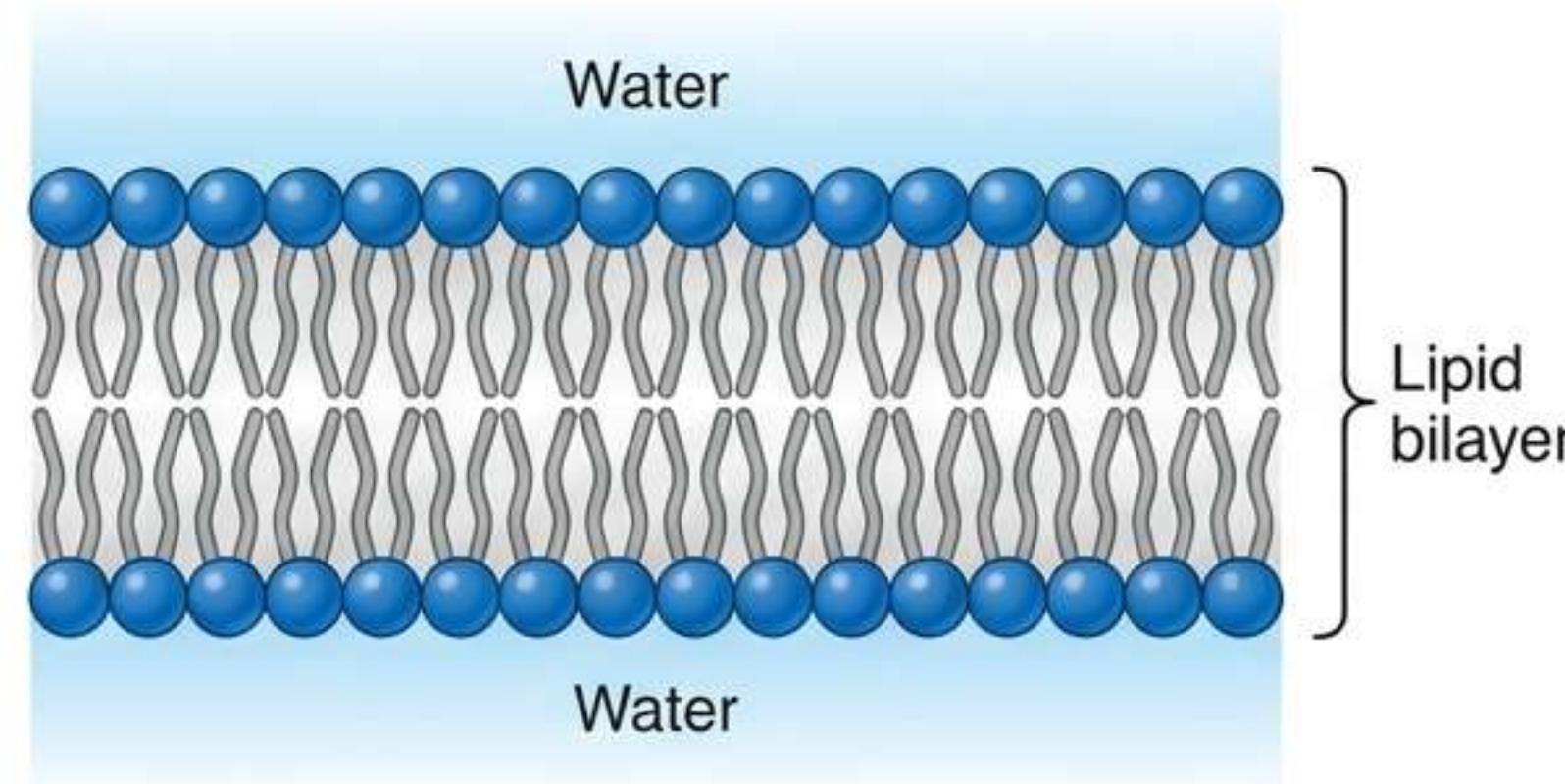


# The Biochemistry of Lipids

## Structure, Classification, and Metabolism



Université des Sciences de la Santé – Faculté de Médecine Dentaire

# The Foundation: Fatty Acids (Acides Gras)

## Definition:

Monocarboxylic acids with an aliphatic chain.

Usually even number of carbons (C16, C18).

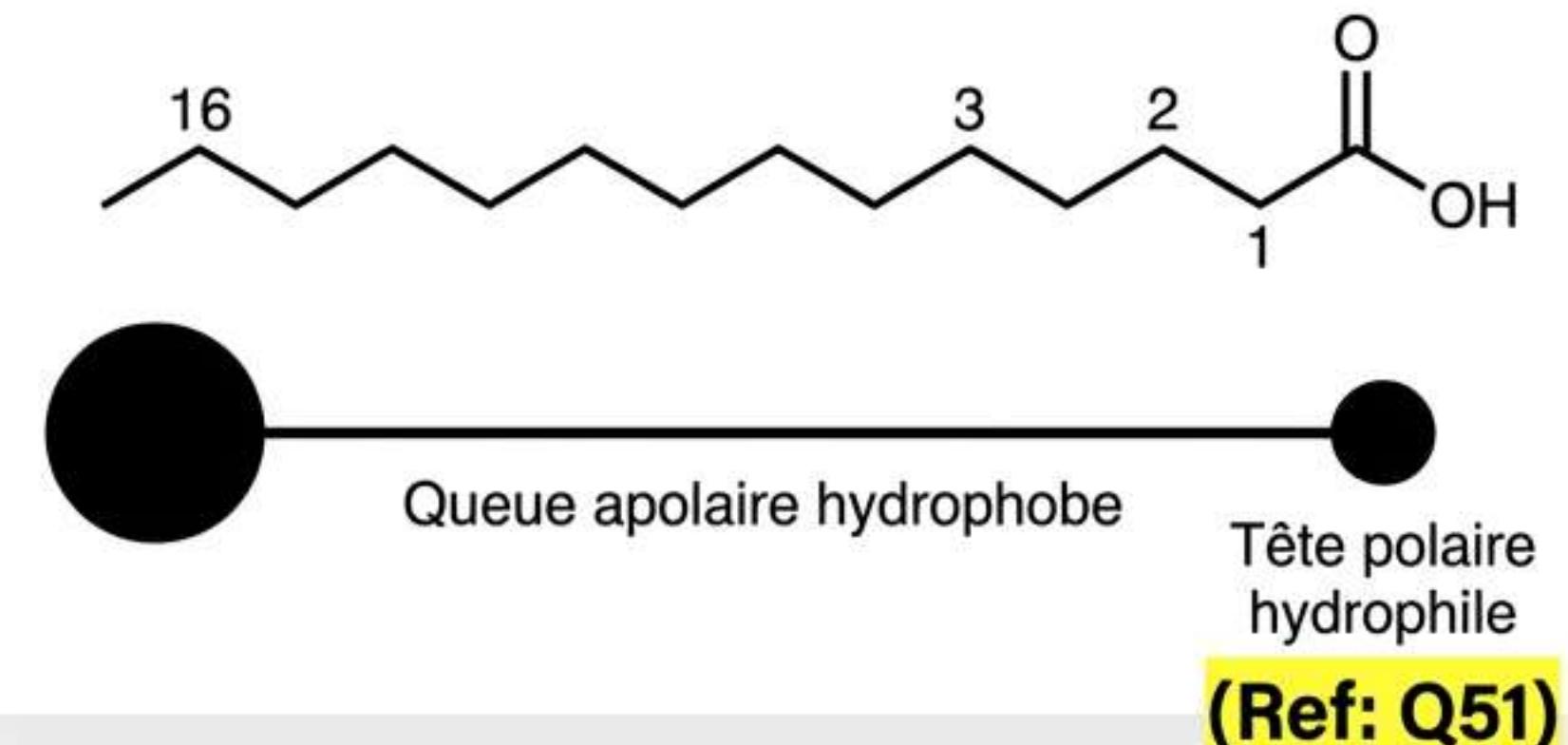
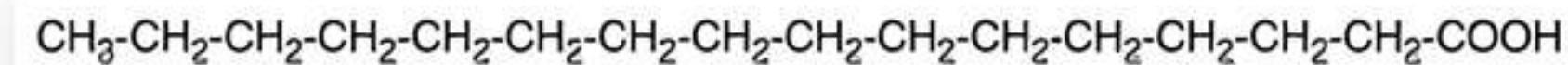
Can be saturated or unsaturated.

## Amphiphilic Nature:

Fatty acids possess two distinct poles:

- Hydrophilic Polar Head:** The Carboxyl group (-COOH). Soluble in water.
- Hydrophobic Non-Polar Tail:** The Methyl group (-CH<sub>3</sub>) and hydrocarbon chain. Insoluble in water.

