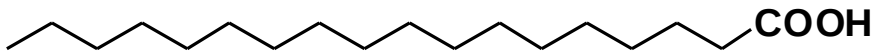
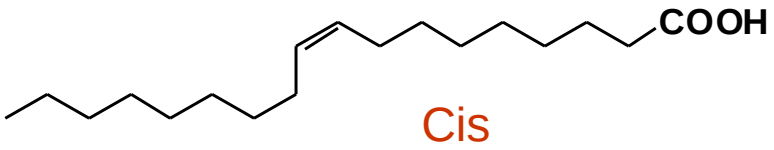
# Fatty acids

Fatty acids are:



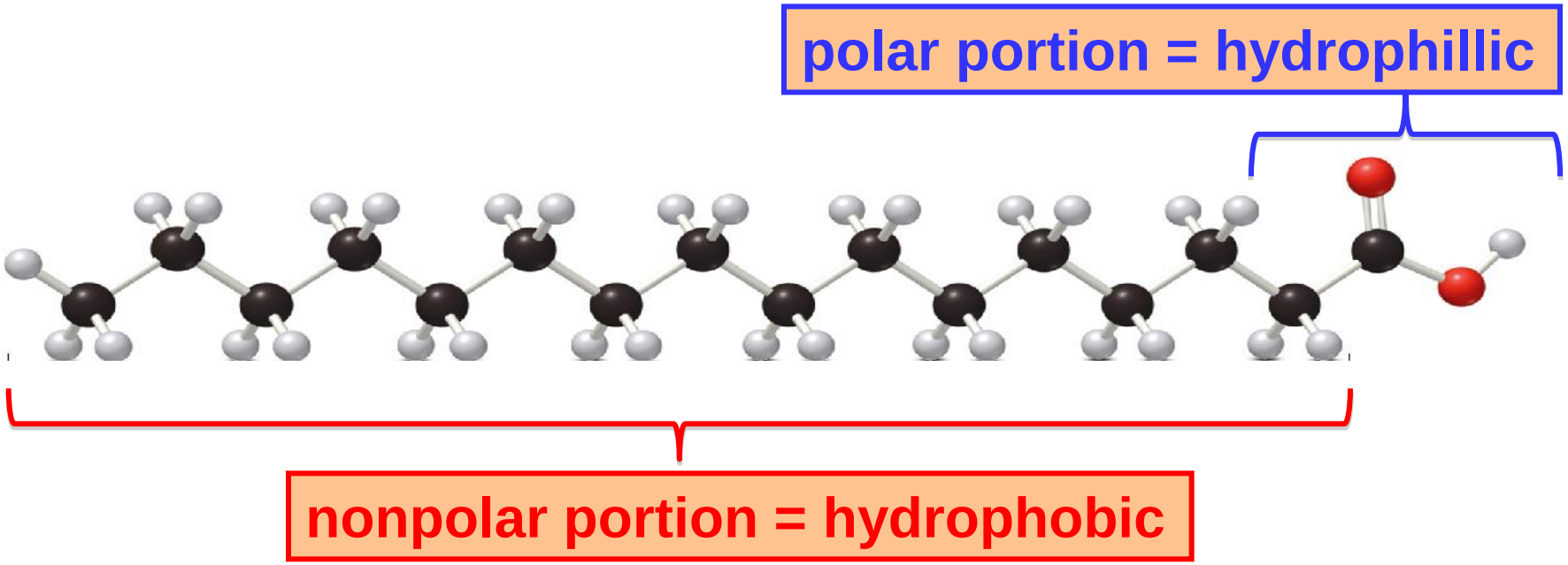

- Long-chain unbranched carbon attached to a carboxyl group (-COOH).
- Typically 12-20 carbon atoms.
- They have an even number of C atoms.
- Insoluble in water.




Cis

# Fatty acids

$CH_3(CH_2)_{14}COOH$ (palmitic acid)

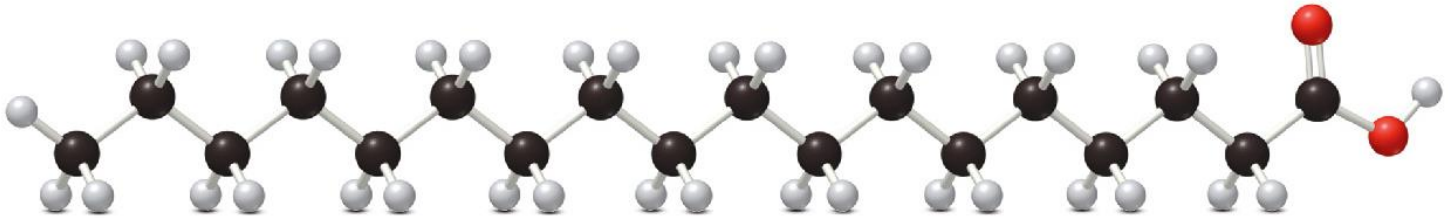



Hydrophobic portion is much bigger than hydrophilic portion. ⟶ Insoluble in water

# Saturated and unsaturated Fatty acids

Saturated fatty acids have no double bonds in their long hydrocarbon chains.

