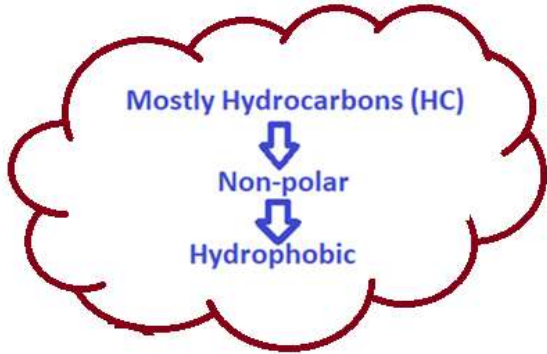


<sup>متنوعة</sup>  
**Lipids:** Heterogeneous group of compounds all are **Insoluble** in water, BUT soluble in Non-polar Organic solvents (Ether, Chloroform, Benzene, Acetone)

المذيبات العضوية



- Lipid definition depends mainly on **Solubility** which is a physical not chemical property.
- Some lipids are amphipathic contain non-polar part and small polar functional group (carboxyl, alcohol, amine...)

### Functions of lipids:

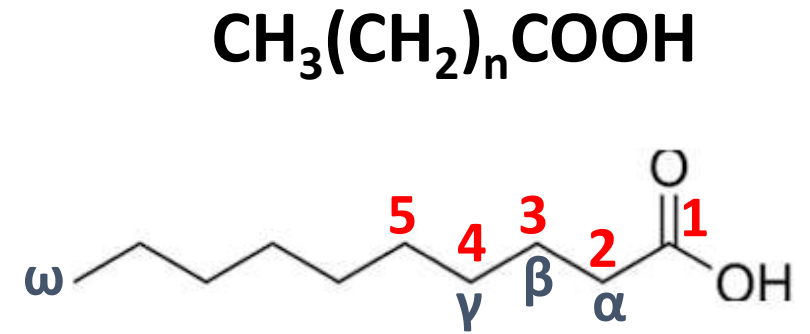
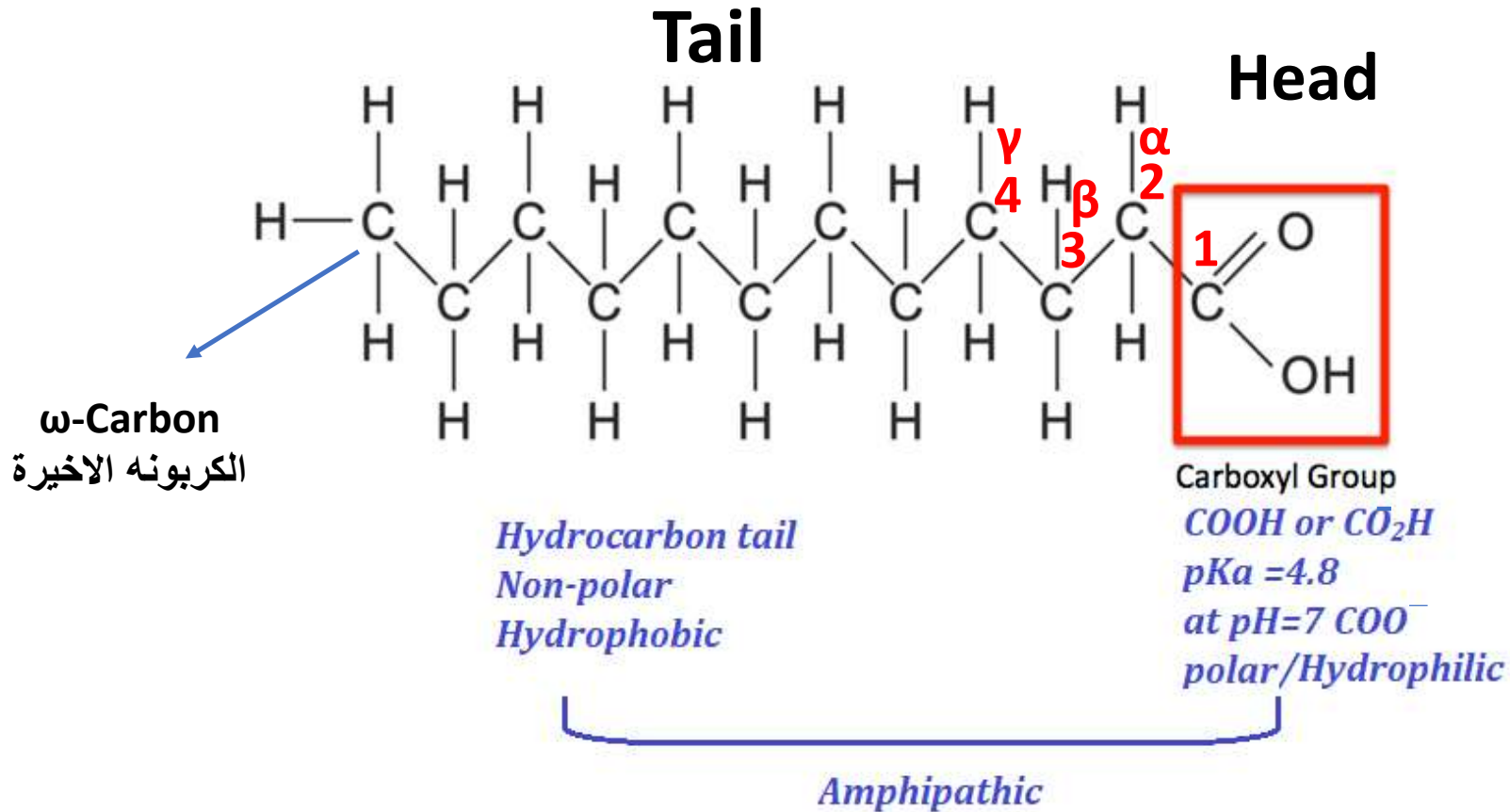
- Long term energy storage
- Component of biological membranes
- Protection and Thermo-insulation
- Vitamin precursors “specifically fat soluble vitamins (A, K, E, D)”

### Lipid families:

1. Fatty acids (FA)
  2. Triglycerides Or Triacylglycerol (TG or TAG) <sup>الدهون والزيوت</sup>
  3. Glycerophospholipids or Phosphoglyceride
  4. Sphingophospholipids
  5. Steroids
  6. Lipoproteins
- } **phospholipids**

