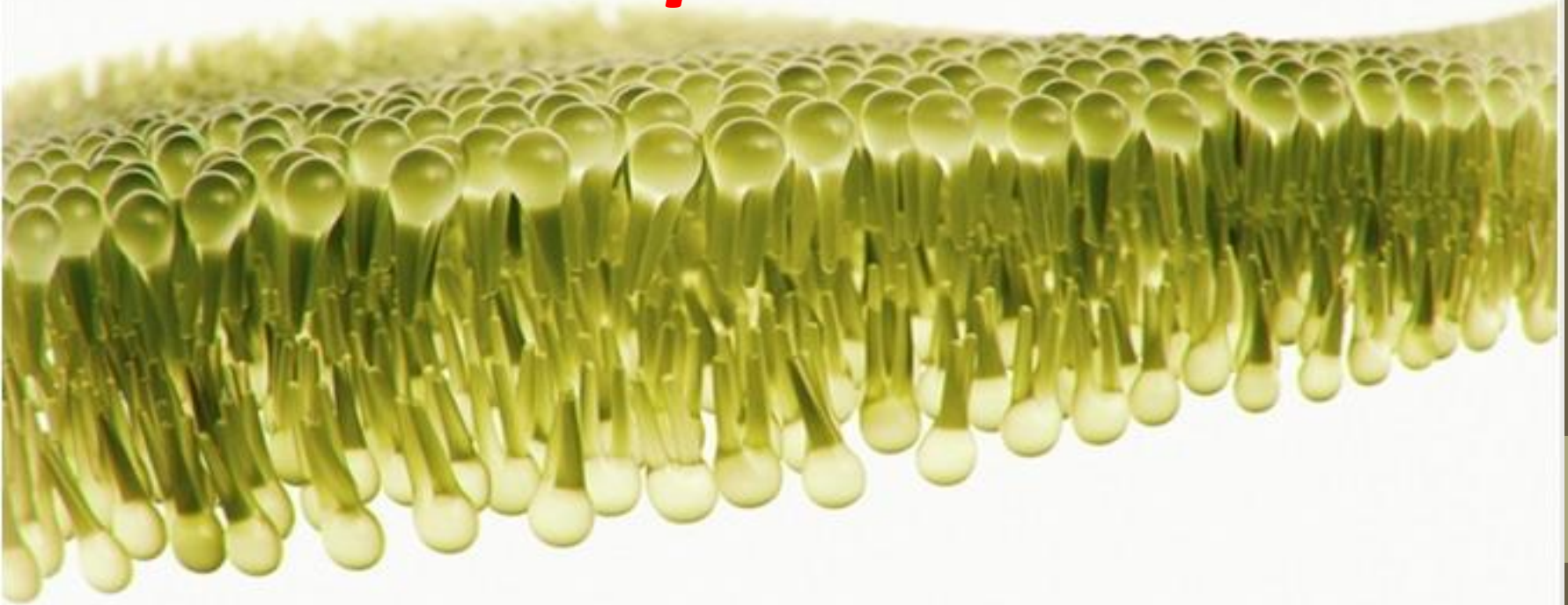


# *Lipids*



- **Introduction**
- **Definition**
- **Function**
- **Nomenclature**
- **Classification**
  - Simple lipid
  - Complex lipid
  - Derived lipid

# Introduction

The word lipid is derived from a Greek word “lipos” which means **FAT**.

These are heterogeneous group of compounds

Unlike : proteins ,nucleic acids, polysaccharides.

Lipids are not polymers rather they are small molecules.

## Definition

Lipids may be regarded as organic substances relatively insoluble in water, soluble in nonpolar organic solvents ex:-

( diethyl ether ,chloroform or benzene ).

# **FUNCTIONS OF LIPIDS**

**Storage  
form of  
energy**

**Structural  
component  
of cell  
membrane.**

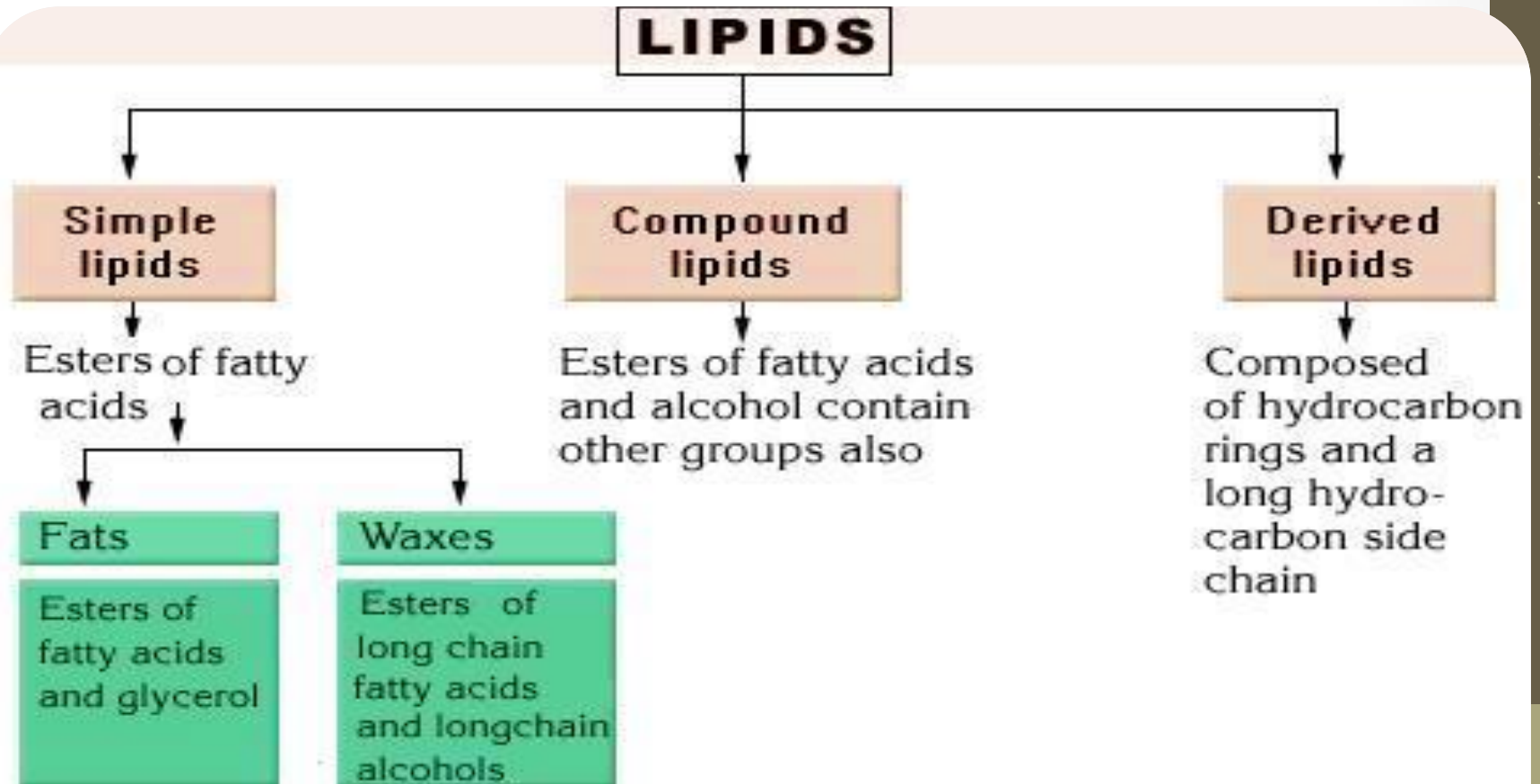
**Insulation**

**Precursor  
of many  
steroid  
hormones,  
vitamin D**

**Protection  
of internal  
organs**

- ✓ **Fuel** : Lipid are important dietary constituents because of the higher energy value . Most of energy stored in the body in the form of triglyceride in fat called adipocytes.
- ✓ **Cell membrane structural compounds** phosphoglycerides , sphingolipids and steroids.
- ✓ **Insulation** : Fat stored beneath the skin serves to insulate the body from extremes of cold temperature .
- ✓ **Vitamins** : A lipid soluble vitamin A,D,E and K.
- ✓ **Hormones** : Steroid hormones and prostaglandins.
- ✓ **Protection**: fats serve as protective layer or shock absorber for vital organ.

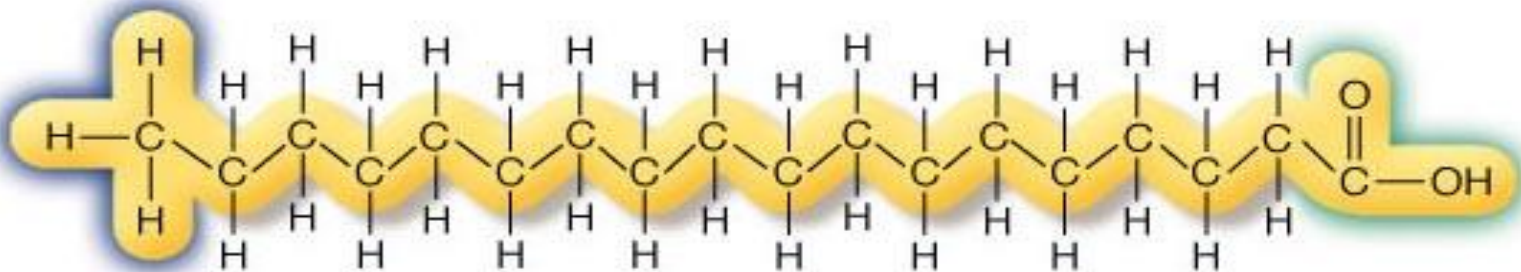
# Classification



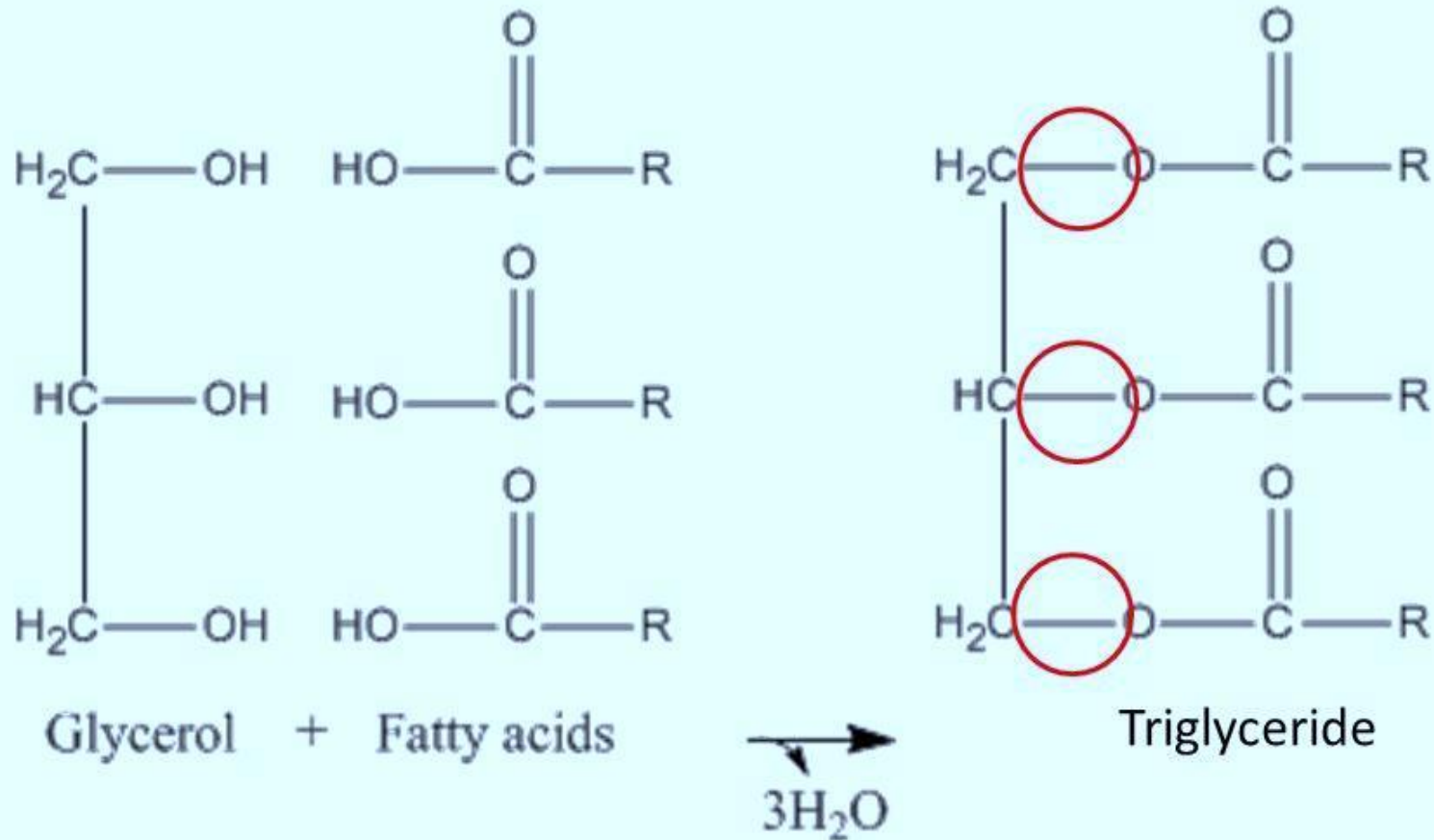
## Major lipids of physiological significance

**Fatty acids** : basic units of fat composed of chains of carbon atoms with an acid group at one end and hydrogen atoms attached all along their length.

