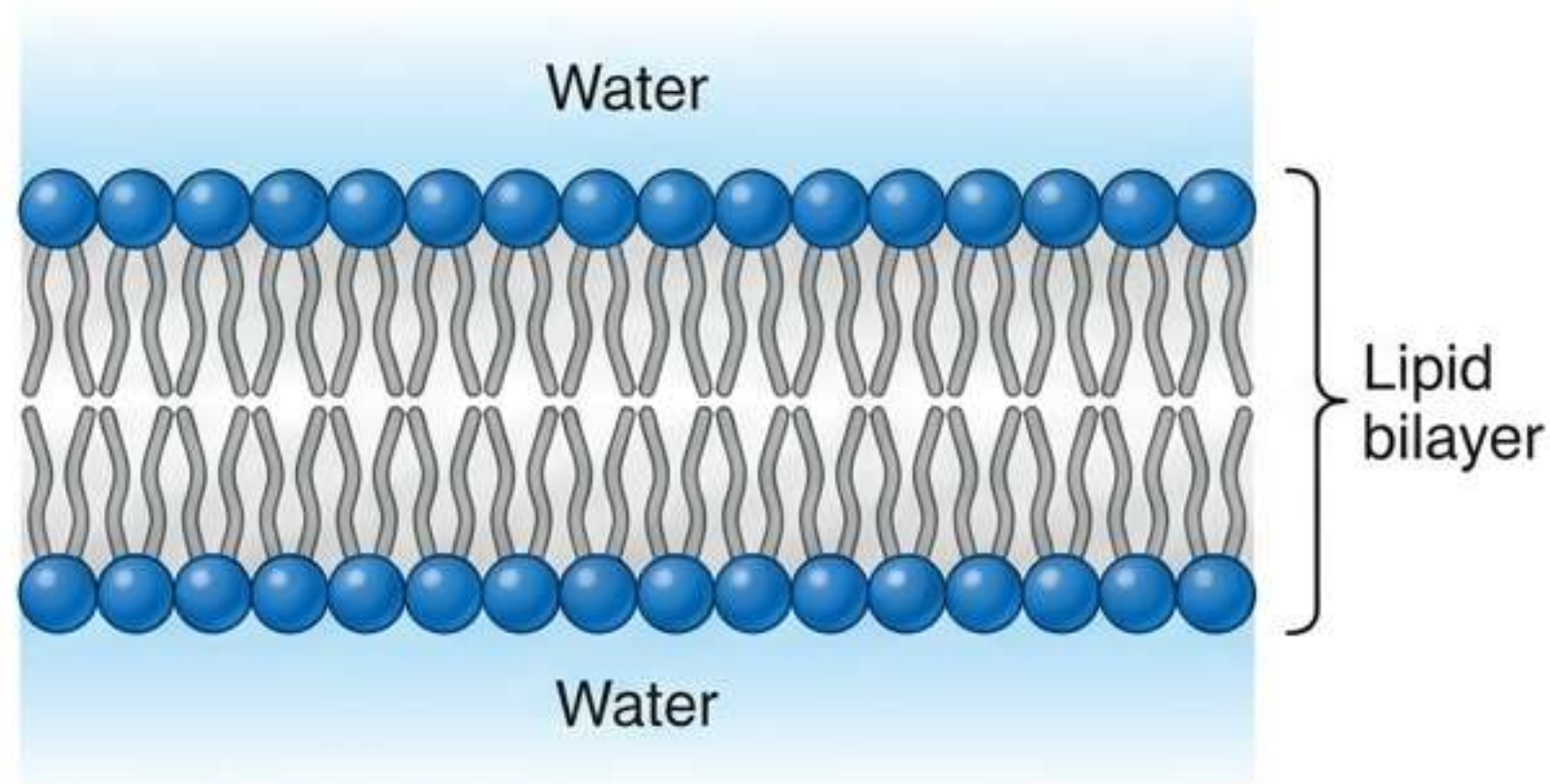


The Biochemistry of Lipids

Structure, Classification, and Metabolism



Université des Sciences de la Santé – Faculté de Médecine Dentaire

The Foundation: Fatty Acids (Acides Gras)

Definition:

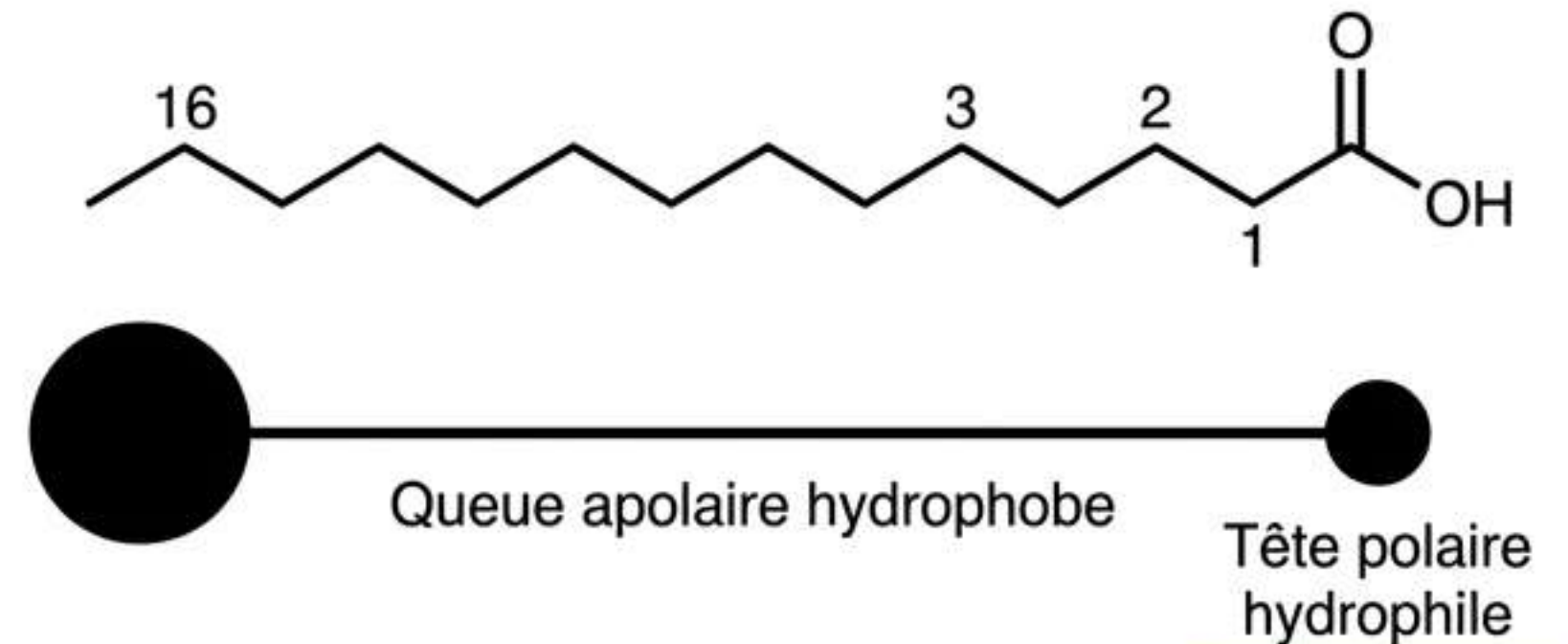
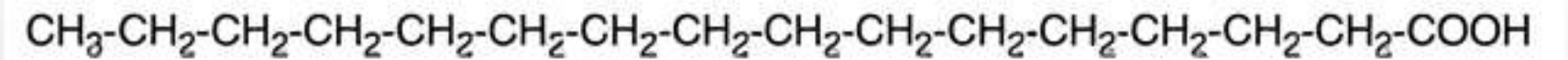
Monocarboxylic acids with an aliphatic chain.
Usually even number of carbons (C16, C18).
Can be saturated or unsaturated.

Amphiphilic Nature:

Fatty acids possess two distinct poles:

1. **Hydrophilic Polar Head:** The Carboxyl group (-COOH). Soluble in water.
2. **Hydrophobic Non-Polar Tail:** The Methyl group (-CH₃) and hydrocarbon chain. Insoluble in water.