## Palmitic acid



# Nomenclature I: The Numbering Systems

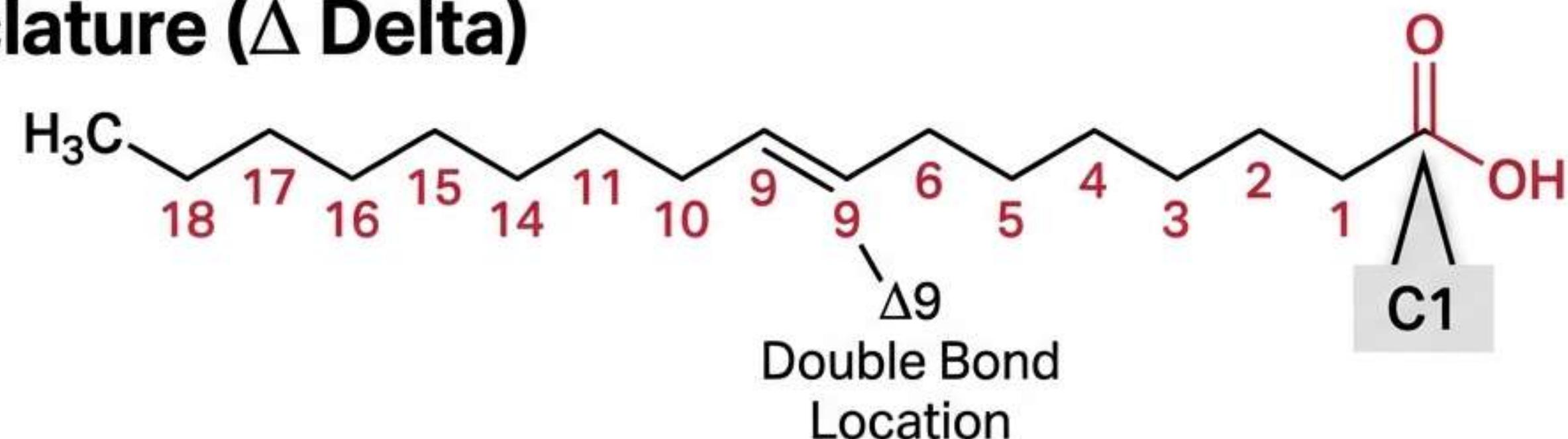
## Systematic Nomenclature ( $\Delta$ Delta)

Start counting from the Carboxyl Carbon (-COOH).

C1 = Carboxyl Carbon.

C2 =  $\alpha$  (Alpha) Carbon.

C3 =  $\beta$  (Beta) Carbon.

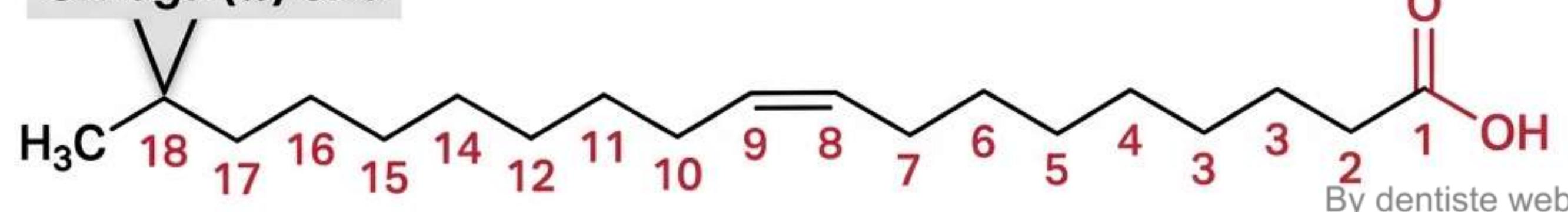


## Nutritional Nomenclature ( $\omega$ Omega)

Start counting from the Methyl Carbon (-CH<sub>3</sub>).

The last carbon is the Omega ( $\omega$ ) carbon.

Omega ( $\omega$ ) end



**Study Aid Box:**  
Never confuse C1 (Acid) with the Omega end (Methyl). (Ref: Q51)

By dentiste web

# Classification: Saturated Fatty Acids

## Structure:

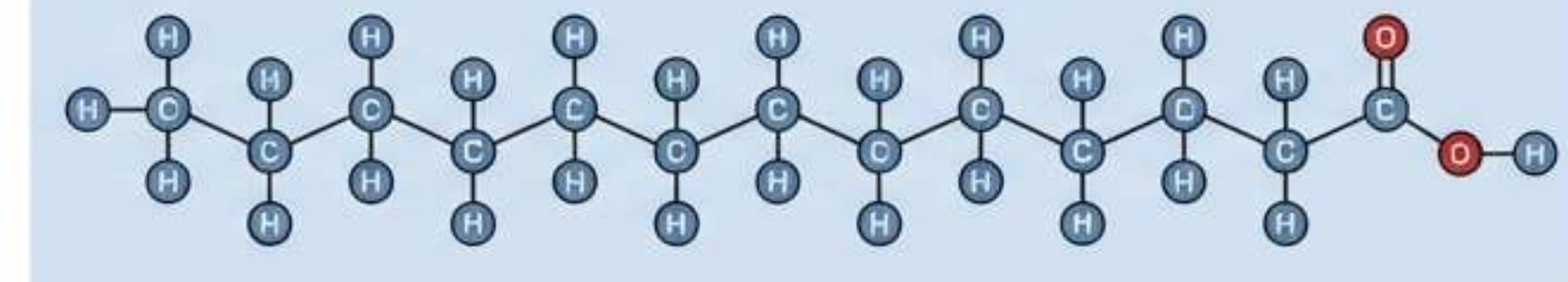
- **Formula:**  $\text{CH}_3-(\text{CH}_2)_n-\text{COOH}$ .
- No double bonds.
- **Conformation:** The C-C single bonds have a fixed angle of  $111^\circ$ , giving the chain a linear, zigzag flexibility.

Carbon Count	Common Name	(Source/Note)
C4	Butyric	(Butter)
C16	Palmitic	(Most common)
C18	Stearic	
C24	Lignoceric	

Saturated fatty acid (no double bonds)

## Properties:

- Solid at room temperature (e.g., butter, animal fat).
- High Melting Point.



● = C ● = O ● = H

# Classification: Unsaturated Fatty Acids & Isomerism

- **Double Bonds (C=C):** Introduce rigidity to the chain.

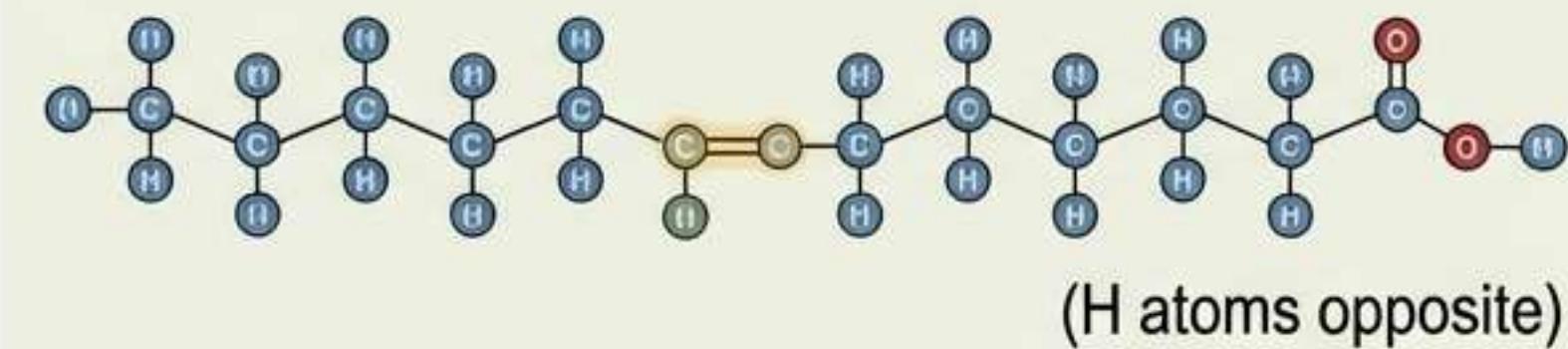
## Cis Configuration:

- Hydrogens on the *same* side of the double bond.
- Creates a **30° kink/bend** in the chain.
- **Occurrence:** Most natural fatty acids.  
**(GREEN: High Yield)**

## Trans Configuration:

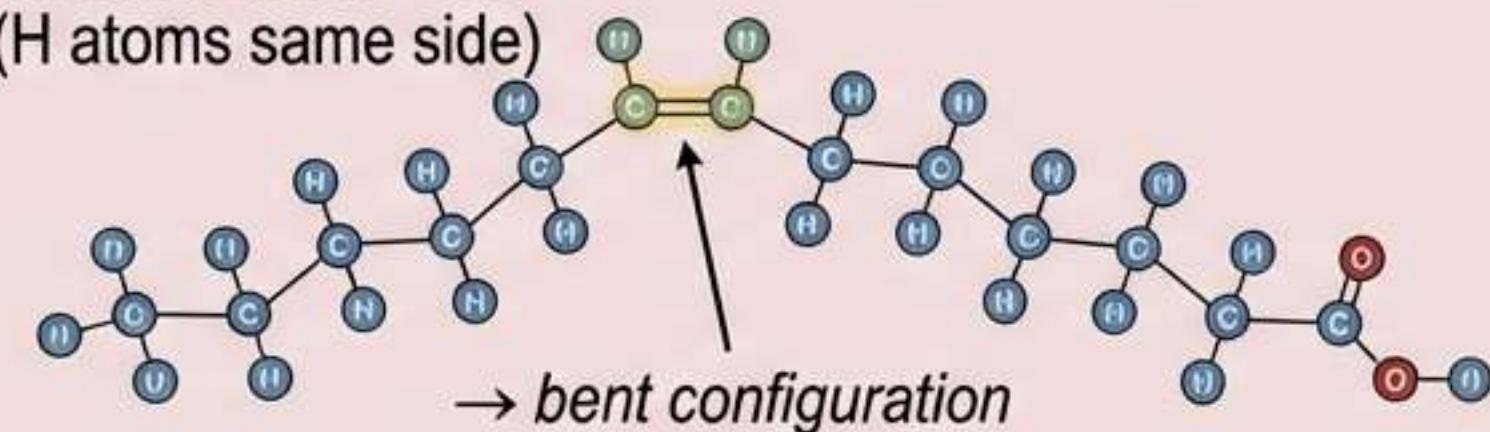
- Hydrogens on *opposite* sides.
- Linear structure (similar to saturated fats).
- **Occurrence:** Rare in nature (rumen bacteria), common in industrial hydrogenation.