Stearic acid: $CH_3(CH_2)_{16}COOH$



They are solids at room temperature.

**Packed together → Maximum London dispersion forces**

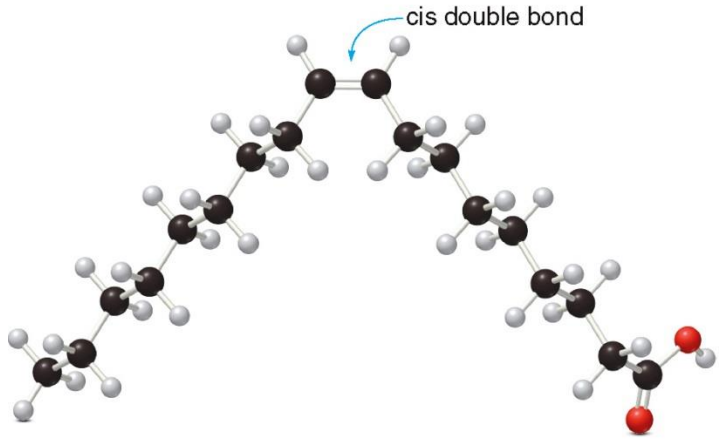





# Saturated and unsaturated Fatty acids

Unsaturated fatty acids have 1 or more double bonds (generally cis) in their long hydrocarbon chains.

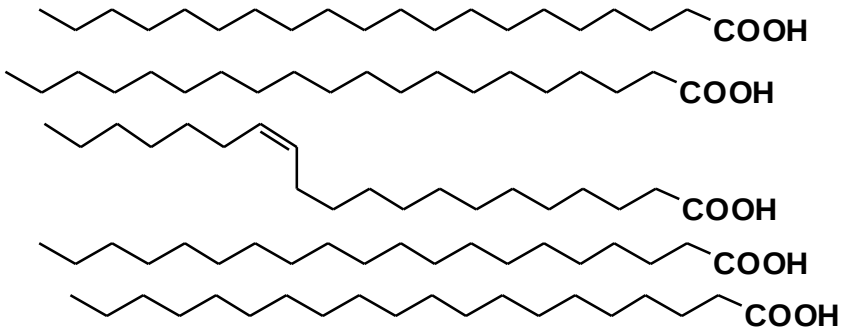
Oleic acid: $CH_3(CH_2)_7CH=CH(CH_2)_7COOH$




They are liquids at room temperature.

**They can not pack together → London dispersion forces ↓**





# Fatty acids

- The human body is capable of synthesizing most fatty acids from carbohydrates or other fatty acids.

- Humans do not synthesize sufficient amounts of fatty acids that have more than one double bond.

- More than one double bond fatty acids are called essential fatty acids and they must be provided by the diet.