Palmitic acid



(Ref: Q51)

Nomenclature I: The Numbering Systems

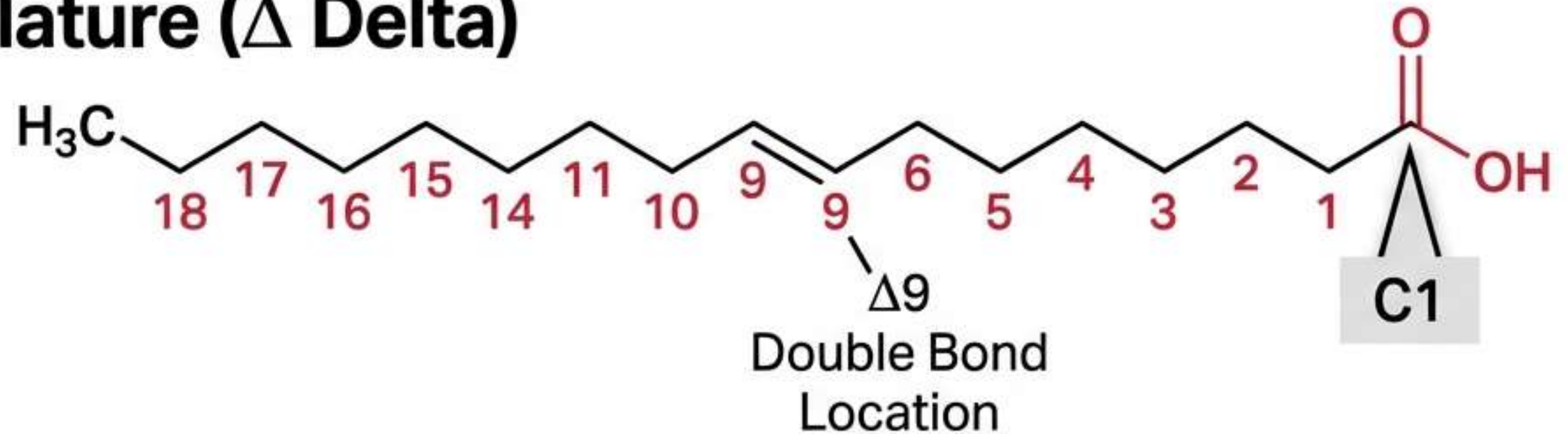
Systematic Nomenclature (Δ Delta)

Start counting from the Carboxyl Carbon (-COOH).

C1 = Carboxyl Carbon.

C2 = α (Alpha) Carbon.

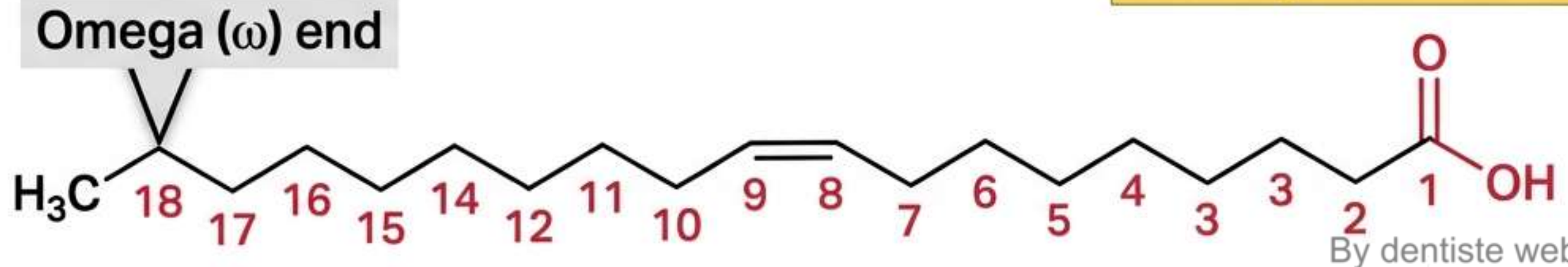
C3 = β (Beta) Carbon.



Nutritional Nomenclature (ω Omega)

Start counting from the Methyl Carbon (-CH₃).

The last carbon is the Omega (ω) carbon.



Study Aid Box:

Never confuse C1 (Acid) with the Omega end (Methyl). (Ref: Q51)

Classification: Saturated Fatty Acids

Structure:

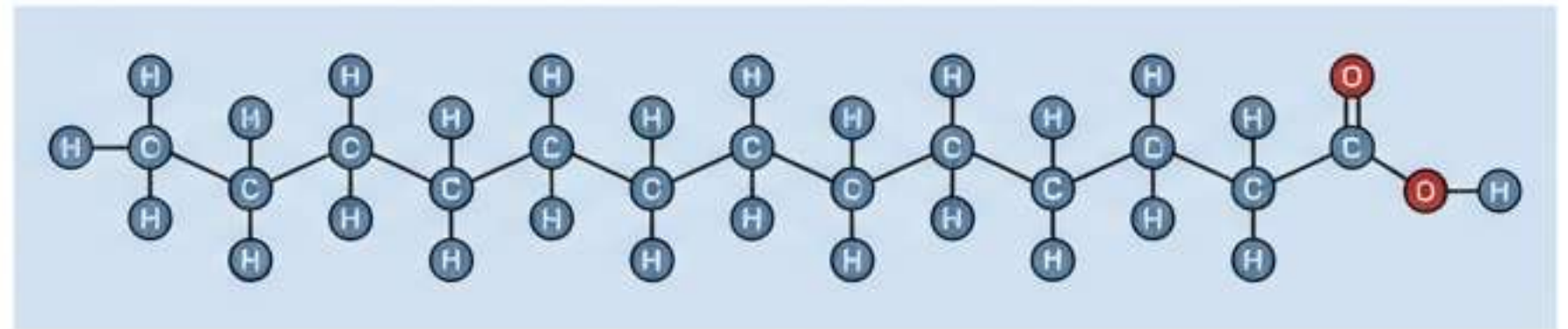
- **Formula:** $\text{CH}_3-(\text{CH}_2)_n-\text{COOH}$.
- **No double bonds.**
- **Conformation:** The C-C single bonds have a fixed angle of 111° , giving the chain a linear, zigzag flexibility.

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

Properties:

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

Saturated fatty acid (no double bonds)



● = C ● = O ● = H

Classification: Unsaturated Fatty Acids & Isomerism

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

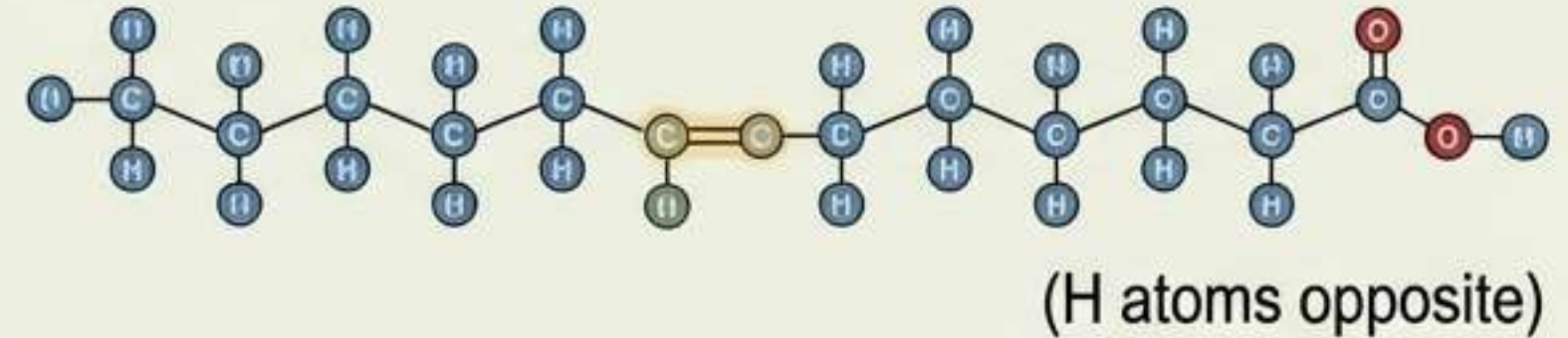
Cis Configuration:

- 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)

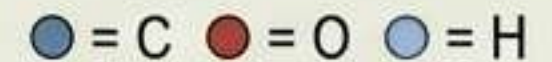
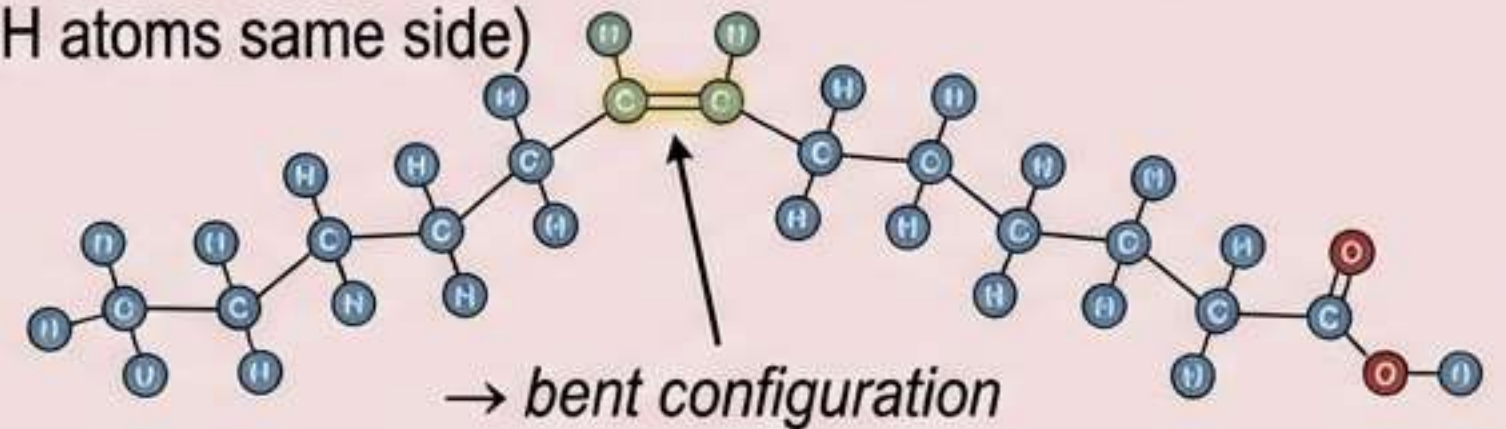
Trans Configuration:

- 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)

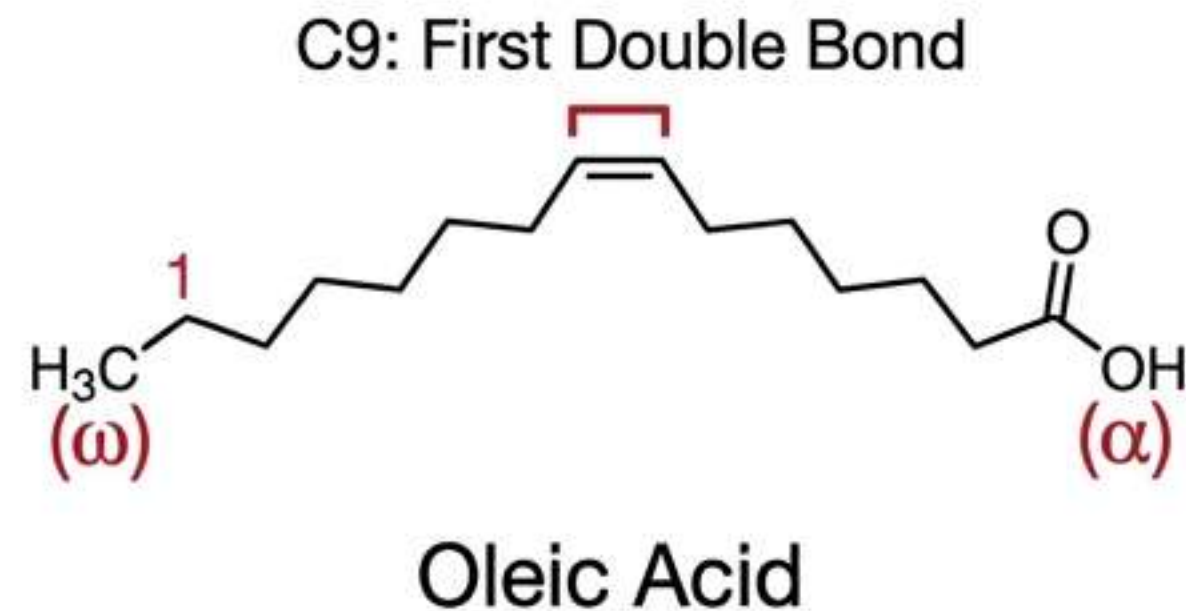


The Omega Families & Essential Fatty Acids

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

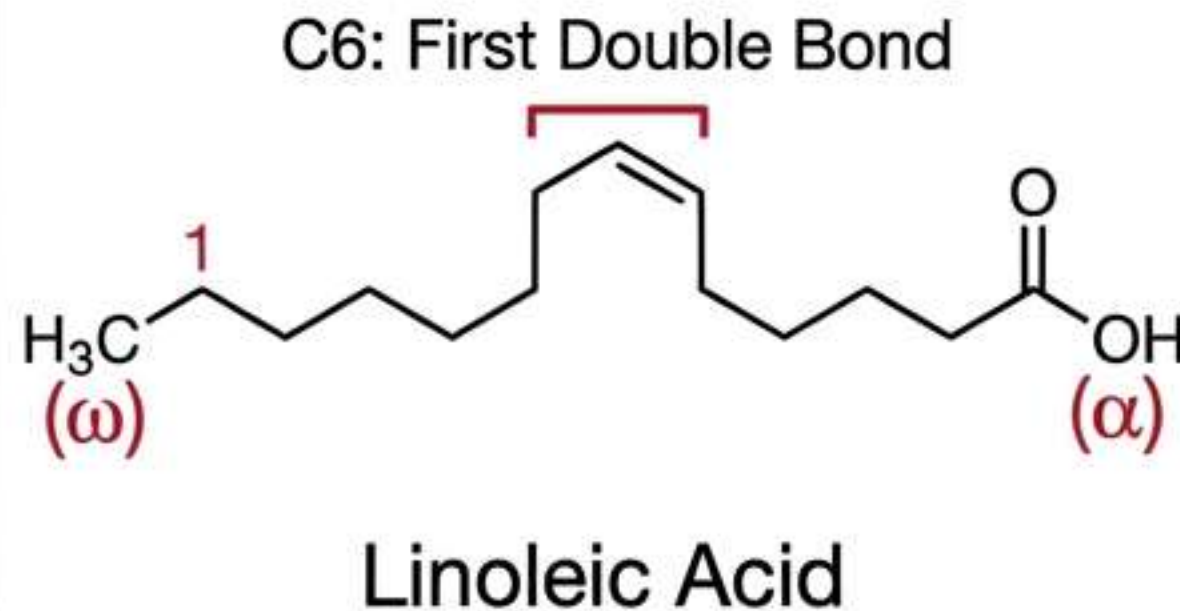
Omega-9 (ω -9)

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



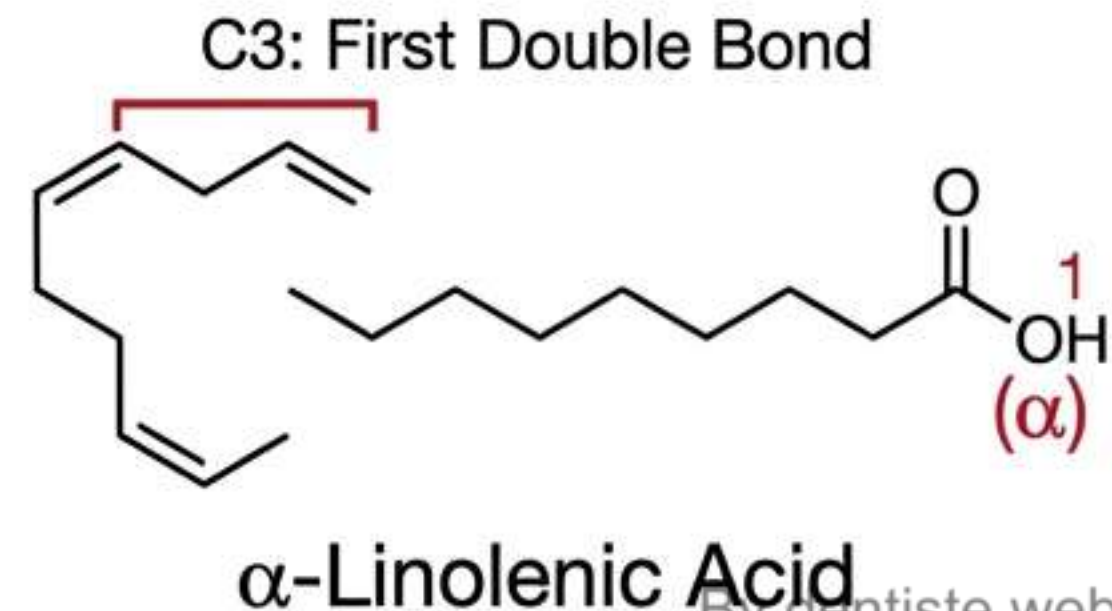
Omega-6 (ω -6)

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



Omega-3 (ω -3)

- α -Linolenic Acid (C18:3 Δ 9,12,15)
- **Essential.**
- Precursor to EPA & DHA (Anti-inflammatory).



Physical Properties: Solubility & Melting Point

Solubility

Rule: Solubility decreases as chain length increases.