# 1. Fatty acids **الأحماض الدهنية** Simplest Type of lipids

عددها كبير بالطبيعة لكن كل الاحماض الدهنية تتكون من **راس وذيل**



**C1** → COO<sup>-</sup> "the carboxyl head" ionized at physiological pH

**C2** →  $\alpha$ - carbon

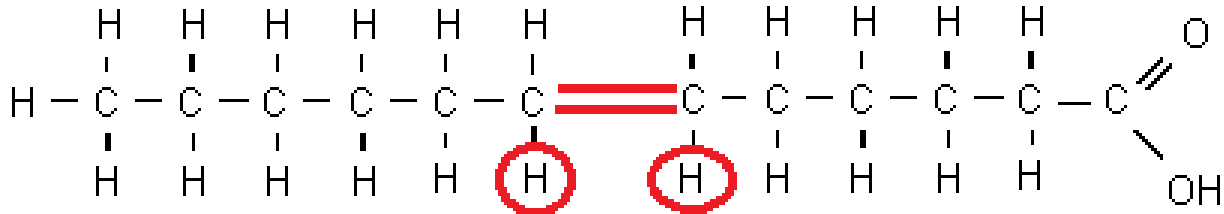
**C3** →  $\beta$ -carbon

**C4** →  $\gamma$ -carbon

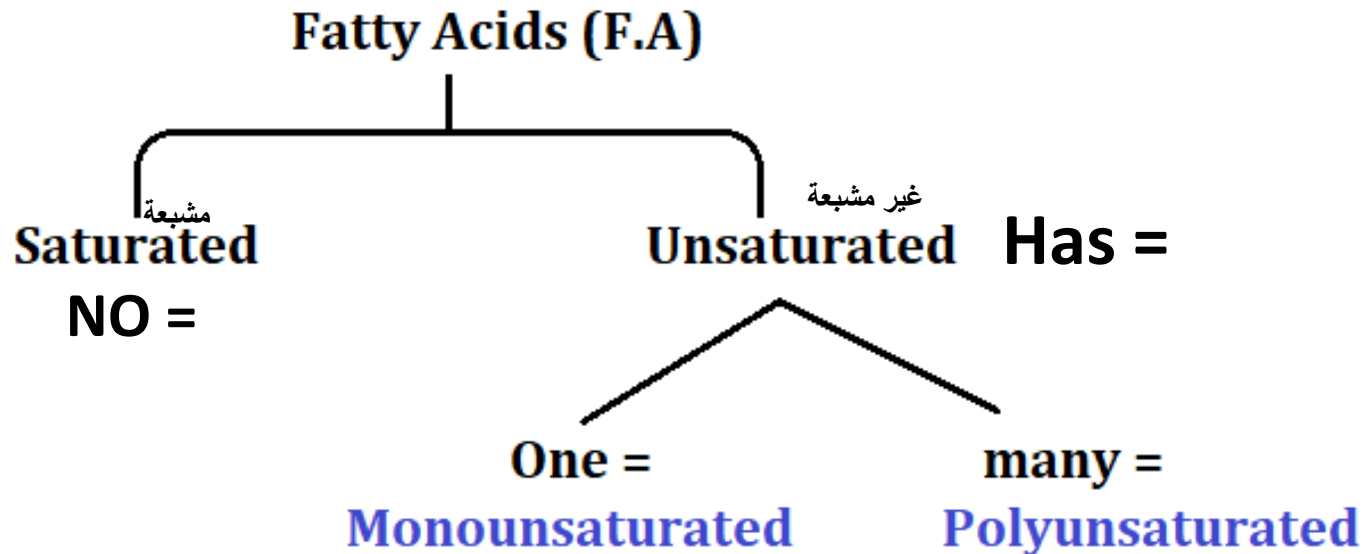
**Last carbon** →  $\omega$ -carbon

# Fatty acids Differ in:

- a. # of Carbon atoms
- b. Presence of double bonds

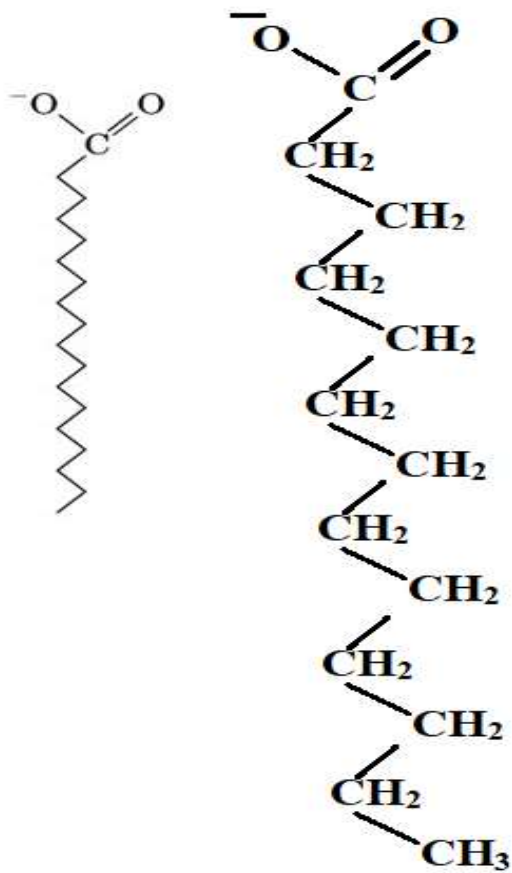


**Unsaturated**  
غير مشبع بال H



(=) : double bond

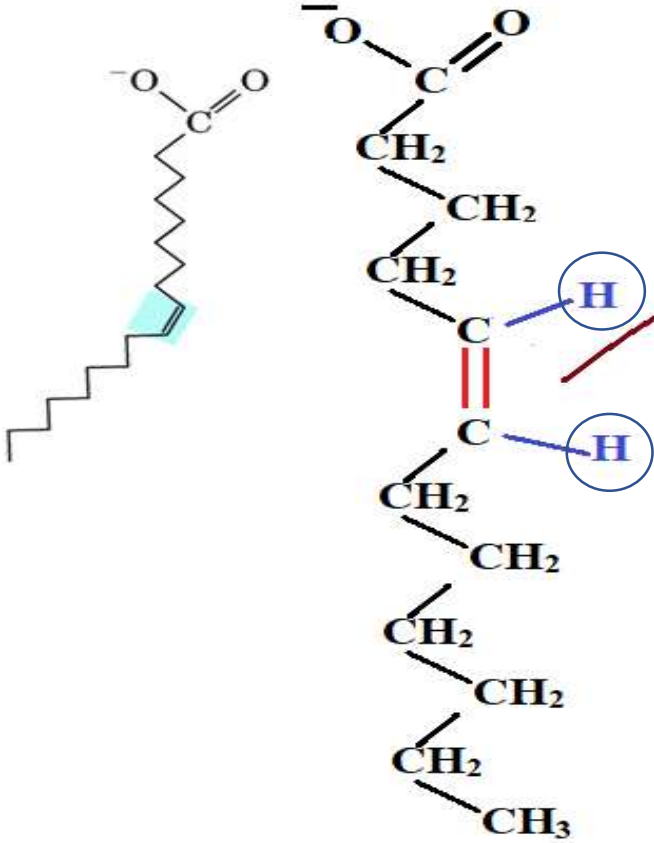
## مشبعة Saturated



Saturated fatty acids increase the level of LDL (Bad Cholesterol) this will increase the risk of cardiovascular diseases (MI and Strokes)  
تزيد خطر الإصابة بأمراض القلب والأوعية الدموية

- No double bonds
- No kinks لا انحناءات
- Ordered مرتبة
- Solid at room Temperature
- Animal Fat contain high % of saturated Fatty acids

## غير مشبعة Unsaturated



**Cis double bond الطبيعي**  
**trans صناعية (No Kink)**  
تنتج من عملية الهدرجة وهي مضرا جدا بالصحة وتزيد خطر الإصابة بأمراض القلب و الأوعية الدموية

- Has one or more double bonds
- Has kinks فيها انحناءات
- Disordered
- Liquid/Fluid at room Temperature (Kinks decrease the hydrophobic interaction)
- plant Oils contain high % of unsaturated Fatty acids

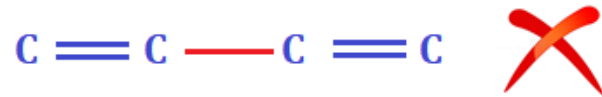
# Fatty acids in nature

الفردى موجود بالطبيعة لكن نادر

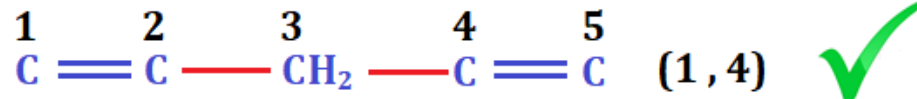
عدد زوجي

1. Mostly have Even number of carbons (Odd number of carbons are Rare)
  - 1 – 5C (Short chain FA), 6 – 11C (Medium chain FA), 12 – 21C (long chain FA),  $\geq 22$ C (very long chain FA)
  - As number of C increase  $\rightarrow$  water solubility decrease (**long and very long chain FA considered hydrophobic**)
  - When the total number of C in a fatty acid is Even, then the hydrocarbon tail will have Odd number of Carbons
2. If unsaturated; the double bond is **Cis** (with Kink) not trans (rare, No kink)
3. If its polyunsaturated; the double bonds are **NOT conjugated** “separated by Methylene group (CH<sub>2</sub>)”