### Unsaturated – *trans*



### Unsaturated – *cis*

(H atoms same side)



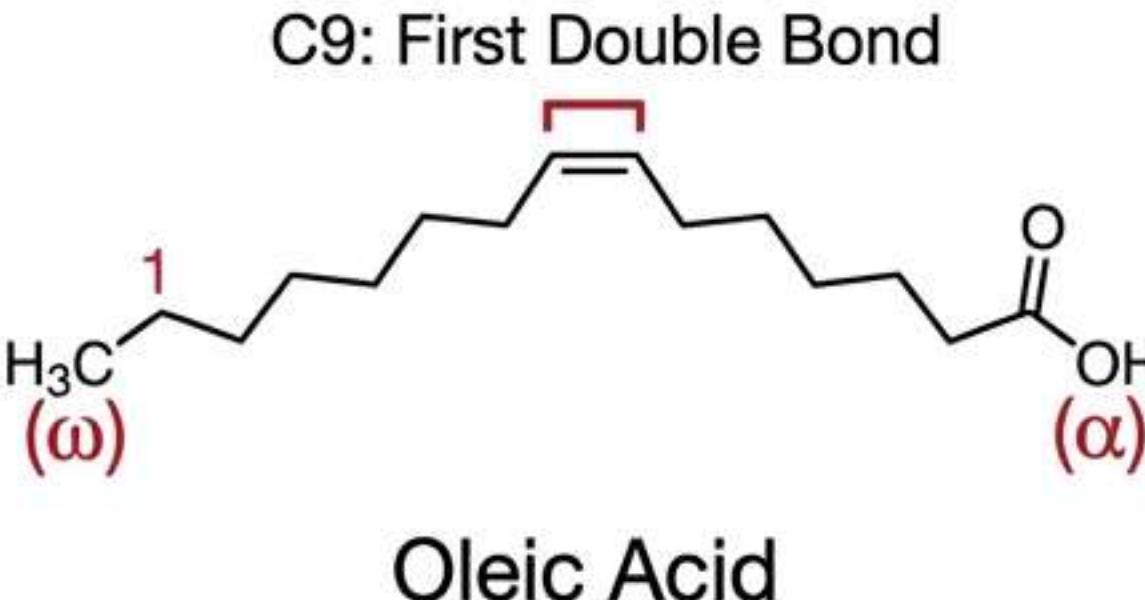
● = C ● = O ○ = H

# The Omega Families & Essential Fatty Acids

**The Omega Rule:** The family is determined by the position of the first double bond counting from the Methyl ( $\omega$ ) end.

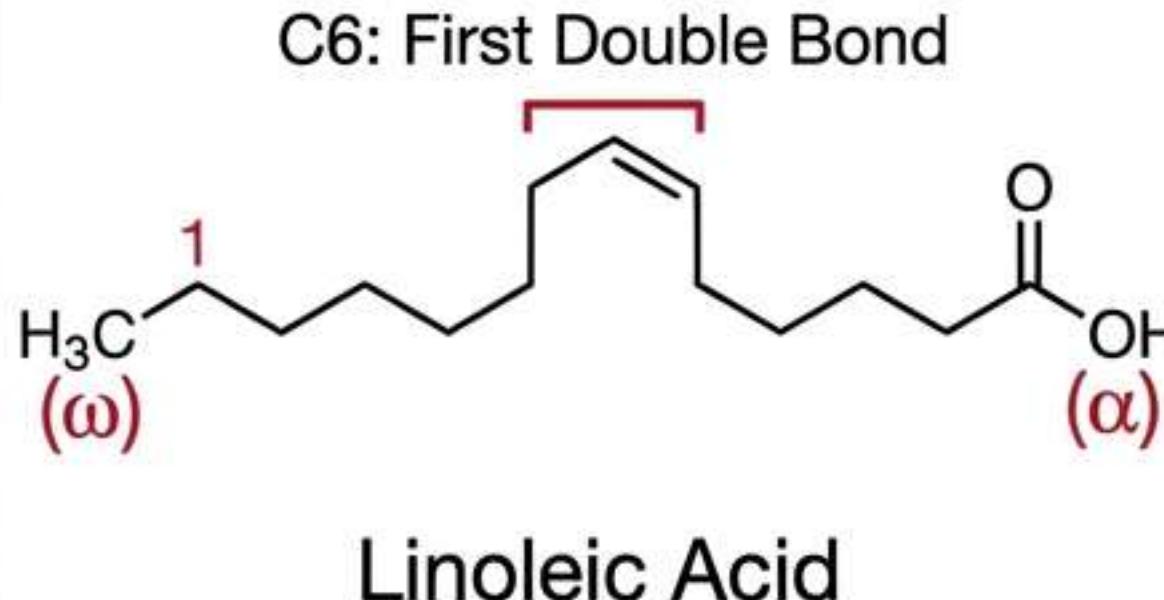
## Omega-9 ( $\omega$ -9)

- Oleic Acid (C18:1  $\Delta$ 9)
- Non-essential  
(synthesized by body).
- Sources: Olive oil.



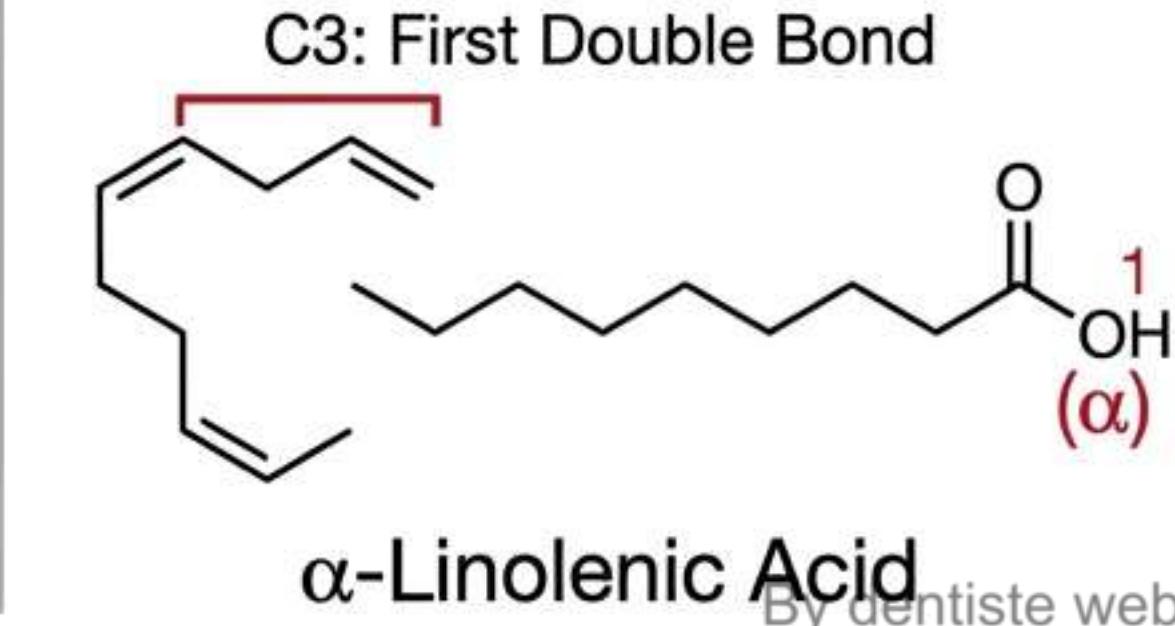
## Omega-6 ( $\omega$ -6)

- Linoleic Acid (C18:2  $\Delta$ 9,12)
- **Essential** (Dietary requirement).
- Precursor to **Arachidonic Acid** (C20:4).



## Omega-3 ( $\omega$ -3)

- $\alpha$ -Linolenic Acid (C18:3  $\Delta$ 9,12,15)
- **Essential**.
- Precursor to EPA & DHA (Anti-inflammatory).



