بسم الله الرحمن الرحيم

**BioChemistry**

وَلَقَدْ خَلَقْنَا الْإِنسَانَ وَنَعْلَمُ مَا تُوَسْوِسُ بِهِ نَفْسُهُ ۖ وَنَحْنُ أَقْرَبُ إِلَيْهِ مِنْ حَبْلِ الْوَرِيدِ

**MID | Lecture 10**

# Lipids Pt.3


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# Color coding used in the modified:

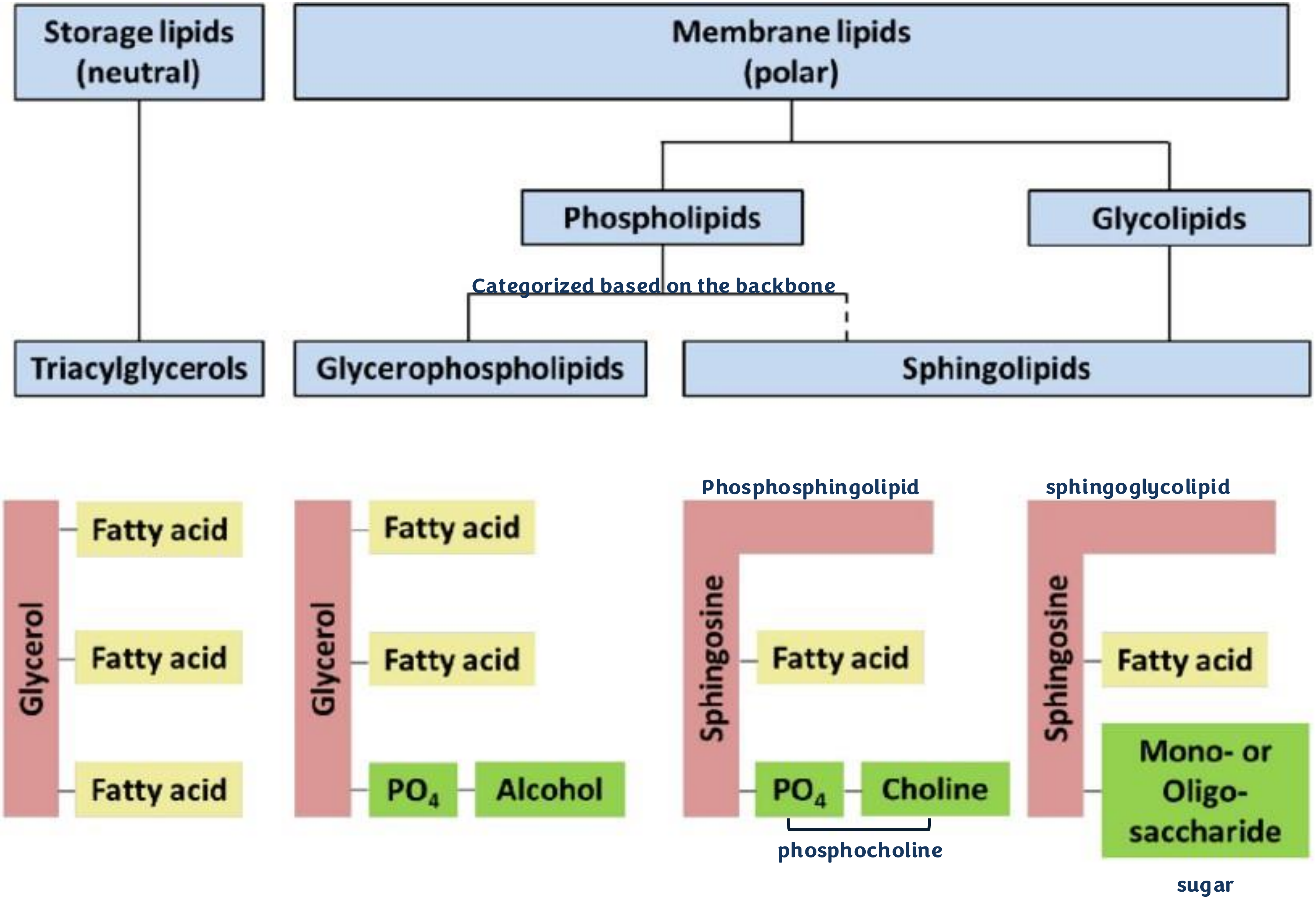
- *Black: the original slides*
- *Navy Blue: the doctor’s explanation/words*
- *Gray: additional information and explanation*
- *Red: important information*

# Complex lipids

All these are characterized for having a backbone (carrier); **the alcohol molecule** that we'll add fatty acids or any other group to.

**Triacylglycerol**
**Tri:** 3 fatty acids
**Acyl:** hydrocarbon chain with RCO- (Fatty acid after attachment to glycerol)
**Glycerol:** the carrier

Note that the acetyl molecule (comes from the acetate) has 2 carbons.
Acyl is like the acetyl but has more than 2 carbons.



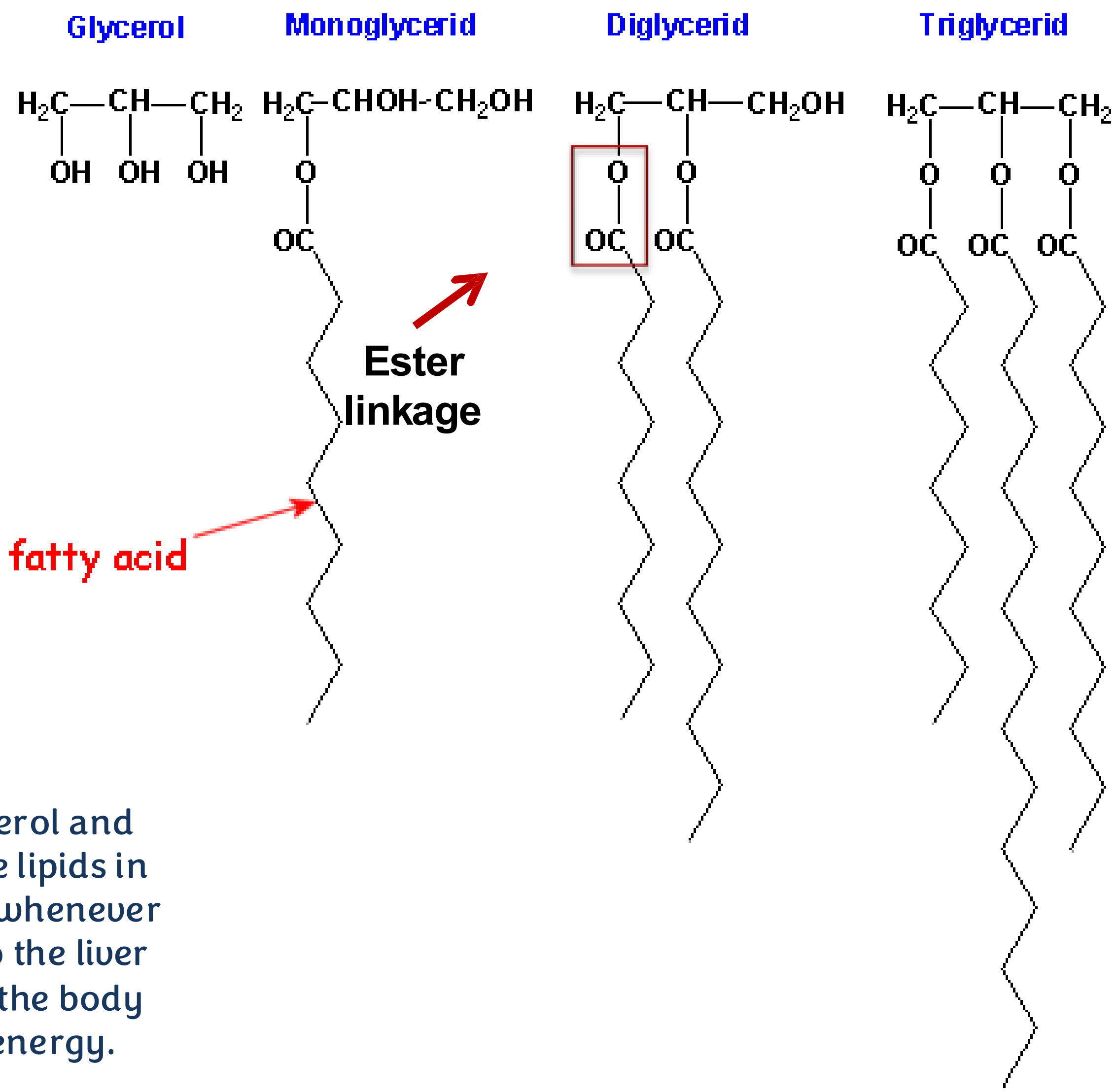
# Triglycerides

**The same as Triacylglycerol**

Glycerol: 3 hydroxyl groups
Monoglyceride (monoacylglycerol): glycerol with one fatty acid and 2 hydroxyl groups.
Diglyceride (diacylglycerol): glycerol with 2 fatty acids and one hydroxyl group.
Triglyceride (triacylglycerol) : glycerol with 3 fatty acids.

Whenever you hear glycer- (as in glyceraldehyde) we're talking about a 3 carbon molecule.

The monoacylglycerol and the diacylglycerol and specifically the triacylglycerol are storage lipids in our cells (liver cells and adipocytes), and whenever the body needs energy it'll send signals to the liver and the adipocytes to send fatty acids so the body can break the fatty acids down and gain energy.




**Usually, the added fatty acids are different (but they could be the same).**

**The reaction of the carboxyl group (from the fatty acid ) and the alcohol group (from the glycerol ) makes the ester group (linkage) as in wax.**

# Types of glycerides

You should memorize the common names of the fatty acids.