Conjugated



Unconjugated



الفرق بين موقع ال = الاولى والمجاورة لها,

بالارقام هو 3

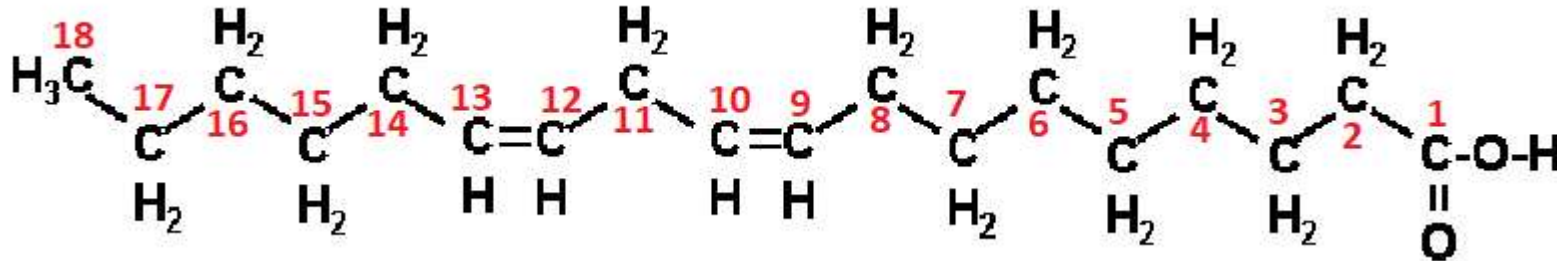
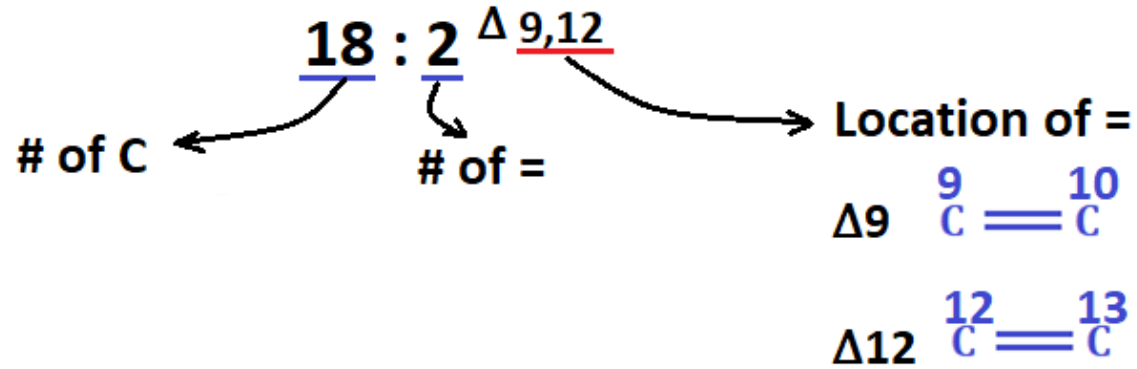
مش اكثر ولا اقل

If the first = at C9, then the next = will be at C12 then C15 and so on

## Notation for Fatty acids:

- # of C atoms
- # of =s
- Location of =

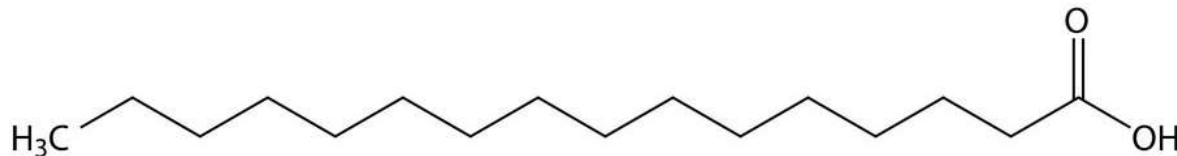
E.g.1



Can be written **18:2(9,12)**

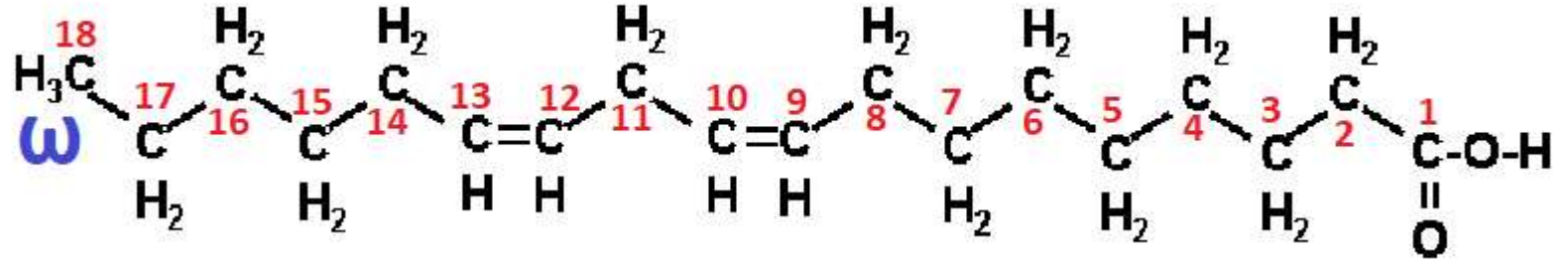
Polyunsaturated fatty acid

E.g.2      **16:0**      16C saturated fatty acid



# Omega ( $\omega$ ) naming for unsaturated Fatty acids (الكربونه الاخيرة $\omega$ )

E.g. 18 : 2 (9,12)



- عدد الكربونات بين الكربونه الاخيرة (Methyl) و اخر = هو  $6 \leftarrow \omega 6$
- للتبسيط (عدد الكربونات - موقع اخر =)

$$18 - 12 = 6$$

- $\omega$ -naming لا تدل على عدد الكربونات او عدد الروابط الثنائية الموجودة

$$18:3^{\Delta 9,12,15} \rightarrow 18 - 15 = 3 \rightarrow \omega 3$$

$$20:4^{\Delta 5,8,11,14} \rightarrow 20 - 14 = 6 \rightarrow \omega 6$$

- Fatty acids that you **can't** synthesize in your body and obtained from diet called **Essential fatty acids** which are:

- **Linoleic acid (Linoleate)** 18:2 (9,12)
- **Linolenic acid (Linolenate)** 18:3 (9,12,15)

- Fatty acids that you can synthesize in the body called **Non-essential fatty acids**

- Milk fat contain medium and short chain fatty acids

- Arachidonic acid** is the <sup>مادة اولية</sup> precursor of group of important chemical signals in the body called **Eicosanoids** (Eicosa = 20) which includes families such as prostaglandins, Leukotrienes and Thromboxanes

Inflammatory mediator

Regulate clotting

**Linoleic acid** is the precursor of **ω6** fatty acids which include Linoleic and arachidonic acids

**Linolenic acids** is the precursor of **ω3** fatty acids

ω3 and ω6 fatty acids are important for growth and development

Fatty acids with chain lengths of four to ten carbons are found in significant quantities in milk.

Structural lipids and triacylglycerols contain primarily fatty acids of at least sixteen carbons.

COMMON NAME	STRUCTURE
Formic acid	1
Acetic acid	2:0
Propionic acid	3:0
Butyric acid	4:0
Capric acid	10:0
Palmitic acid	16:0 ✓
Palmitoleic acid	16:1(9) ✓
Stearic acid	18:0 ✓
Oleic acid	18:1(9) ✓
Linoleic acid	18:2(9,12) ✓
Linolenic acid	18:3(9,12,15) ✓
Arachidonic acid	20:4(5, 8,11,14) ✓
Lignoceric acid	24:0
Nervonic acid	24:1(15)

Precursor of prostaglandins

Essential fatty acids

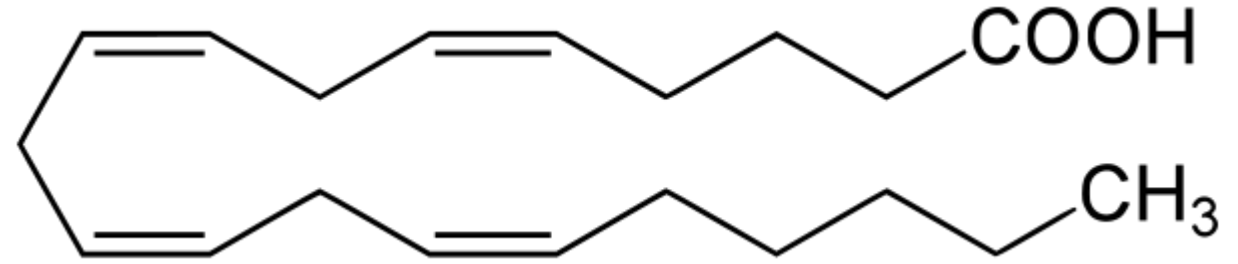


Question: for the following structure, write

Notation?

Common Name?

$\omega$ -name?