# Physical Properties: Solubility & Melting Point

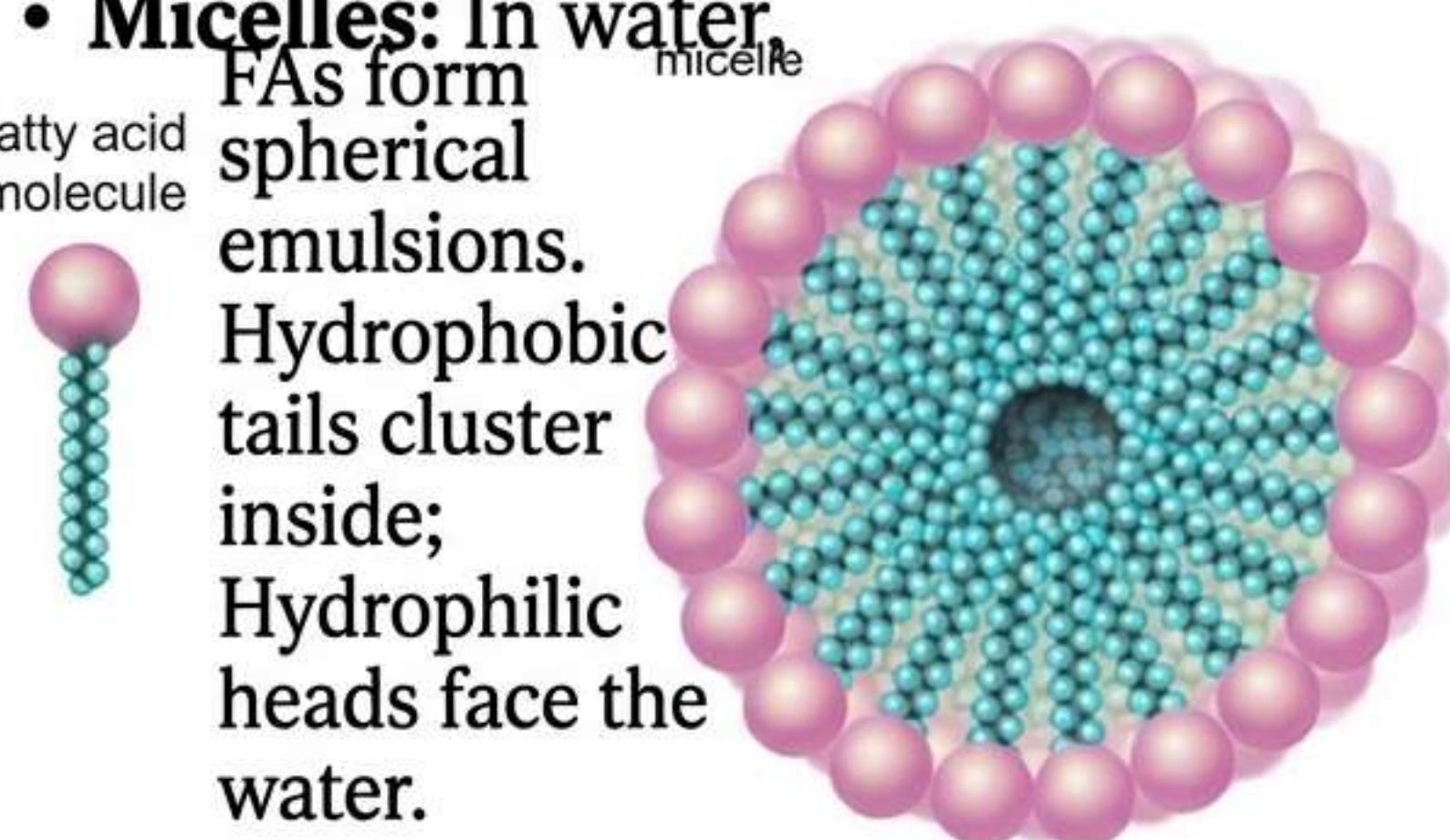
## Solubility

**Rule:** Solubility decreases as chain length increases.

- Short chains (C4) are soluble.
- Long chains (C10+) are insoluble.

• **Micelles:** In water, FAs form spherical emulsions.

fatty acid molecule  
Hydrophobic tails cluster inside;  
Hydrophilic heads face the water.



## Melting Point

**Rule:**

1. Longer chain = Higher MP.
2. More Unsaturation (Double bonds) = **Lower MP.**
  - Why? The Cis-kink prevents tight packing of molecules.

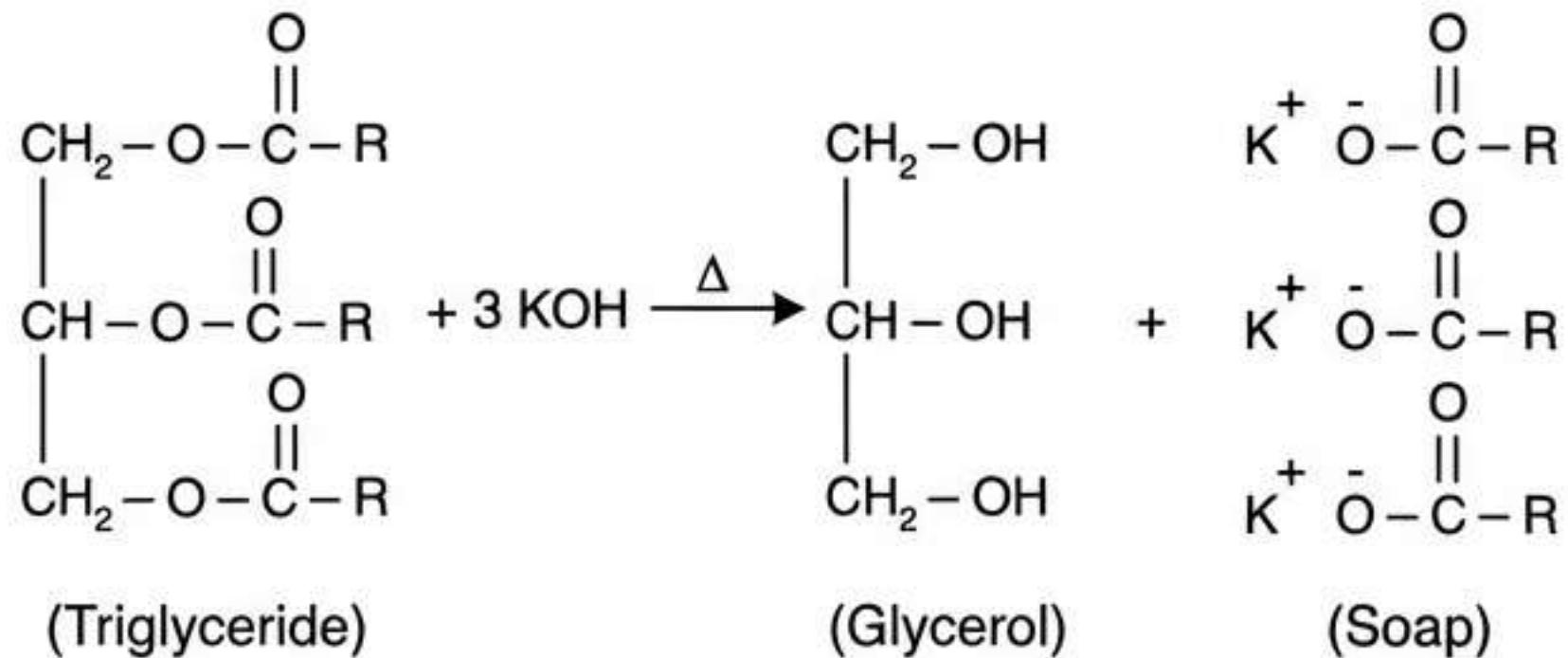
**Hydrogenation:** Adding Hydrogen to vegetable oil (liquid/cis) converts it to semi-solid fat (trans/saturated).  
Example: Margarine.

(YELLOW: Ref Q53)

# Chemical Properties: Indices of Analysis

# Saponification Index (SI)

- **Definition:** mg of KOH required to saponify 1g of fat.
  - **Reaction:** Fat + Base → Glycerol + Soap (Salt).
  - **Relation:** SI is inversely proportional to Molecular Weight.



# Iodine Index (Ii)

- **Definition:** Grams of Iodine bound by 100g of fat.
  - **Logic:** Halogens break double bonds.
  - **Relation:** Measures degree of unsaturation. Saturated FA have  $I_i = 0$ .

**Study Aid:** Calculations of  $I_i$  rely on molecular weight and number of double bonds. (Ref: Q60)

# Simple Lipids I: Acylglycerols (Glycerides)

## Structure

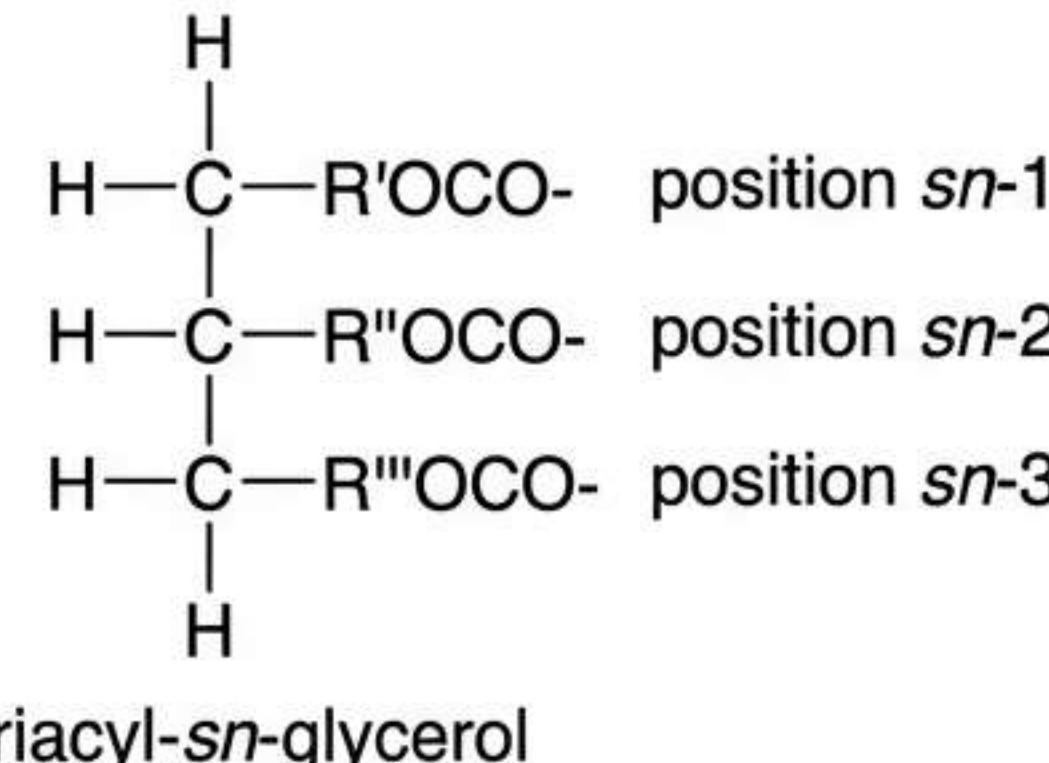
Definition: Esters of Glycerol + Fatty Acids.

- Monoacylglycerol (MAG): 1 FA.
- Diacylglycerol (DAG): 2 FAs.
- Triacylglycerol (TAG): 3 FAs (Energy storage).