**When the 3 fatty acids are the same, we call it a simple molecule.**

**Remember the Steric acid has 18 carbons and its saturated.**

Glycerol unit

Stearic acid units

$$\begin{array}{l} CH_2OCO(CH_2)_{16}CH_3 \\ | \\ CHOCO(CH_2)_{16}CH_3 \\ | \\ CH_2OCO(CH_2)_{16}CH_3 \end{array}$$

Glyceryl tristearate
(a simple triglyceride;
a saturated fat)

**When the 3 fatty acids are different, we call it a mixed molecule.**

Glycerol unit

Palmitic acid unit

Oleic acid unit

Linolenic acid unit

$$\begin{array}{l} CH_2OCO(CH_2)_{14}CH_3 \\ | \\ CHOCO(CH_2)_7CH{=}CH(CH_2)_7CH_3 \\ | \\ CH_2OCO(CH_2)_7(CH{=}CHCH_2)_3CH_3 \end{array}$$

Glyceryl palmitooleolinolenate
(a mixed triglyceride;
a polyunsaturated oil)

## How liquid will a triglyceride be if fatty acids are unsaturated?

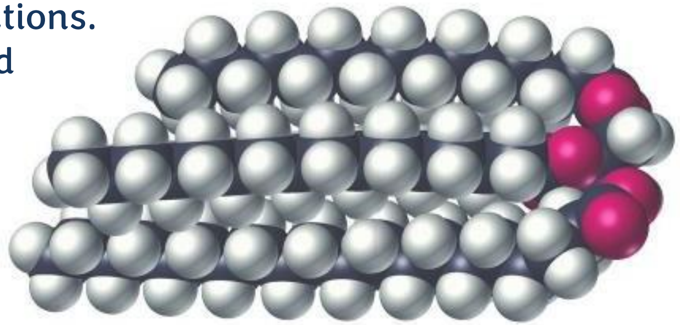
**The more unsaturated the fatty acids are, the more liquid the triglyceride will be.**

Remember:
Oleic acid has 18 carbons with one double bond.
Linolenic acid has 18 carbons with 3 double bonds.
Linolenic and linoleic acids are essential fatty acids (we get them from food).
Linoleic is the precursor of arachidonic acid ( 20 carbon fatty acid ), arachidonic acid is then used to synthesize eicosanoids.
Linoleic acid is an omega-6 fatty acid, whereas linolenic acid is an omega-3 fatty acid.

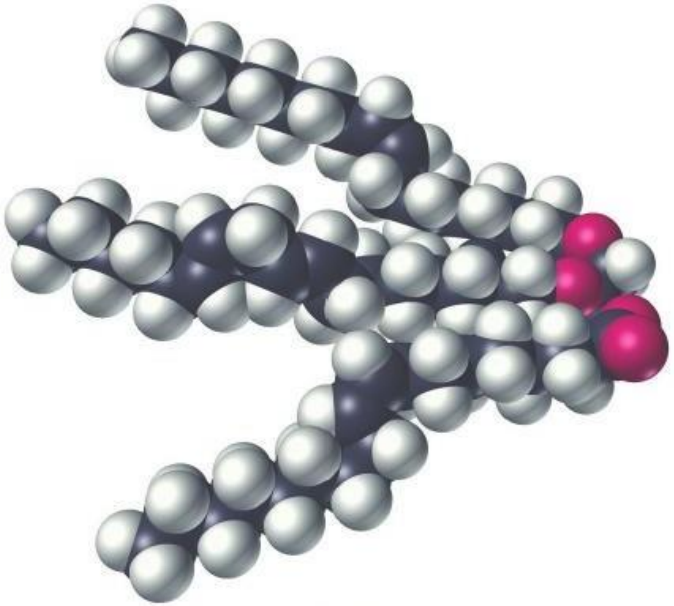
# Solid vs. liquid fats

- Vegetable oils consist almost entirely of unsaturated fatty acids, whereas animal fats contain a much larger percentage of saturated fatty acids.
  - This is the primary reason for the different melting points of fats and oils.

The fat has triacylglycerols with saturated fatty acids. The hydrocarbon chains pack closely together because of strong van der Waals (hydrophobic) interactions. Therefore, the fat is solid and insoluble in water.



A fat



An oil

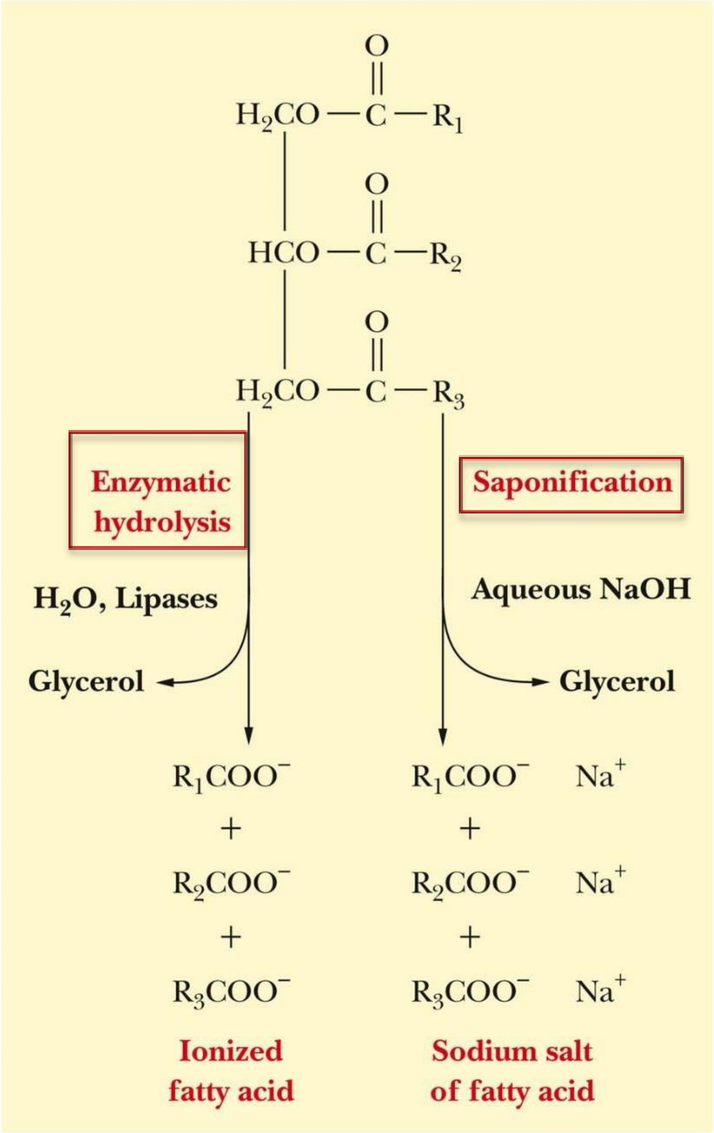
The three fatty acids are unsaturated (they have cis double bonds), so they have kinks that prevent tight packing. Therefore, the fat is liquid and remains hydrophobic and insoluble in water.

# Saponification

The process of making soap.

- Hydrolysis: steam, acid, enzyme (e.g., lipase of pancreas)
- Saponification: Alkaline hydrolysis produces salts of fatty acids (soaps). Soaps cause emulsification of oily material.

Oil undergoes hydrolysis under alkaline conditions (NaOH), releasing glycerol and fatty acid salts (soaps).



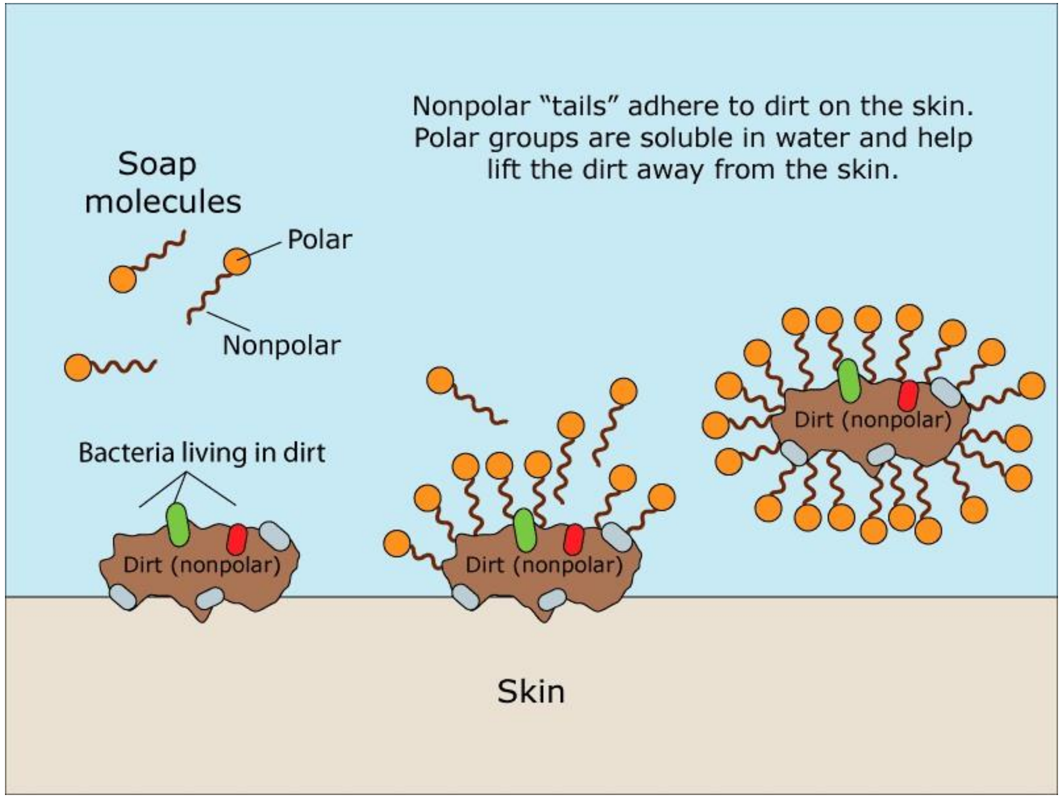
# How does soap work?

**Soap works by forming micelles.**

- When mixed with water, the hydrophobic hydrocarbon tails cluster together to create a nonpolar microenvironment and the hydrophilic ionic heads interact with water.
- The resulting spherical clusters are called micelles.
- Grease and dirt are trapped inside micelles and the complex can be rinsed away.

A micelle is a spherical cluster of fatty acid molecules. The hydrophobic tails are oriented toward the inside, while the carboxyl groups are exposed on the outside, where they interact with water.