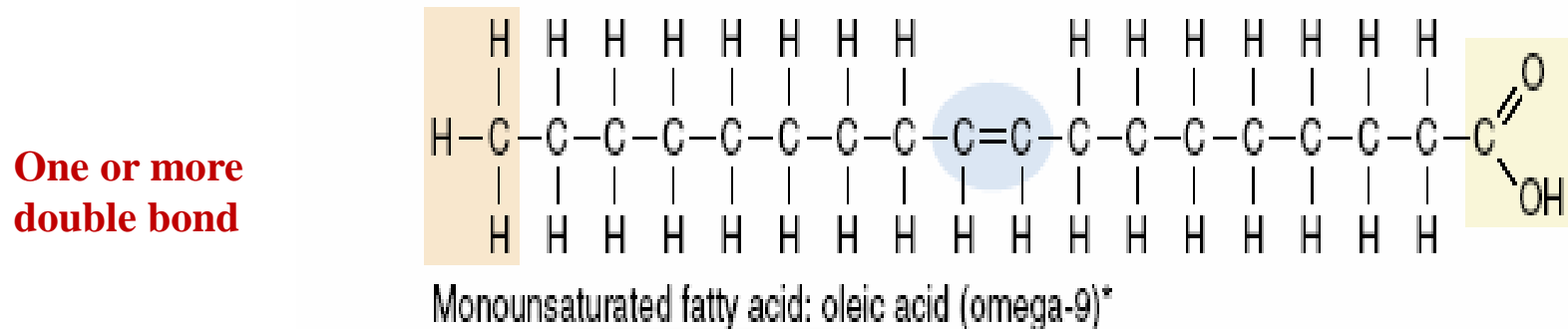
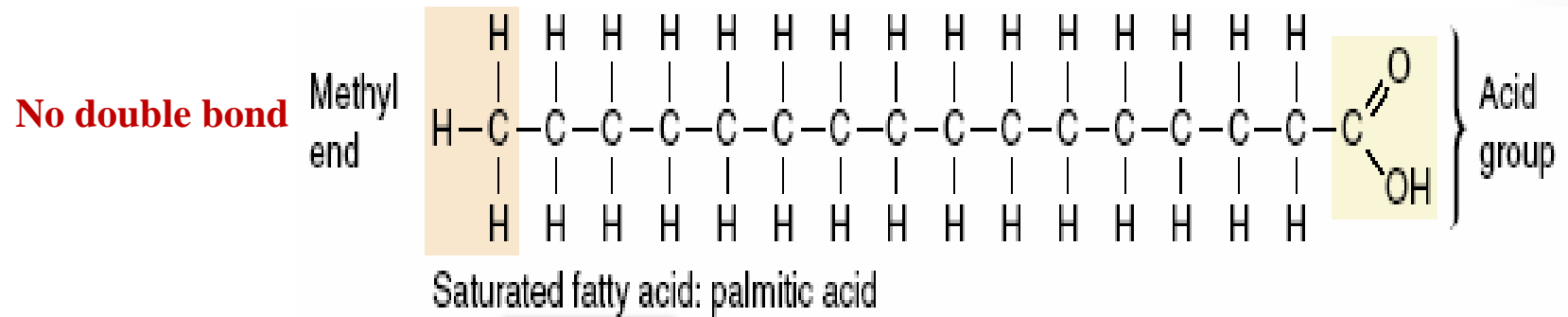
Present as either esterified(free fatty acid) or unesterified form in fats and oils.



# Ester Bonds



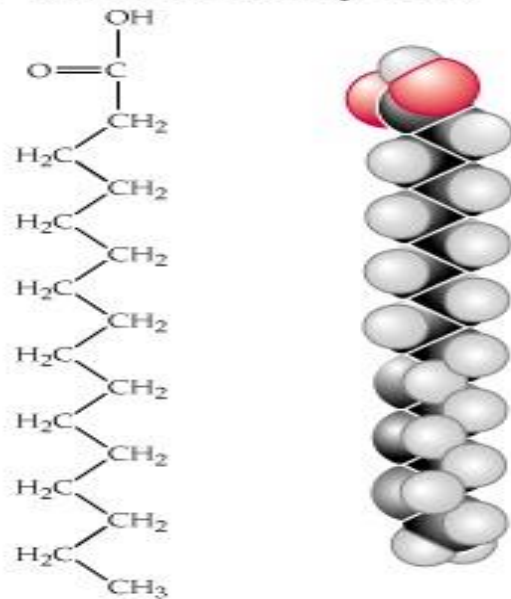
**Fatty acids:** are aliphatic carboxylic acids with unbranched hydrocarbons chain of 4 -24 carbons atoms. They are present in all organisms as compound of fats and membrane lipids.



Mono unsaturated = one double bond

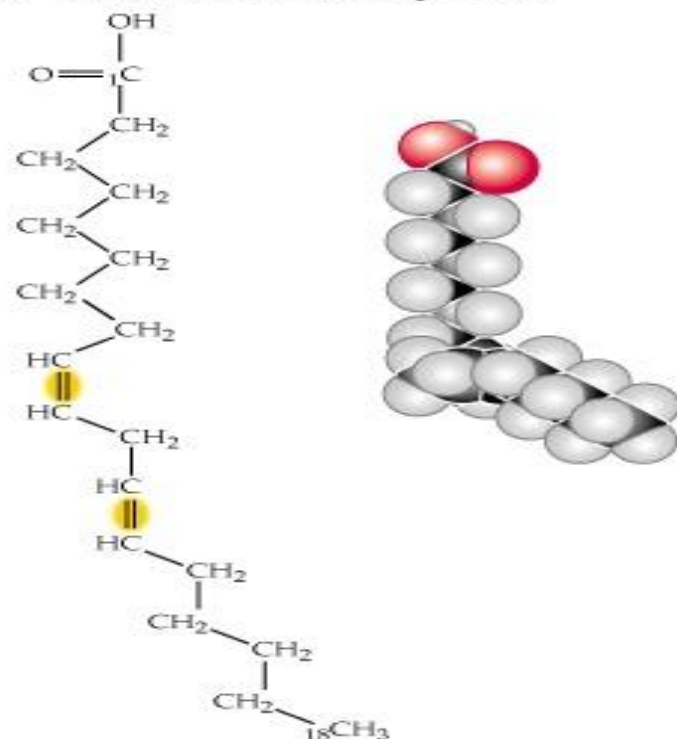
Poly unsaturated = 2 or more double bond

(a) Saturated fatty acid



Palmitic acid

(b) Unsaturated fatty acid



Linoleic acid

# Fatty acids

```
graph TD; A[Fatty acids] --> B[saturated Fatty acids]; A --> C[Unsaturated Fatty acids]; C --> D[MUFA]; C --> E[PUFA]; C --> F[Eicosanoids];
```

saturated Fatty acids

Unsaturated Fatty acids

MUFA

PUFA

Eicosanoids

# ***Eicosanoids***

are oxygenated derivatives of C<sub>20</sub> polyunsaturated fatty acids Arachidonic Acids .

## *Examples of eicosanoids*

**Prostaglandins E<sub>2</sub>** : Are derivative of arachidonic acid that contain cyclopentane hydroxyl group isolated from seminal fluid produced by prostate gland .

Arachidonic acid

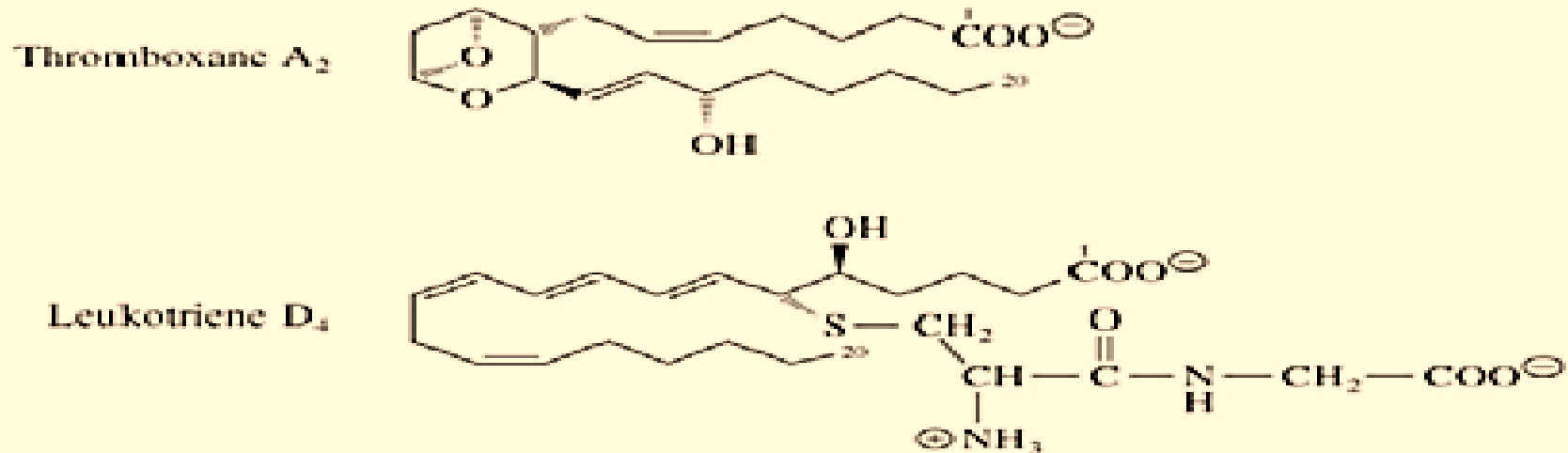


Prostaglandin E<sub>2</sub>



**Thromboxanes  $A_2$**  : Are derivative of arachidonic acid that contain sixed member ring have cyclic ether.

**Leukotrienes  $D_4$**  : Linear derivative of arachidonic acid containing 3 double bond



## Another classification

Non essential  
fatty acid

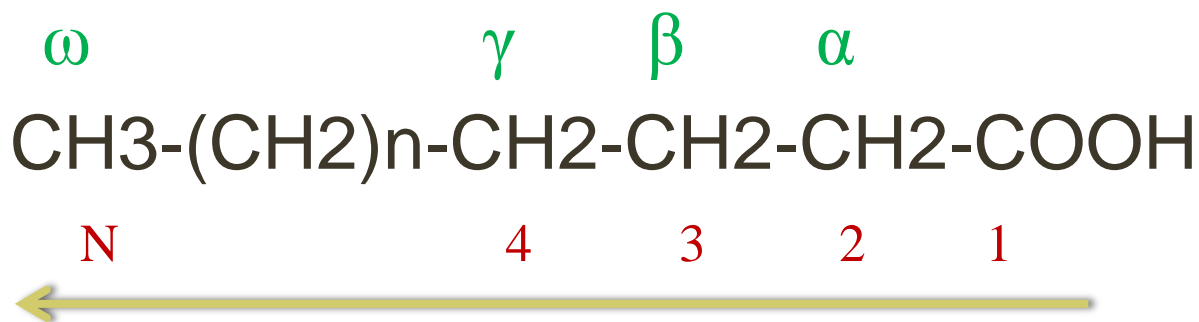
- Can be synthesized in the body

essential fatty  
acid

- Can not be synthesized in the body so should obtain from the diet

## Nomenclature

The carbon atom are numbered from carboxylic carbon.



The carbon atoms adjacent to the carboxyl carbon(No. 1,2,3,4.....) are also known as  $\alpha$   $\beta$   $\gamma$  respectively and terminal methyl carbon known as  $\omega$  carbon atom.

## Systemic Nomenclature

It is based on naming the fatty acid after hydrocarbon with the same number of carbon atom with **oic** being substituted for the final **e** .

Ex., Hexane  $\longrightarrow$  Hexanoic

## Common name ( Trivial name)

The name typically derived from common source from which it was first isolated

Oleic acid  $\longrightarrow$  olive oil

Palmitic acid  $\longrightarrow$  palm oil

The number of carbon atoms is given along with the number of double bond .

|               |        |             |
|---------------|--------|-------------|
| Palmitic acid | C16: 0 | saturated   |
| Oleic acid    | C18: 1 | unsaturated |

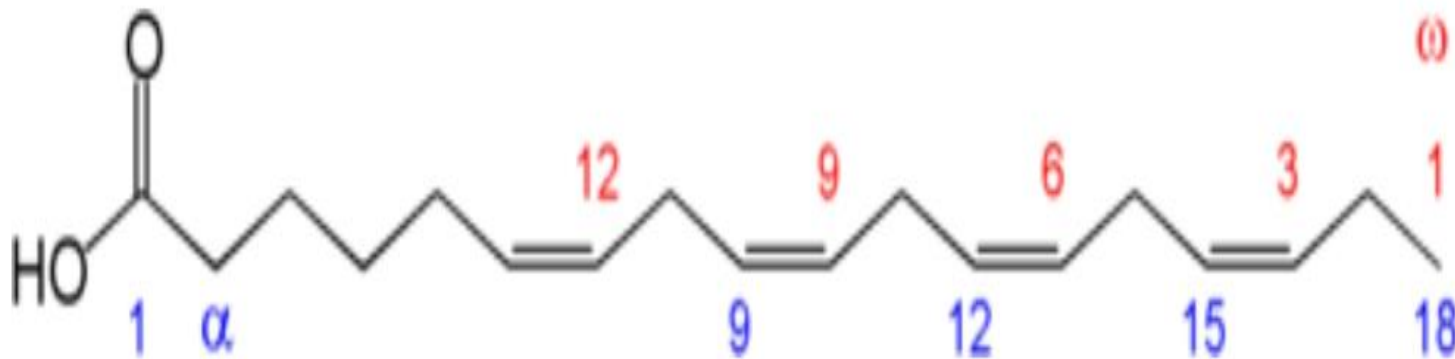
← **No of double bond**

And the number and position of double bond after semicolon or use superscripts numbering following  $\Delta$

|            |                  |  |
|------------|------------------|--|
| Oleic acid | C18:1;9          | } Position of double bond between C9 and C10 |
|            | C18:1 $\Delta^9$ |  |

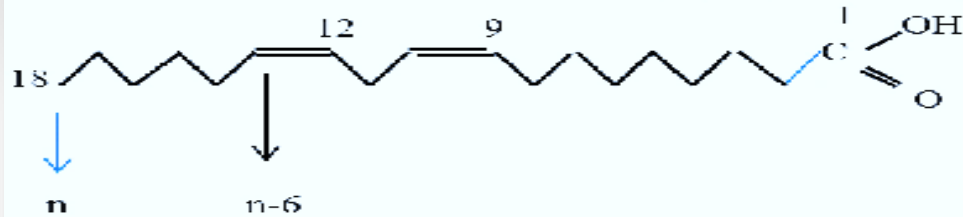
## Omega ( $\omega$ ) numbering system

The  $\omega$  family describes the position of the last double bond (unsaturated fatty acid) relative to the end the chain (the-CH<sub>3</sub>) or  $\omega$ -end .

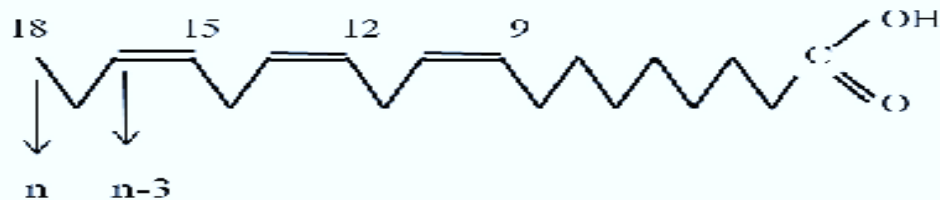


Numbering of carbon atoms

**Linoleic acid – LA - 18:2 (9,12) - n-6 ( $\omega$ -6)**



**Linolenic acid – ALA (alpha-linolenic acid) - 18:3 (9,12,15) - n-3 ( $\omega$ -3)**



What is the  $\omega$  family????