## Stereochemistry

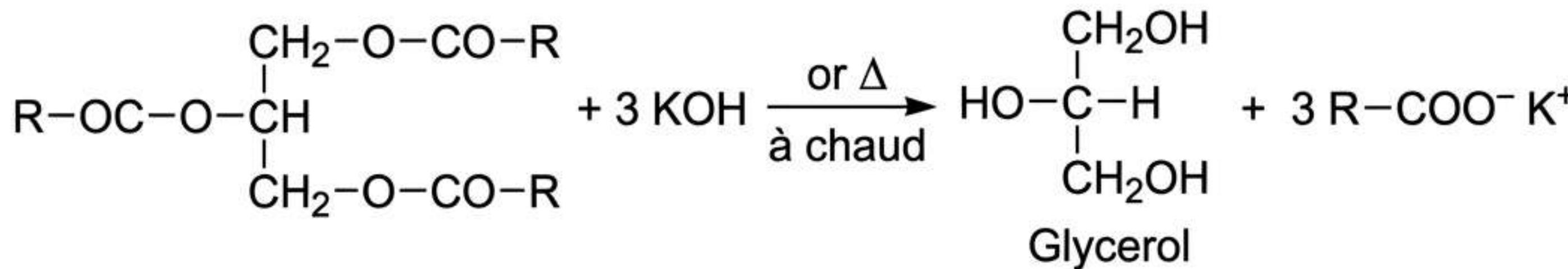
- Glycerol is a pro-chiral molecule.
- If the fatty acid at C1 is different from C3, the central carbon (C2) becomes a Chiral Center.
- Numbering: *sn*-1, *sn*-2, *sn*-3.

Important for enzyme specificity.



# Reactions of Triacylglycerols: Hydrolysis

- In Vivo Hydrolysis (Lipases):
  - Sequential removal of fatty acids.
  - TAG → DAG → MAG → Glycerol + Free FAs.
  - Occurs in digestion (Pancreatic Lipase) and Adipose tissue (Hormone Sensitive Lipase).
- Saponification (In Vitro):
  - Alkaline hydrolysis (KOH/NaOH) at high heat.
  - Irreversible breakdown.
  - Products: Glycerol + 3 Fatty Acid Salts (Soaps).



# Simple Lipids II: Cérides (Waxes)

## Definition

Esters of a Fatty Acid + High Molecular Weight Alcohol (Alcool gras).

## Reaction

Fatty Acid ( $R\text{-COOH}$ ) + Long Chain Alcohol ( $R'\text{-OH}$ )  $\rightarrow$  Céride ( $R\text{-COO-R'}$ ) +  $H_2O$ .

## Properties

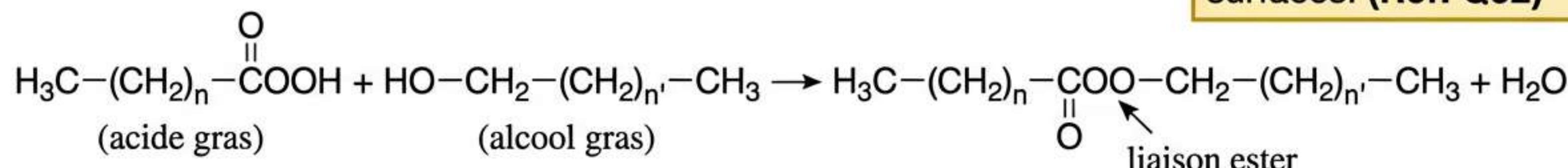
- Very insoluble (Hydrophobic).
- High melting point (Solid/Hard at room temp).

## Function

- Protective coating for living organisms (skin, fur, leaves, fruit).

### Study Aid

Primary role is protection of surfaces. (Ref: Q52)



# Simple Lipids III: Stérides (Cholesterol Esters)

## Cholesterol Structure

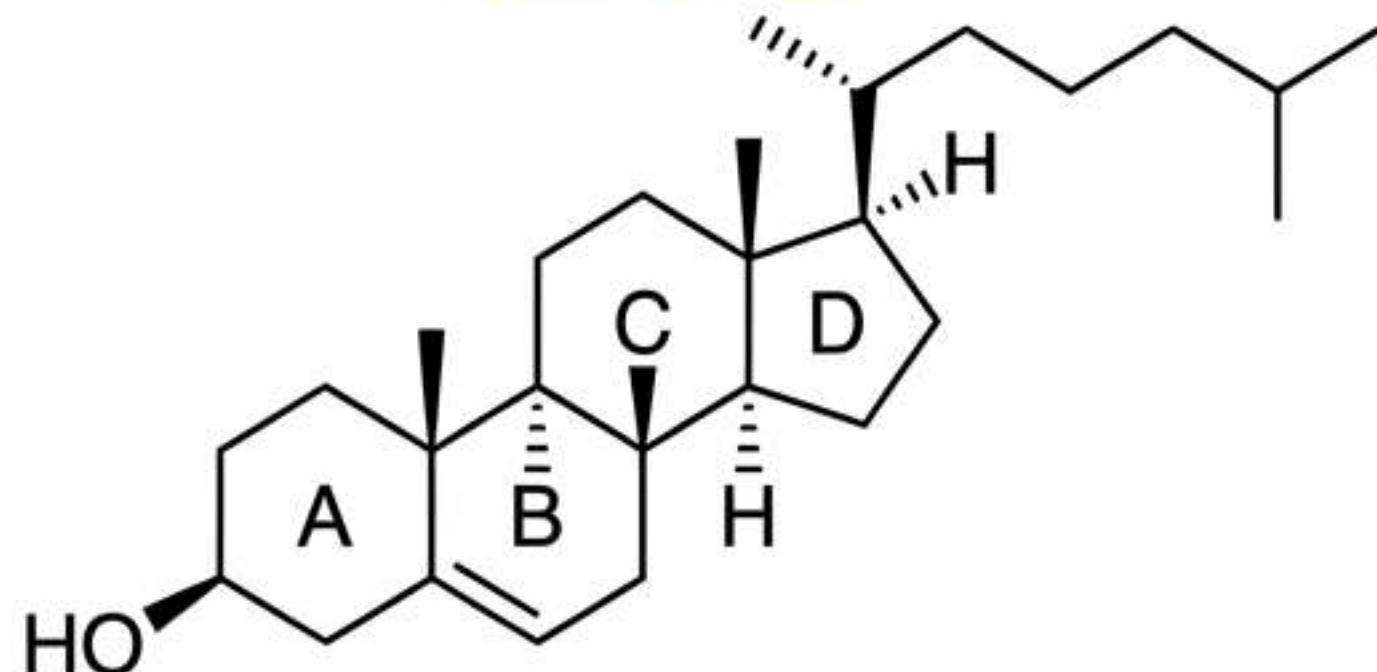
**Steroid Nucleus:**

Cyclopentanoperhydrophenanthrene (4 fused rings: A, B, C, D).

Hydroxyl (-OH) group at **C3**.

Double bond at  $\Delta 5$ .

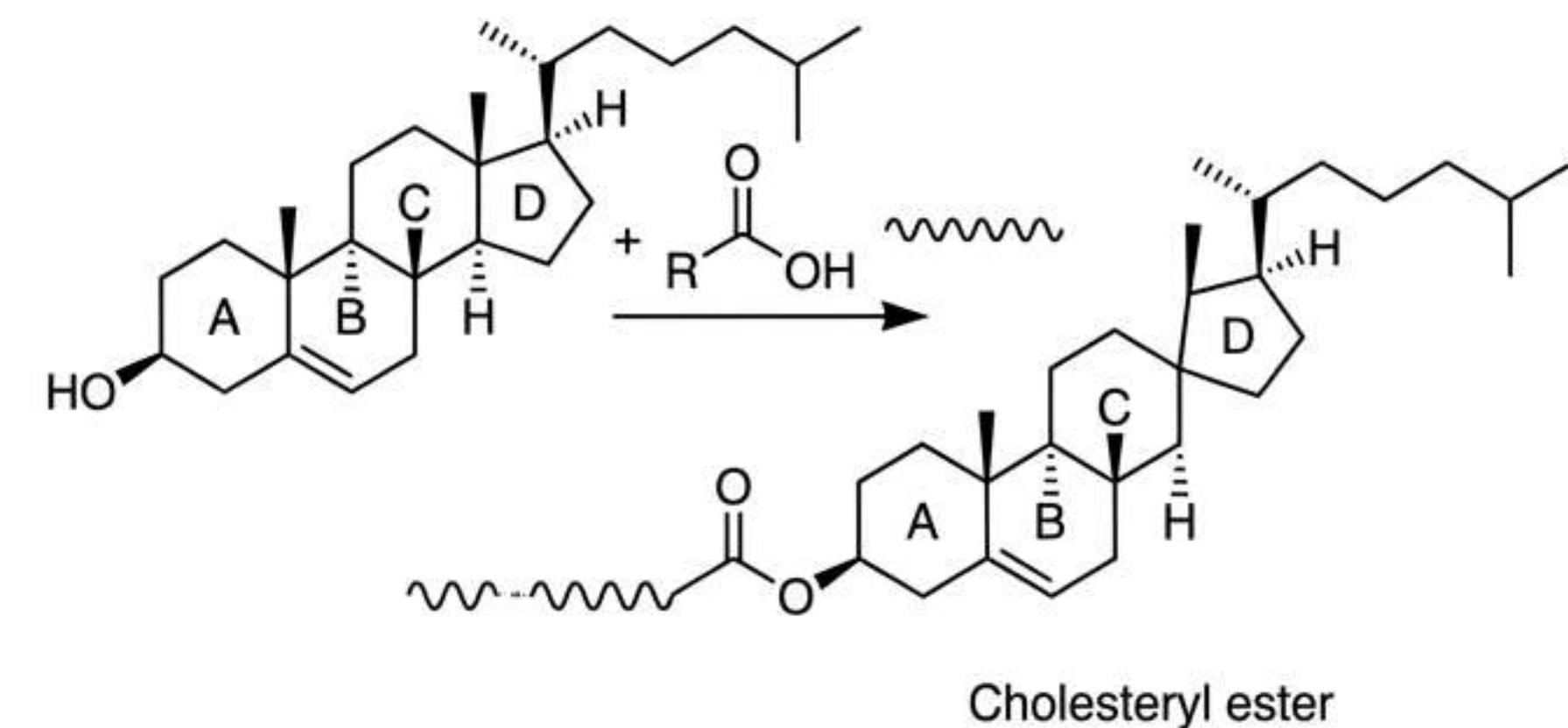
**Source:** Strictly Animal (Plants contain phytosterols). (Ref Q59)



## Stéride Formation

Esterification of a Fatty Acid to the -OH at C3.