1) **Dirt and grease are usually hydrophobic. Therefore, the hydrophobic tails of soap surround the grease and dirt. Because soap molecules are amphipathic, their hydrophilic carboxyl groups remain on the outside, where they interact with water.**

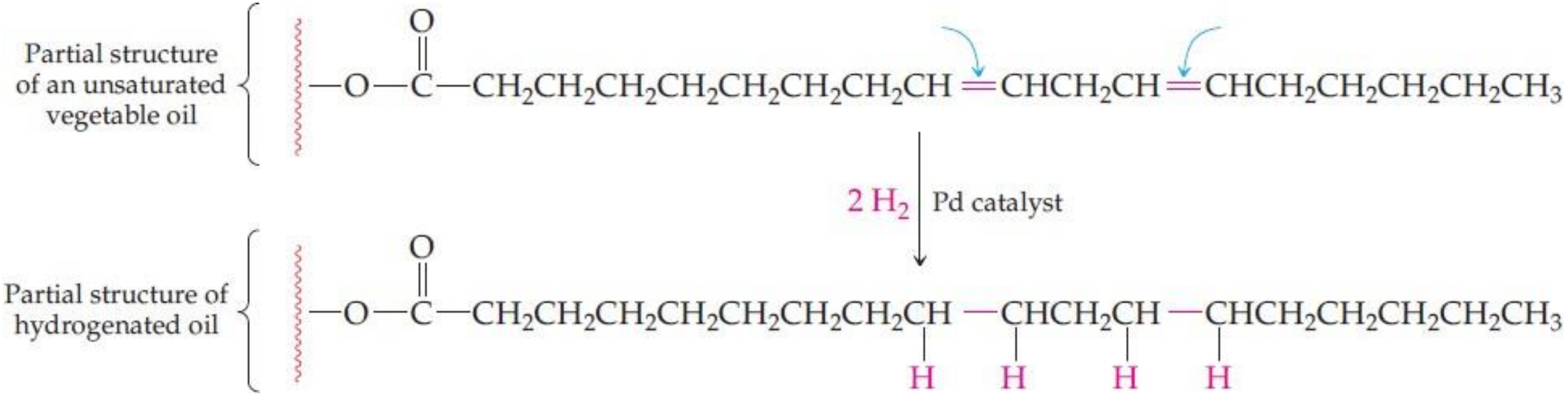



2) **When water is added, the hydrophobic fatty acid tails accumulate around the grease. The tails surround the grease on the inside, while the carboxyl groups remain on the outside and interact with water. As a result, the grease is eventually washed away with water.**

# Hydrogenation

In industry, hydrogen is added to the double bonds of unsaturated fatty acids to make them single bonds. converting monounsaturated and polyunsaturated fatty acids into saturated fatty acids.

- The carbon-carbon double bonds in vegetable oils can be hydrogenated to yield saturated fats in the same way that any alkene can react with hydrogen to yield an alkane.

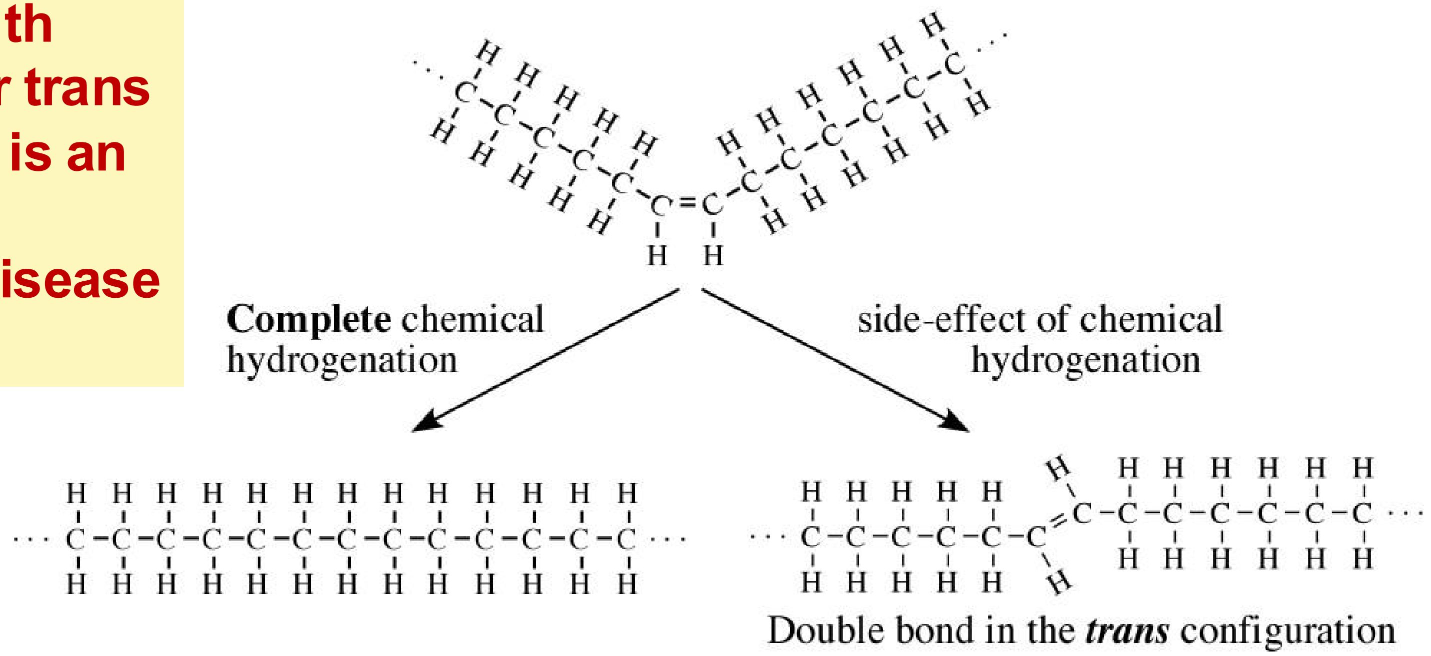


# Trans fat

When unsaturated fatty acids are converted into saturated fatty acids, some trans fats are formed. Trans fats are unsaturated fatty acids with double bonds in the trans orientation. They are secondary products of hydrogenation. They are used in the food industry because they have a long shelf life and improve taste. However, they are harmful because they increase the risk of coronary heart disease (CHD).

- Although the animal fat is unhealthy, it has better cooking properties and better taste.
- Therefore, chemists invented a method of converting unsaturated oil into solid form by partially hydrogenating it.
- Partial hydrogenation converts some, but not all, double bonds into single bonds generating (trans fats).

**The primary health risk identified for trans fat consumption is an elevated risk of coronary heart disease (CHD).**



# Example: margarine

Incomplete hydrogenation of unsaturated fatty acids converts some of them into trans fats, producing soft margarine. It's harmful to health too.

- In margarine, only about two-thirds of the double bonds present in the starting vegetable oil are hydrogenated, so that the margarine remains soft in the refrigerator and melts on warm toast.

**Nutrition Facts**

Serving Size 1 Tbsp (14g)
Servings Per Container 32

Amount Per Serving

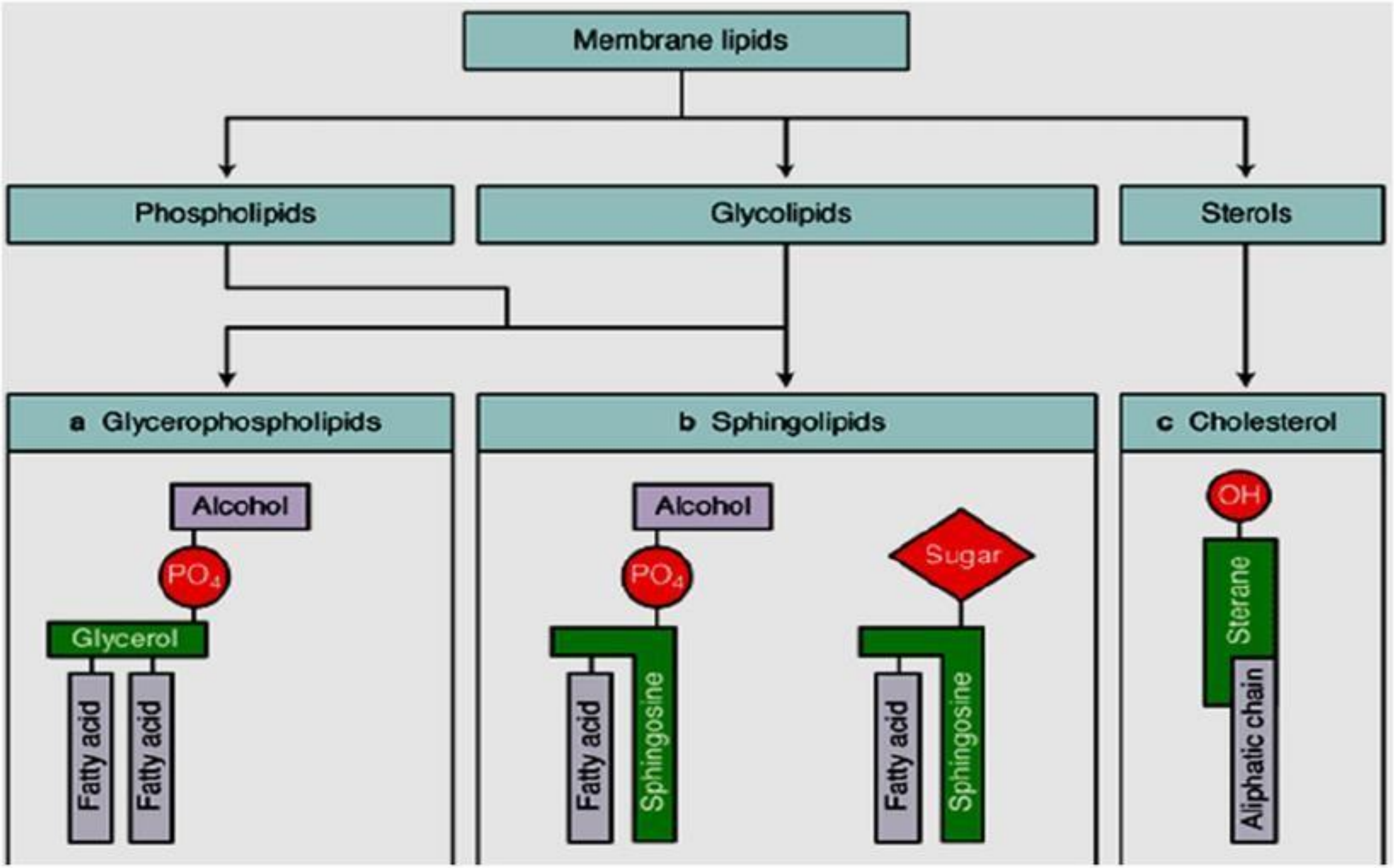
| | | |
|---|---|---|
| **Calories** 100 | Calories from Fat 100 | |
| | | % Daily Value* |
| **Total Fat** 11g | | 17% |
| Saturated Fat 2g | | 10% |
| *Trans* Fat 3g | | |
| **Cholesterol** 0mg | | 0% |

# Membrane lipids

Glycerophospholipids and sphingolipids are the major membrane lipids that form the cell membrane. Cholesterol is also an important component of the membrane.