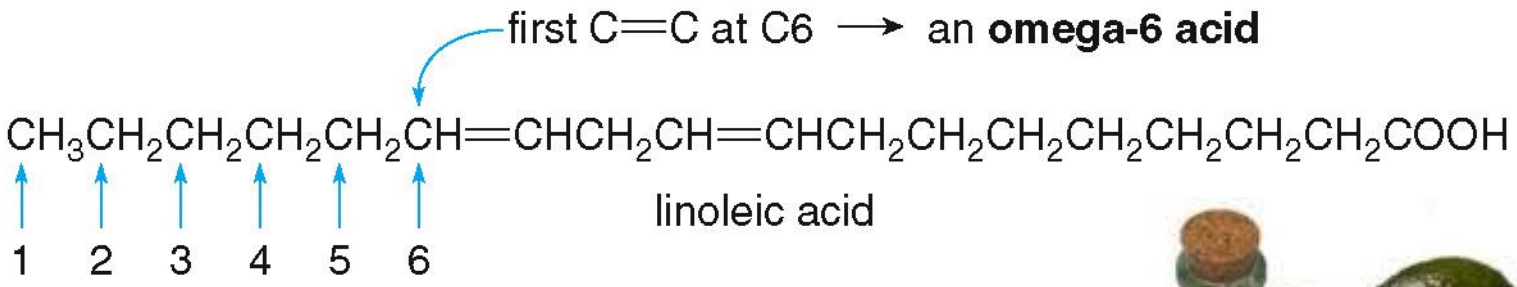
Linoleic acid  linolenic acid

# Essential Fatty acids

## Omega-n acids

n: the position of the first double bond

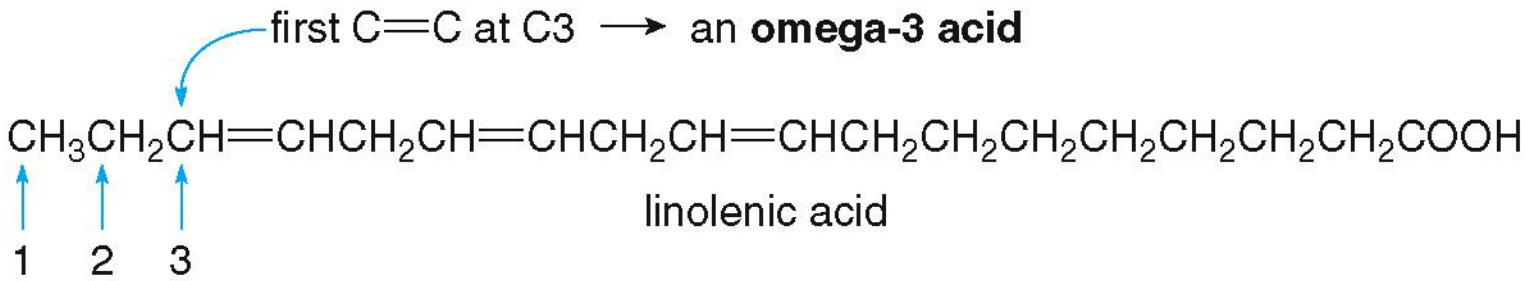
Linoleic acid is called an omega-6 acid, because of the position of the first C=C in the nonpolar chain.






# Essential Fatty acids

Linolenic acid is called an omega-3 acid, because of the position of the first C=C in the nonpolar chain.



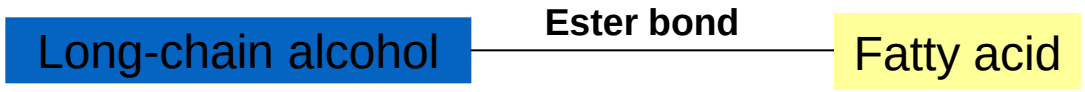


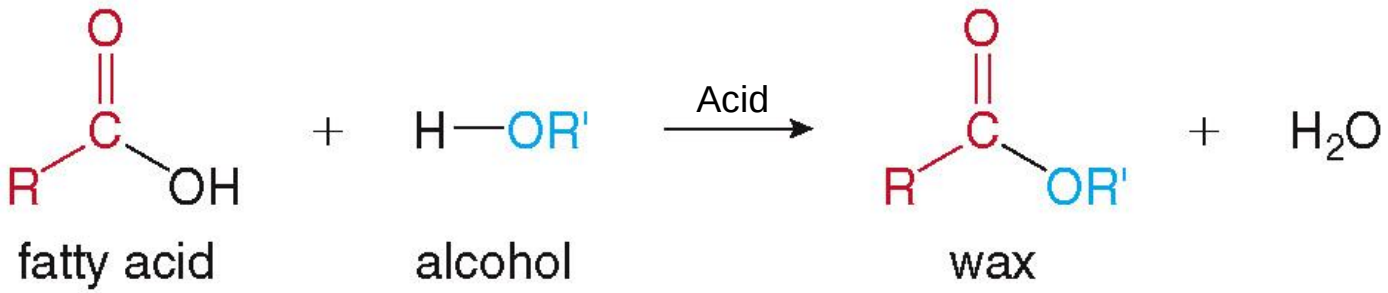




# Waxes

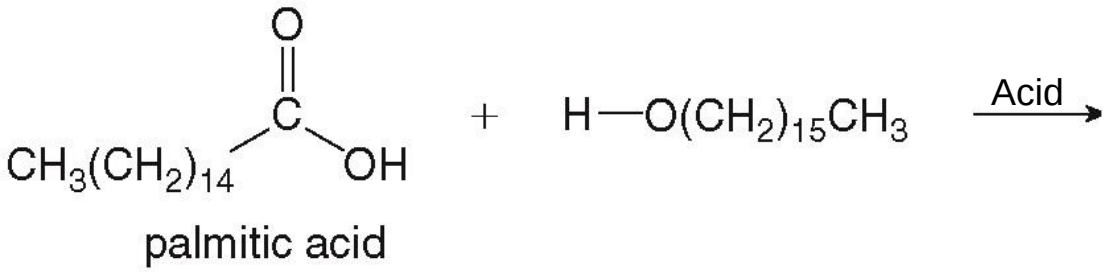
Wax is an ester of saturated fatty acid and long chain alcohol.