**Function:** Storage form of cholesterol, transport in lipoproteins.

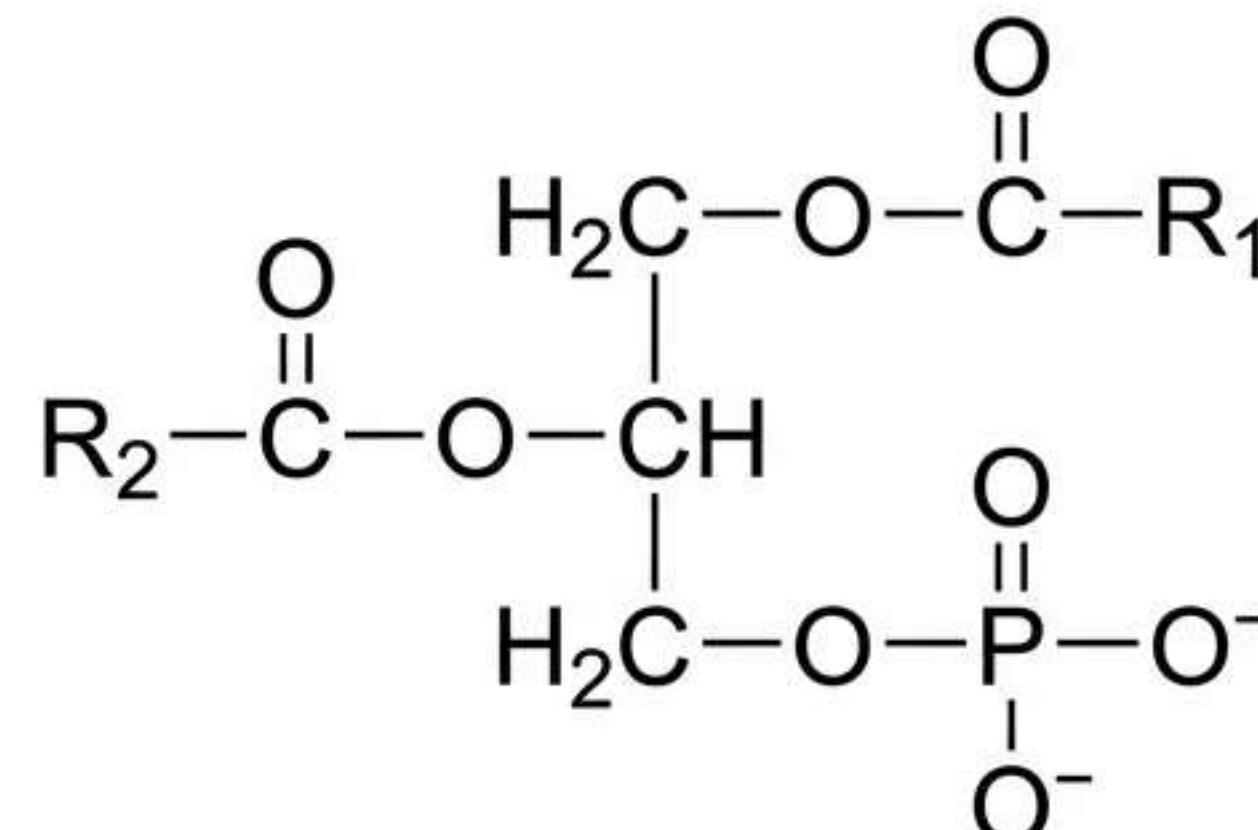


# Complex Lipids: Glycerophospholipids

## The Parent Molecule

**Phosphatidic Acid (PA):** The fundamental building block.

- Backbone: **Glycerol**.
- C1: Fatty Acid (Usually Saturated).
- C2: Fatty Acid (Usually Unsaturated).
- C3: Phosphate Group.



Phosphatidic Acid

## Amphipathic Nature

### Polarity:

- Head: Phosphate (Hydrophilic).
- Tail: 2 Fatty Acid chains (Hydrophobic).

**Role:** Major component of cell membranes.

### Study Aid

PA is the simplest glycerophospholipid and the precursor for others. Its amphipathic nature is crucial for membrane formation. (Ref: Q65)

# Glycerophospholipids: The Alcohols

The classification depends on the alcohol attached to the Phosphate group.

## Phosphatidylcholine (PC):

- Alcohol: Choline.
- Common Name: **Lecithin**. (Yellow: Ref Q54)

## Phosphatidylethanolamine (PE):

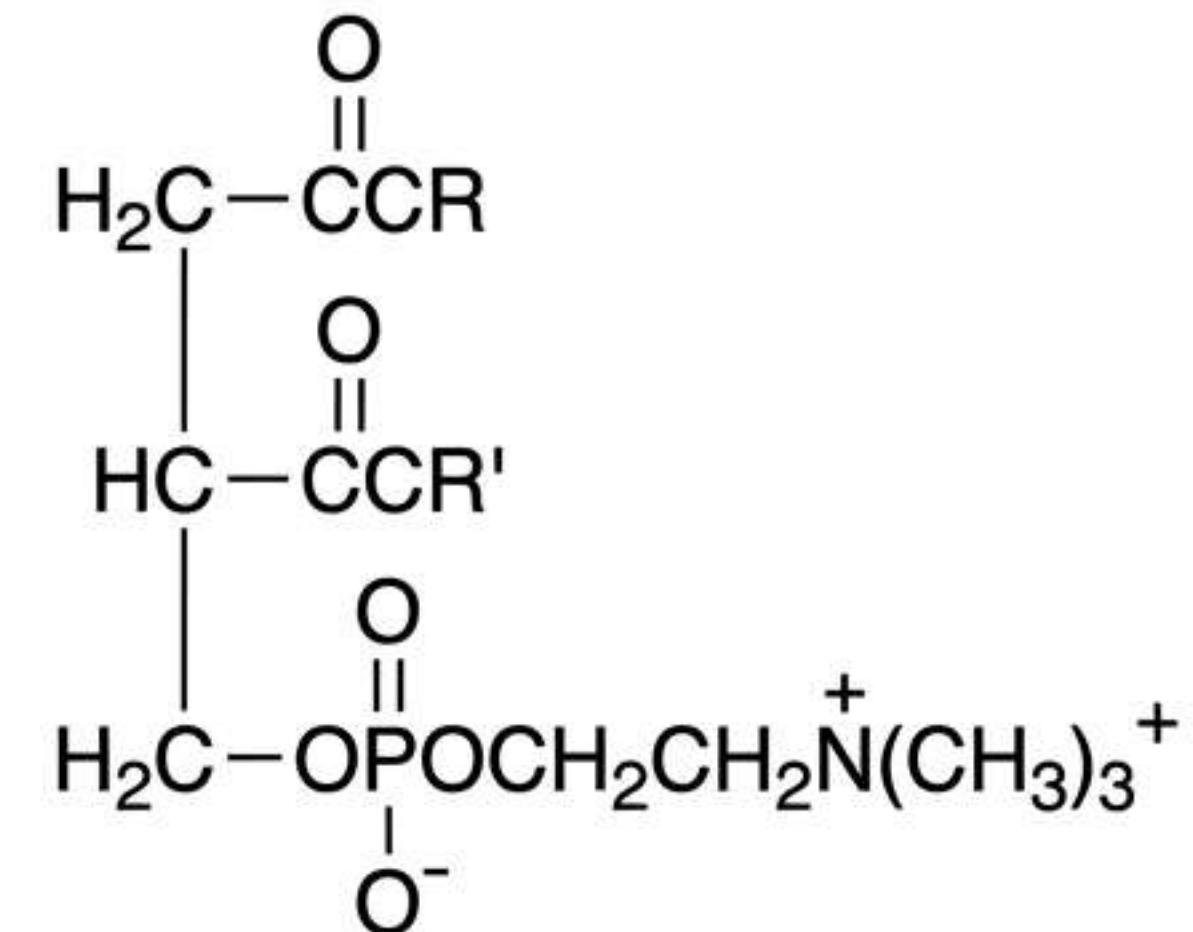
- Alcohol: Ethanolamine.
- Common Name: **Cephalin**.

## Phosphatidylserine (PS):

- Alcohol: Serine (Amino acid).

## Phosphatidylinositol (PI):

- Alcohol: Inositol (Cyclic sugar).