There is a rare type of glycolipid called a glycerosphingolipid, which consists of glycerol, two fatty acids, a phosphate group, and a sugar.

**The most prevalent class of lipids in membranes is the glycerophospholipids**



# Phospholipids (phosphoacylglycerols)

- Phosphatidic acids
- Phosphatidylcholine (lecithin)
  - Most abundant membrane lipid

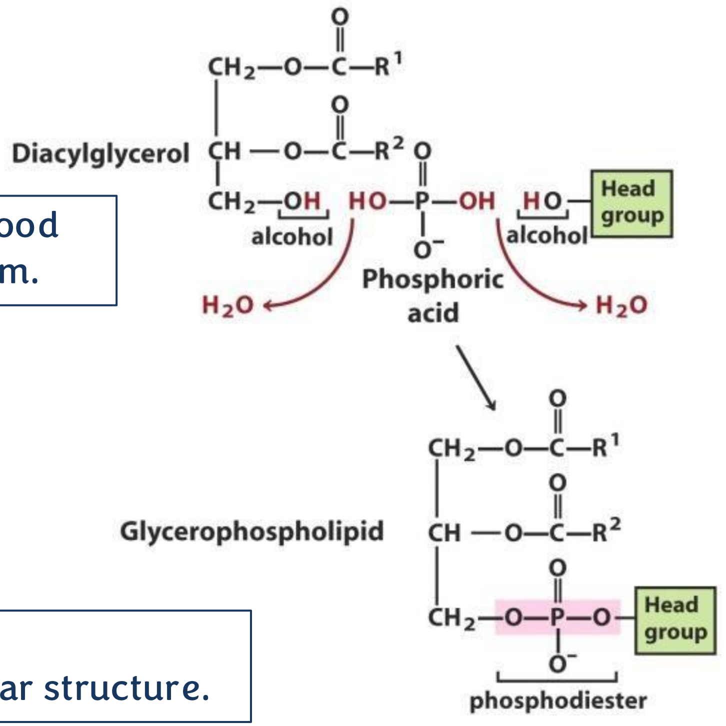
commonly found on food labels such as ice cream.

- Cephalins
  - Phosphatidylethanolamine
  - Phosphatidylserine
    - abundant in brain
- Phosphatidylinositol
  - sends messages across cell membranes

Whose head group is inositol.
Remember: the inositol is ring sugar structure.

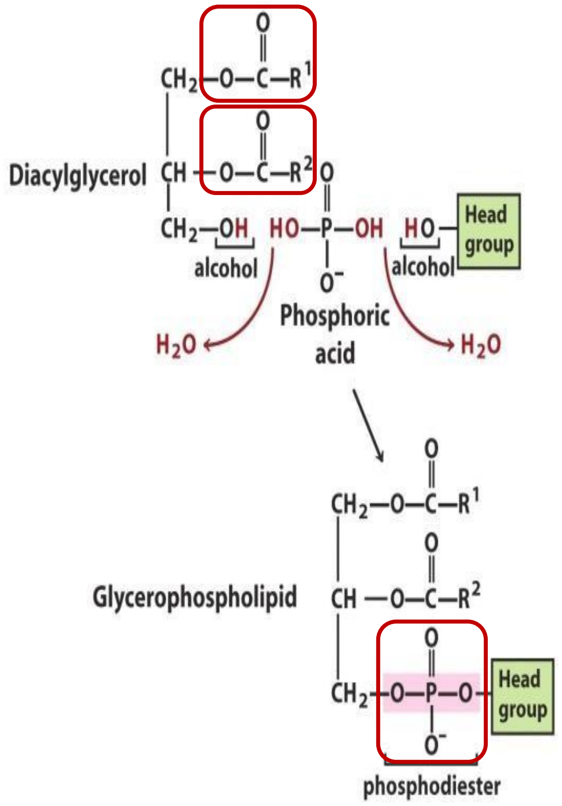
Unlike most glycolipids, which are sphingolipids (their backbone is sphingosine) , phosphatidylinositol has a glycerol backbone.

- Cardiolipin
- Plasmalogens




| | | |
|---|---|---|
| Phosphatidic acid | — | $-H$ |
| Phosphatidylethanolamine | Ethanolamine | $-CH_2-CH_2-\overset{+}{N}H_3$ |
| Phosphatidylcholine | Choline | $-CH_2-CH_2-\overset{+}{N}(CH_3)_3$ |
| Phosphatidylserine | Serine | $-CH_2-CH(COO^-)-\overset{+}{N}H_3$ |

- Phosphoacylglycerols are built on a glycerol backbone consisting of three carbon atoms ($CH_2O–CHO–CH_2O$).
- At carbon 1, a fatty acid ($R_1$) is attached through an ester bond. The $R_1$ group is a hydrocarbon chain that may vary in length (e.g., 8, 10, 12, 14, or more carbon atoms).
- At carbon 2, another fatty acid ($R_2$) is also attached by an ester bond. Although $R_2$ can be identical to $R_1$, it is usually different.
- At carbon 3, the hydroxyl group of glycerol is esterified with a phosphate group, producing phosphatidic acid. Therefore, phosphatidic acid consists of a glycerol molecule with two fatty acids attached to carbons 1 and 2 and a phosphate group attached to carbon 3.
- Under physiological conditions, the phosphate group is usually onprotonated, making the molecule negatively charged. In this form, it is called phosphatidate, which is the conjugate base of phosphatidic acid, just as palmitic acid forms palmitate and stearic acid forms stearate.




| | | |
|---|---|---|
| Phosphatidic acid | — | $-H$ |
| Phosphatidylethanolamine | Ethanolamine | $-CH_2-CH_2-\overset{+}{N}H_3$ |
| Phosphatidylcholine | Choline | $-CH_2-CH_2-\overset{+}{N}(CH_3)_3$ |
| Phosphatidylserine | Serine | $-CH_2-CH(COO^-)-\overset{+}{N}H_3$ |

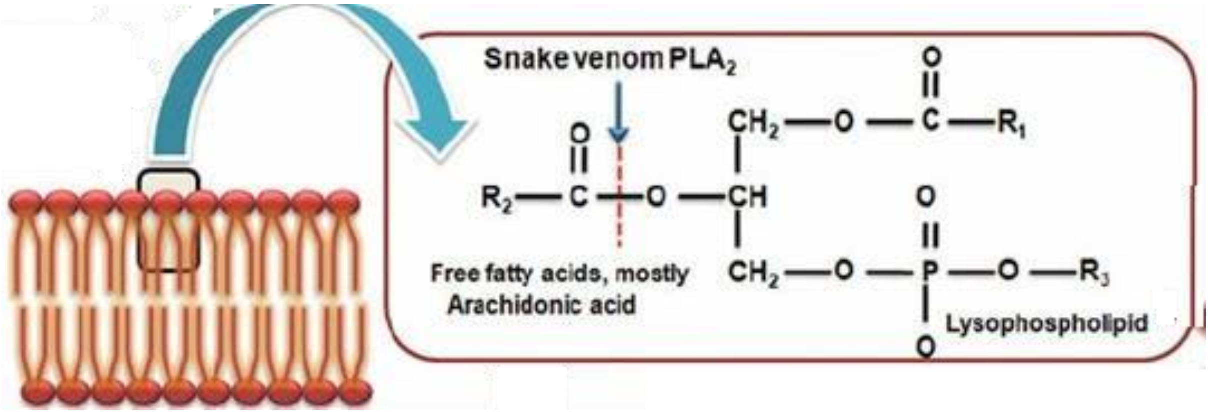
Knowing the structure is important

- Phosphatidic acid is the simplest phosphoacylglycerol and serves as the precursor for the synthesis of the other phospholipids. These phospholipids are formed by attaching **different head groups** to the **phosphate group**.
- One possible head group is **ethanolamine**. When ethanolamine is attached to phosphatidate, the resulting phospholipid is called **phosphatidylethanolamine** (PE).
- Another important head group is **choline**. When choline is attached to phosphatidate, the product is **phosphatidylcholine** (PC).
- Another major phospholipid is **phosphatidylserine** (PS), in which the head group is the amino acid **serine**.

# Glycerophospholipids - Lecithins

Because the Phosphatidylcholine (lecithin) is the most abundant phospholipid in cell membranes, It is the target of snake venoms. These venoms contain an **enzyme called lecithinase** (phospholipase A2), which **hydrolysis** the lecithin (phosphatidylcholine). When snake venom enters the bloodstream, lecithinase attacks the phosphatidylcholine present in the plasma membrane of red blood cells (RBCs). As a result, the membrane is disrupted, leading to the lysis of **red blood cells.**

- Snake venom contains an enzyme called lecithinase, specifically phospholipase A2, which hydrolyzes polyunsaturated fatty acids and converts lecithin into lysolecithin.
  - hemolysis of RBCs

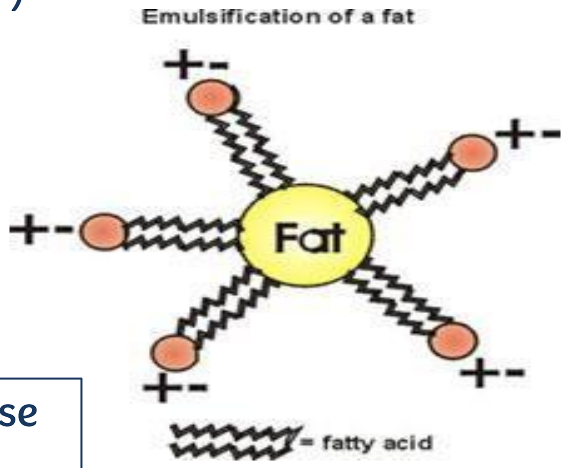




# Emulsification

Emulsification is the process of dissolving or dispersing fat in a hydrophilic (aqueous) solvents

(important in the human body and in industry )

- Because of their amphipathic nature, they act as emulsifying agents, that is substances that can surround nonpolar molecules and keep them in suspension in water.