### Melting Point of Fatty acids

a.  $\uparrow$  # of Double bonds  $\downarrow$  Melting point

Cis double bond lowers Melting temperature

a.  $\uparrow$  # of Carbon atoms  $\uparrow$  Melting point

اولا رتب الاحماض الدهنية حسب عدد الروابط الثنائية  
اذا تساوى عدد الروابط الثنائية رتب حسب عدد الكربونات  
تأثير الرابطة الثنائية على Melting point اقوى من تأثير عدد الكربونات

- The majority of human fatty acids are saturated and monounsaturated
- Polyunsaturated fatty acids found in the cell membrane as part of phospholipids to maintain the membrane fluidity

Q: Arrange the following Fatty acids according to melting point ascending (lowest to highest)

**12:0**

**14:0**

**16:1(9)**

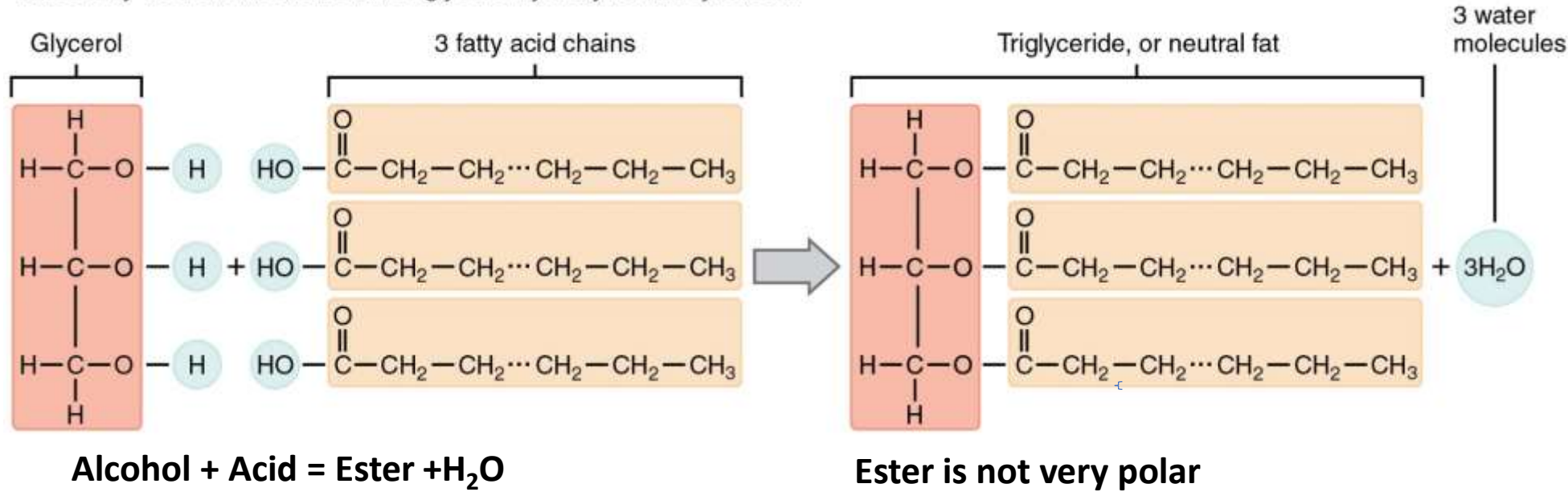
**18:1(9)**

**18:2(9,12)**

**20:4(5,8,11,14)**

## 2. Triglycerides Or Triacylglycerol (TG or TAG) = Fat and Oils

Three fatty acid chains are bound to glycerol by dehydration synthesis.

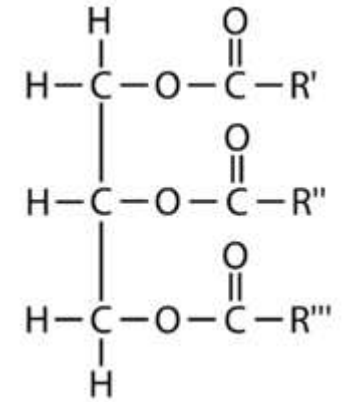


All Triglycerides consist of:

- Glycerol (Alcohol): 3C each bears OH group
- 3 Fatty acids which are esterified (bound by ester bond) to Glycerol

The Ester bond between Glycerol and fatty acids formed by dehydration (**OH from the carboxyl head** of the fatty acid and **H from the hydroxyl group** of glycerol)

Triglycerides are Hydrophobic not Amphipathic



- If the three fatty acids bound to Glycerol are Identical (**Simple TAG**) rare
- If the three fatty acids bound to Glycerol are Different (**Mixed TAG**) common
- Animal Triglycerides called **FAT** (solid, higher % of Saturated fatty acids)
- Plant Triglycerides called **Oils** (liquid, higher % of Unsaturated fatty acids)

### Triglycerides Function:

- Store Fatty acids in adipose tissue (Adipocytes), fat is aggregate inside the adipocytes as large oily droplets.
- Fatty acids are the major source of energy in the liver, heart and resting muscle in the normal physiologic condition.
- erythrocyte and brain cannot use fatty acids as source of energy

During fasting or starvation ↓Glucose; body cells increase Utilization of fatty acids as source of energy

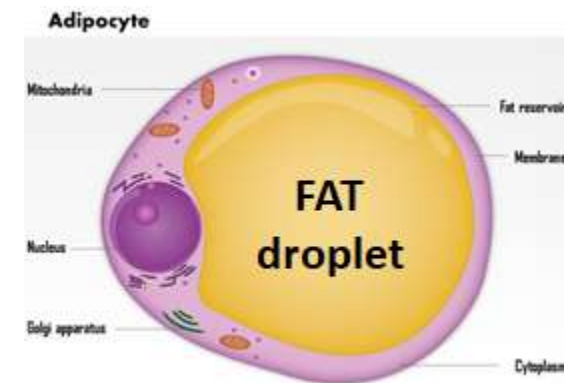
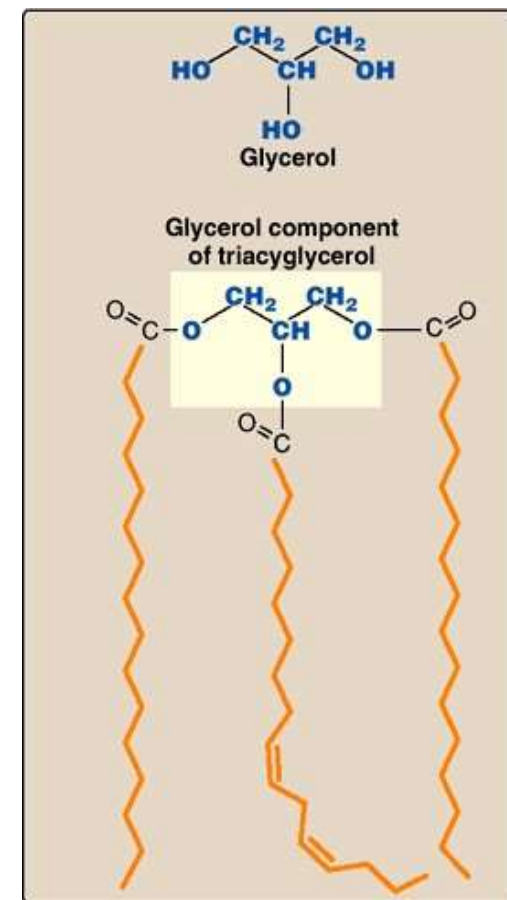
### Now from where we get these fatty acids??

Answer: Triacylglycerol (FAT) in Adipocytes

Hydrolysis of TAG by Hormone sensitive lipase →  
Glycerol

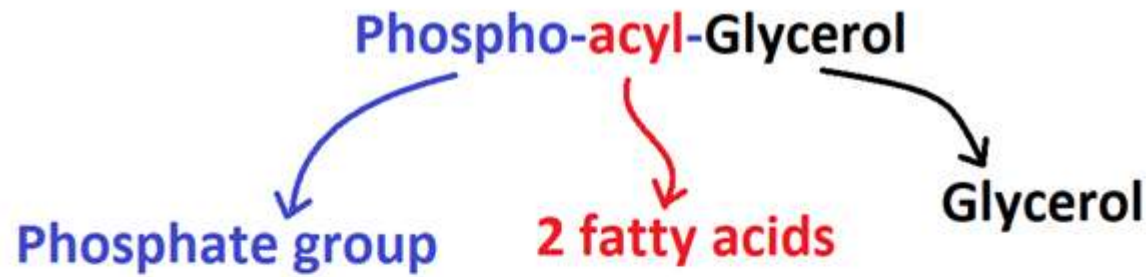
3 Fatty acids transported to body tissues in blood via albumin