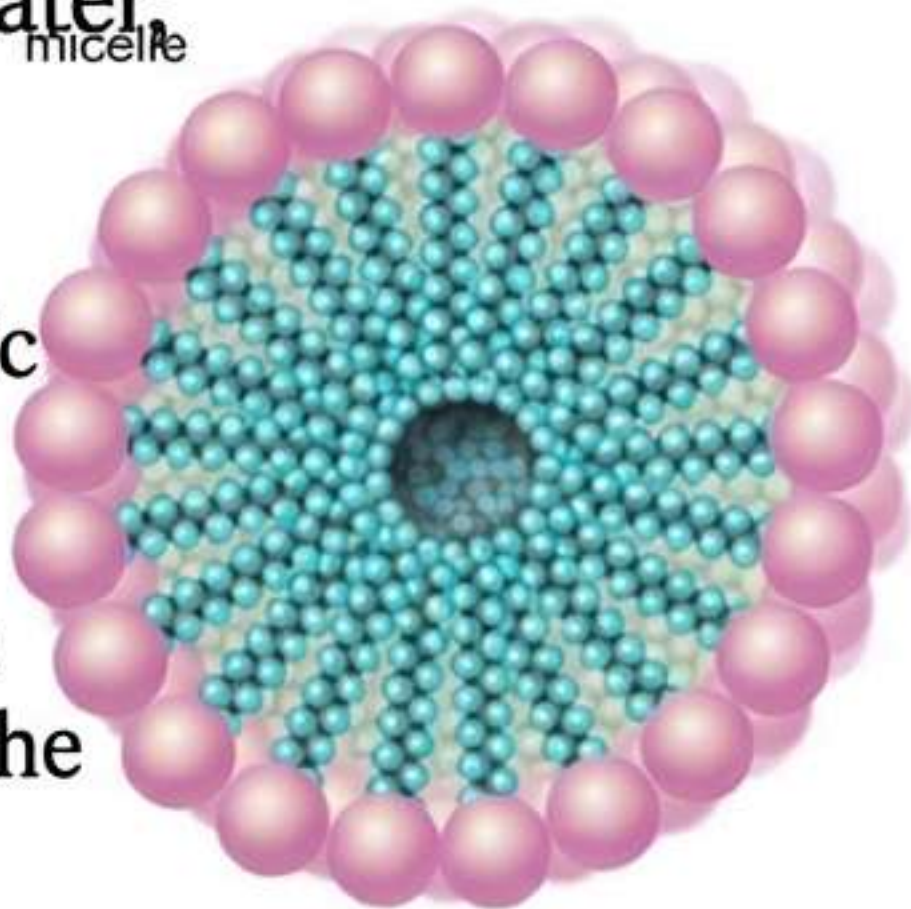
- Short chains (C4) are soluble.
- Long chains (C10+) are insoluble.

• **Micelles:** In water,

fatty acid
molecule



FAs form spherical emulsions. 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.

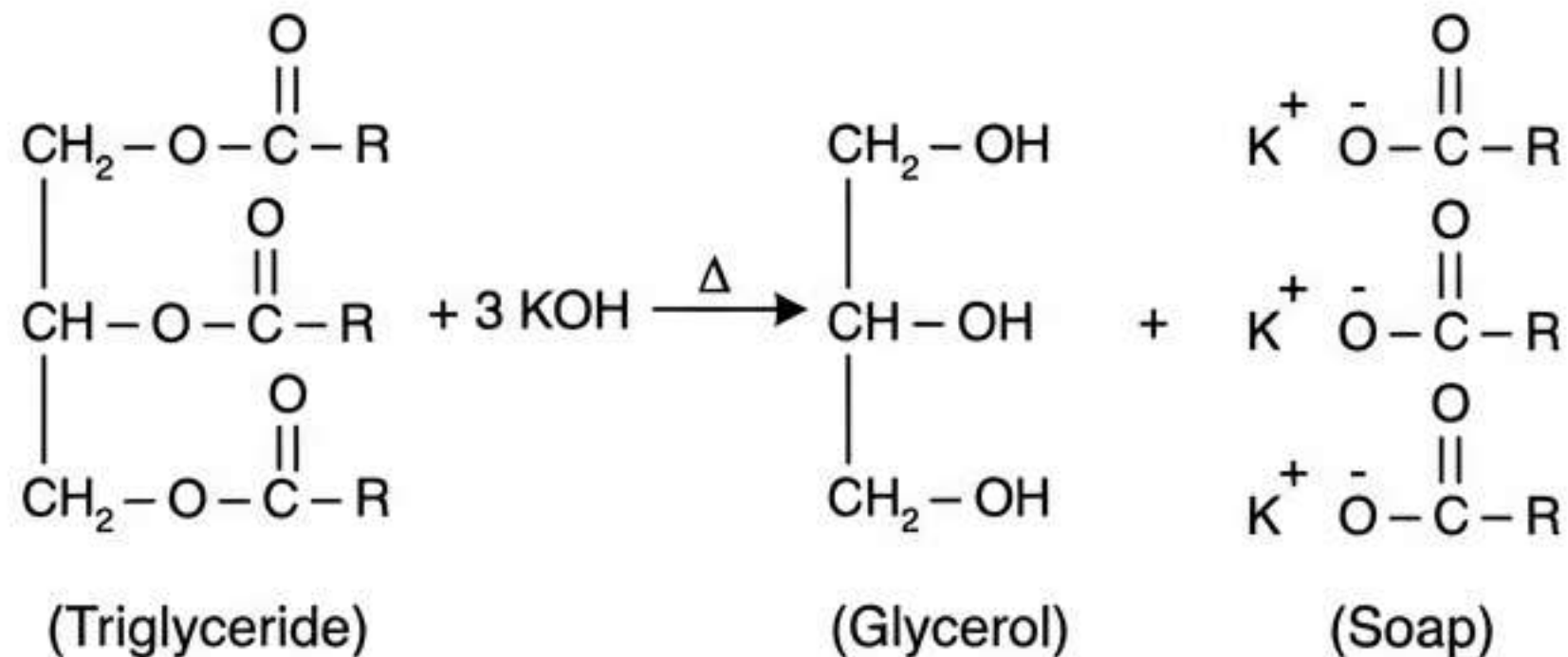
Hydrogenation: Adding Hydrogen to vegetable oil (liquid/cis) converts it to semi-solid fat (trans/saturated).
Example: Margarine.

(YELLOW: Ref Q53)

Chemical Properties: Indices of Analysis

Saponification Index (SI)

- **Definition:** mg of KOH required to saponify 1g of fat.
- **Reaction:** Fat + Base \rightarrow 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 Ii = 0.

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

Simple Lipids I: Acylglycerols (Glycerides)

Structure

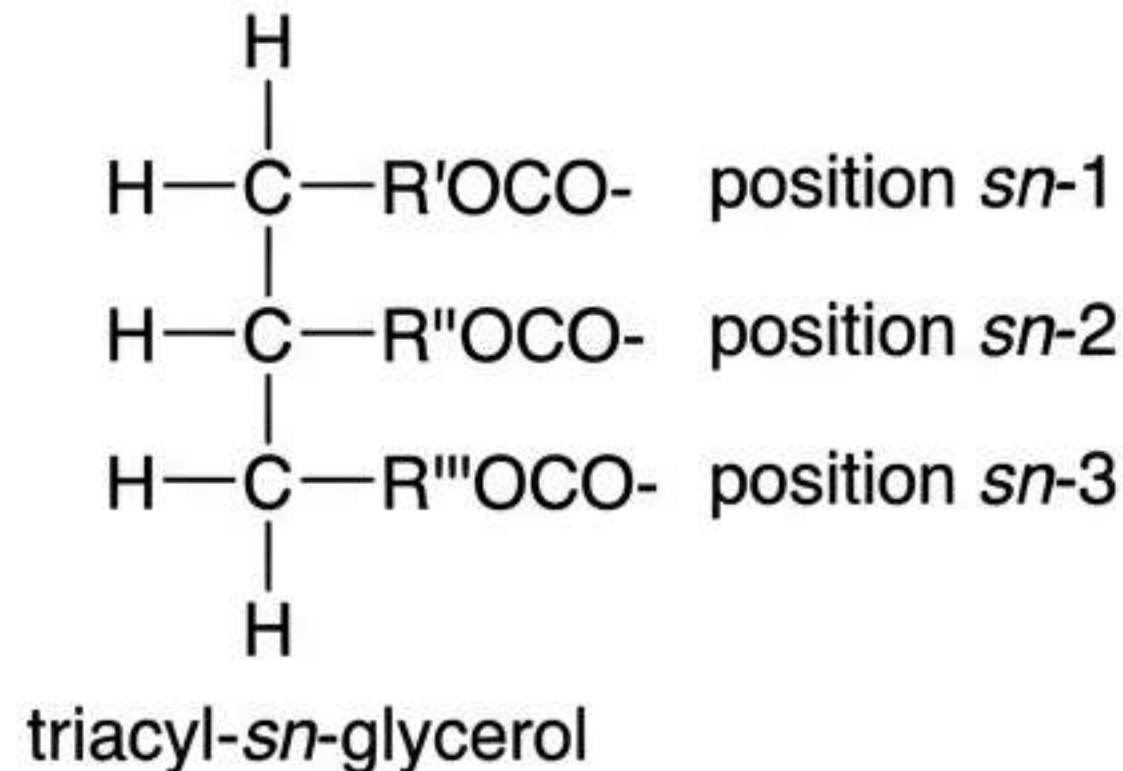
Definition: Esters of Glycerol + Fatty Acids.