This arrangement surrounds the fat with phospholipid molecules, producing small fat droplets that remain suspended in water, in a manner similar to the action of soap.

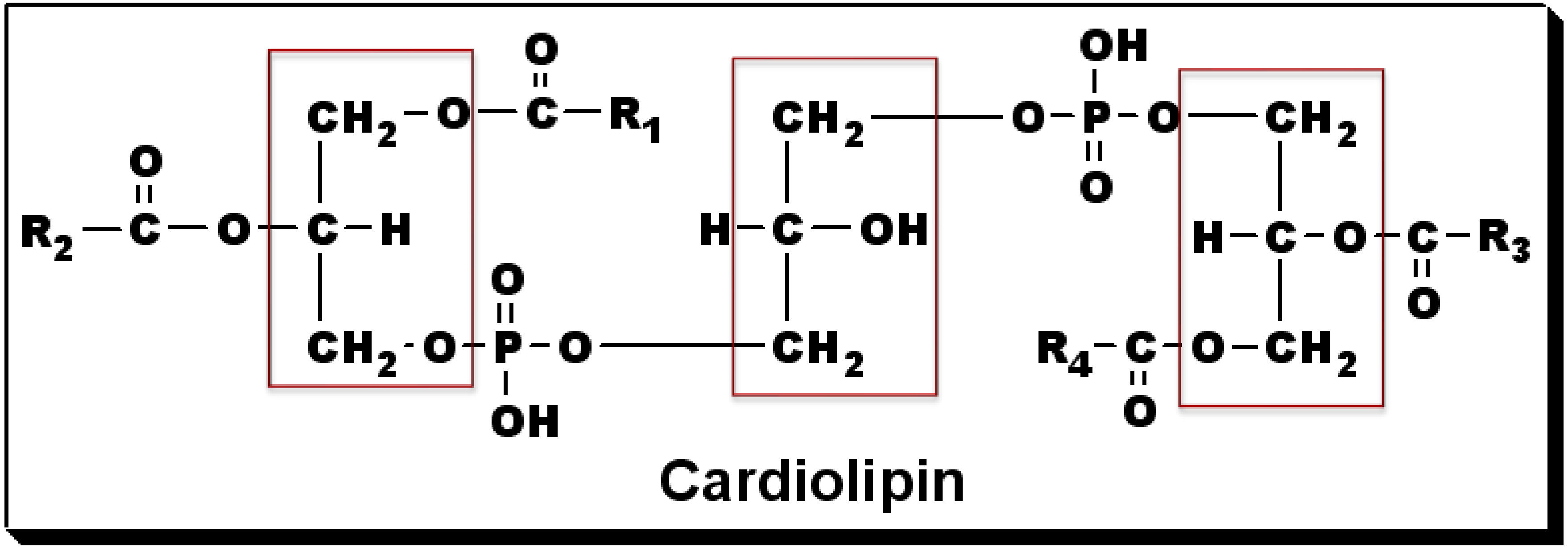
Phosphatidylcholine acts as an emulsifier because it is an amphipathic molecule. Its hydrophobic fatty acid tails interact with lipid droplets, while its hydrophilic phosphate-containing head group faces the surrounding water.

Lecithin is also widely used in food products such as ice cream, mayonnaise, and chocolate because of its emulsifying properties. This emulsifying property explains why lecithin is commonly added to foods such as ice cream, mayonnaise, and chocolate to improve their texture, stability, and consistency.

# Glycerophospholipids - Cardiolipins

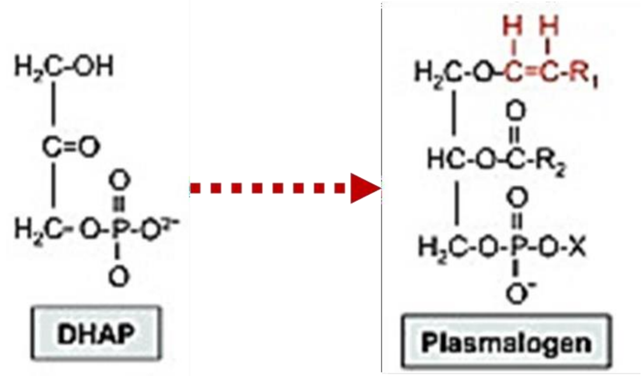
- Diphosphatidyl-glycerol (large molecule)
- Found in the inner membrane of mitochondria
- Initially isolated from heart muscle (cardio)
- Structure: 3 molecules of glycerol, 4 fatty acids & 2 phosphate groups (really complex structure)

**Do not memorize the structures but study them**

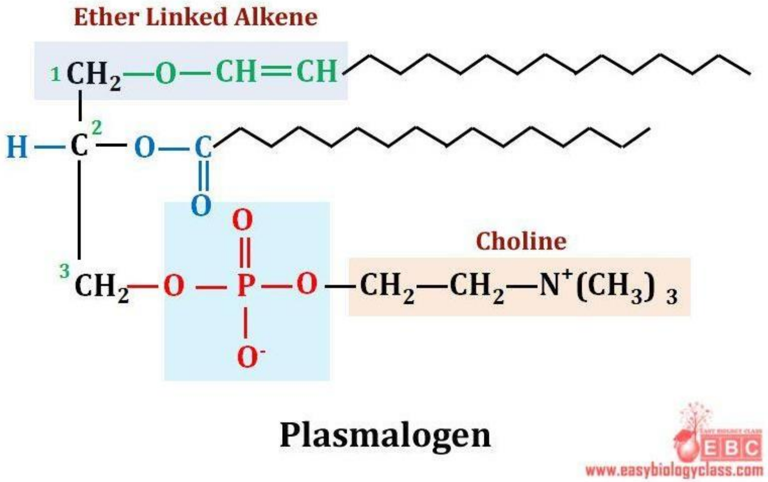


# Plasmalogens

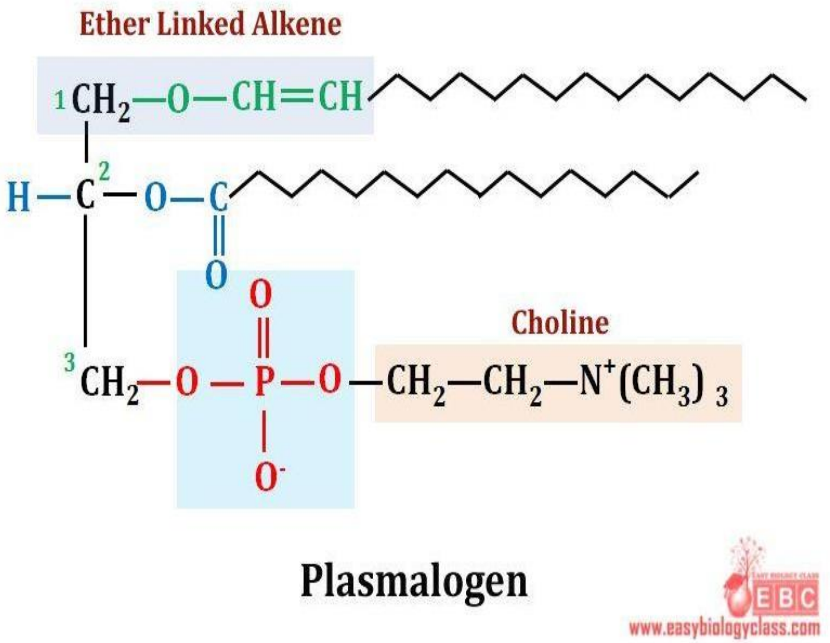
- They are found in the cell membrane phospholipids fraction of brain & muscle, liver, and semen.
- They have a protective role against reactive oxygen species
- Structure:
  (The simplest carbohydrate)
  - Precursor: Dihydroxyacetone phosphate
  - Unsaturated fatty alcohol at C1 connected by ether bond
  - In mammals: at C3; phosphate + ethanolamine or choline




- Major classes of plasmalogens
  - Ethanolamine plasmalogen (myelin-nervous tissues)
  - Choline plasmalogen (cardiac tissue)
    - Platelet activating factor
  - Serine plasmalogens

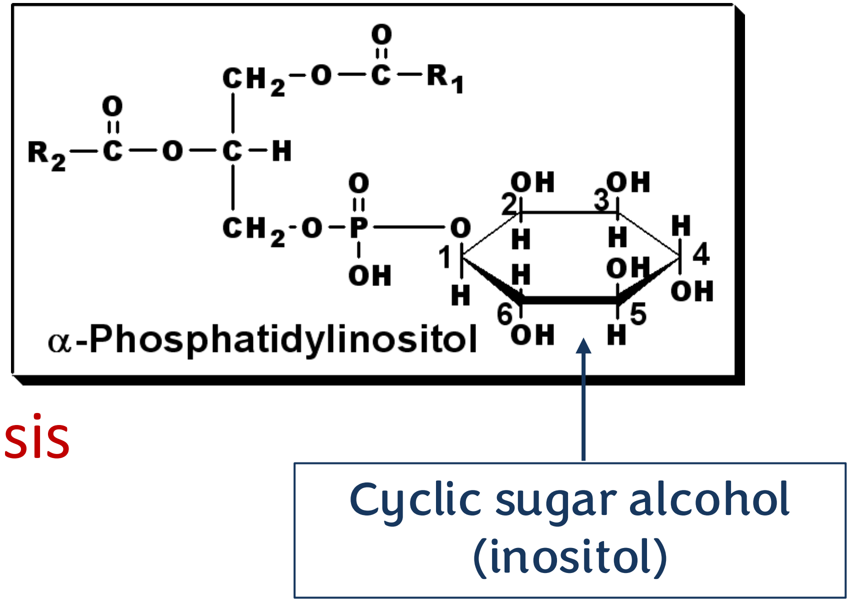


- Structurally, plasmalogens resemble glycerophospholipids but differ in one important feature. In a typical glycerophospholipid, both fatty acids are attached to glycerol by ester linkages.
- In plasmalogens the fatty chain at carbon 1 is attached through an ether linkage with alkene specifically a vinyl ether bond, while the fatty acid at **carbon 2 remains attached by an ester linkage and carbon 3 carries a phosphate group with a polar head group** such as choline, ethanolamine, or serine (amino acid).
- Therefore, when identifying plasmalogens by their structures, the key distinguishing feature is the **presence of an ether linkage in place of one of the ester linkages** found in ordinary glycerophospholipids.