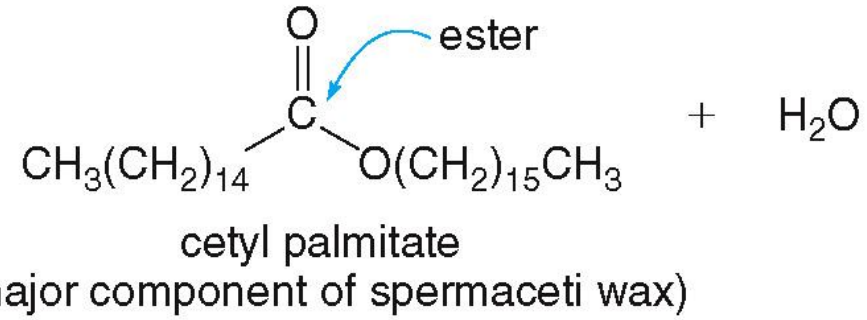


# Waxes

For example, shown below is the formation of spermaceti wax, isolated from the heads of sperm whales.



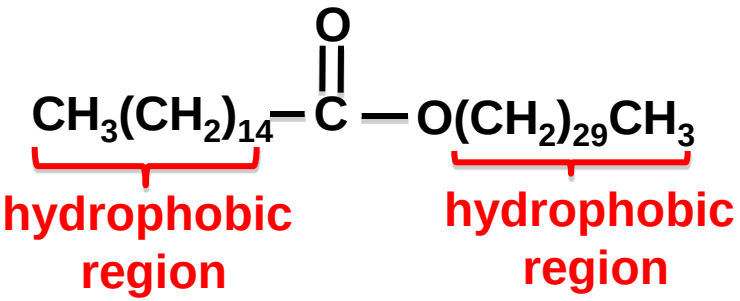




+ $H_2O$

# Waxes

Because of their long nonpolar C chains, waxes are very hydrophobic.

Beeswax
(myricyl palmitate)




They form protective coatings:

- In plants, they help prevent loss of water and damage from pests.

- In humans and animals, provide waterproof coating on skin and fur.

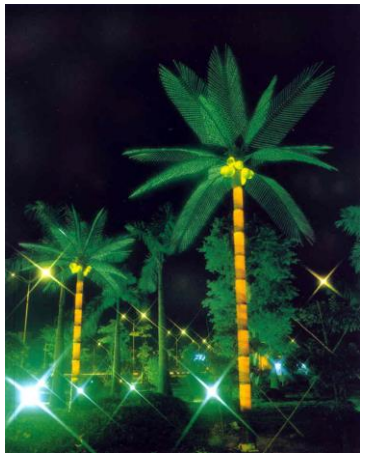




Beeswax



Carnauba



Coating



Jojoba







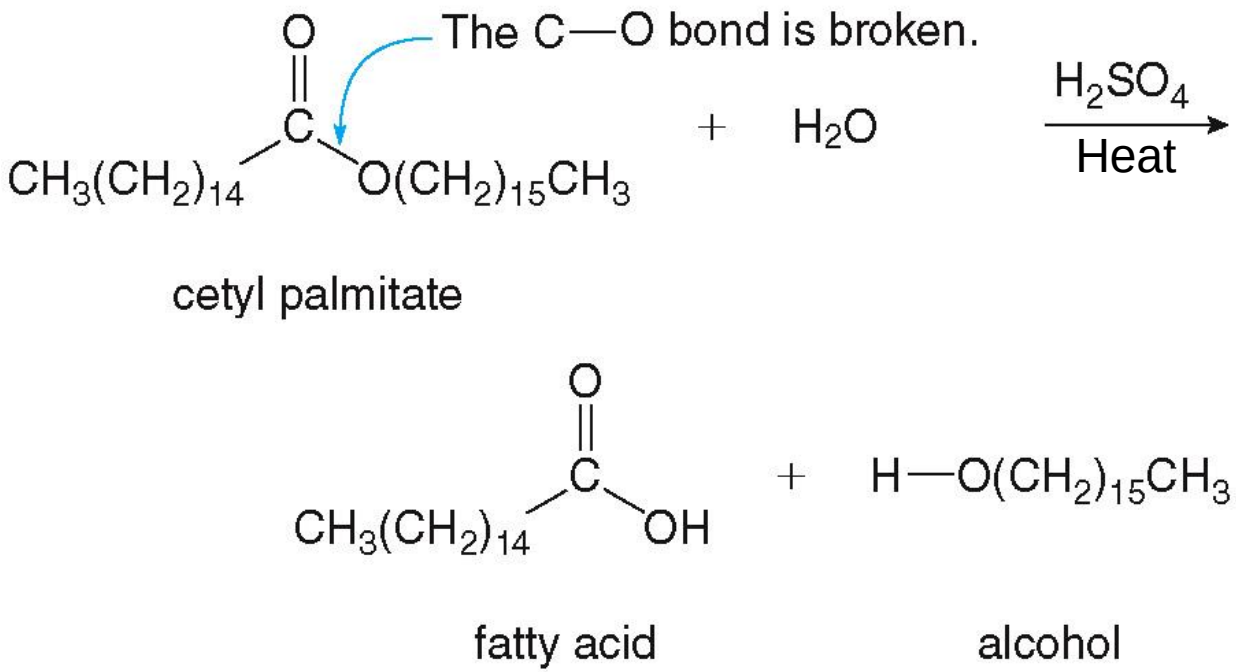
Lanolin from wool




lotions

# Waxes

Hydrolysis reaction: like other esters, waxes are hydrolyzed.