- ❖ Eicosapentaenoic acid.
- ❖ Docosahexaenoic acid.
- ❖ Arachidonic acid



eicosapentaenoic acid (C20:5 ω-3)



docosahexaenoic acid (C22:6 ω-3)



arachidonic acid (C20:4 ω-6)

# CLASSIFICATION OF LIPIDS

Simple  
lipid

Complex  
lipid

Derived  
lipids

# 1. Simple lipids

They are esters of fatty acids with alcohols:

- a. Fats and oils: esters of fatty acids with glycerol(triacylglycerol) , **a fat in liquid state is known as an oil.**
- b. Waxes : esters of long chain fatty acids (having 14-36) C atoms with long chain alcohol(having 16-30) C atoms .

Neutral fats or oils

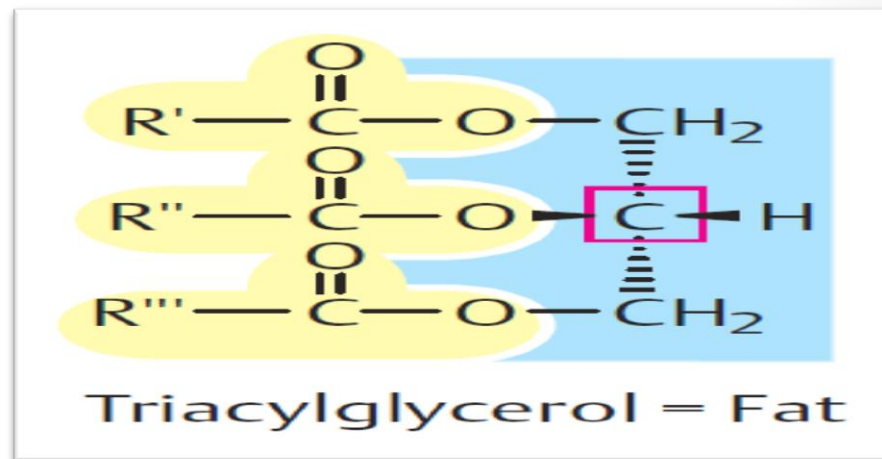
Alcohol is  
GLYCEROL

Waxes

Alcohol is  
other than  
glycerol

# NEUTRAL FATS OR OILS

- Fats and oils are
  - also called triglycerides.
  - esters of glycerol+ 3 FA

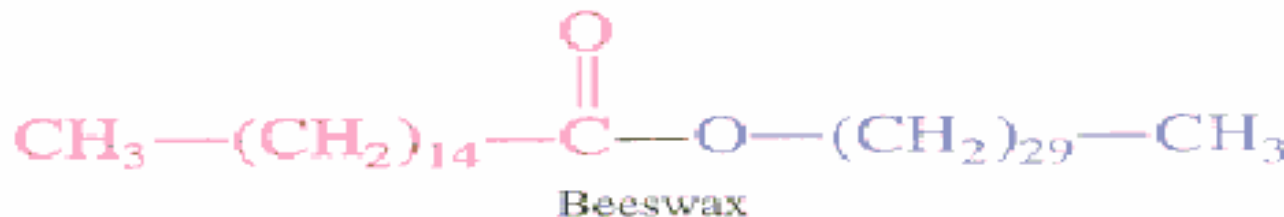


The block diagram:

Fatty acid

Long-chain alcohol

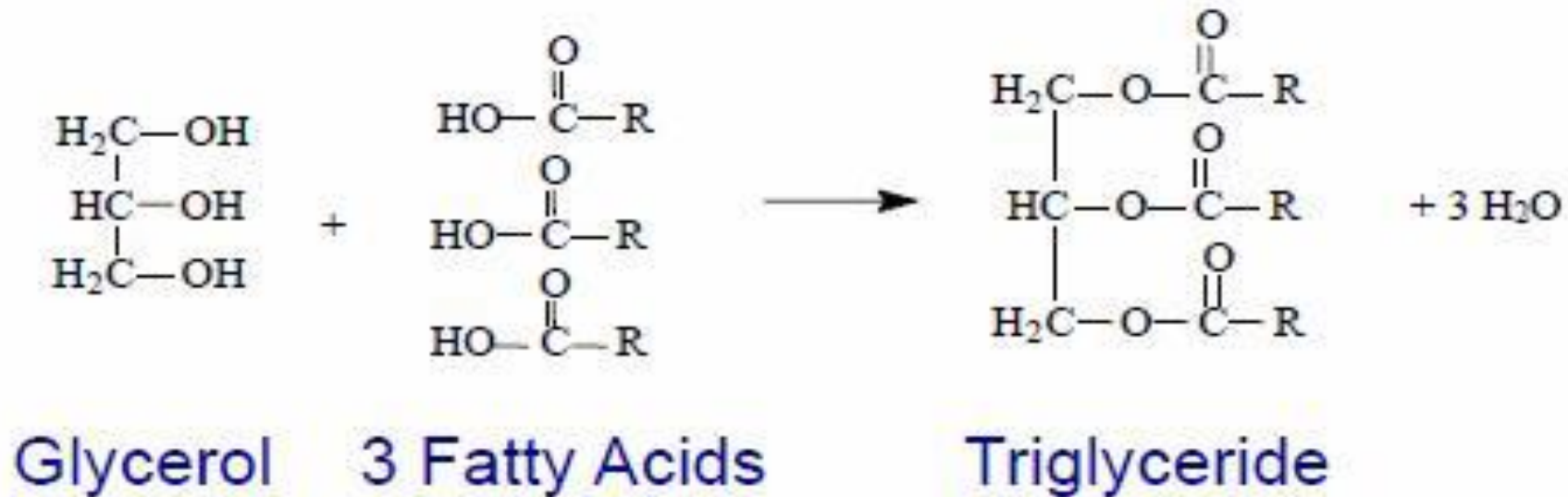
**Example**

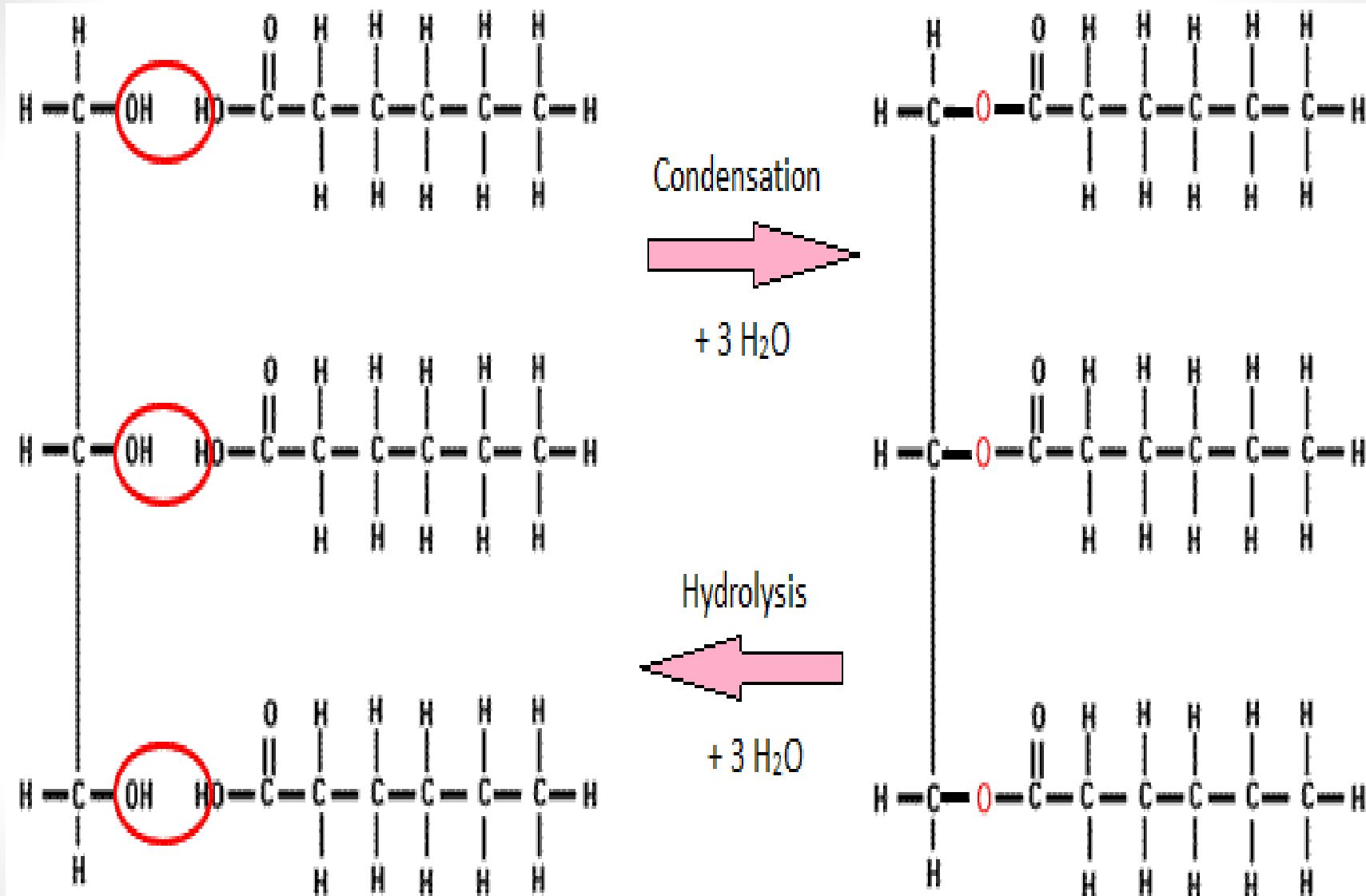


## Triglycerides (Triacylglycerol)

Are esters of glycerol with three fatty acid molecules.

Partial hydrolysis consisting of mono- and diacylglycerol, where in a single fatty acid or two fatty acids are esterified with glycerol.

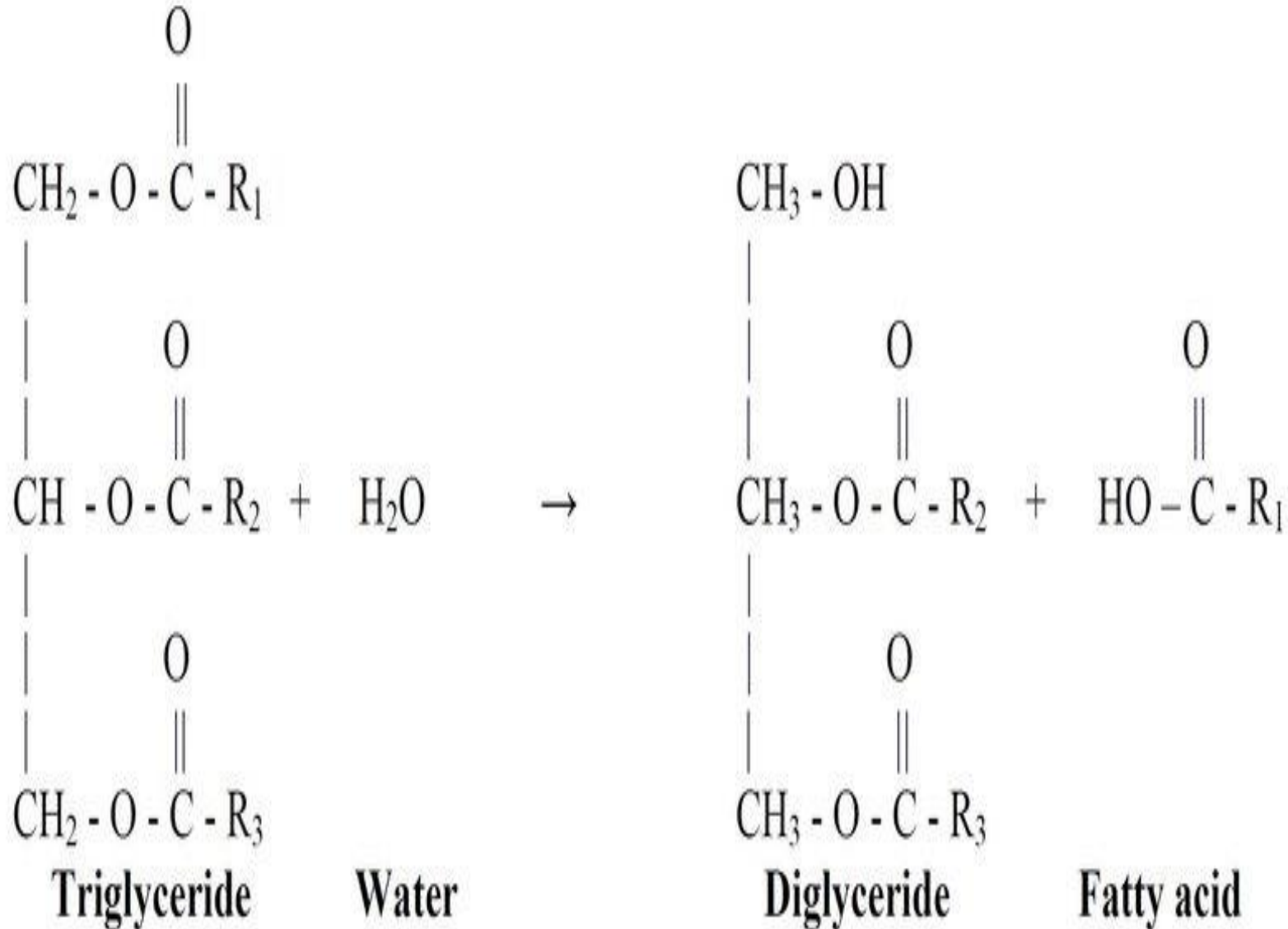




Glycerol

Fatty Acids

Triglyceride Molecule



Triglyceride can be found as:

- a. **Fats** are **solid** at room temperature have acyl group that contain saturated fatty acid.
- b. **Oil** are **liquid** at room temperature have acyl group that contain unsaturated fatty acid.

- Triglyceride is form in **liver and adipose tissue**.
- Transport from liver and intestine to the various tissues as **lipoproteins**.

1/4/2020

# COMPLEX LIPIDS

Result of hydrolysis gives FA with alcohol and containing **additional[prosthetic] groups.**

Subclassified according to the type of prosthetic group

Phospholipids

Glycolipids

Lipoproteins

## 2. Complex lipids

Chemical analysis of the isolated materials shows that lipids are the major components of most membranes. These lipids are not triglycerides but another group of compounds called **complex lipids**.