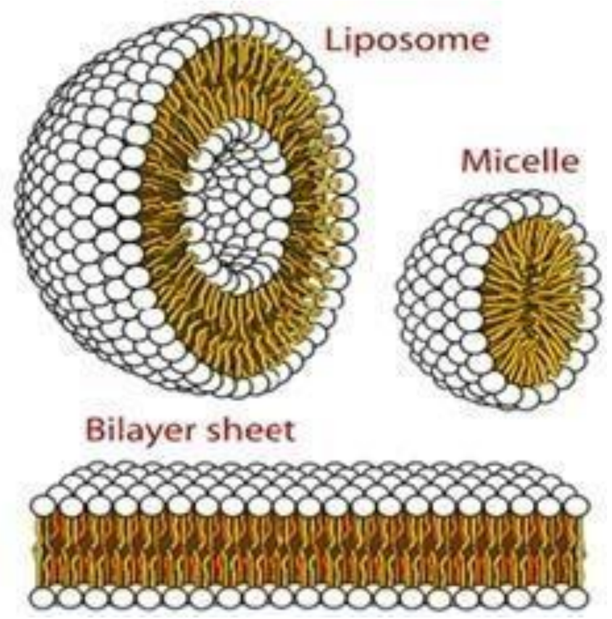

# Glycerophospholipids - Inositides

- Phosphatidyl inositol
- Cyclic sugar alcohol (inositol)
- Structure: glycerol, saturated FA, unsaturated FA, phosphoric acid, & inositol
- Source: Brain tissues
- Functions:
  - Major component of the cell membrane
  - Signalling molecules are produced upon hydrolysis



# The different structures of phospholipids

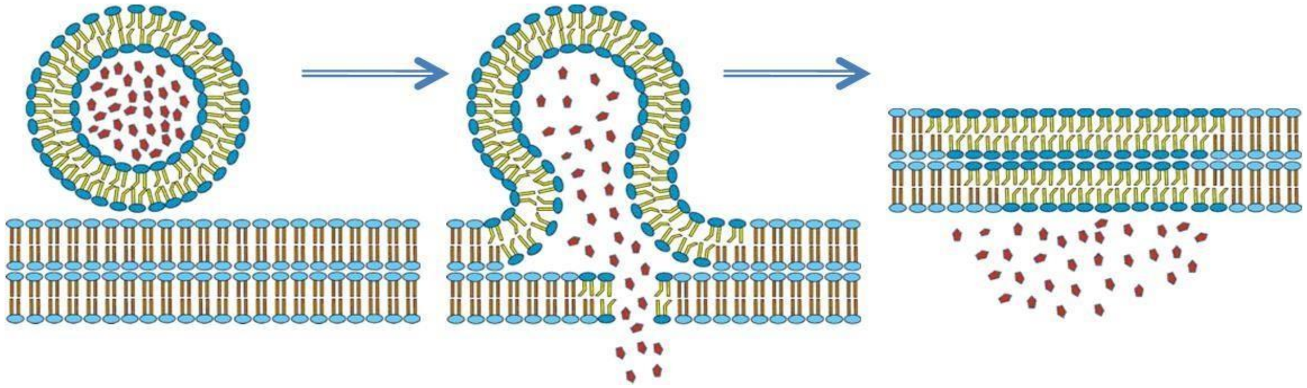
Because phospholipids are **amphipathic** molecules, they can assemble into different three-dimensional structures in aqueous environments.




- One such structure is the **micelle**, in which the hydrophobic fatty acid tails are oriented **inward** while the hydrophilic head groups **face the surrounding water**. Micelles are the structures formed by soap, allowing it to surround and solubilize hydrophobic substances.
- **Phosphatidylcholine (lecithin)** functions as an **emulsifying agent**, enabling fats to be dispersed in hydrophilic solvents such as water.
- Unlike micelles, **liposomes** consist of a phospholipid bilayer, resulting in an **aqueous (hydrophilic) interior as well as a hydrophilic exterior**, **separated by a hydrophobic membrane**.
- A **phospholipid bilayer** is the fundamental structural component of **cell membranes**. It consists of two layers of phospholipids, with the hydrophobic tails facing each other and the hydrophilic heads exposed to the aqueous environments on both sides.

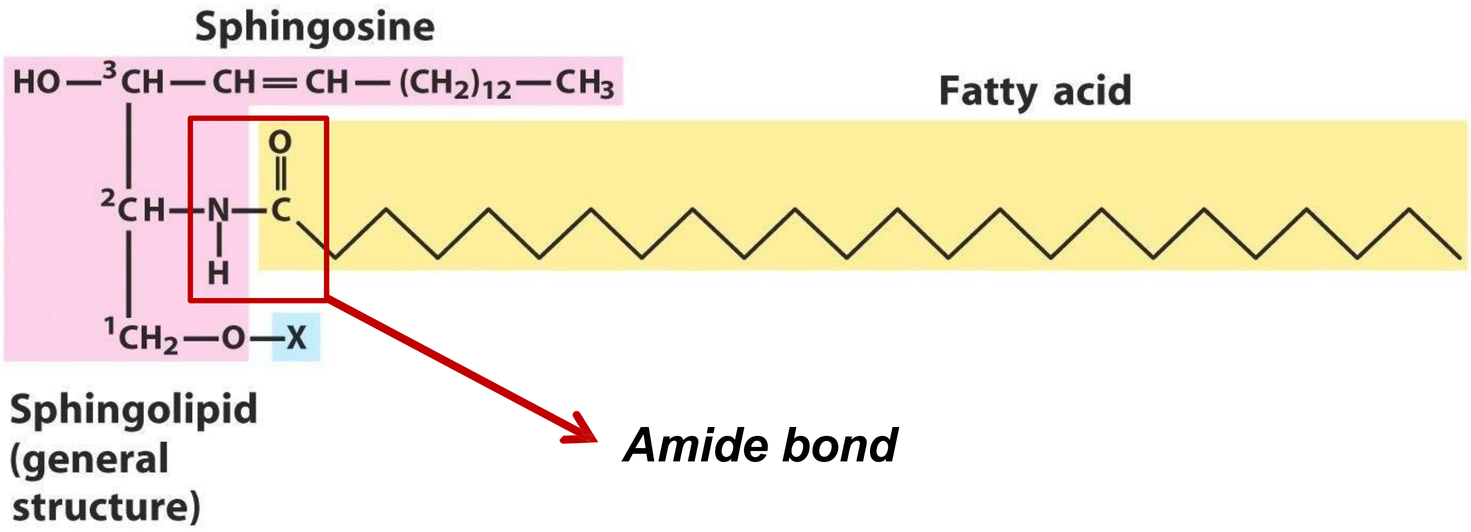
- Because Liposomes have shape-liked the structure of cell membranes. They can be loaded with drugs and administered into the body. When a liposome reaches a target cell, it fuses or merges with the plasma membrane, releasing its contents directly into the cell. **This property makes liposomes valuable drug delivery systems.**
- Liposomes are also widely used in **vaccine** technology. For example, lipid-based delivery systems are used to transport **DNA** or **mRNA** into cells. After entering the cell, the genetic material is translated into proteins that stimulate an immune response. This technology formed the basis of several COVID-19 mRNA vaccines.

## Uses of liposomes: delivery

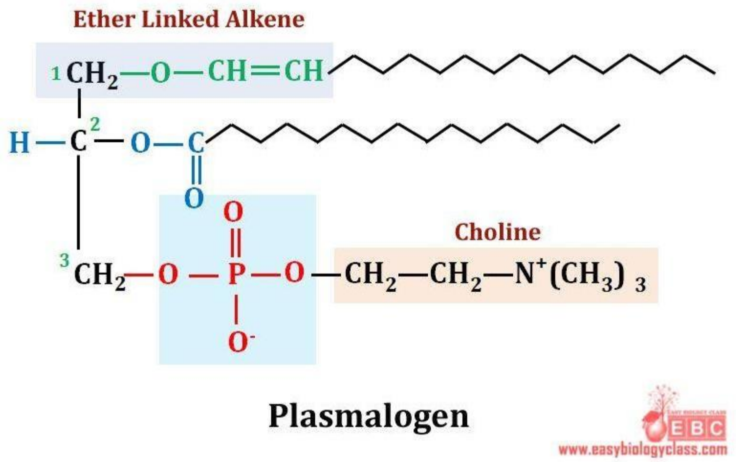


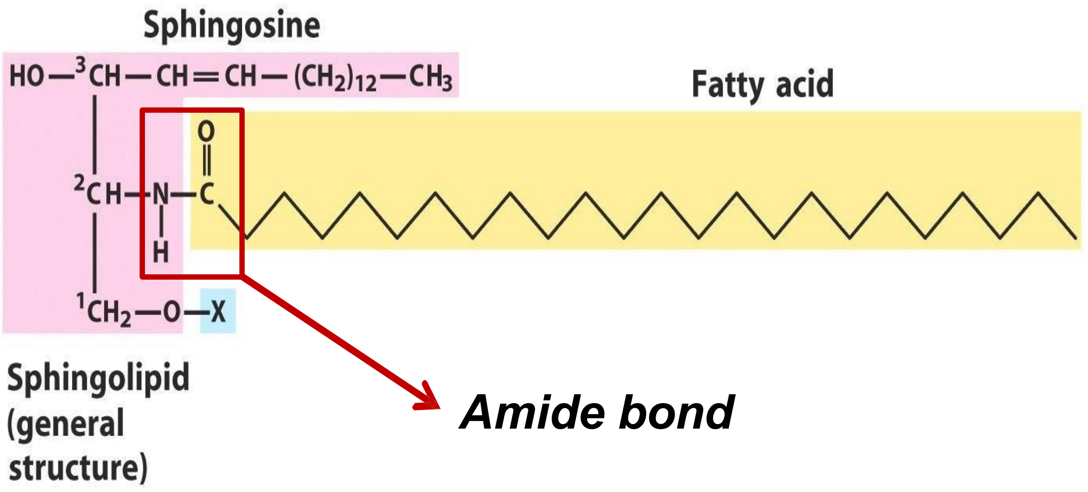
# Sphingolipids

- Sphingolipids are found in the plasma membranes of all eukaryotic cells and is highest in the cells of the central nervous system.
- The core of sphingolipids is the long-chain amino alcohol, sphingosine.