# Triacylglycerols (Triglycerides)

Triacylglycerols are:

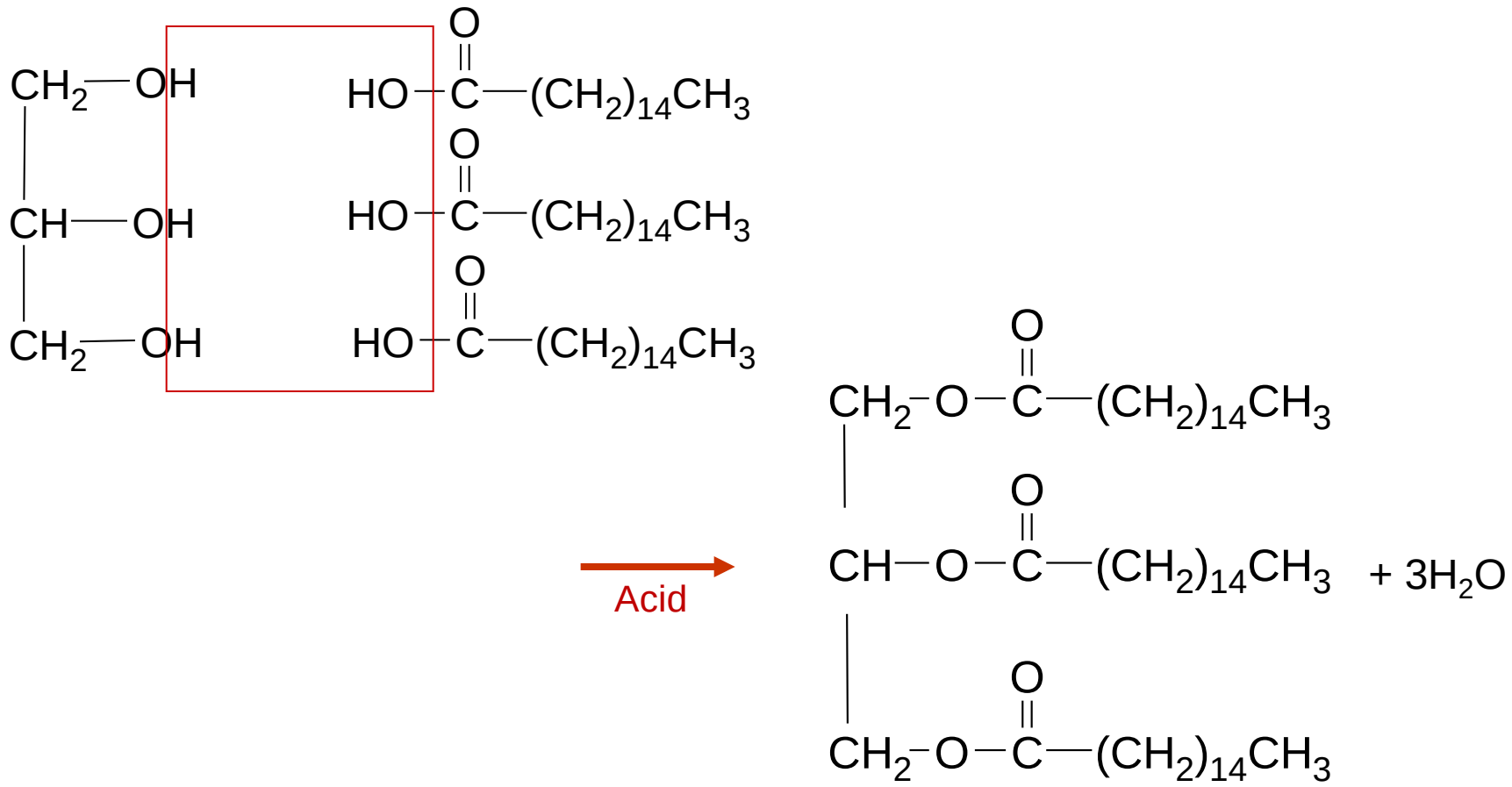
- Fats and oils (are stored in the body).
- Triesters of glycerol.
- Produced by Fischer esterification.
- Formed when the hydroxyl groups of glycerol react with the carboxyl groups of fatty acids.