**Triglycerides Cannot be found in the cell membrane because they are not amphipathic**

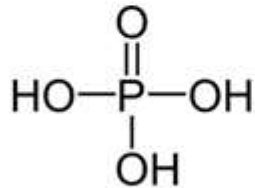


### 3. Glycerophospholipid OR phosphoacylglycerol OR Phosphoglyceride

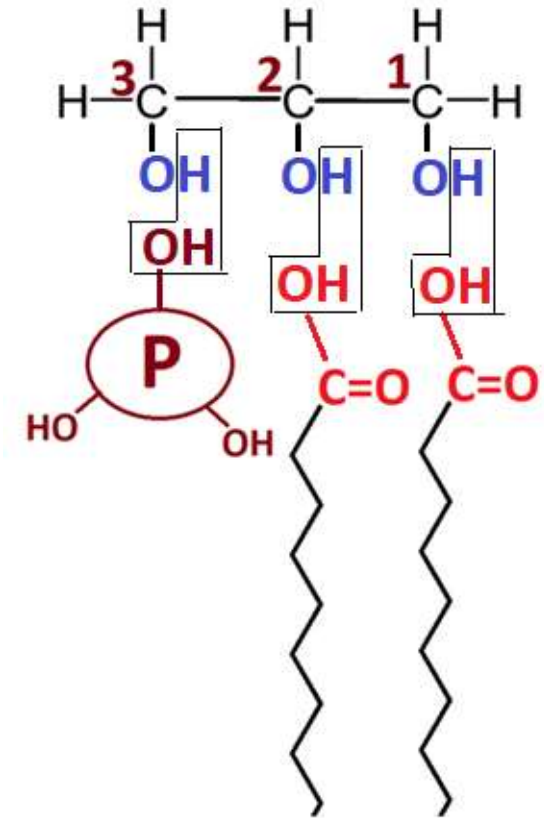
- Most abundant <sup>وفرة</sup> lipid in the cell membranes



Phosphoric acid  
(H<sub>3</sub>PO<sub>4</sub>)

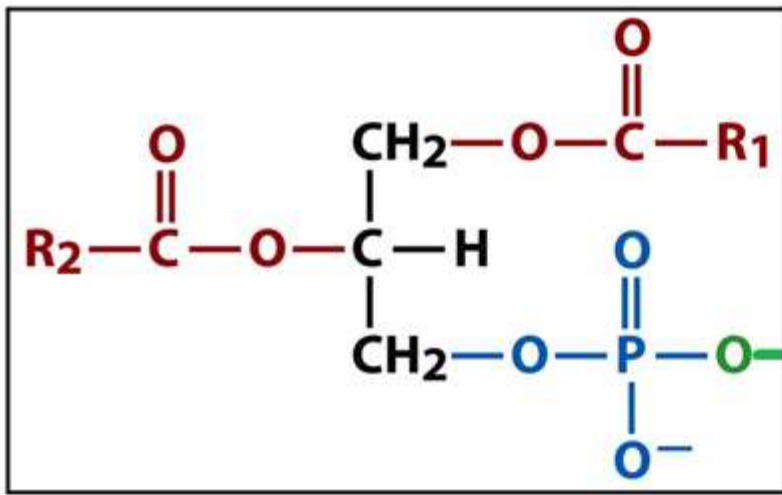


Tri protic acid يعطي 3H<sup>+</sup>  
can form more than one  
ESTER with alcohols



**Phosphatidic acid (Phosphatidate) =**  
Glycerol + 2 fatty acids + Phosphate group  
Simplest Glycerophospholipid

- Fatty acid at C1 usually saturated
- Fatty acid at C2 usually unsaturated



**Phosphatidic acid**

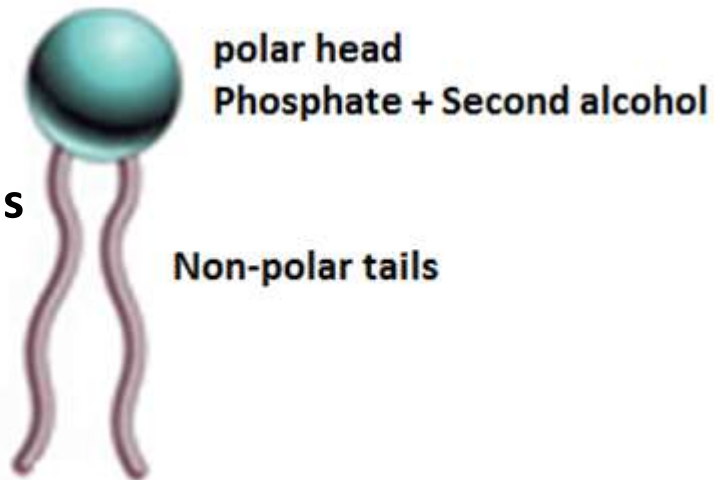
**Polar or Charged**

- Ethanolamine
- Serine
- X Choline
- Glycerol
- Inositol

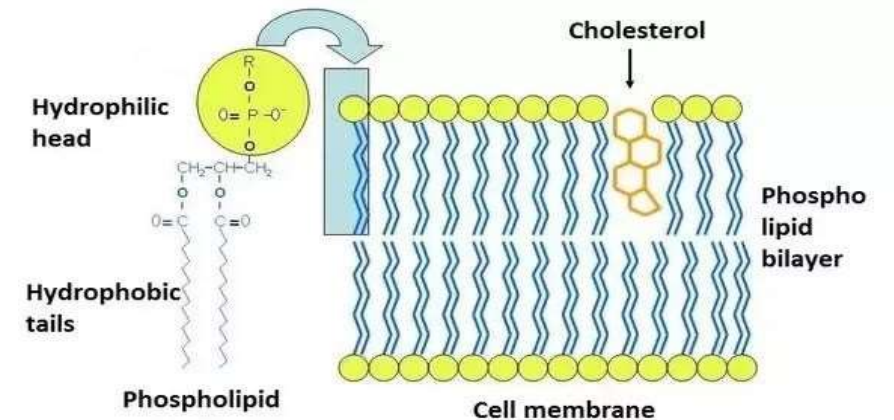
Phosphate group form another Ester with other Alcohol  
متغير X

**Glycerophospholipid**

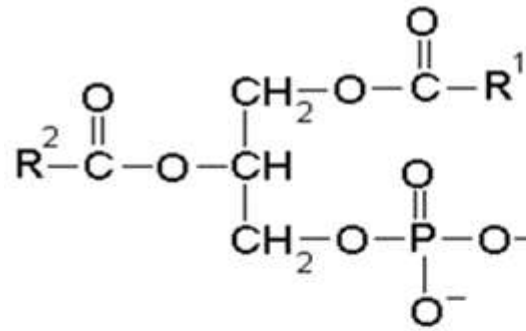
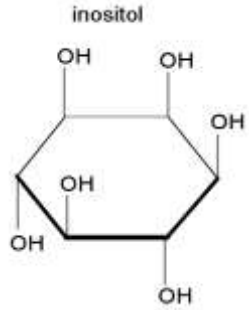
Glycerophospholipids are **Amphipathic**



**Function of Glycerophospholipids:  
Main component of the cell membrane**



- Many types of glycerophospholipids, differ in the second alcohol that esterified to phosphate group



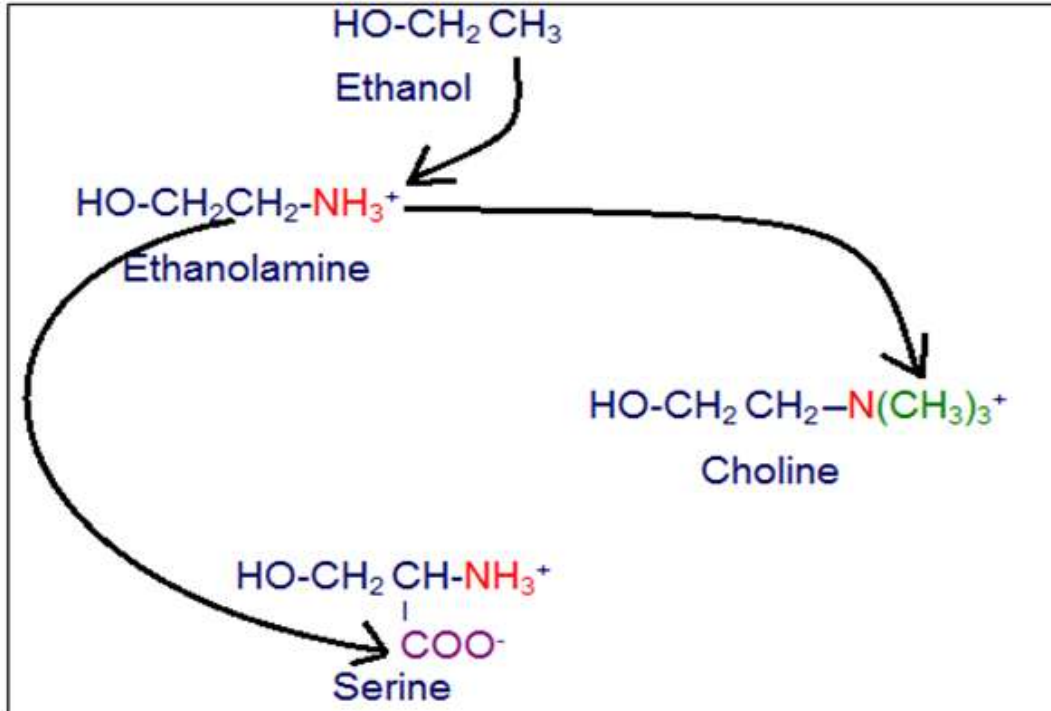
-CH<sub>2</sub>CH<sub>2</sub>-NH<sub>3</sub><sup>+</sup> **Phosphatidyl-Ethanolamine**