- It is important to recognize the structure of sphingolipids and distinguish it from the glycerophospholipids and plasmalogens. When comparing plasmalogens with sphingolipids, both molecules contain a hydrocarbon chain and a carbon-carbon double bond (alkene).
- In plasmalogens, the backbone is **glycerol**, with an ether linkage at carbon 1, an ester linkage at carbon 2, and a phosphate-containing head group attached to carbon 3.




- In contrast, the backbone of the sphingolipids is sphingosine and it contains a hydrocarbon chain with a double bond (alkene) without an ether bond at carbon 1. The fatty acid isn't attached through an ester bond as it is in glycerophospholipids. Instead, it is linked to the **amino group** of sphingosine by an **amide bond** at carbon 2. A head group (X) is then attached to the hydroxyl group of sphingosine, generating the various classes of sphingolipids.
- Recognizing the **presence of an amide bond** instead of an ester bond is one of the easiest ways to identify a sphingolipid.

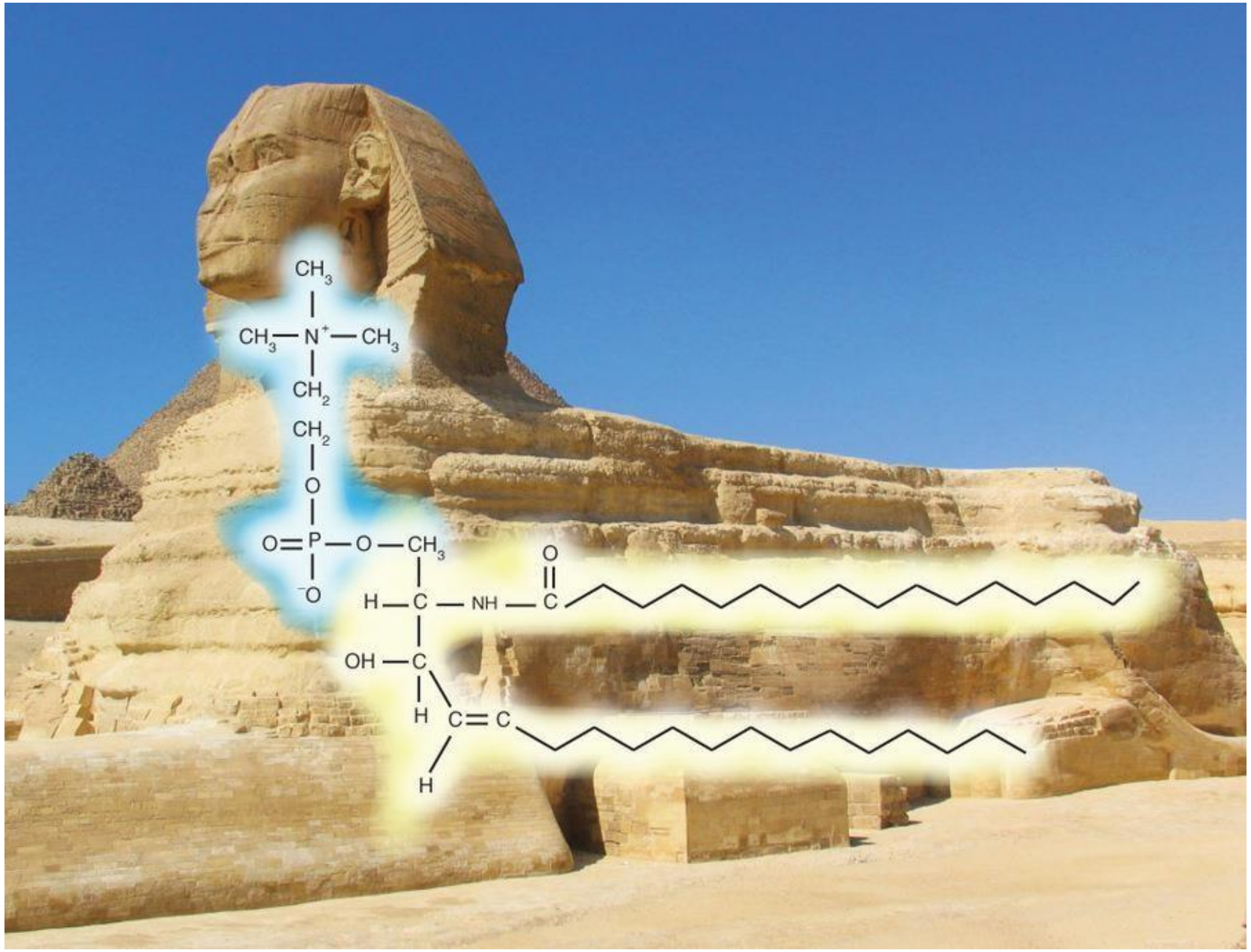
# *Mysterious* lipids

The name "sphingolipid" originates from the word Sphinx. When early biochemists first discovered these molecules, their unusual structure reminded them of the Greek Sphinx.

## ***Sphynx → sphingolipids***

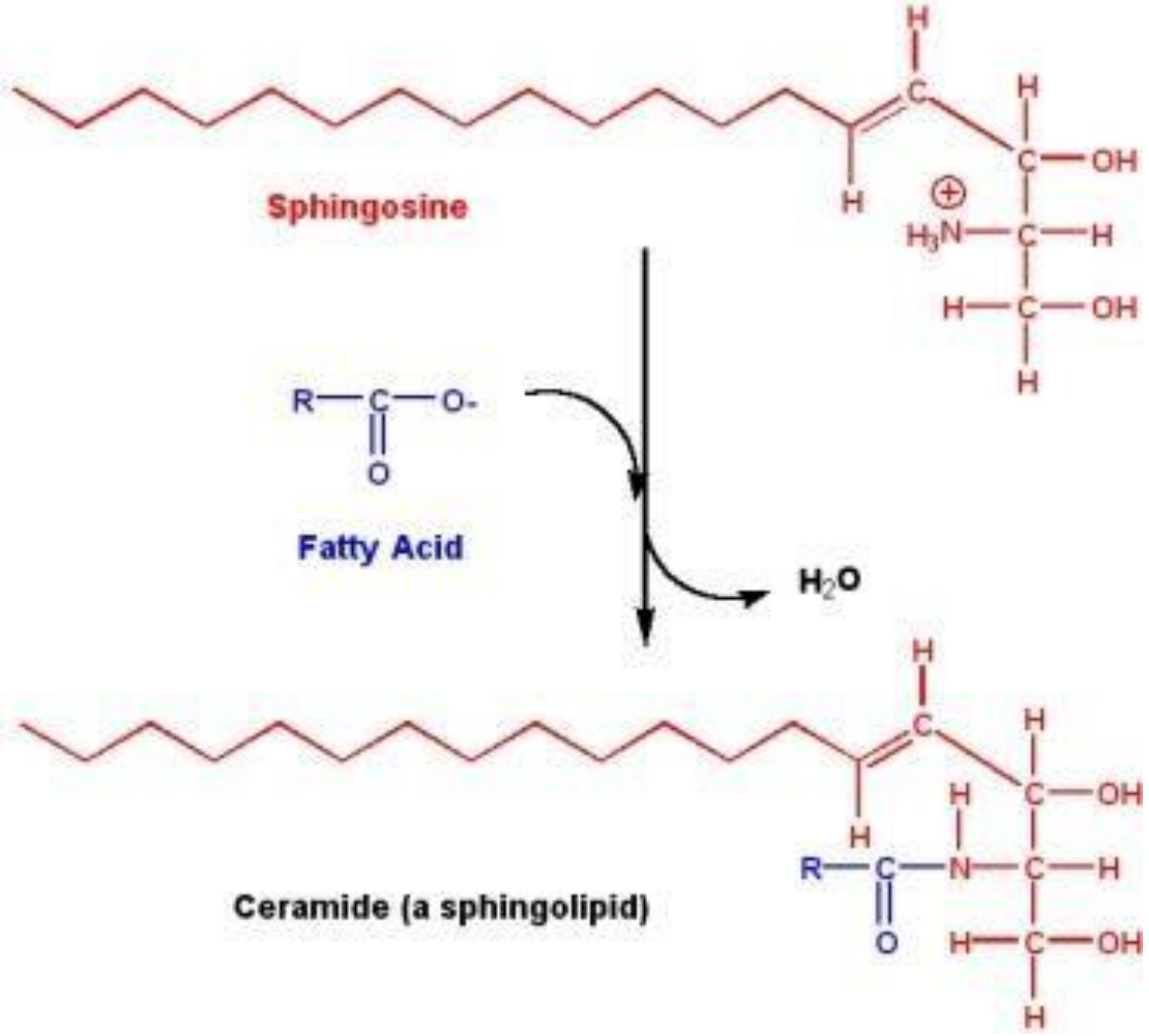
Trivia

*Named for the Sphinx of Thebes, who killed travelers that could not solve her riddles*

# Ceramide

The **simplest** sphingolipid is ceramide. Ceramide consists of a sphingosine backbone with a fatty acid attached through an amide bond. Notice that sphingosine contains a double bond (alkene) and does not contain an ester linkage.




Ceramide has no head group, making it the simplest sphingolipid, just as phosphatidate is the simplest glycerophospholipid.