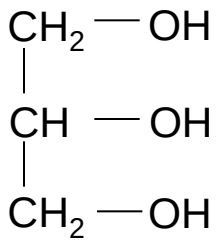
Vegetable oils

# Esterification

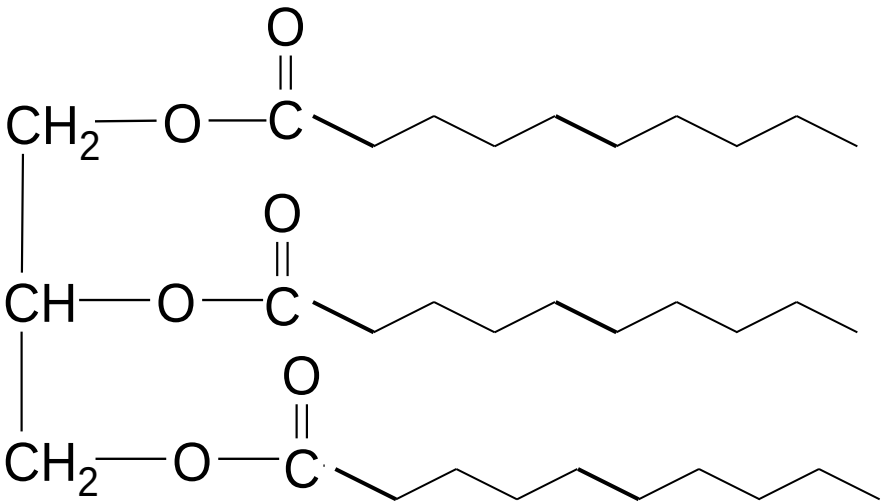
glycerol three fatty acids → triacylglycerol

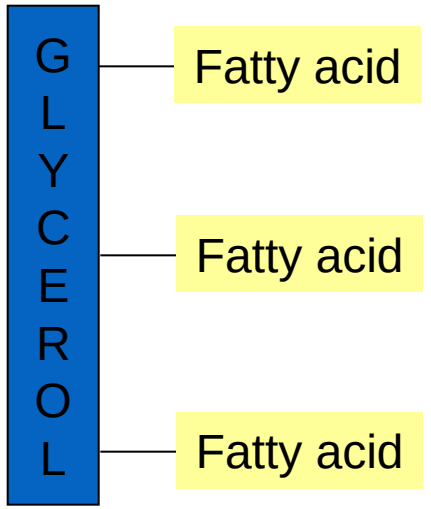


# Triacylglycerols (Triglycerides)




Glycerol

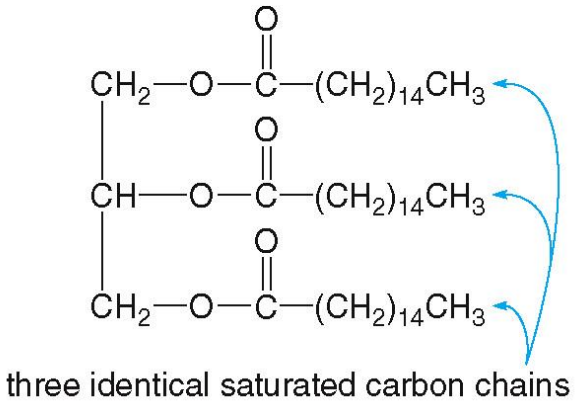


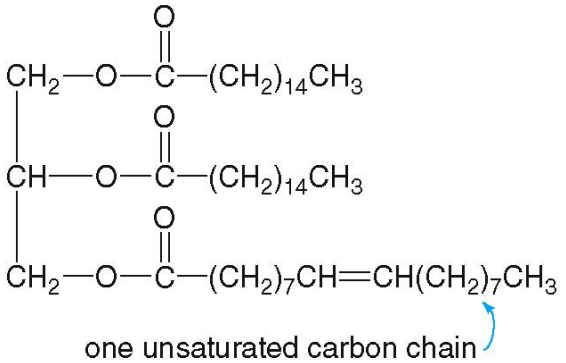

Produced by esterification of glycerol (a trihydroxyl alcohol).

# Triacylglycerols (Triglycerides)

Simple triacylglycerols have three identical fatty acid side chains.




Mixed triacylglycerols have two or three different fatty acids.



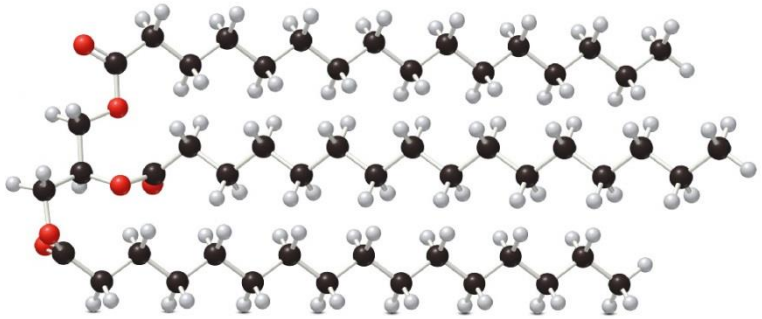
# Triacylglycerols (Triglycerides)

Saturated triacylglycerols contain only saturated fatty acids.