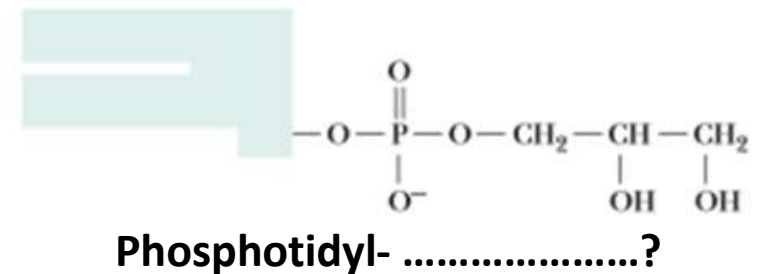
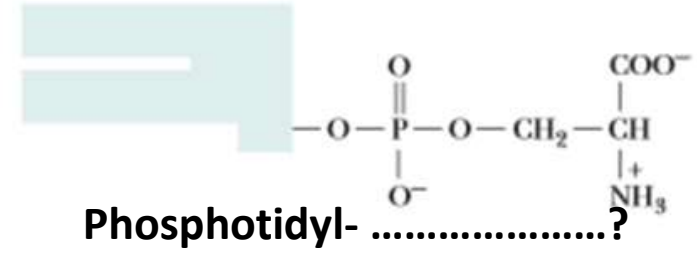
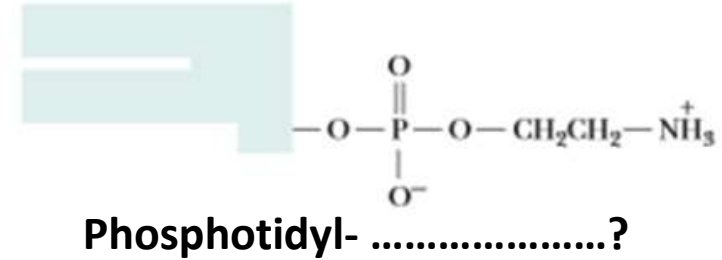
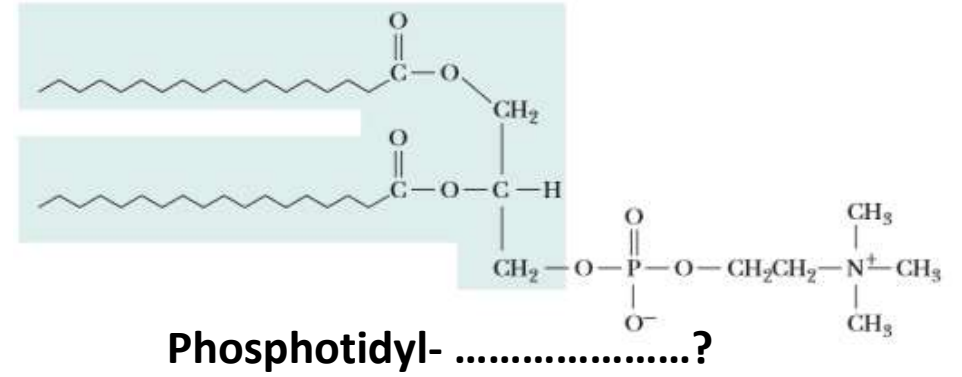
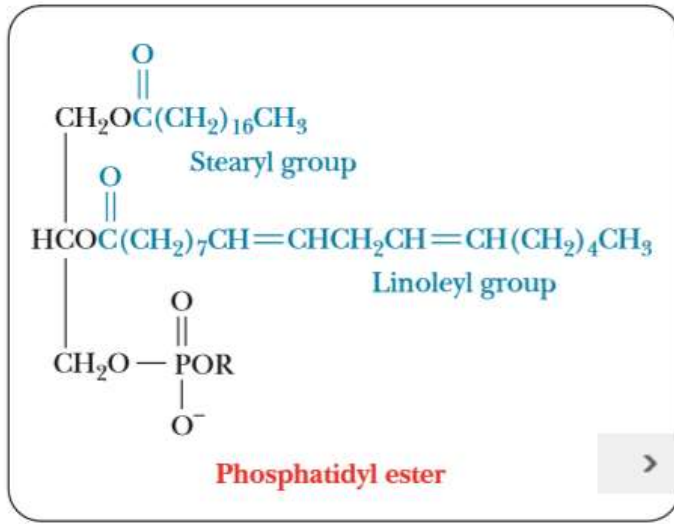
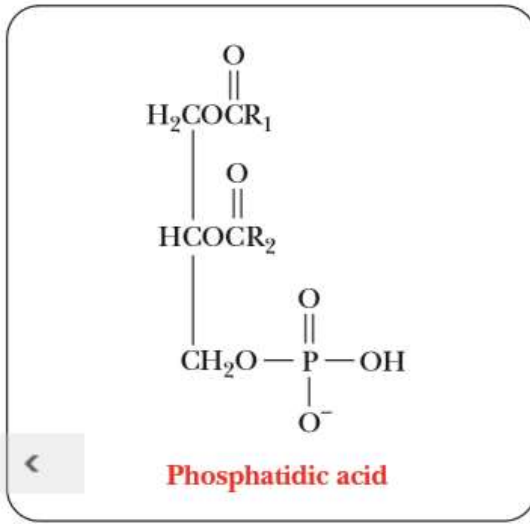
-CH<sub>2</sub>CH<sub>2</sub>-N(CH<sub>3</sub>)<sub>3</sub><sup>+</sup> **Phosphatidyl-Choline (Lecithin)**

-CH<sub>2</sub>CH(NH<sub>3</sub><sup>+</sup>)COO<sup>-</sup> **Phosphatidyl-Serine**



CH<sub>2</sub>-CH(OH)-CH<sub>2</sub>(OH) **Phosphatidyl-Glycerol**

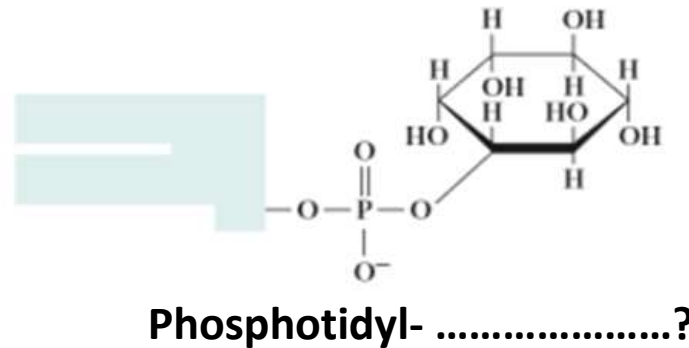
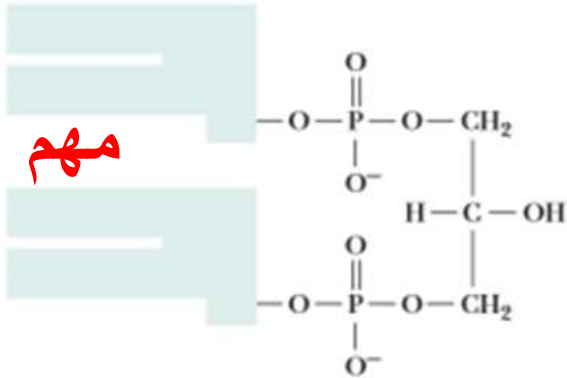