Esters of fatty acid containing group in addition to an alcohol and fatty acid. There are three main types of complex lipids in cellular membranes:

- Phospholipids
- Glycolipids
- Lipoprotein

## ■ Phospholipids

They are esters of phosphoric acids , also have nitrogen - containing base .There are two main types of phospholipids in cellular membranes , Where :

alcohol is glycerol                      →                      glycerophospholipid or phosphoglycerides

alcohol is sphingosine                      →                      sphingophospholipid or sphingomyelins

### • Phosphoglycerides:

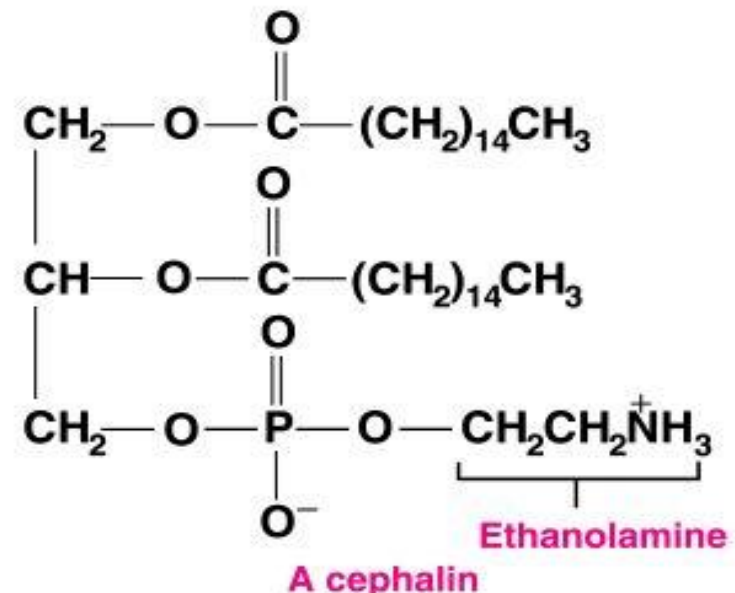
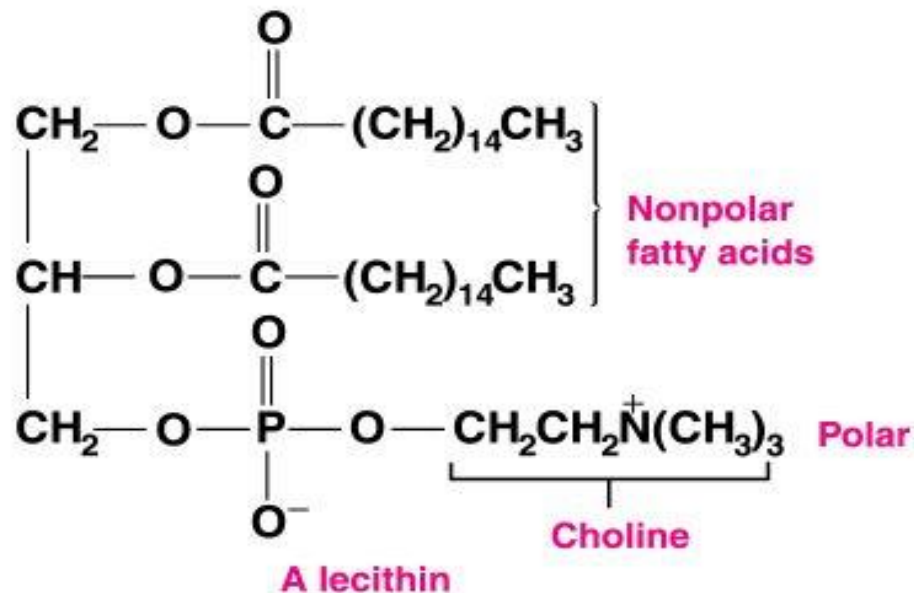
They are also known as **Phosphatidyl choline** (lecithin) containing choline as amino alcohol. They are built from long chain fatty acid, glycerol and phosphoric acids.

# Lecithins and Cephalins

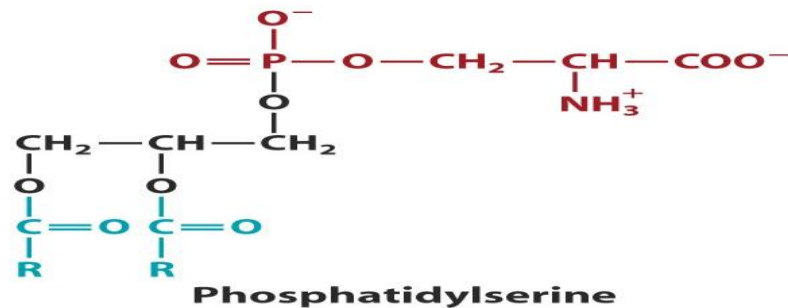
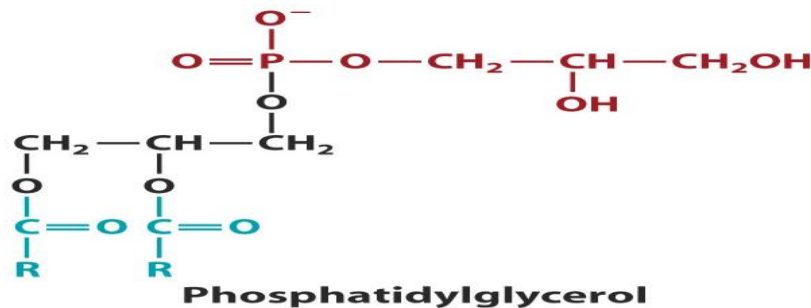
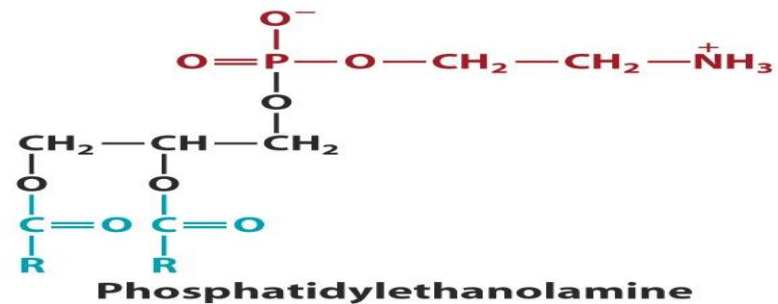
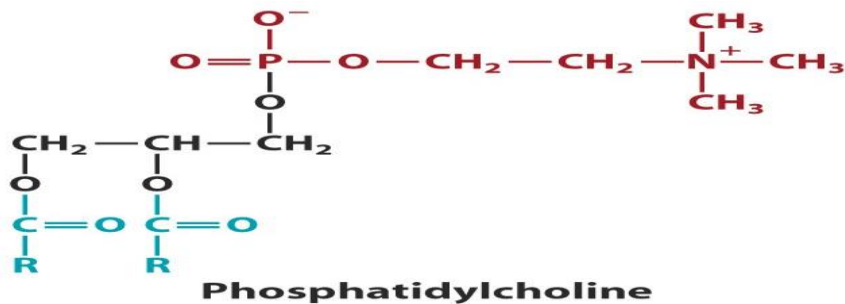
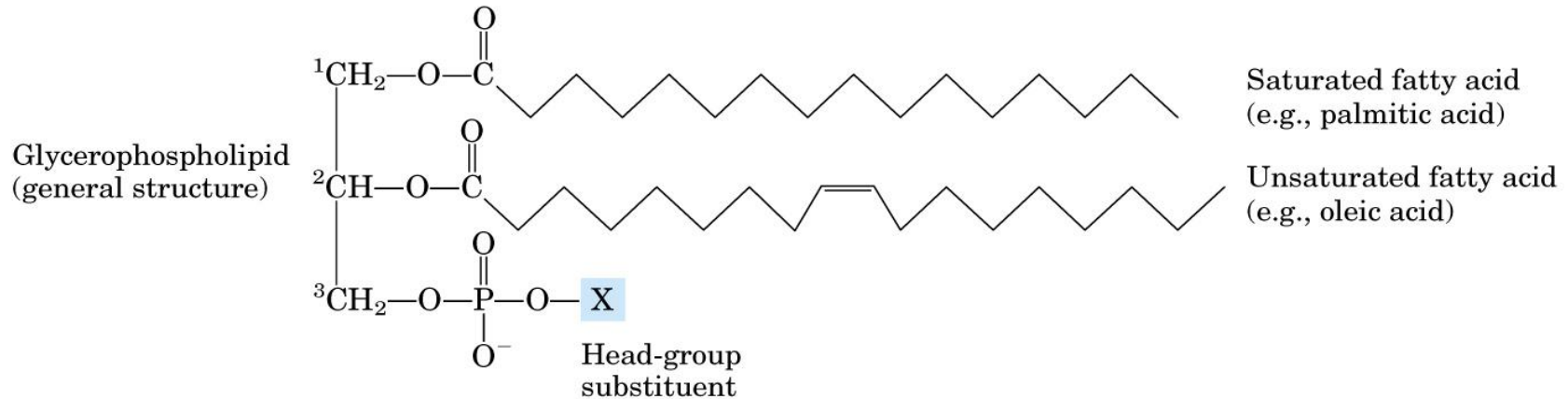
**Glycerophospholipids** can be classified based on the amino alcohol group

Two common types are **lecithins** (which contain choline) and **cephalins** (which contain ethanolamine).

Lecithins and cephalins are highly abundant in brain and nerve tissues.



# General structure of a glycerophospholipid. Note the glycerol-3-phosphate backbone



- **sphingomyelins:**

These are found in large quantities in brain and nerve tissue . On hydrolysis yield a fatty acid , phosphoric acid , choline , and a complex amino acid alcohol , sphingosine . No glycerol is present . The combination sphingosine plus fatty acid is known as **ceramide** .

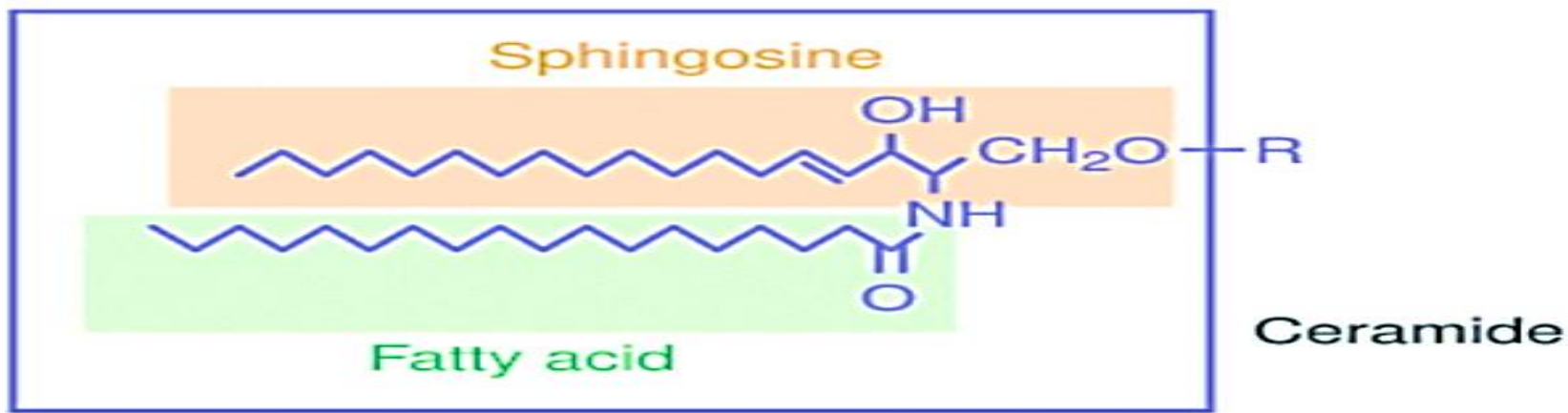
Also the sphingolipids backbone is able to be linked to a charged head group ( polar part ) such as ethanolamine , serine , or choline.

Sphingosine + Fatty acid + phosphate + polar molecule

or

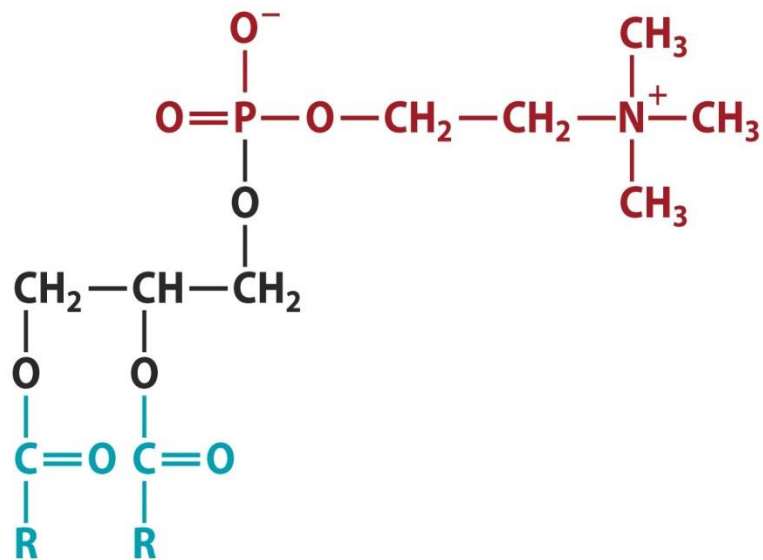
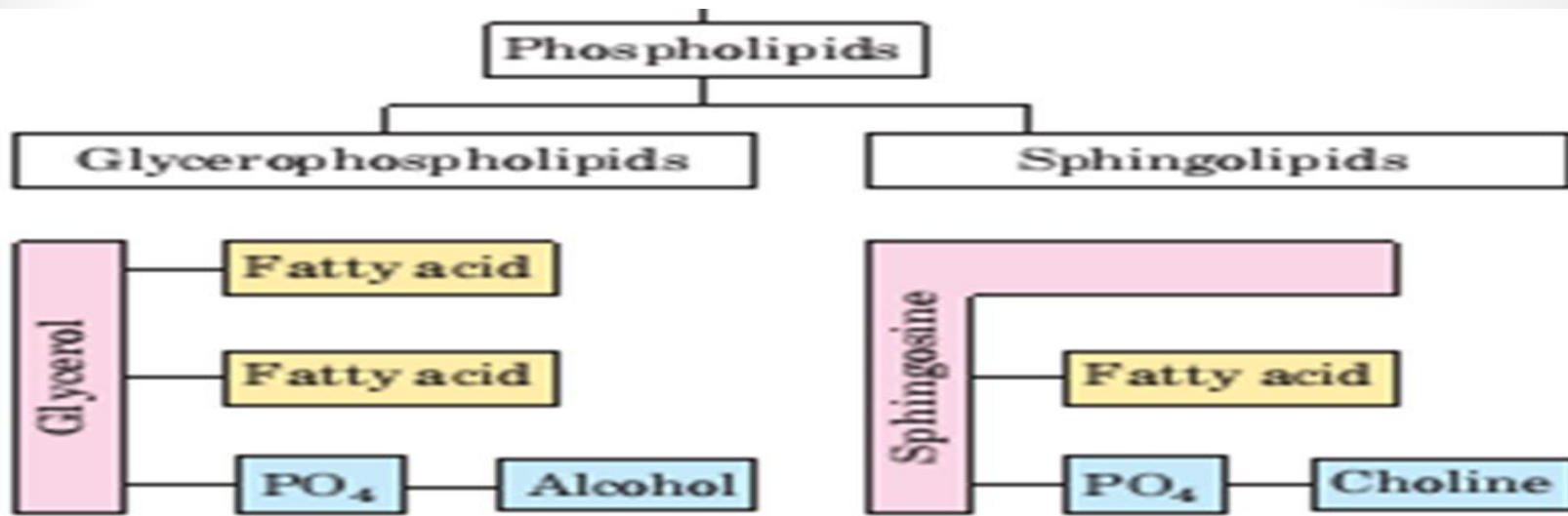
Ceramide + phosphate + polar molecule

