cholesterol

- Cholesterol is a wax-like substance, found only in animal source foods. Triglycerides, LDL, HDL, VLDL are different types of cholesterol found in the blood cells.
- Cholesterol is an important lipid found in the cell membrane. It is a sterol, which means that cholesterol is a combination of steroid and alcohol. In the human body, cholesterol is synthesized in the liver.





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- These compounds are biosynthesized by all living cells and are essential for the structural component of the cell membrane.
- In the cell membrane, the steroid ring structure of cholesterol provides a rigid hydrophobic structure that helps boost the rigidity of the cell membrane. Without cholesterol, the cell membrane would be too fluid.
- It is an important component of cell membranes and is also the basis for the synthesis of other steroids, including the sex hormones estradiol and testosterone, as well as other steroids such as cortisone and vitamin D.

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## Examples of Lipids:

There are different types of lipids. Some examples of lipids include butter, ghee, vegetable oil, cheese, cholesterol and other steroids, waxes, phospholipids, and fat-soluble vitamins. All these compounds have similar features, i.e. insoluble in water and soluble in organic solvents, etc.

## Functions or Significance of Lipids:

It is established that lipids play extremely important roles in the normal functions of a cell. Not only do lipids serve as highly reduced



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storage forms of energy, but they also play an intimate role in the structure of cell membrane and organellar membranes. Lipids perform many functions, such as:

1. Energy Storage
2. Making Biological Membranes
3. Insulation
4. Protection – e.g. protecting plant leaves from drying up
5. Buoyancy
6. Acting as hormones



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7. Act as the structural component of the body and provide the hydrophobic barrier that permits partitioning of the aqueous contents of the cell and subcellular structures.
8. Lipids are major sources of energy in animals and high lipid-containing seeds.
9. Activators of enzymes eg. glucose-6-phosphatase, stearyl CoA desaturase and  $\omega$ -monooxygenase, and  $\beta$ -hydroxybutyric dehydrogenase (a mitochondrial enzyme) require phosphatidylcholine micelles for activation.



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## Frequently Asked Questions

### What are lipids?

Lipids are organic compounds that are fatty acids or derivatives of fatty acids, which are insoluble in water but soluble in organic solvents. For eg., natural oil, steroid, waxes.

### How are lipids important to our body?

Lipids play a very important role in our body. They are the structural component of the cell membrane. They help in providing



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energy and produce hormones in our body. They help in proper digestion and absorption of food. They are a healthy part of our diet if taken in proper amounts. They also play an important role in signalling.

## **How are lipids digested?**

The enzyme lipase breaks down fats into fatty acids and glycerol, which is facilitated by bile in the liver.



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## **What is lipid emulsion?**

It refers to an emulsion of lipid for human intravenous use. These are also referred to as intralipids which is the emulsion of soybean oil, glycerin and egg phospholipids. It is available in 10%, 20% and 30% concentrations.

## **How are lipids metabolized?**

Lipid metabolism involves oxidation of fatty acids to generate energy to synthesize new lipids from smaller molecules. The



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metabolism of lipids is associated with carbohydrate metabolism as the products of glucose are converted into lipids.

## **How are lipids released in the blood?**

The medium-chain triglycerides with 8-12 carbons are digested and absorbed in the small intestine. Since lipids are insoluble in water, they are carried to the bloodstream by lipoproteins which are water-soluble and can carry the lipids internally.





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## **What are the main types of lipids?**

There are two major types of lipids- simple lipids and complex lipids. Simple lipids are esters of fatty acids with various alcohols. For eg., fats and waxes. On the contrary, complex lipids are esters of fatty acids with groups other than alcohol and fatty acids. For eg., phospholipids and sphingolipids.

## **What are lipids made up of?**

Lipids are made up of a glycerol molecule attached to three fatty acid molecules. Such a lipid is called triglyceride.

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**THANK YOU**

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