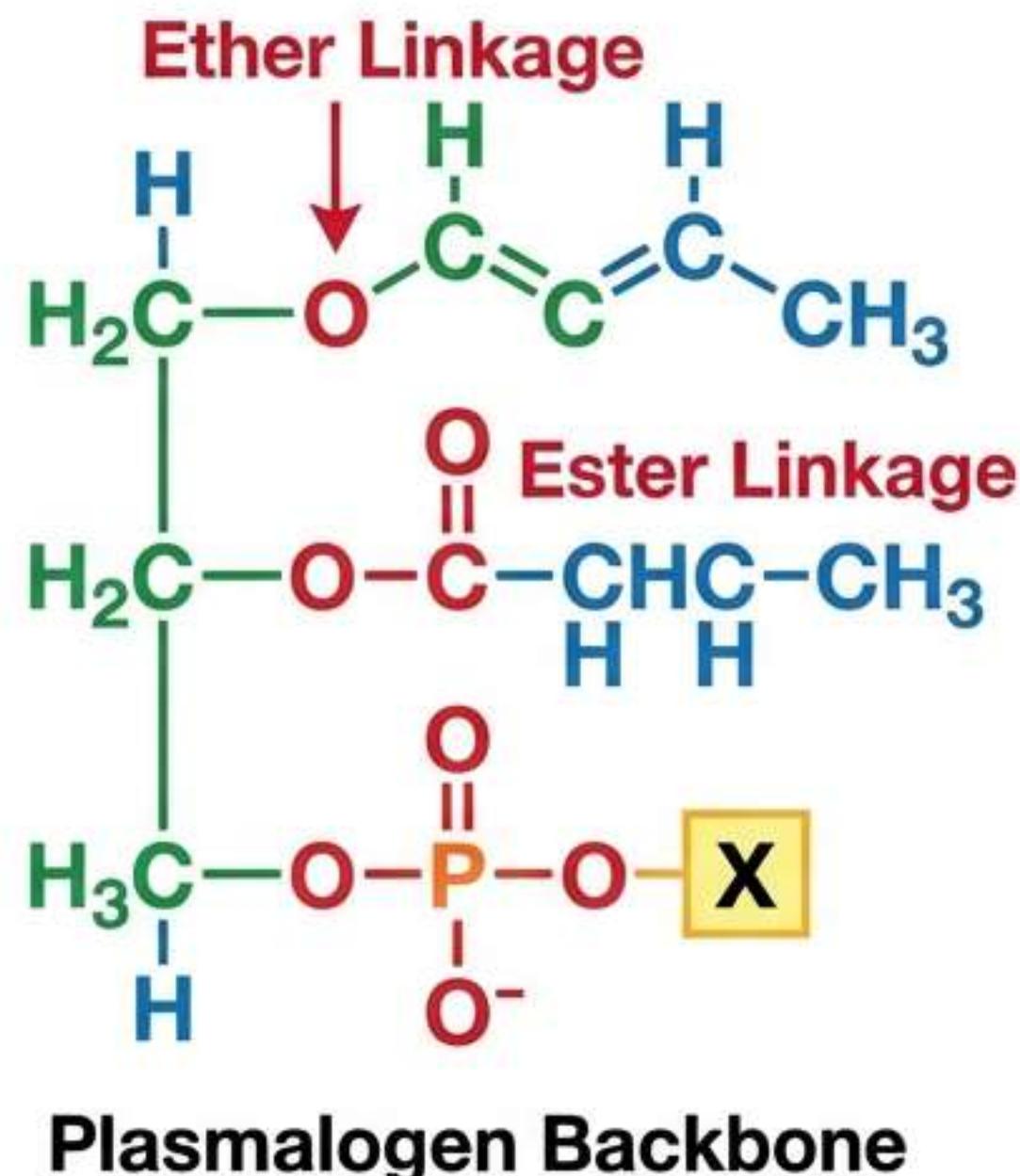
phosphatidylcholine

lecithin

# Etherglycerolipids: Plasmalogens & PAF

## Plasmalogens

- **Structure Difference:** Fatty acid at **C1** is attached via an **Ether bond** (-O-CH=CH-) instead of an Ester bond.
- **Location:** Abundant in Myelin and Cardiac muscle.



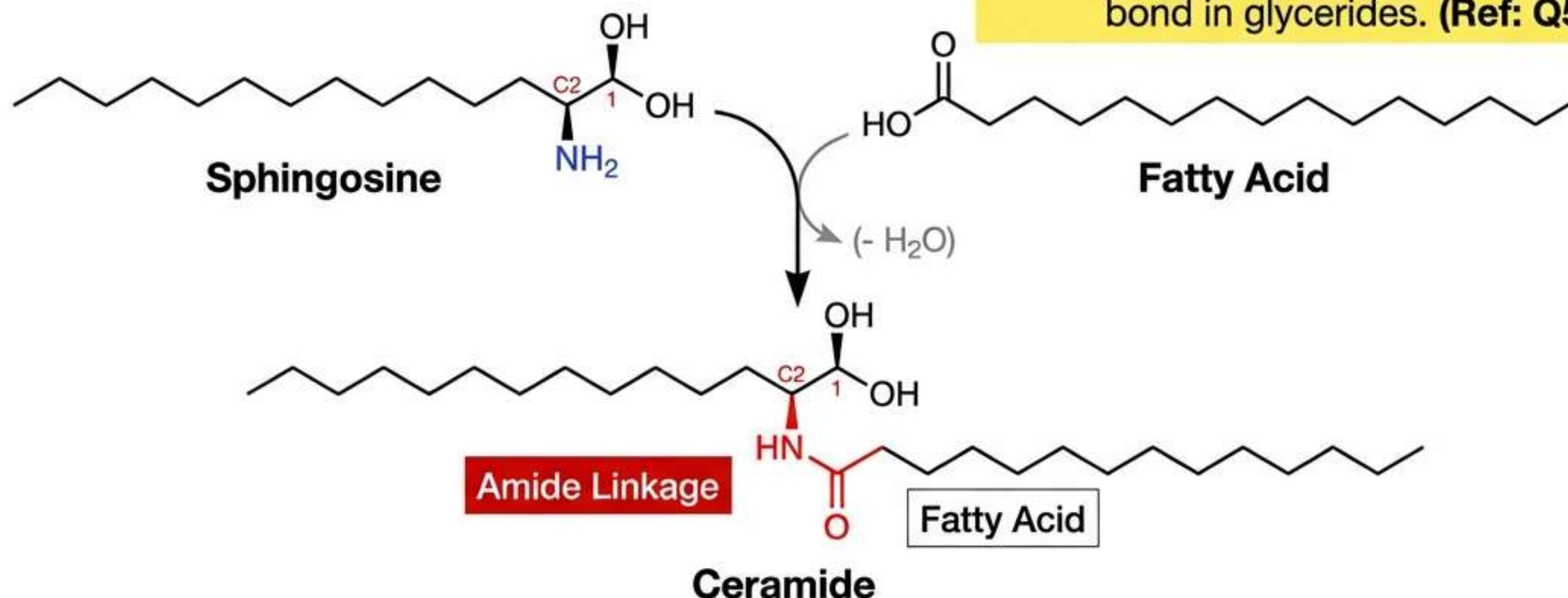
## Platelet Activating Factor (PAF)

- Ether linkage at C1.
- Acetyl group (short chain) at C2.
- **Function:** Potent mediator of inflammation, allergic response, and platelet aggregation.

# Complex Lipids: Sphingolipids & Ceramide

## Sphingosine:

- \* A long-chain amino-alcohol (C18).
- \* Replaces Glycerol as the backbone.

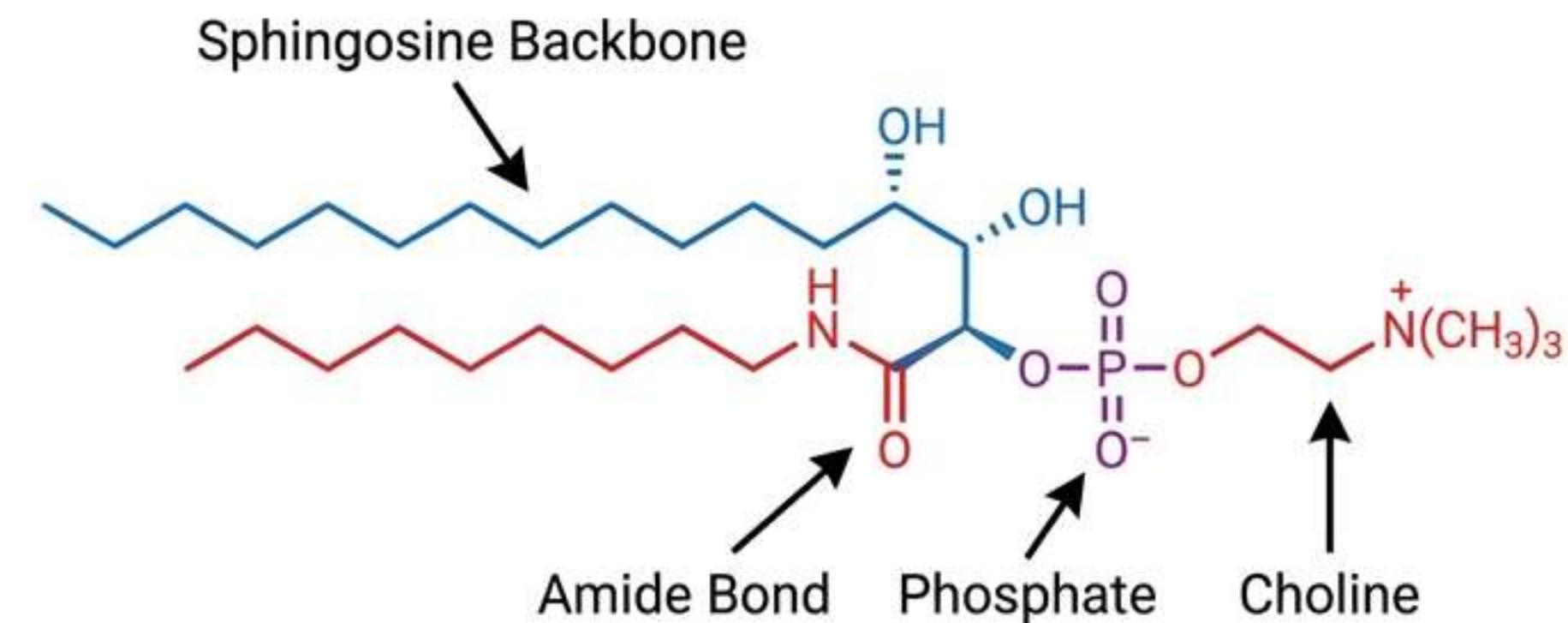


## Ceramide:

- \* **Structure:** Sphingosine + Fatty Acid.
- \* **The Bond:** Amide Linkage (-NH-CO-)
  - con Defined by the Amide bond, unlike the Ester bond in glycerides. (Ref: Q58)