موجود بكثرة في الغشاء الداخلي للميتوكوندريا ومهم لعمل سلسلة نقل الالكترونات

### Diphosphotidyl-Glycerol (Cardiolipin)

Found in both prokaryotes and Eukaryotes

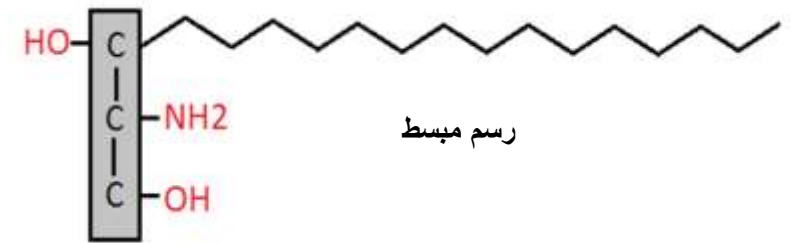
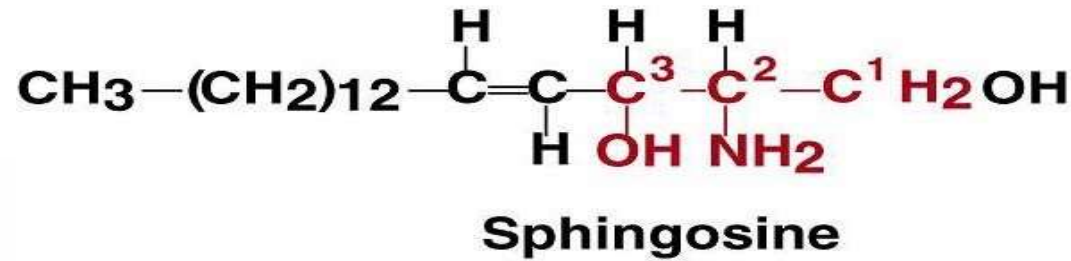
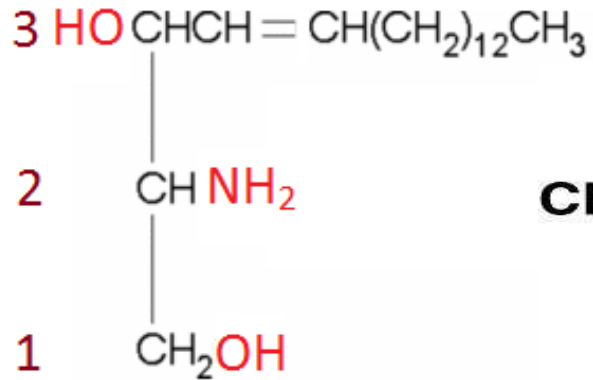


- 3 Glycerols
- 4 Fatty acids
- 2 Phosphate groups

# 4. Sphingolipids

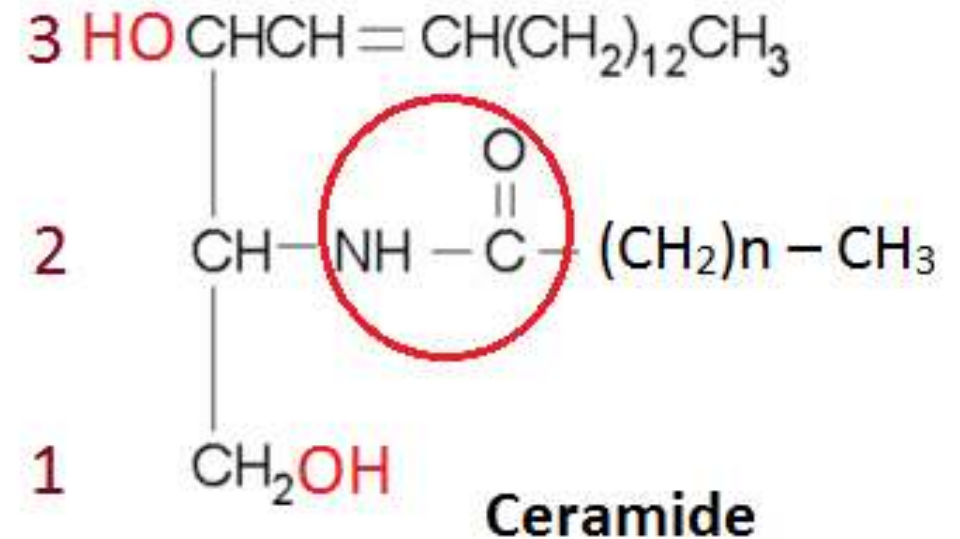
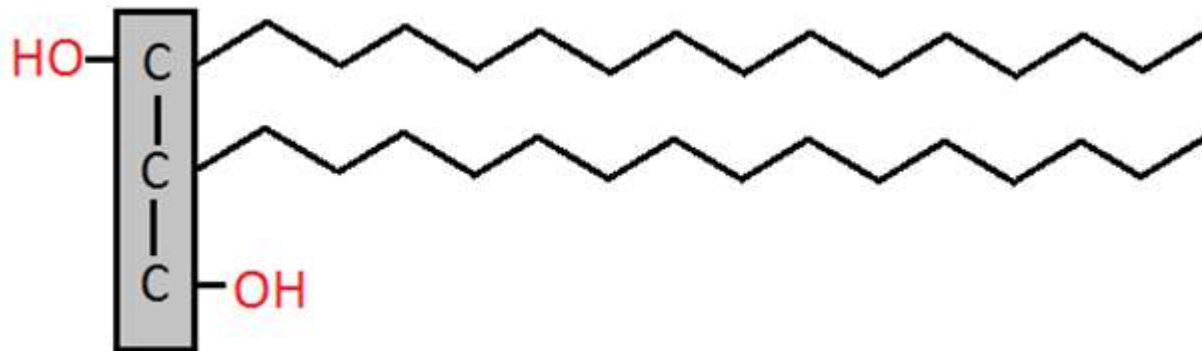
Amphipathic lipids, component of cell membrane mainly in the Nervous system cell membrane

The backbone of sphingolipid is a large molecule called **Sphingosine (18 C)**

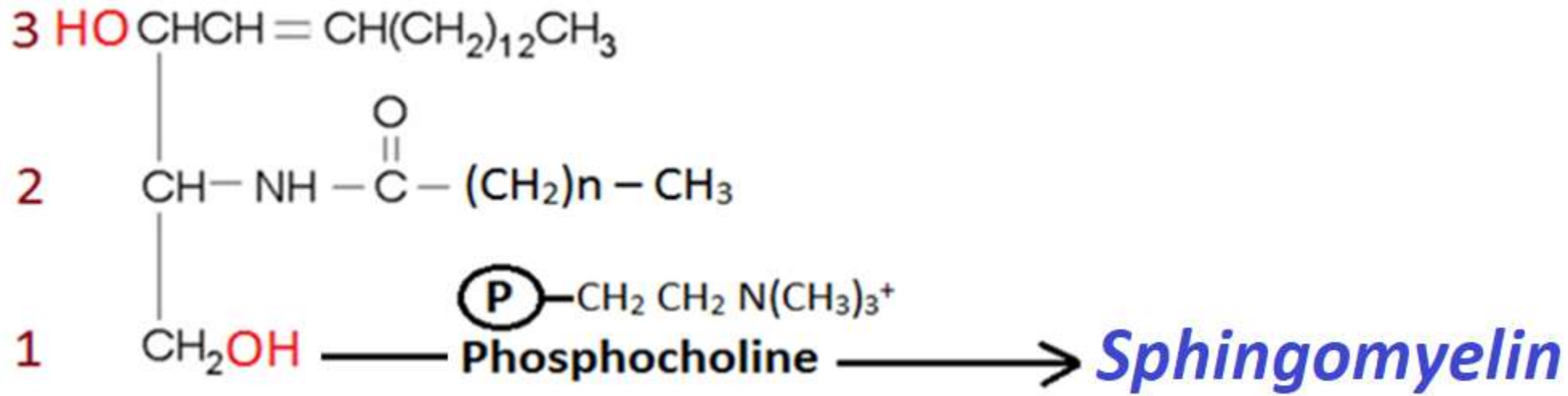


Sphingosine (Amino-Alcohol)

The simplest sphingolipid called **Ceramide**  
 Sphingosine + fatty acid bind to C2 by amide bond