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

Stereochemistry

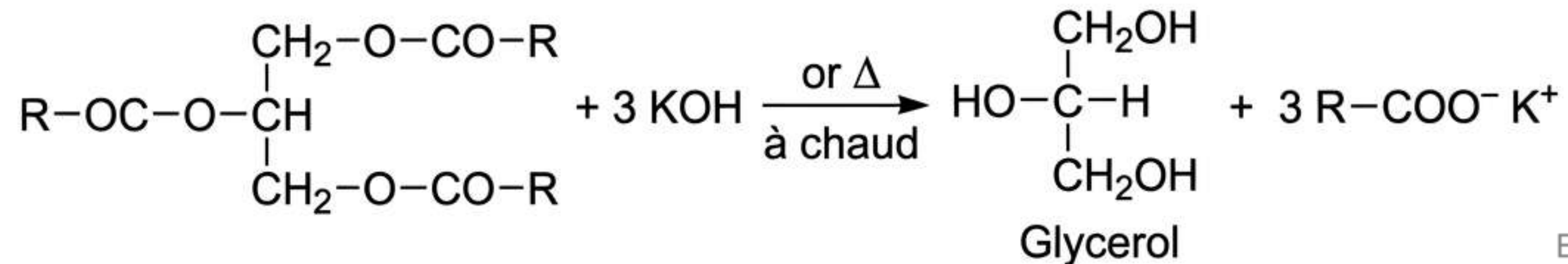
- Glycerol is a pro-chiral molecule.
- If the fatty acid at C1 is different from C3, the central carbon (C2) becomes a Chiral Center.
- Numbering: sn-1, sn-2, sn-3.

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-COOH) + Long Chain Alcohol (R'-OH) \rightarrow Céride (R-COO-R') + H₂O.

Properties

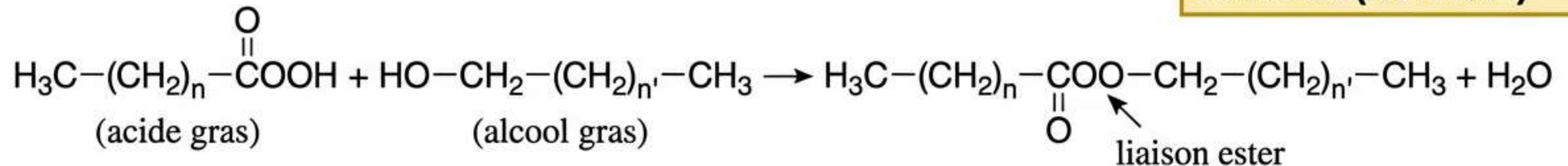
- Very insoluble (Hydrophobic).
- High melting point (Solid/Hard at room temp).

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

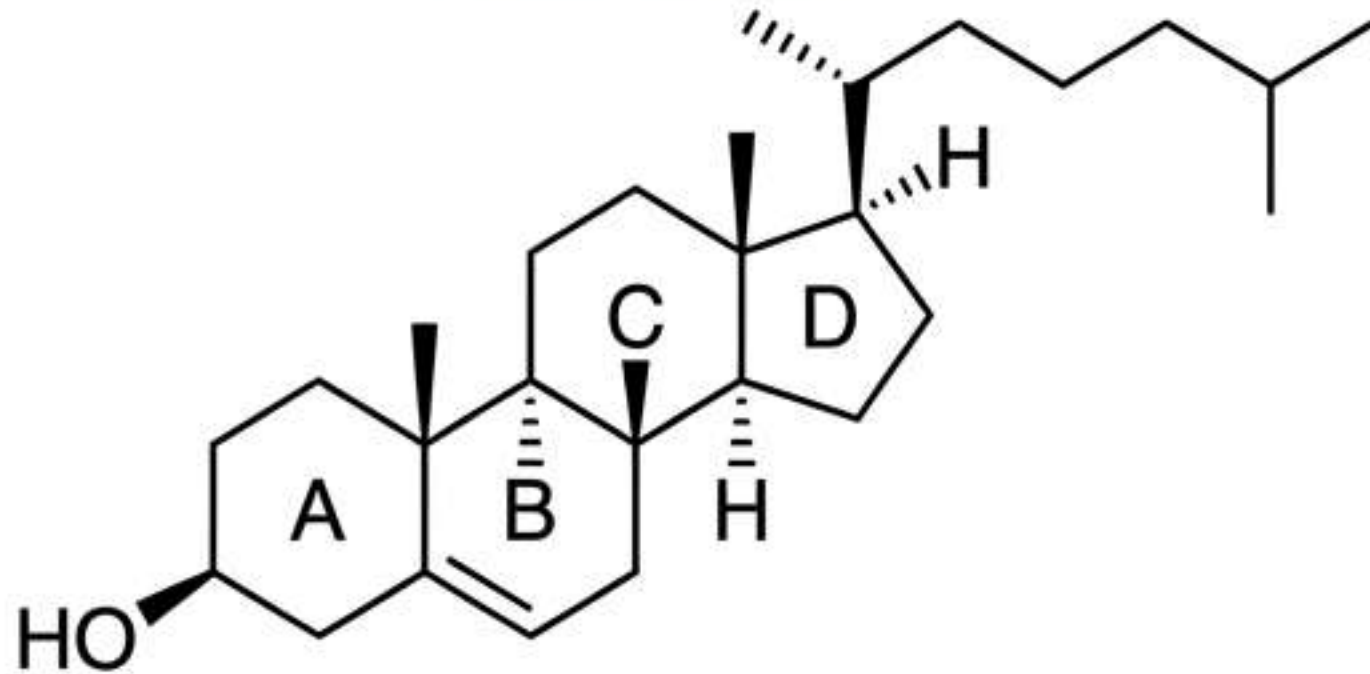
Steroid Nucleus:

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

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

Double bond at $\Delta 5$.

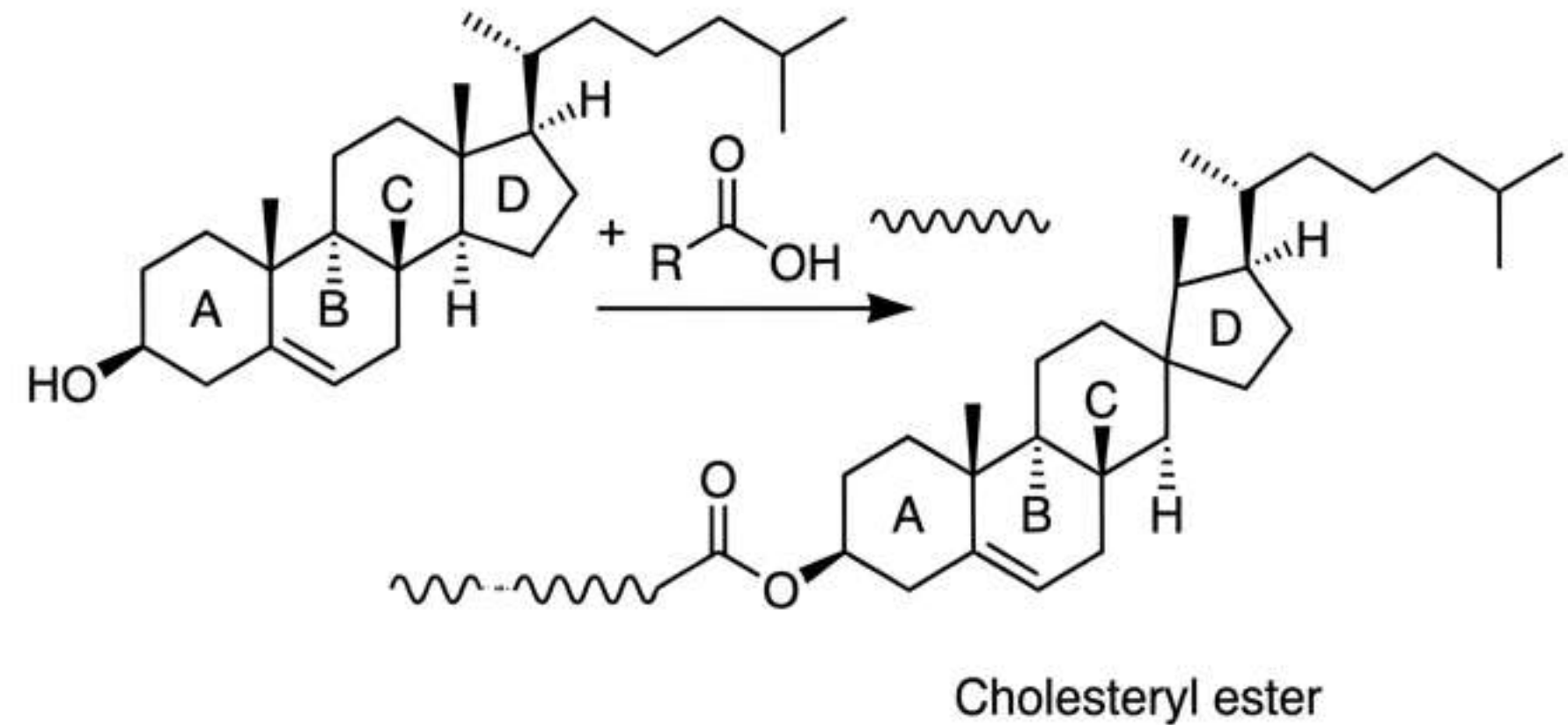
Source: Strictly Animal (Plants contain phytosterols). (Ref Q59)



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.