A sphingosine bonded to fatty acid through an amide bond is known as ceramide (parallel to acyl glycerol). E.g. sphingomyline and glycolipids

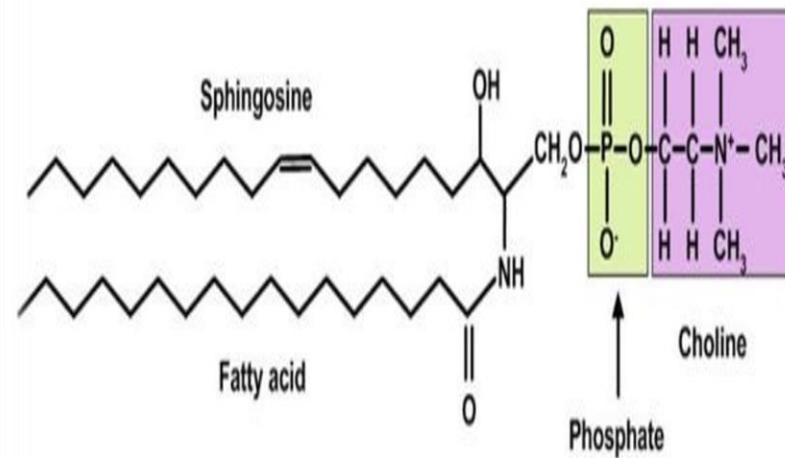


| Substituent (R) | Sphingolipid      |
|-----------------|-------------------|
| H               | Ceramide          |
| Phosphocholine  | Sphingomyelin     |
| Sugar(s)        | Glycosphingolipid |

General sphingolipid structure



**Phosphatidylcholine**



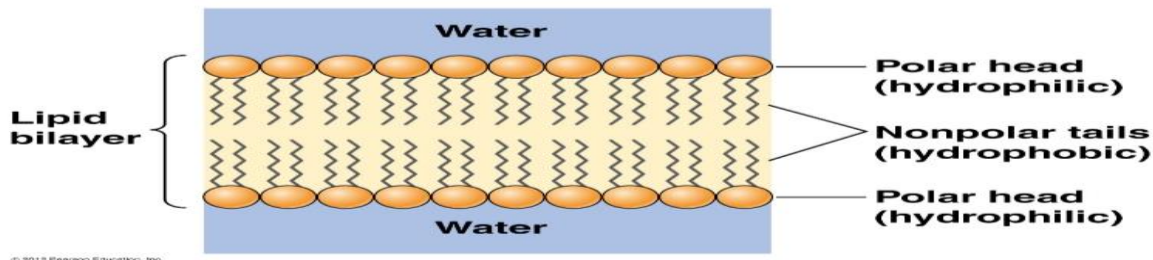
**Sphingolipids: Sphingomyelin**

# Phospholipids

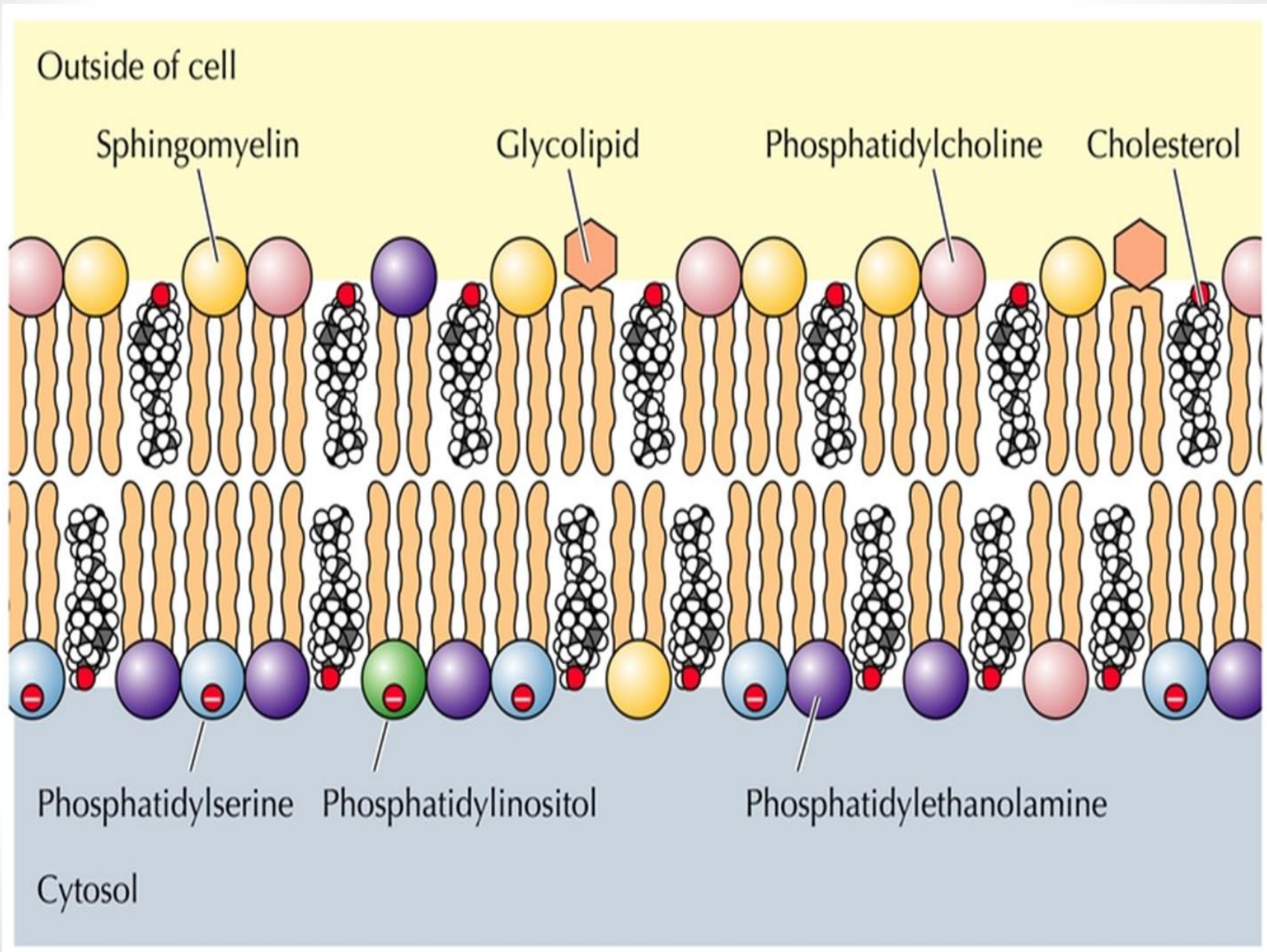
Phospholipids : naturally aggregate in form of bilayers (which fuse to form spherical liposomes)

- glycerophospholipids
- sphingophospholipids

It is the main component of the **cell membrane** because they are amphipathic molecule, the phosphate group head **hydrophilic** (water – loving) while the fatty acid tails are **hydrophobic** ( water – hating).



*Amphipathic: non-polar and polar regions*



# Glycolipids (glycosphingolipids)

Are components of cellular membranes comprised of a hydrophobic lipid tail and one or more hydrophilic sugar groups linked by glycosidic bond (in place of the amino alcohol phosphate ester) , generally are found on the outside of the cellular membranes , it plays role as **structural membranes and receptors** .

Compounds of the fatty acids with carbohydrate , containing nitrogen , **but no phosphoric acid**.

# GLYCOLIPIDS

**FA + Alcohol(Sphingosine) + Carbohydrate  
with nitrogen base**

❑ They do not contain phosphate group

## Example

- ✓ Cerebrosides
- ✓ Gangliosides

The term glycosphingolipids designates lipids containing at least one monosaccharide residues and either a sphingosine or a ceramide .

Sphingosine + Fatty acid + Sugar(oligosaccharides) **or**  
Ceramide + Sugar(oligosaccharides)

they may also classified with Sphingomyelins why ?  
(same as sphingosine but instead of having a (phosphate + polar molecule) residue, Glycolipids have simple or oligosaccharides.

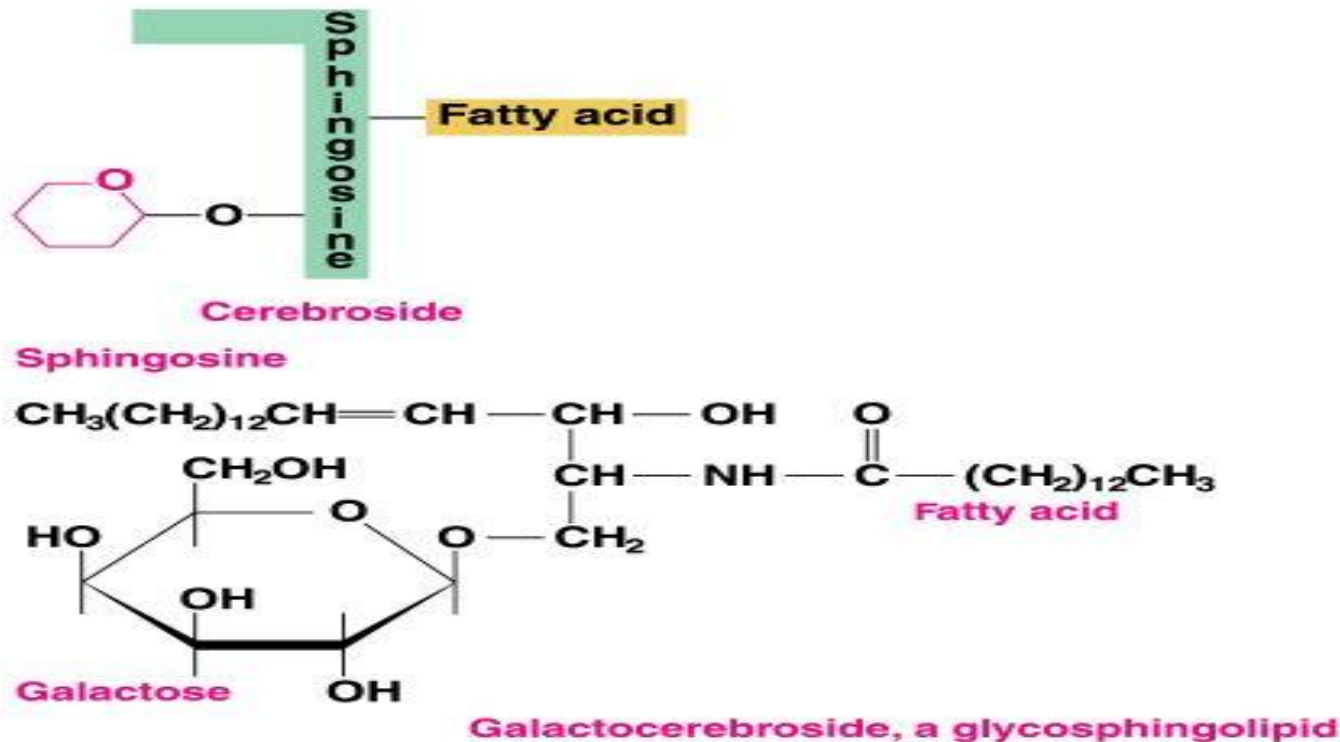
**Naming = Saccharide name + y l + ceramide **or****  
**= Saccharide name + cerebroside**

- Glycosylceramide , Galatosylceramide
- Glycocerebrosides , Galatocerebrosides

The glycosphingolipids are known as :

a. Cerebrosides( monoglycosylceramide)

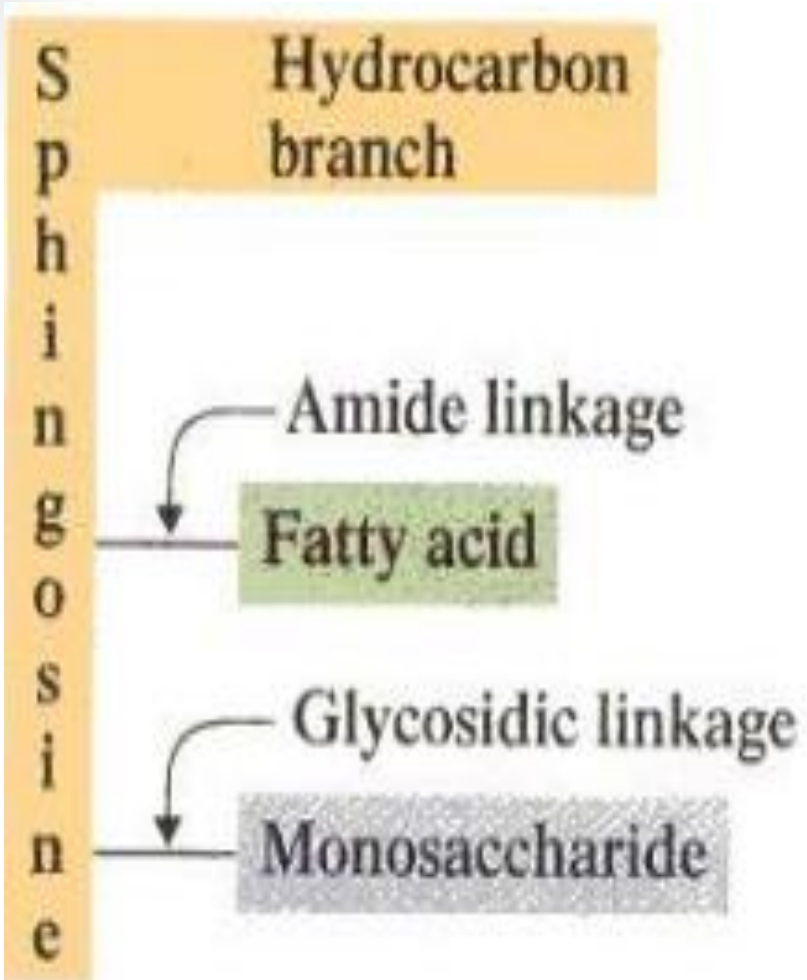
The simplest form of glycosphingolipids Contains of ceramide with a single sugar residue can be glucose or (usually galactose) , the two major types are glucocerebrosides and galactocerebrosides .