# Sphingomyelin: The Phosphate Exception

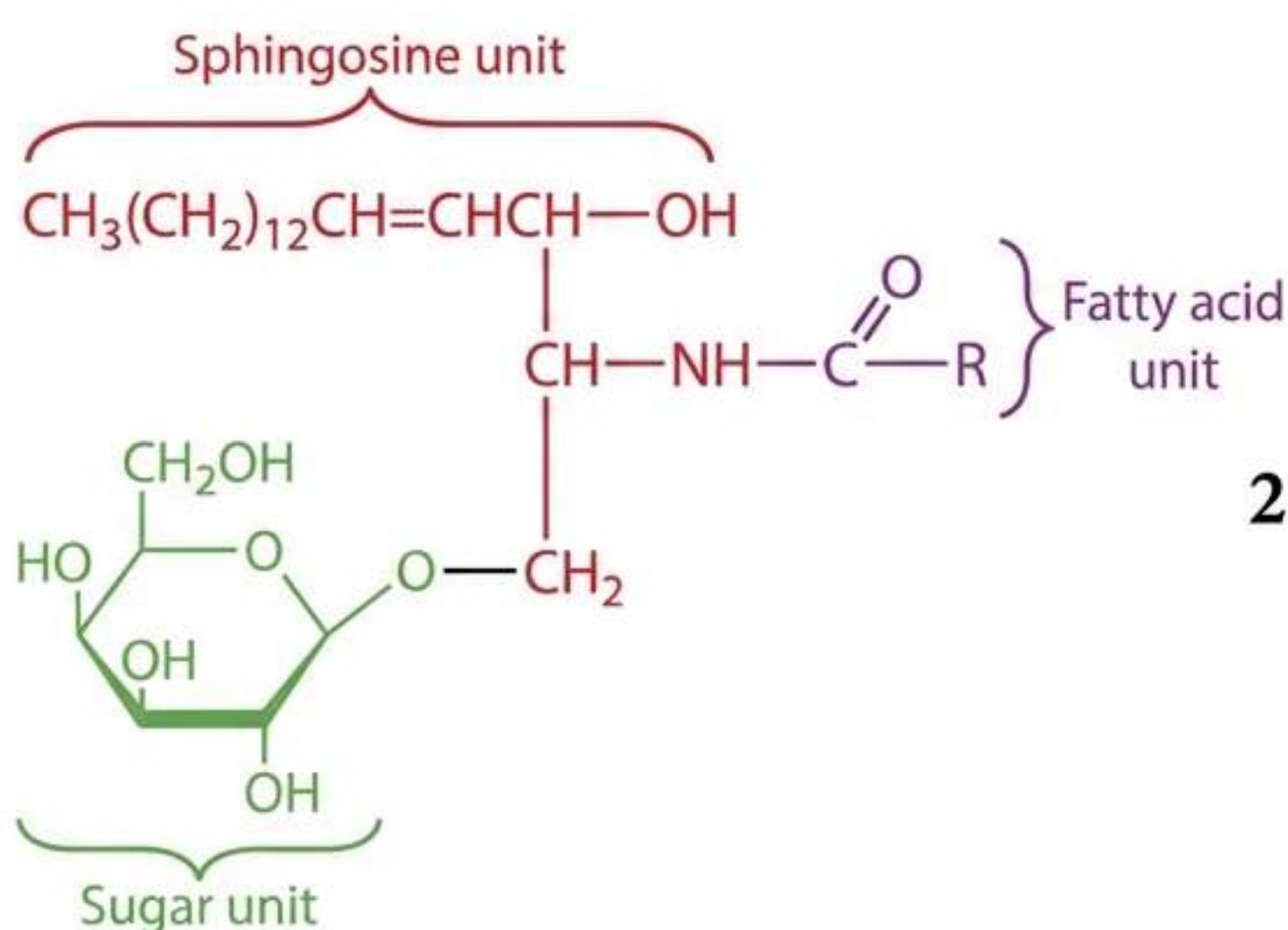
- **Sphingomyelin:**
  - **Composition:** Ceramide + Phosphate + Choline.
  - **Key Feature:** It is the *only* Sphingolipid that contains Phosphate.
  - **Location:** Major component of the Myelin sheath in nerve fibers.



# Glycosphingolipids: Sugar Heads

## Characteristics

- Structure: Ceramide + Carbohydrate.
- NO Phosphate.
- NO Glycerol.



## Types

1. **Cerebrosides:**
  - Single sugar (Glucose or Galactose).
  - [Yellow Box: Contains Glucose/Galactose. No Phosphate. (Ref: Q62)]
2. **Gangliosides:**
  - Complex Oligosaccharide head group.
  - Contains Sialic Acid (NANA).
  - Cell surface receptors.

# Lipoproteins: Solubilizing the Hydrophobic

## The Problem & Solution:

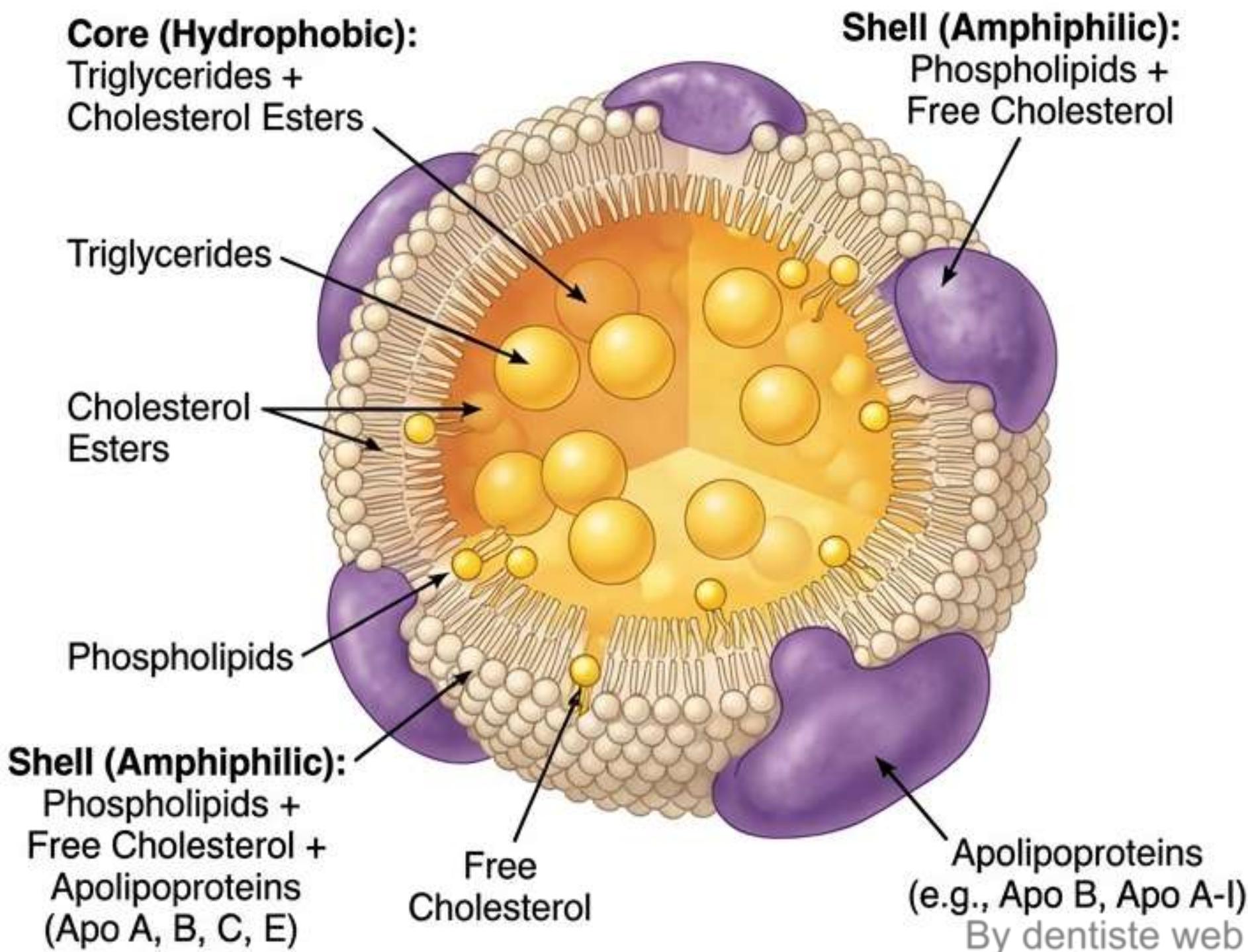
**The Problem:** Lipids (TG, Cholesterol) are hydrophobic. Blood is aqueous.

**The Solution:** Lipoproteins.

- Micelle-like macromolecular complexes.
- Make hydrophobic lipids soluble for transport.

**(Ref Q55)**

## Anatomy of a Lipoprotein:



# Lipoprotein Classification: Density vs. Size