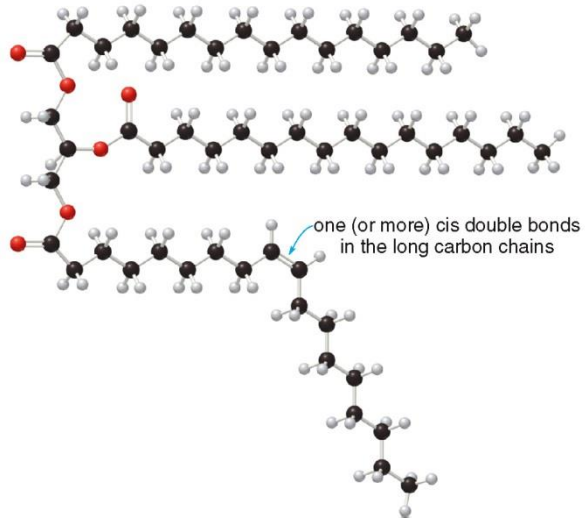
Monounsaturated triacylglycerols have 1 C=C  bond.

Polyunsaturated triacylglycerols have many C=C bonds.

Increasing the number of double bonds in the fatty acid chain decreases the melting point of the triacylglycerol.



a saturated triacylglycerol



# Triacylglycerols (Triglycerides)

Fat: is a triacylglycerol that is solid at room temperature.

Made by more saturated fatty acids (Saturated triacylglycerols).

Meat, milk, butter and cheese (animal sources).



Oil: is a triacylglycerol that is liquid at room temperature.

Made by more unsaturated fatty acids (Unsaturated triacylglycerols).

Corn, cotton seed, safflower and sunflower (plant sources).




Both are colorless, odorless, and tasteless.

# Fat & Health

- Fats are used to build cell membranes and store energy for later use.

- It is recommended that no more than 20-35% of a person's caloric intake should come from lipids.

- A high intake of saturated triacylglycerols is linked to heart disease.

- Saturated fats stimulate cholesterol synthesis in the liver, which can lead to cholesterol plaques building up inside arteries.

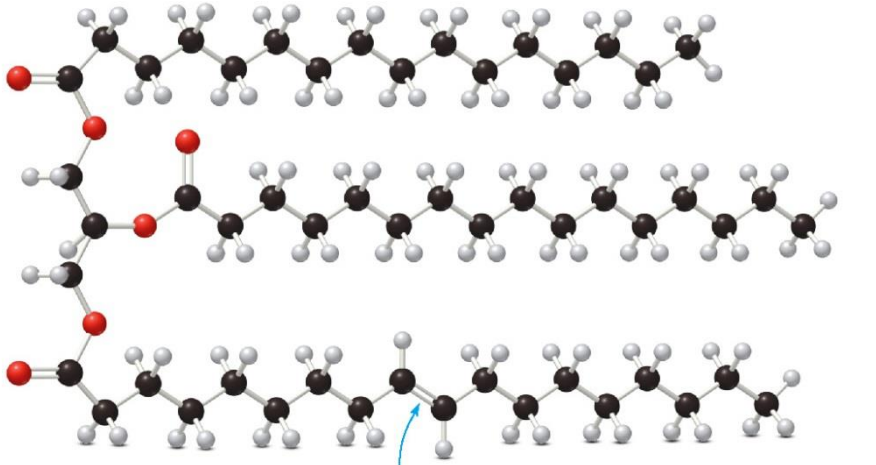
- The result is high blood pressure, heart attack, and even stroke.

- Unlike other vegetable oils, oils from palm and coconut trees are very high in saturated fats.

# Fat & Health

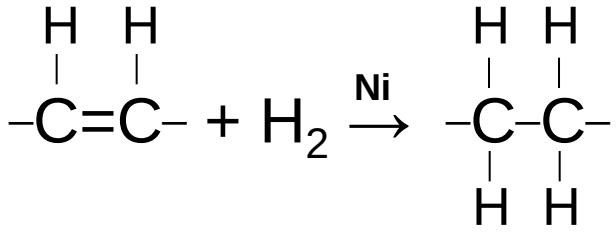
- Unsaturated triacylglycerols (omega-3 fatty acids from fish) lower the risk of heart disease by decreasing the level of cholesterol in the blood.

- Trans fats, which are primarily synthesized instead of naturally occurring, act like saturated fats and increase the cholesterol levels in the blood.