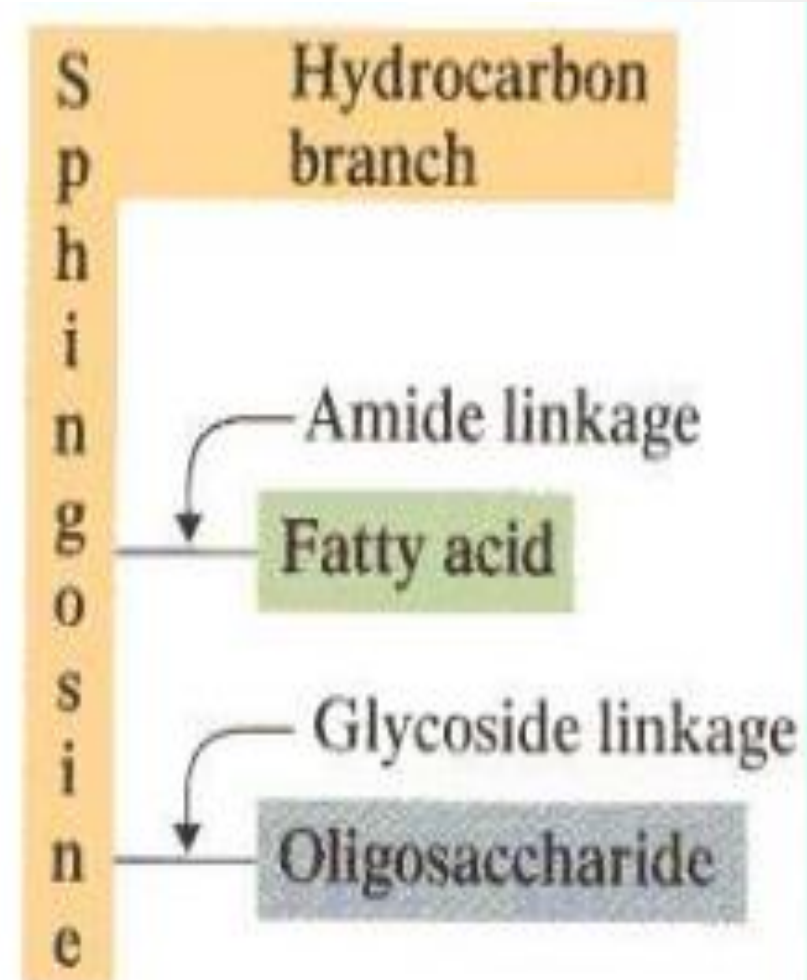
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**( ٤٢ )**





**Cerebrosides**



**Gangliosides**

# LIPOPROTEINS

The lipids are insoluble in water ; therefore cannot homogenized with the blood. This difficulty is overcome as the neutral lipids (TG) are associated with polar phospholipids and protein in structure called **lipoproteins** .

These lipoprotein are differing in their lipids and proteins :

Composition

Amount that present in each type

Function

Density

The lipids and the proteins in the lipoprotein are connected together by non-covalent bonds

Lipoproteins are soluble in water because their surface is polar

- the polar : head groups of phospholipids, proteins and the hydroxyl groups of cholesterol. phospholipids and proteins that are used to transport lipids through the blood.

form a polar layer on the surface of the lipoprotein.

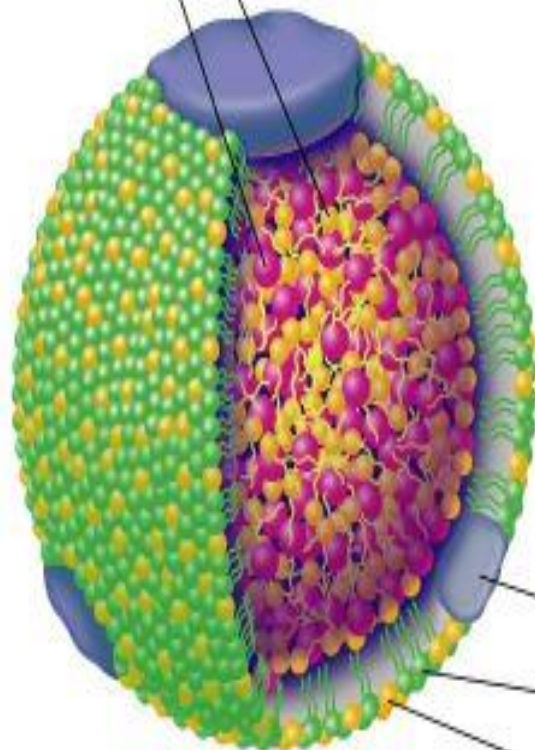
- Nonpolar : triacylglycerides and cholesterol esters (cholesterol in the blood is mostly fatty acid esters) are stored in the interior.

Inner core of nonpolar lipids:

Cholesteryl esters

Triacylglycerols

Membrane protein

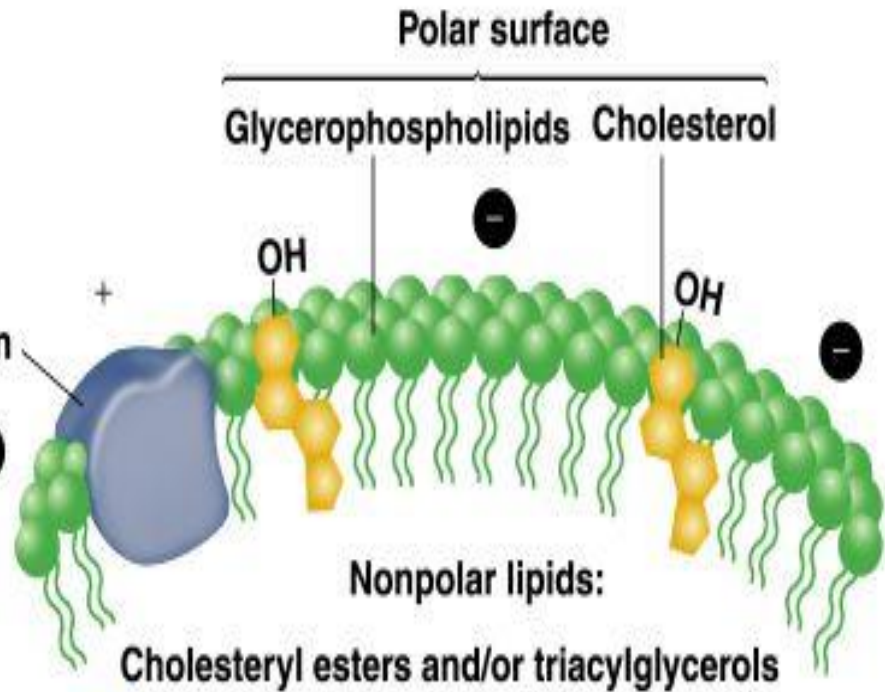


Surface:

Membrane protein

Glycerophospholipids

Cholesterol



# TYPES OF LIPOPROTEINS

Lipid with  
prosthetic  
group  
PROTEIN

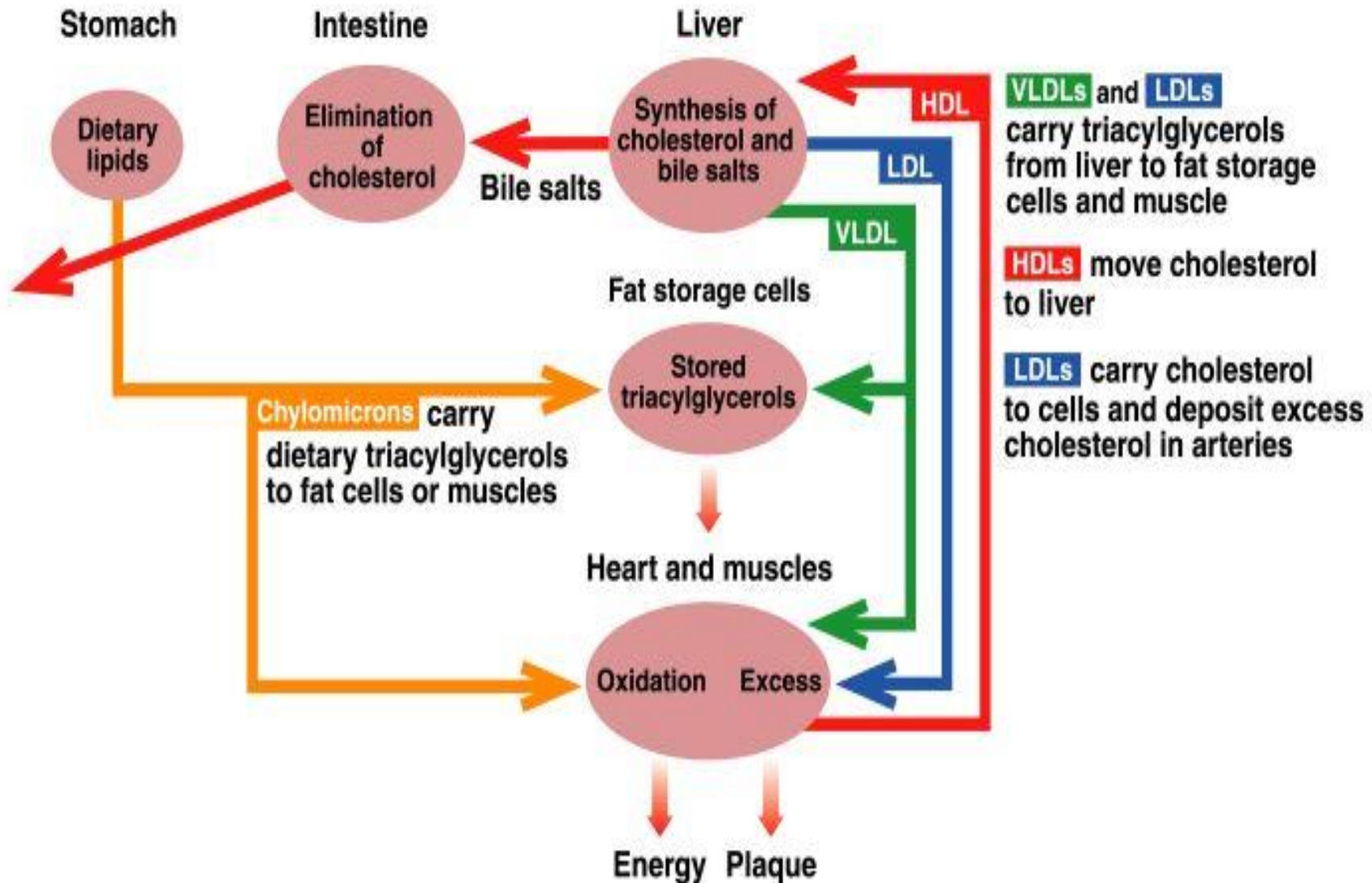
- ✓ Chylomicrons
- ✓ Very low density lipoprotein (VLDL) or Pre- $\beta$
- ✓ Low density lipoprotein (LDL) or  $\beta$
- ✓ High density lipoprotein (HDL) or  $\alpha$

The density of the lipoproteins is inversely proportional to the lipids contents, while it is directly proportional to the proteins contents in each type of lipoproteins.

|                         | Chylomicron | VLDL        | LDL         | HDL         |
|-------------------------|-------------|-------------|-------------|-------------|
| Density (g/mL)          | 0.94        | 0.950–1.006 | 1.006–1.063 | 1.063–1.210 |
| Composition (% by mass) |             |             |             |             |
| Triacylglycerol         | 86          | 55          | 6           | 4           |
| Phospholipids           | 7           | 18          | 22          | 24          |
| Cholesterol             | 2           | 7           | 8           | 2           |
| Cholesteryl esters      | 3           | 12          | 42          | 15          |
| Protein                 | 2           | 8           | 22          | 55          |

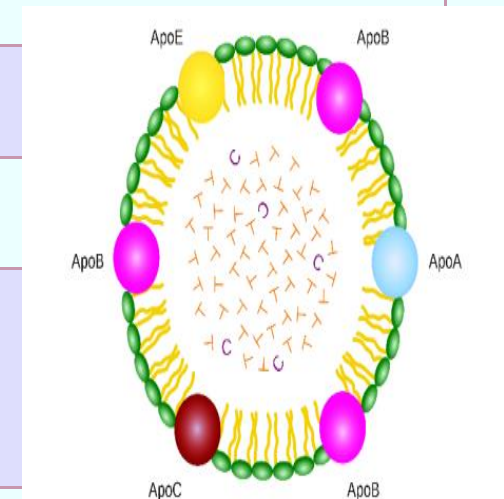
Sometimes, a fifth type could be detected between the VLDL and LDL known as Intermediate Density Lipoprotein (**IDL**).