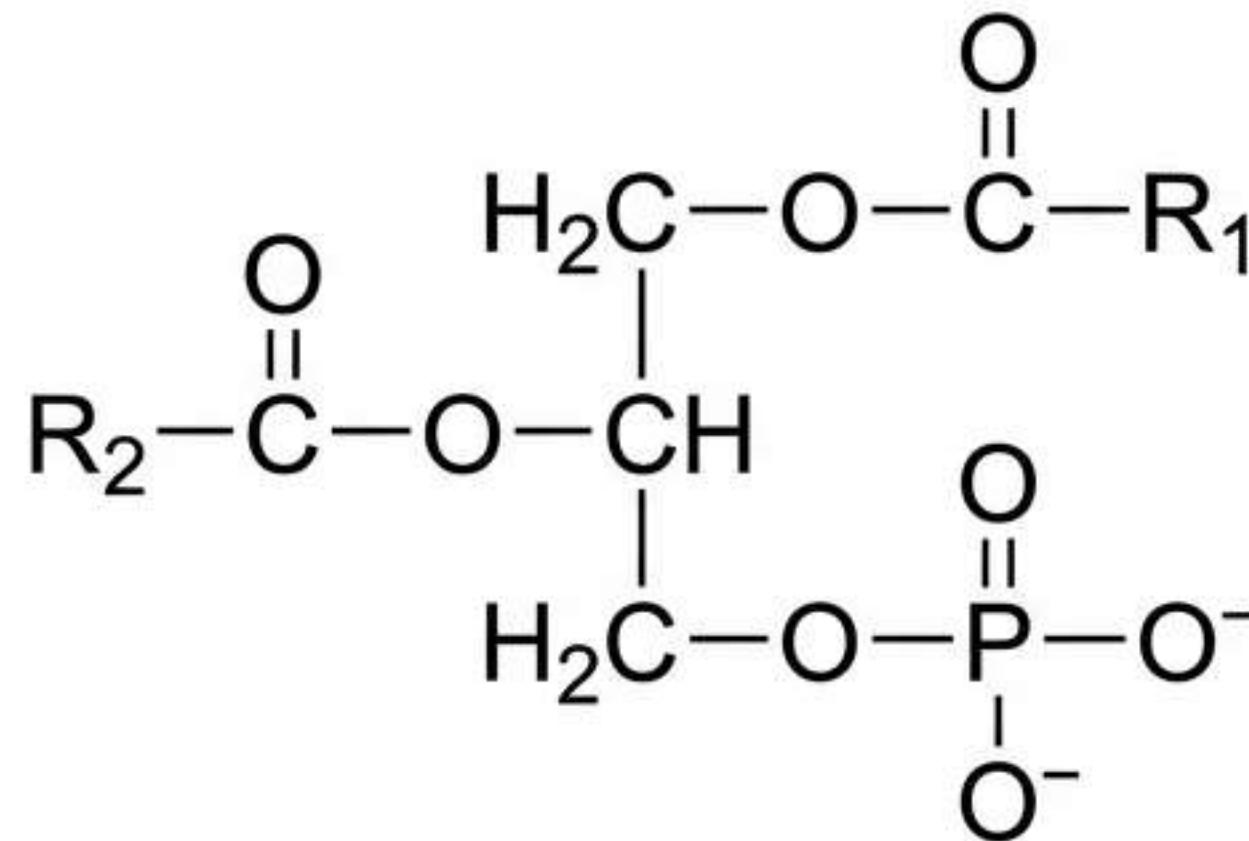
- Backbone: **Glycerol**.
- C1: Fatty Acid (Usually Saturated).
- C2: Fatty Acid (Usually Unsaturated).
- C3: Phosphate Group.

Amphipathic Nature

Polarity:

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

Role: Major component of cell membranes.



Phosphatidic Acid

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):

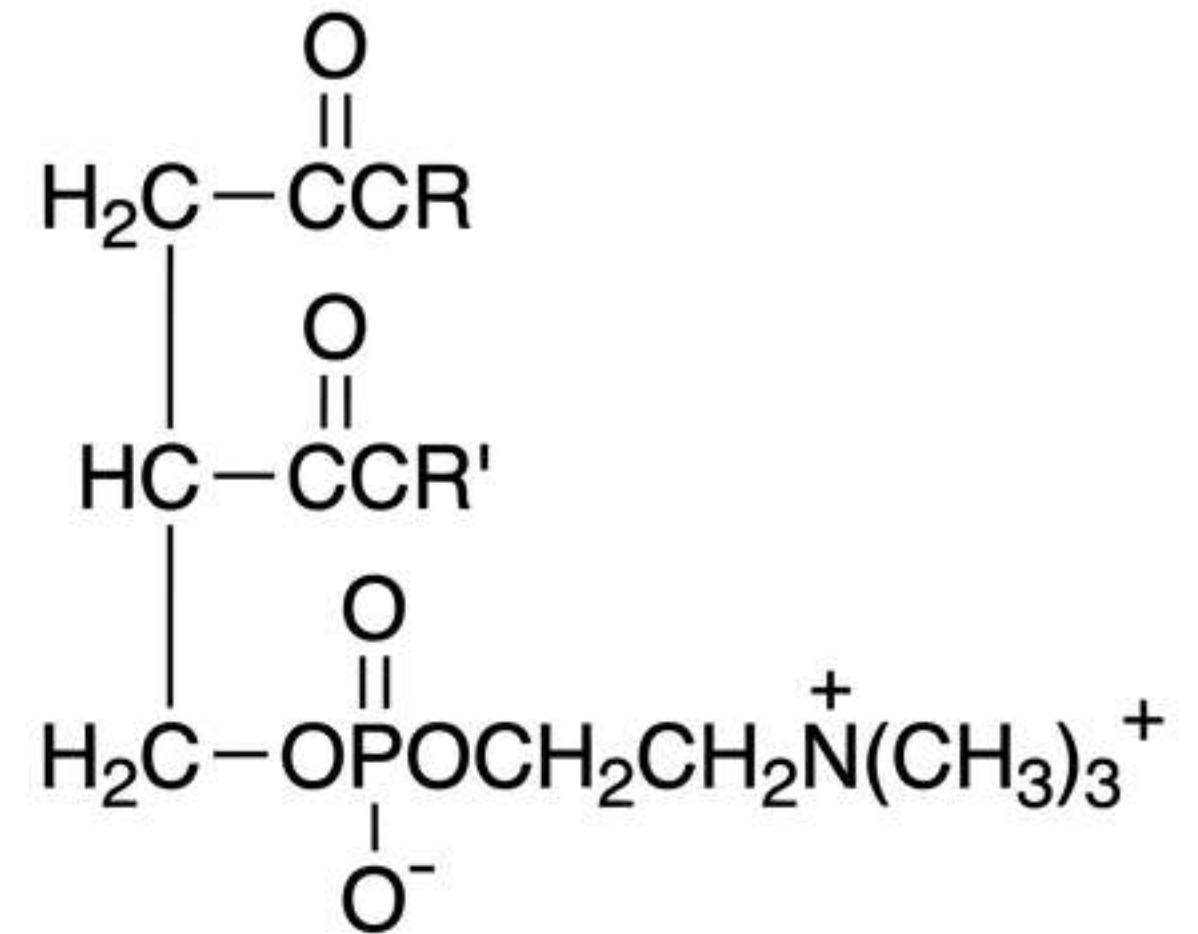
- Alcohol: Ethanolamine.
- Common Name: **Cephalin.**

Phosphatidylserine (PS):

- Alcohol: Serine (Amino acid).

Phosphatidylinositol (PI):

- Alcohol: Inositol (Cyclic sugar).