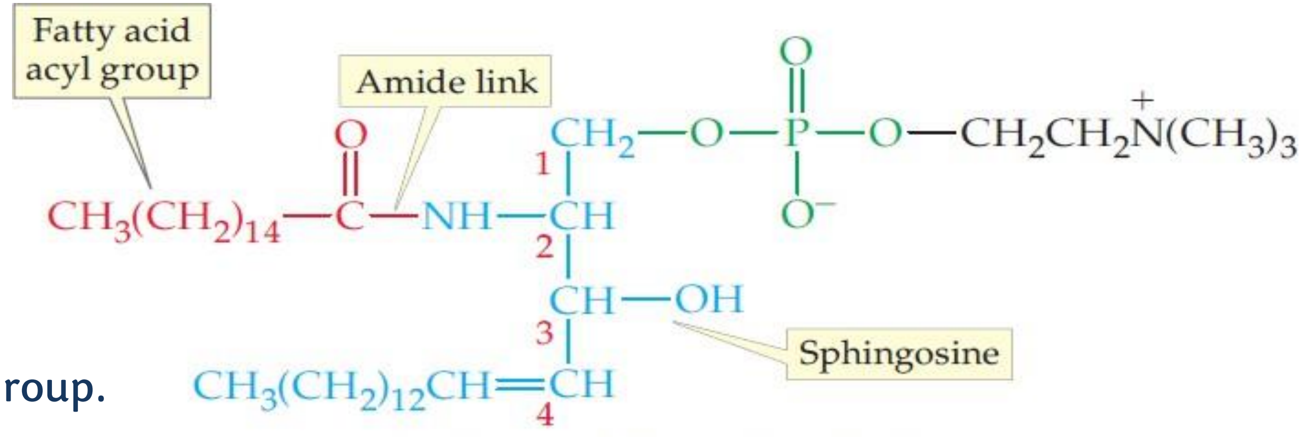
# Types of sphingolipids

Different head groups can be attached to ceramide, giving rise to different classes of sphingolipids.

- The sphingolipids are divided into two subcategories:
  - Sphingomyelin The **simplest** sphingophospholipid
    - It is a sphingolipid that is a major component of the coating around nerve fibers.
    - The group attached to C1 is a phosphocholine
  - Glycosphingolipid (or glycolipids)

The other major class of sphingolipids is the glycosphingolipids (glycolipids). Instead of a phosphate-containing head group, these molecules contain one or more **sugar** residues attached to ceramide.

Sphingomyelin is a major component of the myelin sheath, the insulating layer that surrounds the axons of nerve cells. Similar to the plastic insulation surrounding electrical wires, the myelin sheath electrically insulates nerve fibers, allowing nerve impulses to travel rapidly and efficiently while minimizing signal loss.

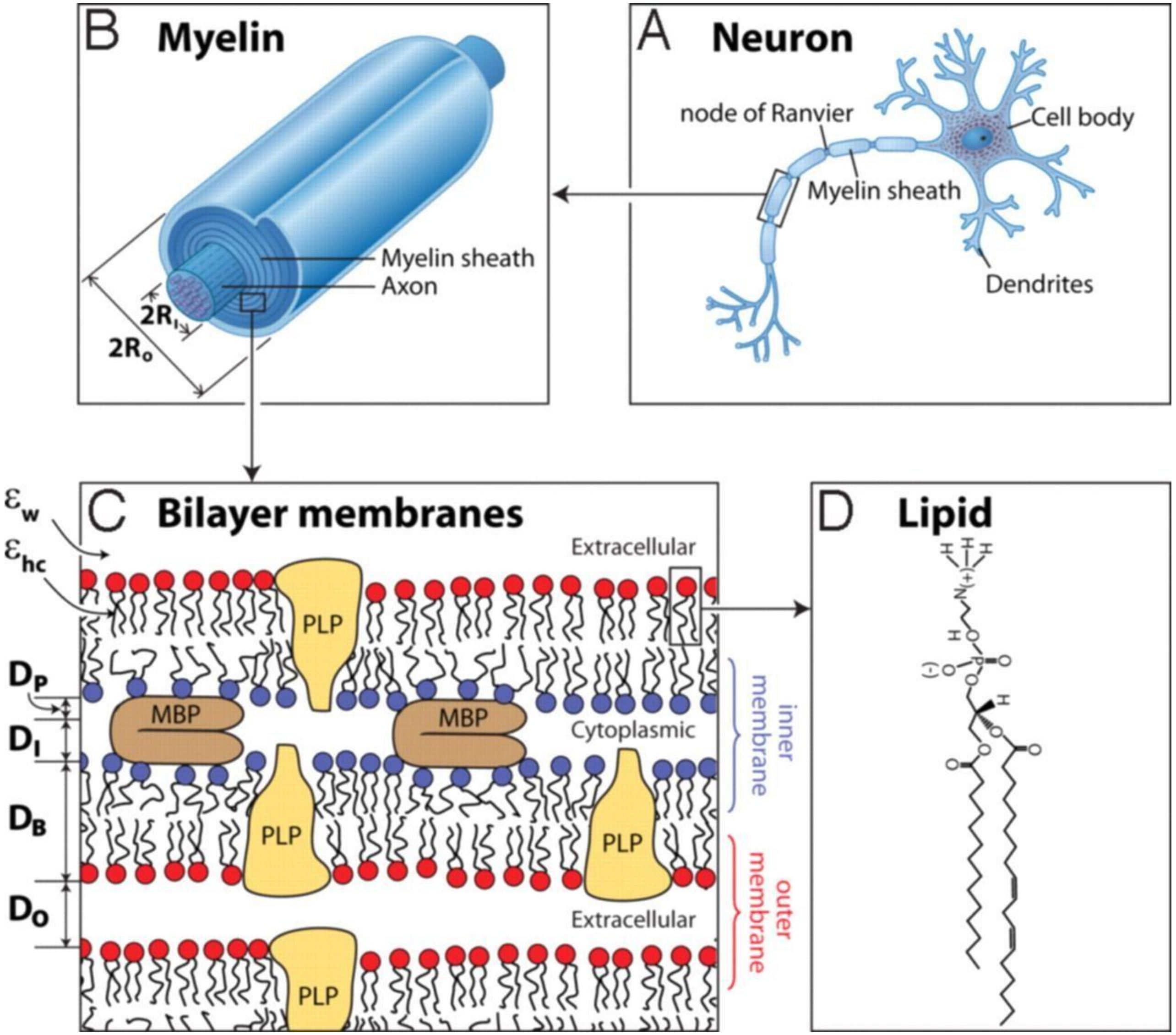


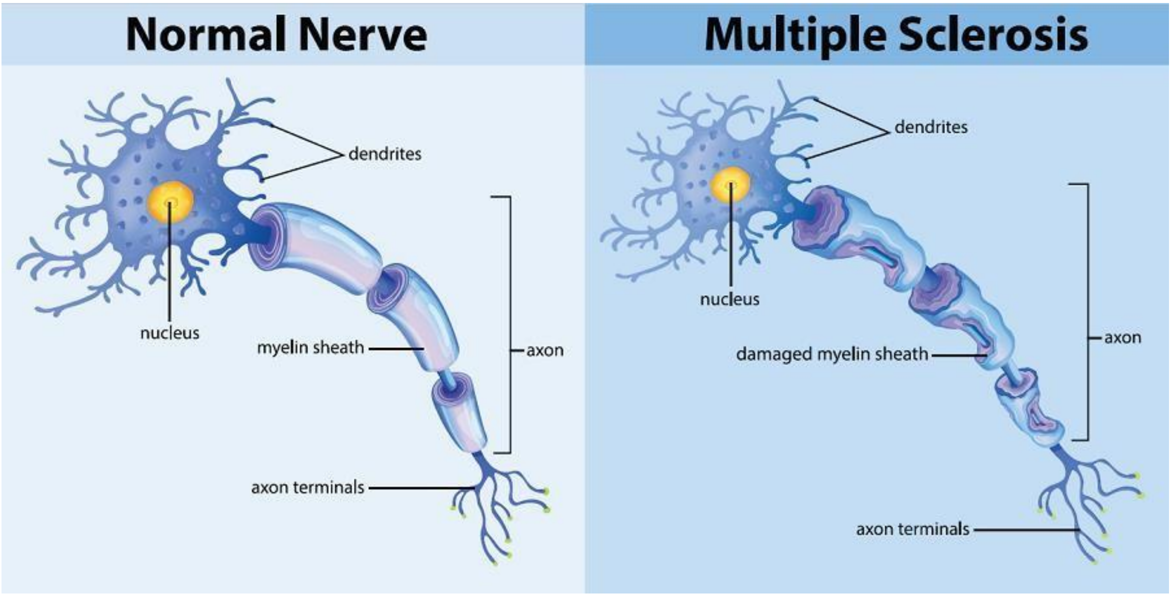

A sphingomyelin (a sphingolipid)

- Sphingomyelin = Ceramide + phosphate-containing head group.
- Glycosphingolipids = Ceramide + sugar head group.

# Zooming into the myelin

The myelin sheath is composed largely of sphingomyelin.



# Test yourself :)

## QUIZ

# For any feedback, scan the code or click on it.

Corrections from previous versions:

| Versions | Slide # and Place of Error | Before Correction | After Correction |
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| V0 → V1 | | | |
| V1 → V2 | | | |

# Additional Resources:

Reference Used:

1. Prof. Mamoun Ahram's live lecture

Extra References for the Reader to Use:

1. Marks' Basic Medical Biochemistry

# رسالة من الفريق العلمي:

تحتسبُ وترتب ما عليكَ من مقرّرات ومذاكرة، وتحزِم أمركَ بجدولةٍ تُنظّم الأوقات وتوزّع المهام..
وعندما تعزِم على المُضيّ، لا تنسَ التوكل على من لا حول ولا قوة لك إلا به، فقد كان ماشاء وسيكون مايشاء..
استشعر قوله عز وجل في سورة الكهف {إِلَّآ أَن يَشَآءَ ٱللَّهُۚ }، فما تبذلُ من جهدٍ في كل كلمة تُذاكرها لم تكن إلا أن شاء الله، وكذا كلُ علامة تربط قلبكَ وطموحك بها ستكون بمشيته جلّ في عُلاه.
لذا قبل أن تُشكّل قائمة مثالية بالمهام الدراسية، تذكر:
[وَلَا تَقُولَنَّ لِشَاْىۡءٍ إِنِّى فَاعِلٌ ذَٰلِكَ غَدًا • إِلَّآ أَن يَشَآءَ ٱللَّهُۚ ]

-لا حَول ولا قوة الا بالله 💙 .