# Transport of Lipoproteins in the Body

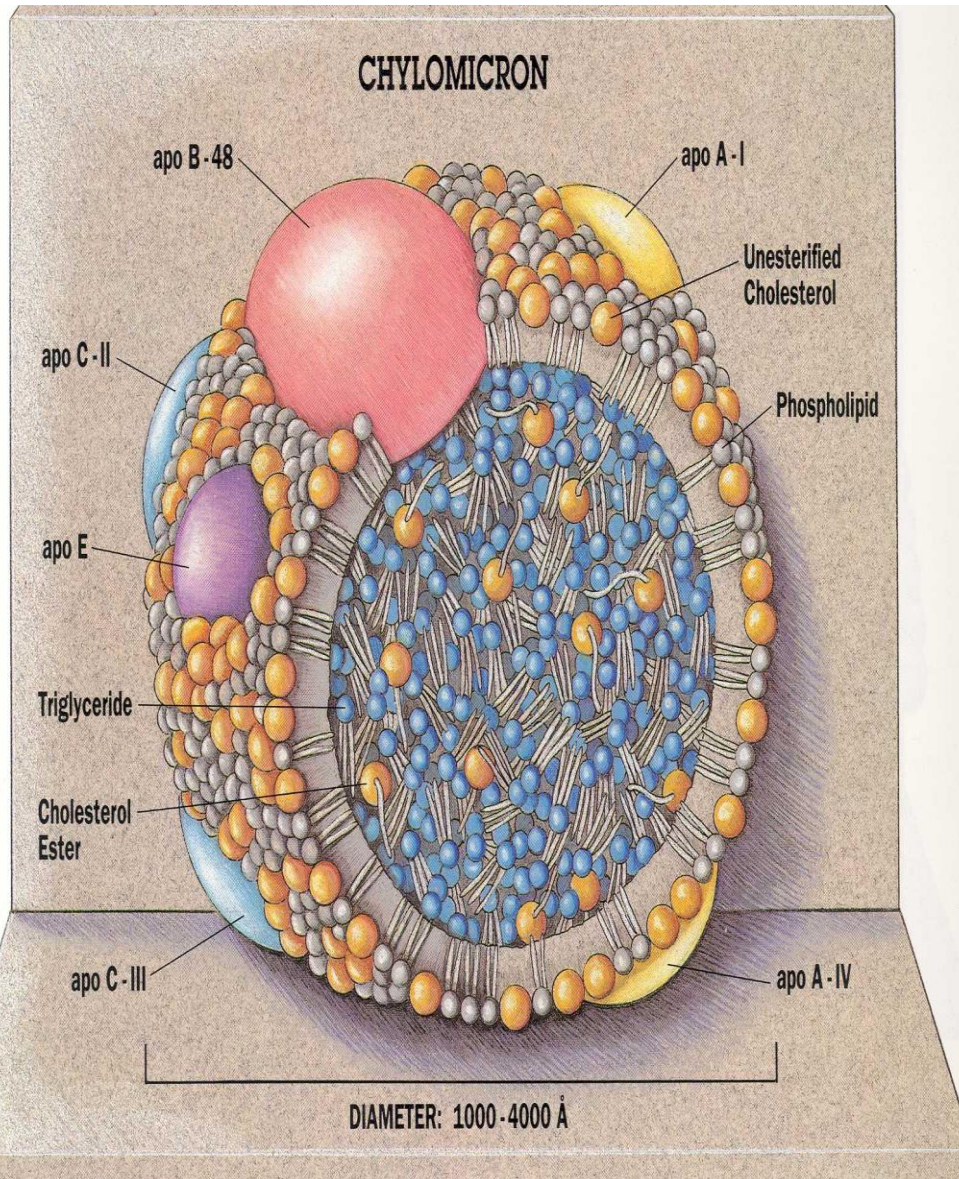


The proteins in the lipoproteins are known as **Apo-proteins** or **Apo- lipoproteins** . There are several types and sub-types of these Apo-proteins, each type of lipoproteins contains different composition of Apo-proteins

| LP           | Apo-proteins   |
|--------------|--|
| Chylomicrons | <b>A</b><br><b>B</b><br><b>C</b><br><b>E</b> (small amounts in chylomicrons).                |
| VLDL         | <b>B</b><br><b>C</b>   |
| IDL          | <b>B</b><br><b>E</b>   |
| LDL          | <b>B</b><br><b>C</b> (small amounts)   |
| HDL          | <b>A</b><br><b>C</b> (small amounts)<br><b>D</b> (small amounts)<br><b>E</b> (small amounts) |



## Chylomicrons : - TG rich

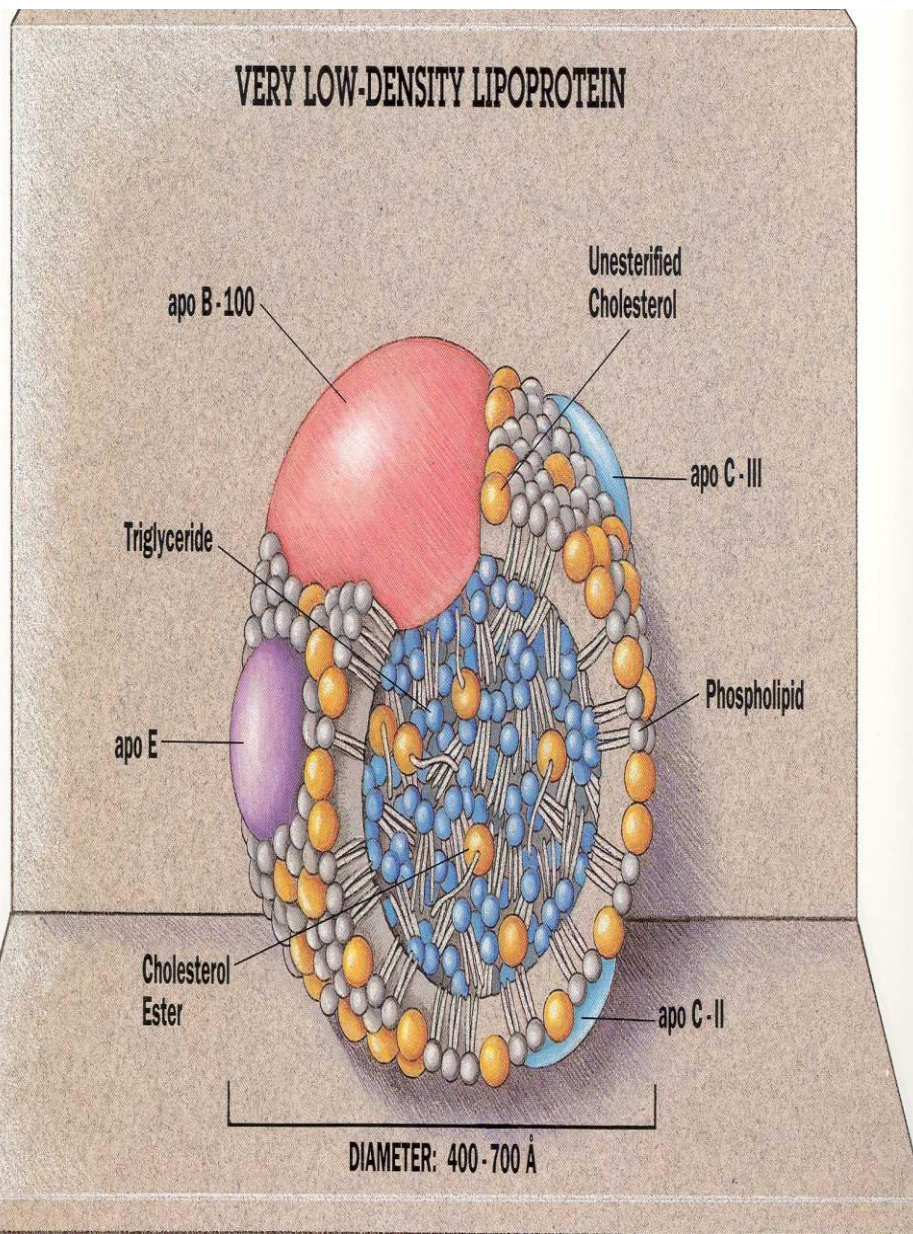


Transports endogenous TGs(dietary). Lesser extent cholesterol, fat soluble vitamins , and other lipids transported from the intestine to the systemic circulation .

Hydrophobic Core  
Triglyceride (86%)  
Cholesteryl Esters(3%)  
Cholesterol (2%)

Synthesized in intestine

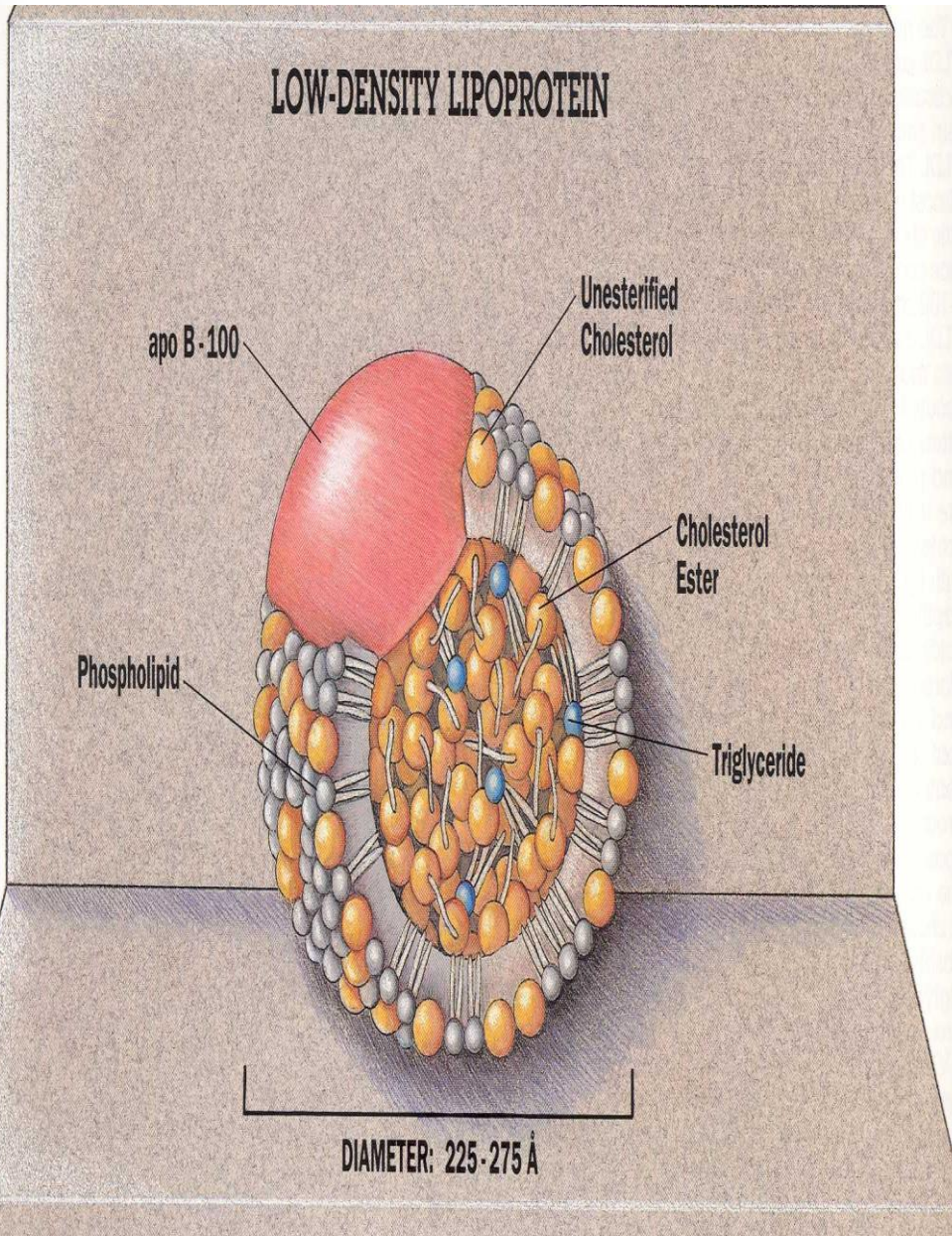
# VLDL : - rich in CE and TGs



Surface Monolayer  
Phospholipids Free(18%)  
Cholesterol (7%)  
Protein (8%)  
Hydrophobic Core  
Triglyceride (55%)  
Cholesteryl Esters (12%)

Transport endogenous  
triglyceried from the liver  
to the peripheral tissues

# LDL : - cholesterol rich



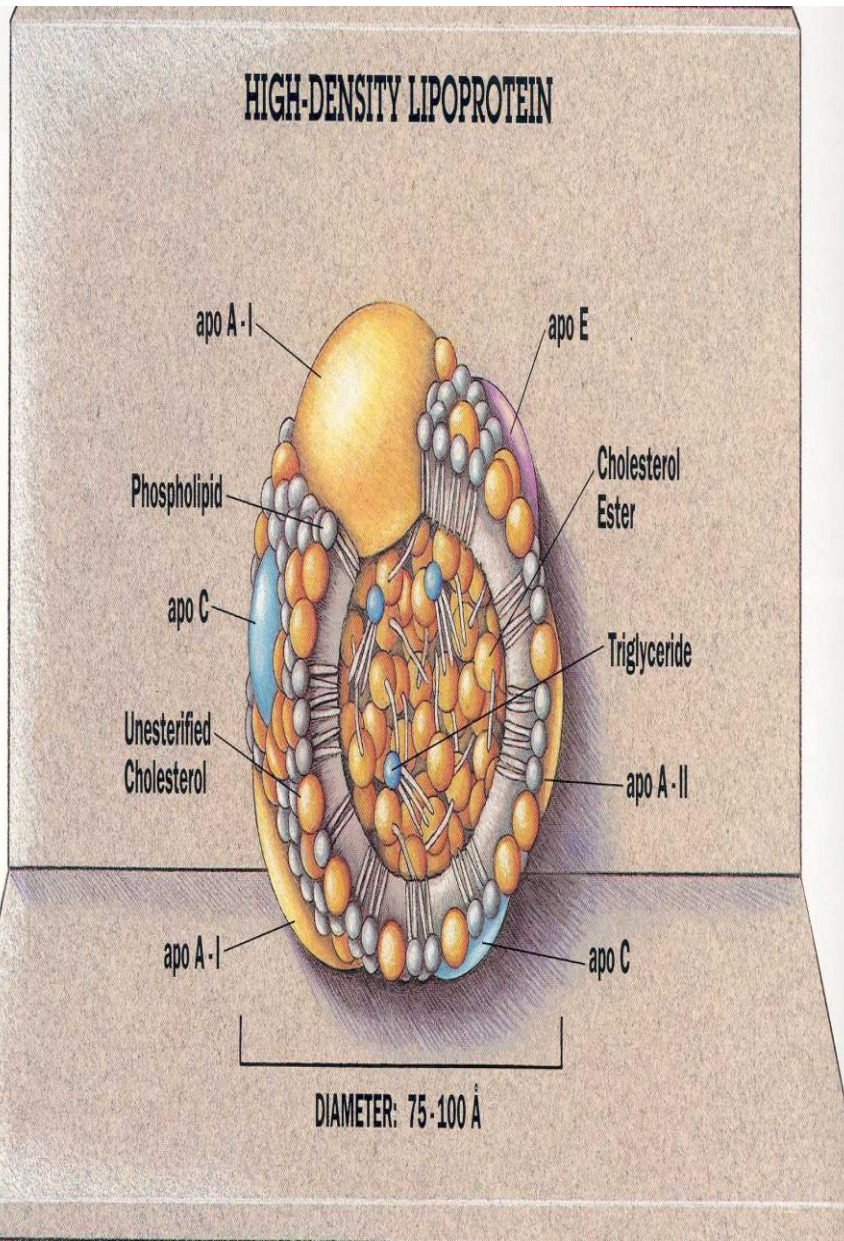
Surface Monolayer  
Phospholipids (22%)  
Free Cholesterol (8%)  
Protein (22%)

Synthesized from VLDL  
in blood circulation.