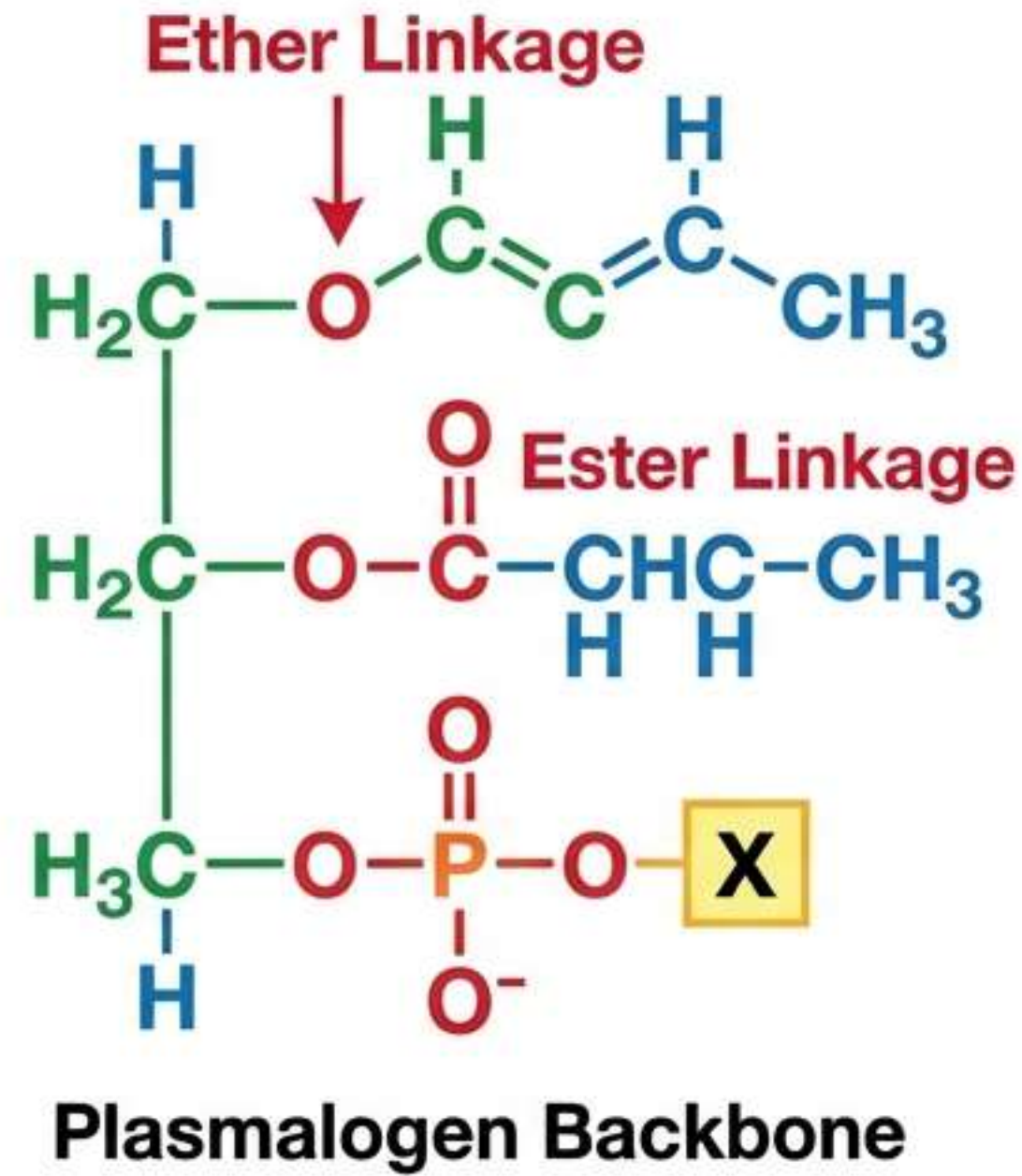
phosphatidylcholine

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.

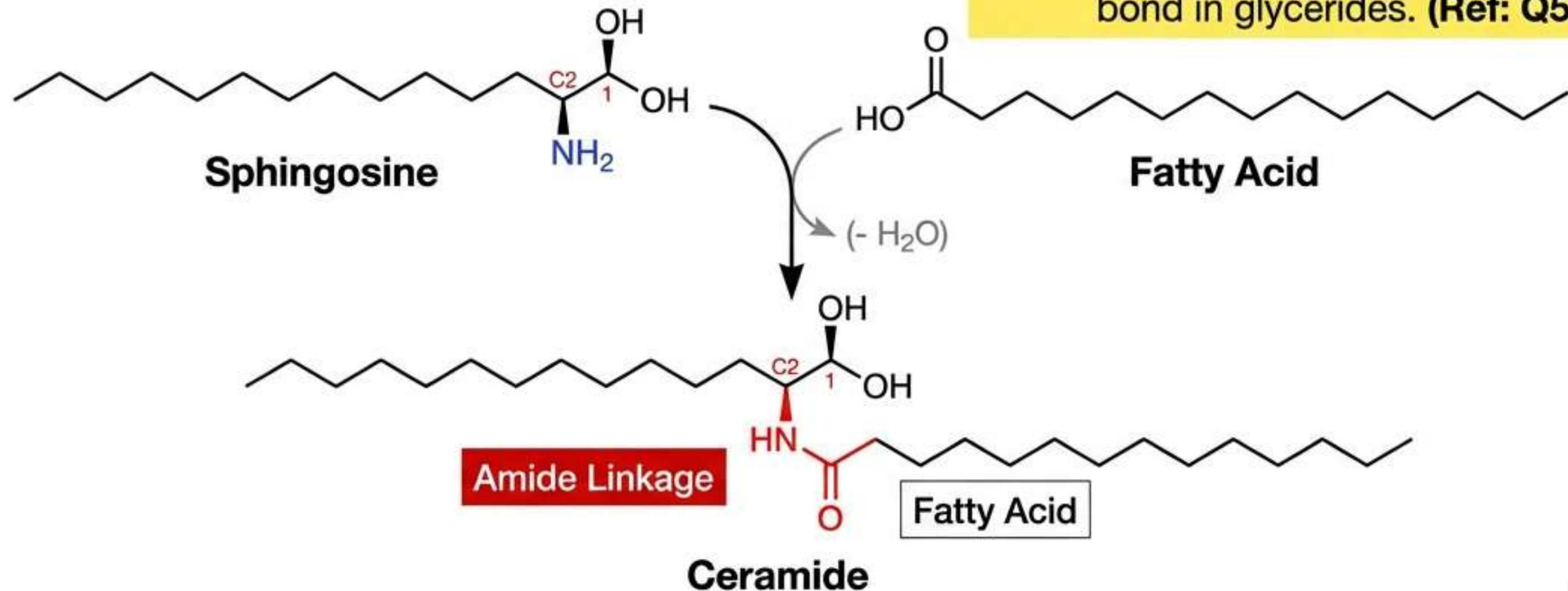
Complex Lipids: Sphingolipids & Ceramide

Sphingosine:

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

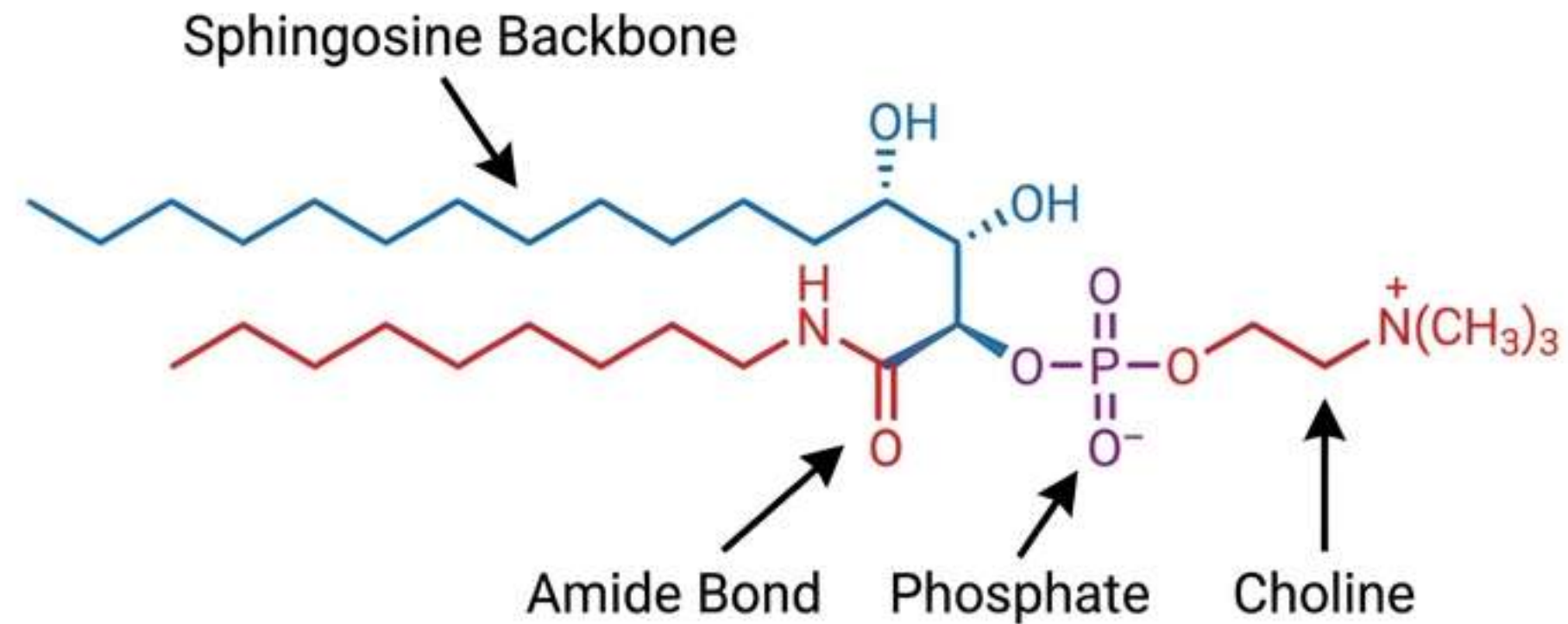
Ceramide:

- * **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

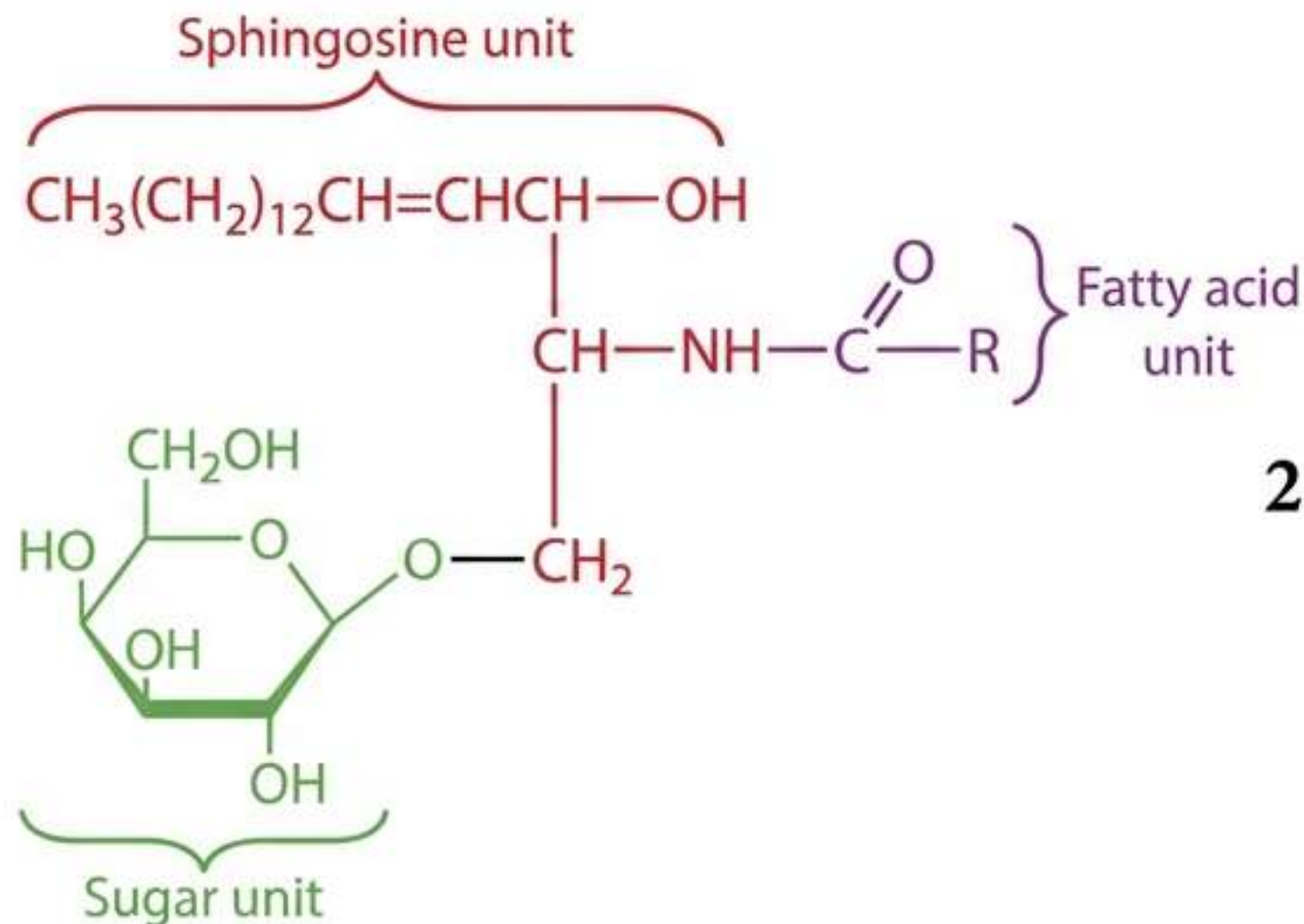
- **Sphingomyelin:**
 - **Composition:** Ceramide + Phosphate + Choline.
 - **Key Feature:** It is the *only* Sphingolipid that contains Phosphate.
 - **Location:** Major component of the Myelin sheath in nerve fibers.



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:

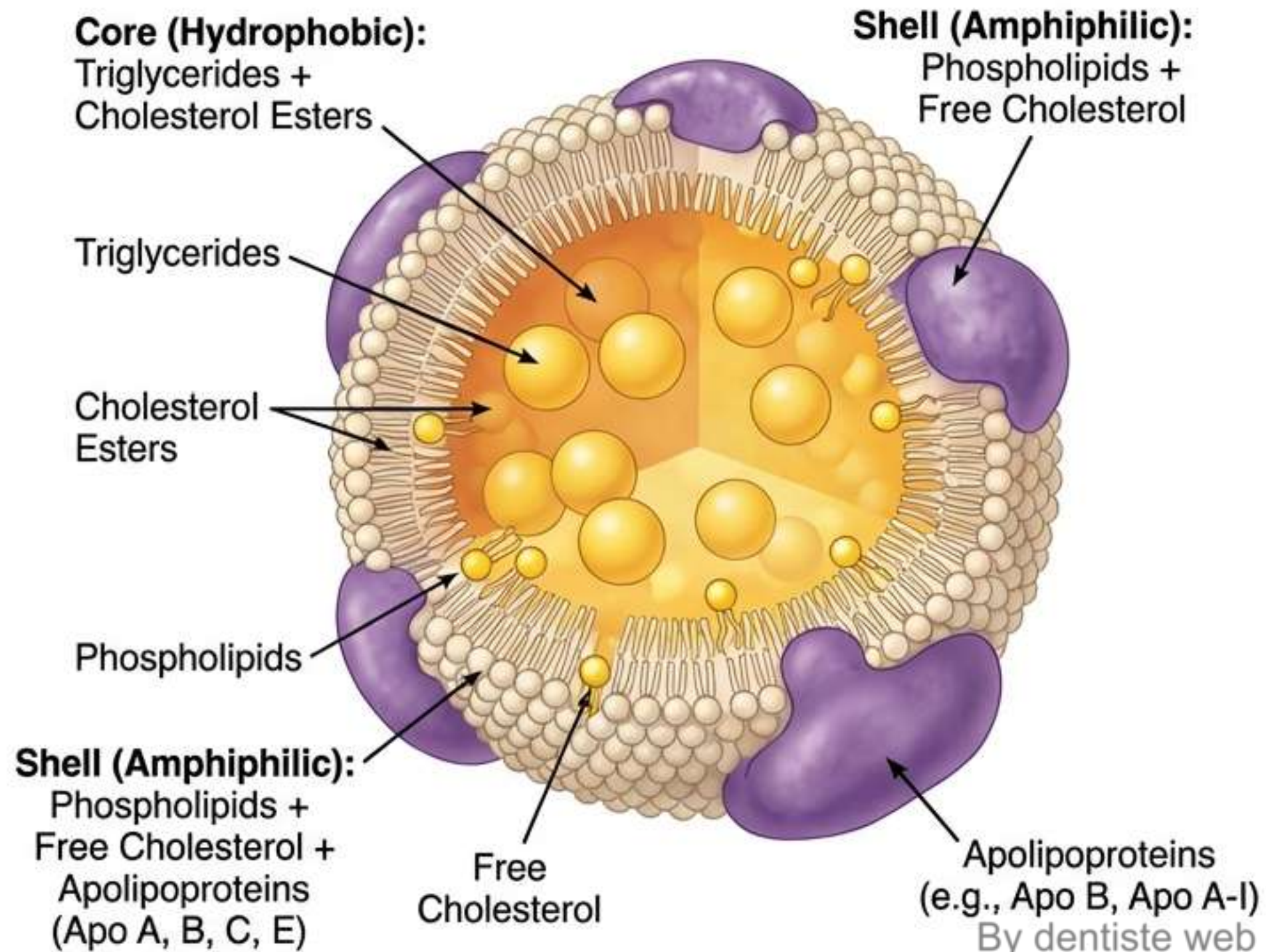
The Problem: Lipids (TG, Cholesterol) are hydrophobic. Blood is aqueous.

The Solution: Lipoproteins.

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

(Ref Q55)

Anatomy of a Lipoprotein:



Lipoprotein Classification: Density vs. Size