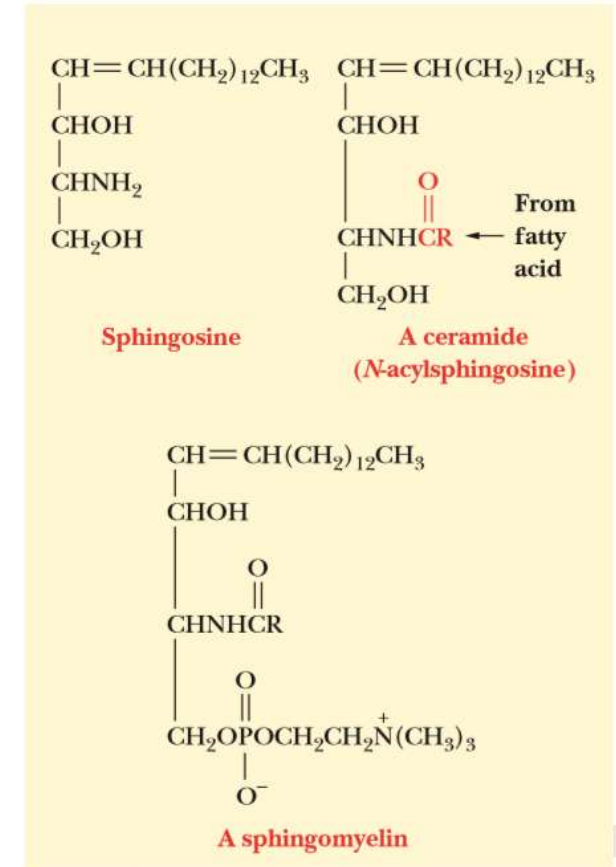






**Sphingomyelin** = Sphingosine + Fatty acid + Phosphate group + Choline  
 = Ceramide + Phosphate group + Choline

**Sphingomyelin is the Major lipid in the Myelin Sheath**

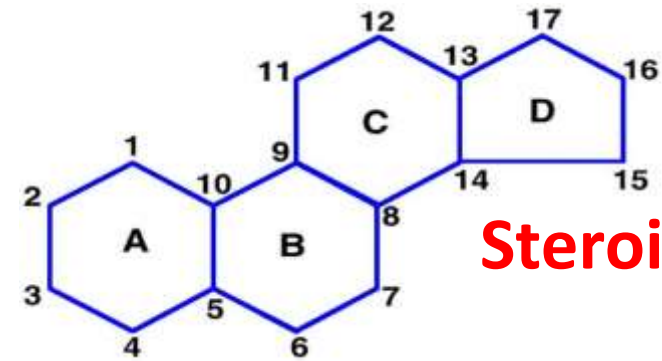


## 5. Steroids

- General structure: 4 fused rings

A,B,C → six-membered rings (Cyclohexane rings)

D → five membered ring (Cyclopentane ring)

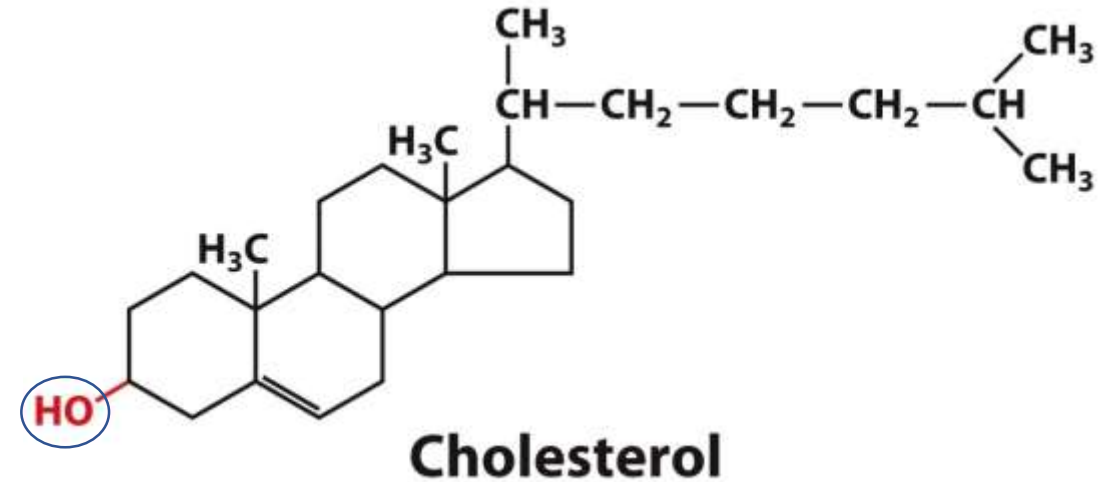


### Animal Steroids

Most important animal steroids is **Cholesterol**

#### Features:

- 27 C atoms
- OH on carbon 3 of Ring A (the only polar Part)
- Double bond C<sub>5</sub> = C<sub>6</sub>
- 8 hydrocarbon tail at C17
- Its amphipathic due to OH at ring A  
So it can be found in cell membrane



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- Cholesterol is the precursor of other animal steroids such as sex hormones, adrenal gland hormones and Bile salts
- Also Cholesterol is the precursor of Vitamin D<sub>3</sub>
- High plasma cholesterol level correlate to atherosclerosis and cardiovascular diseases

Cholesterol is stored in tissue as **cholesteryl-Ester**: Fatty acid esterified to the OH group at C3 of cholesterol)

Cholesteryl-ester is highly hydrophobic and cannot be found in the cell membrane

Cholesterol in cells or plasma found in 2 forms:

- Free (unesterified) cholesterol
- Cholesteryl-ester

## 6. Lipoproteins

They are aggregate of Lipids and Proteins (Multi-molecular complex)

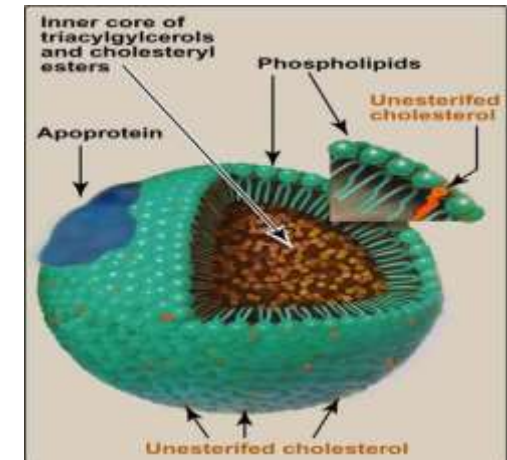
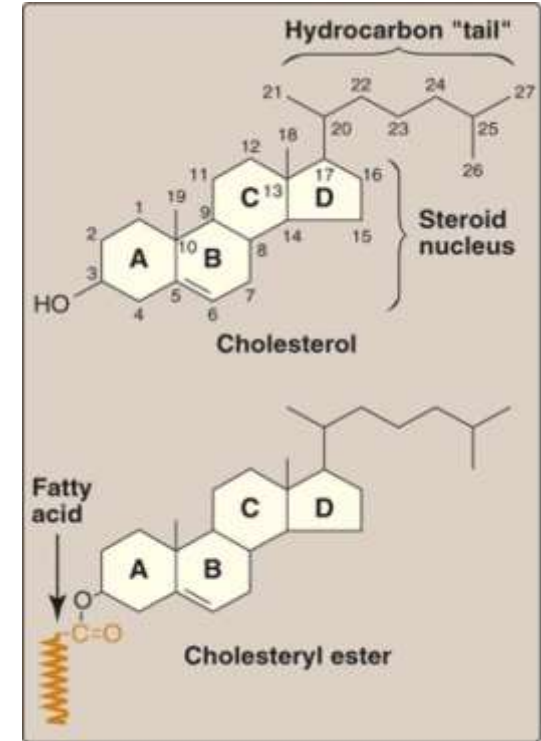
**Function:** Transport lipids in blood (plasma), we know that lipids are not soluble in plasma so to transport them from one organ to another in blood they aggregate with proteins forming lipoproteins

-Lipoproteins have spherical shape, polar from outside in contact with plasma, non-polar inside away from plasma

-At the surface of lipoprotein you find amphipathic molecules such as phospholipids free cholesterol and proteins

-Inside lipoproteins you find hydrophobic molecules such as TAG and Cholesteryl-ester

Many types: HDL, LDL, VLDL, and Chylomicron



## Final notes:

- Fatty acids found in plasma in 2 forms:
    - 10% Free fatty acids carried by albumin
    - 90% as Fatty acid esters (bound to cholesterol or to Glycerol in TAG or PL) where they are transported via Lipoproteins
  - Fat store energy more than carbohydrates or protein
- 9Kcal/g FAT  
4Kcal/g Carbohydrate or protein