Transports cholesterol  
from liver and delivers  
to other tissues.

And have a role in the  
Transport of the  
phospholipid

# High density lipoprotein



Surface Monolayer  
Phospholipids (24%)  
Free Cholesterol (2%)  
Protein (55%)

Promotes re-esterification process of cholesterol or esterification of unesterified cholesterol by **LCAT** enzyme (**Lecithin-Cholesterol Acyl Transferase**), Reverse Cholesterol transport (from the peripheral tissue to the liver).

### 3.DERIVED LIPIDS

Derived from lipids (simple or complex) or precursors of lipids

#### Example

Fatty  
acids

Steroids

Cholesterol

Vitamin  
A and D

These include fatty acids (saturated and unsaturated) , glycerol , steroid , sterols , aldehyde and ketone bodies.

Because they are uncharged , glycerides (acylglycerols) , cholesterol and cholesteryl ester are termed **neutral lipids**.

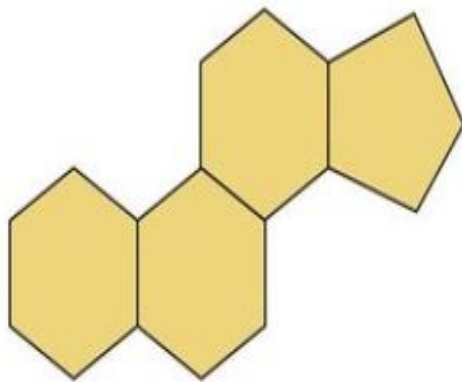
## **Classification**

1. Cholesterol (sterols)
2. Sex(steroid) hormone
3. Bile acids
4. D vitamin

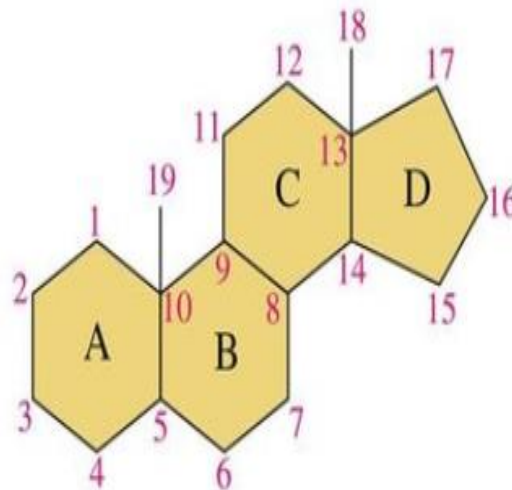
# Steroids

All steroids contain a **steroid nucleus**, which consists of

- three cyclohexane rings and one cyclopentane ring, fused together.
- rings designated as A, B, C, and D.
- numbered carbon atoms beginning in ring A.
- two methyl groups at positions 18 and 19.

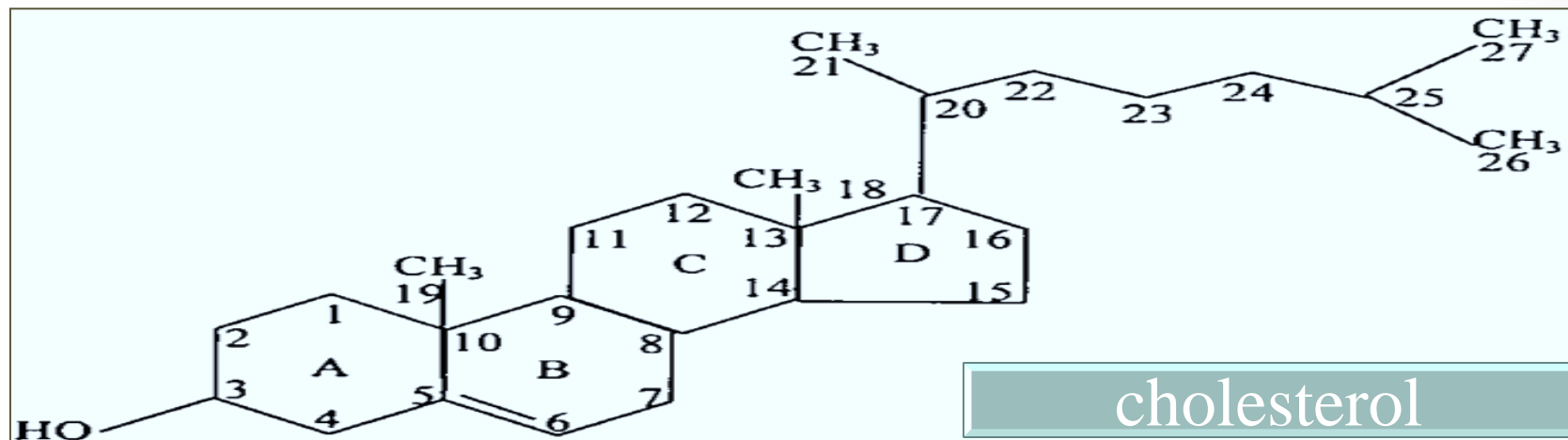


Steroid nucleus



Steroid numbering system

Who does cholesterol differ from steroid nucleus ?  
It has OH in C3 , long alphatic chain in C17 ,  
double bond in C5.



## Cholesterol

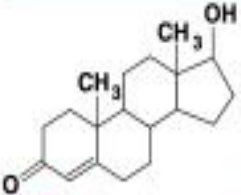
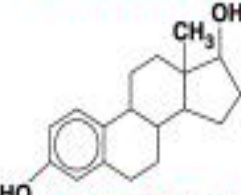
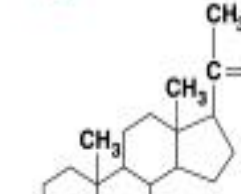
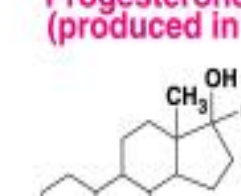
- ❑ Cholesterol is the best known and most abundant steroid in the animals.
- ❑ Is a precursor for biosynthesis of many other steroids.

- ❑ It's a major component of cell membranes, and affects the fluidity of the membrane due to its bulky structure.
- ❑ Cholesterol is called a sterol because it contains an alcohol group.
- ❑ We can obtain cholesterol from our diet (animal products), but our liver can also synthesize all the cholesterol that we need.
- ❑ the liver synthesizes more cholesterol when dietary intake is low .
- ❑ excessive blood cholesterol is associated with atherosclerosis and formation of gallstones

- ❑ Through the interaction with the phospholipid fatty acid chains , cholesterol increases membrane packing , which reduces membrane fluidity. This helps slightly immobilize the outer surface of the membrane and make it less soluble to small water – soluble molecules that could otherwise pass through more easily. Without cholesterol , cell membranes would be too fluid , not firm enough , and too permeable to some molecules

# Steroid Hormones

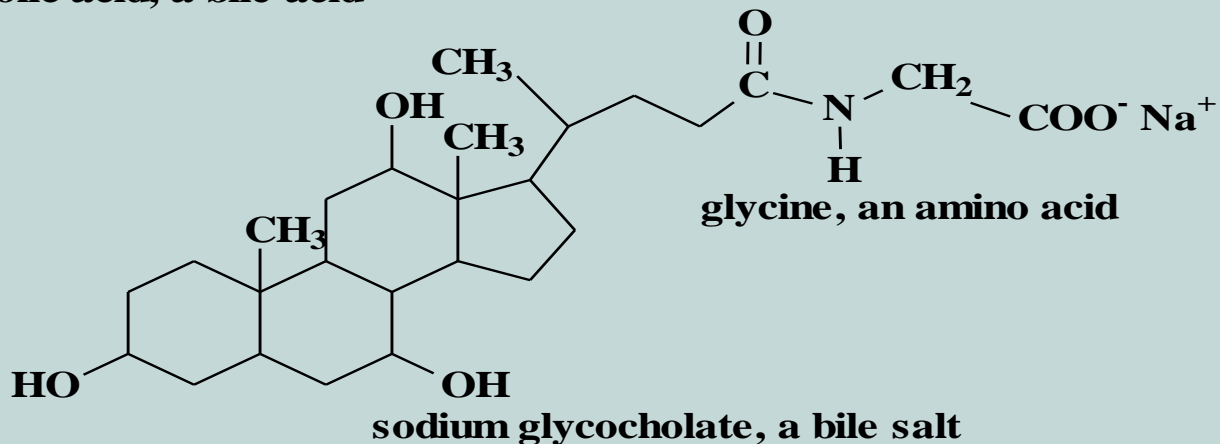
- **Hormones** act as chemical messengers
- They are important in control of many biological functions
- They are secreted from endocrine glands (and placenta)
- They react with receptors on cell surfaces to trigger a cascade response
- Usually control metabolism at the gene level
- **Steroid hormones** are biosynthesized from cholesterol

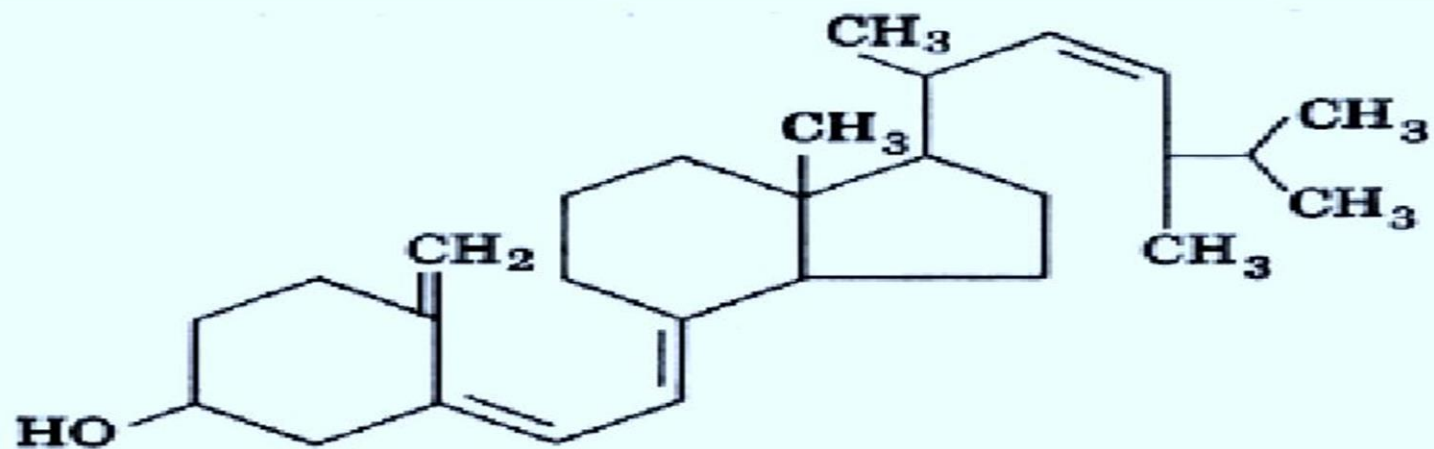
| Hormone  | Biological Effects   |
|--|--|
| <br><b>Testosterone (androgen)</b><br>(produced in testes) | Development of male organs; male sexual characteristics including muscles and facial hair; sperm formation |
| <br><b>Estradiol (estrogen)</b><br>(produced in ovaries)   | Development of female sexual characteristics; ovulation  |
| <br><b>Progesterone</b><br>(produced in ovaries)           | Prepares uterus for fertilized egg   |
| <br><b>Norethindrone</b><br>(synthetic progestin)        | Contraceptive (birth control) pill   |

# Bile Salts

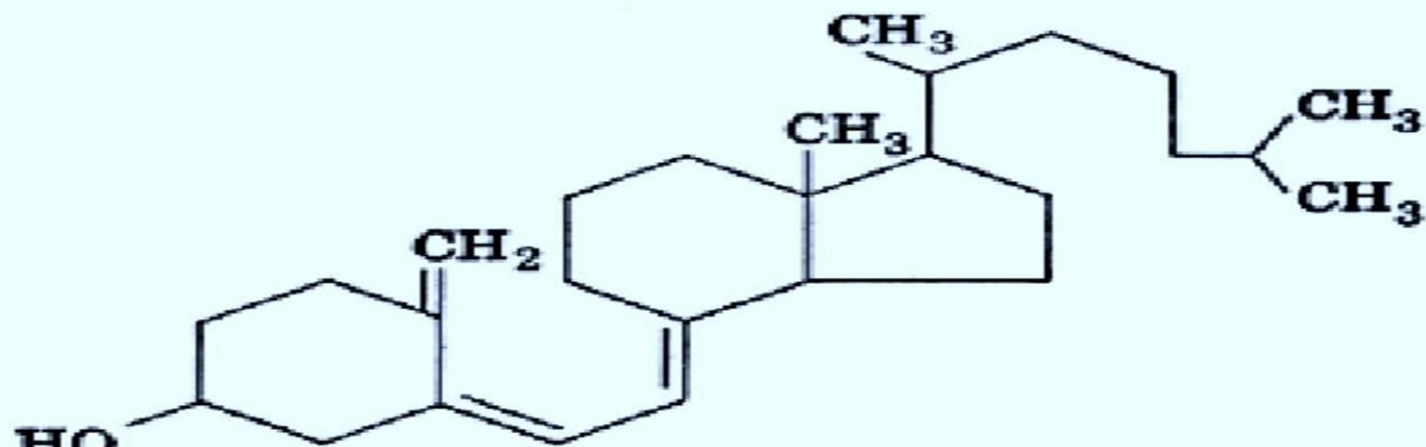
- **Bile salts** are synthesized from cholesterol in the liver
  - they are stored in the gallbladder and released into the upper small intestine to help break down fats and oils (like soaps)
  - too much accumulated cholesterol in the gall bladder can lead to gallstones; if a gallstone passes into the bile duct, severe pain results and the gallbladder often has to be removed

**cholic acid, a bile acid**





**Vitamin D<sub>2</sub>**



**Vitamin D<sub>3</sub>**

# Thank you