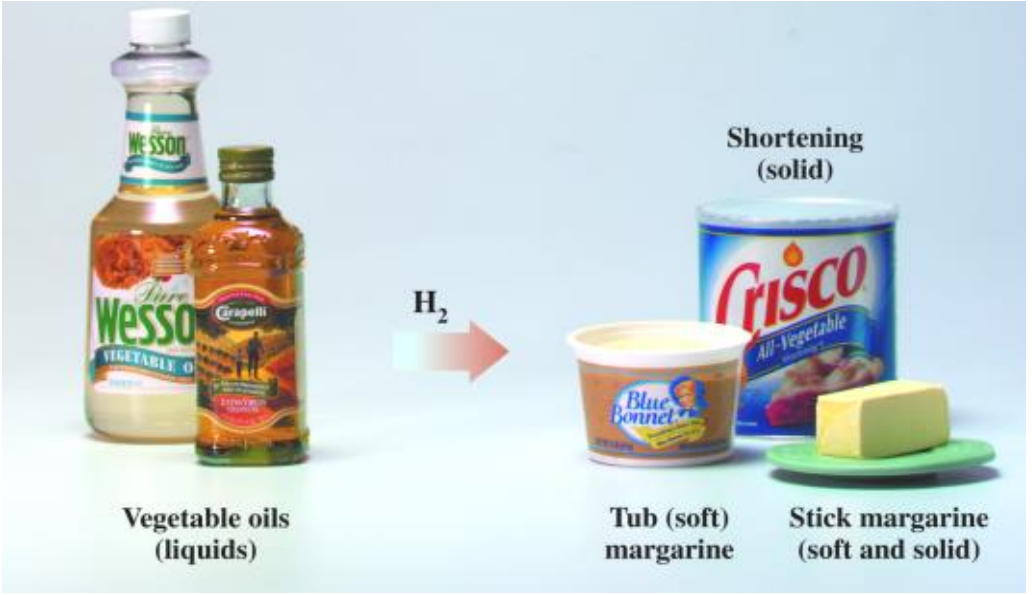
# 1- Hydrogenation

- Hydrogen adds to the double bonds of unsaturated fats (using transition metal catalyst such as Ni).

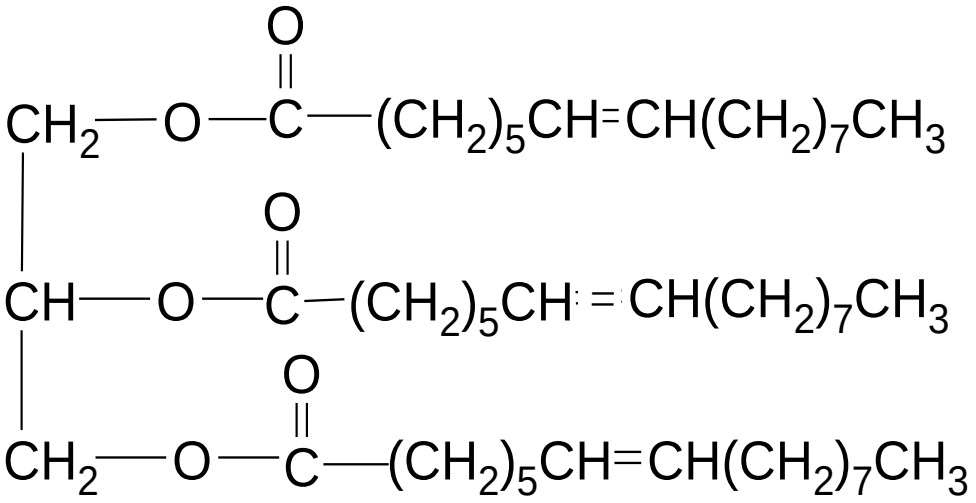



- Melting point is increased.

- Liquid oils are converted to semi-solid fats.



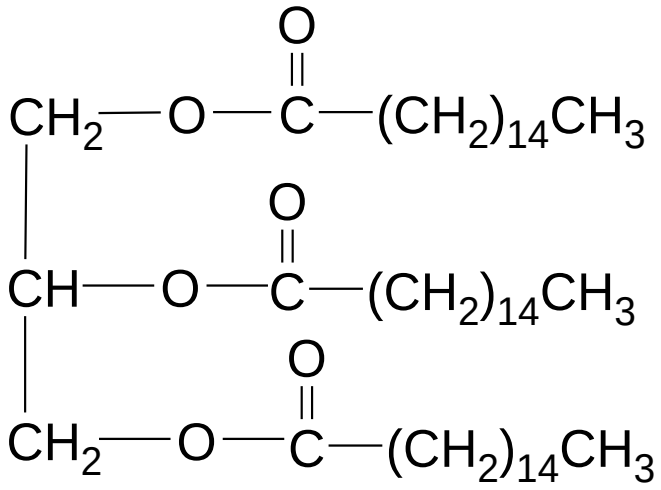
# 1- Hydrogenation



glyceryl Trioleate
(triolein)

Ni

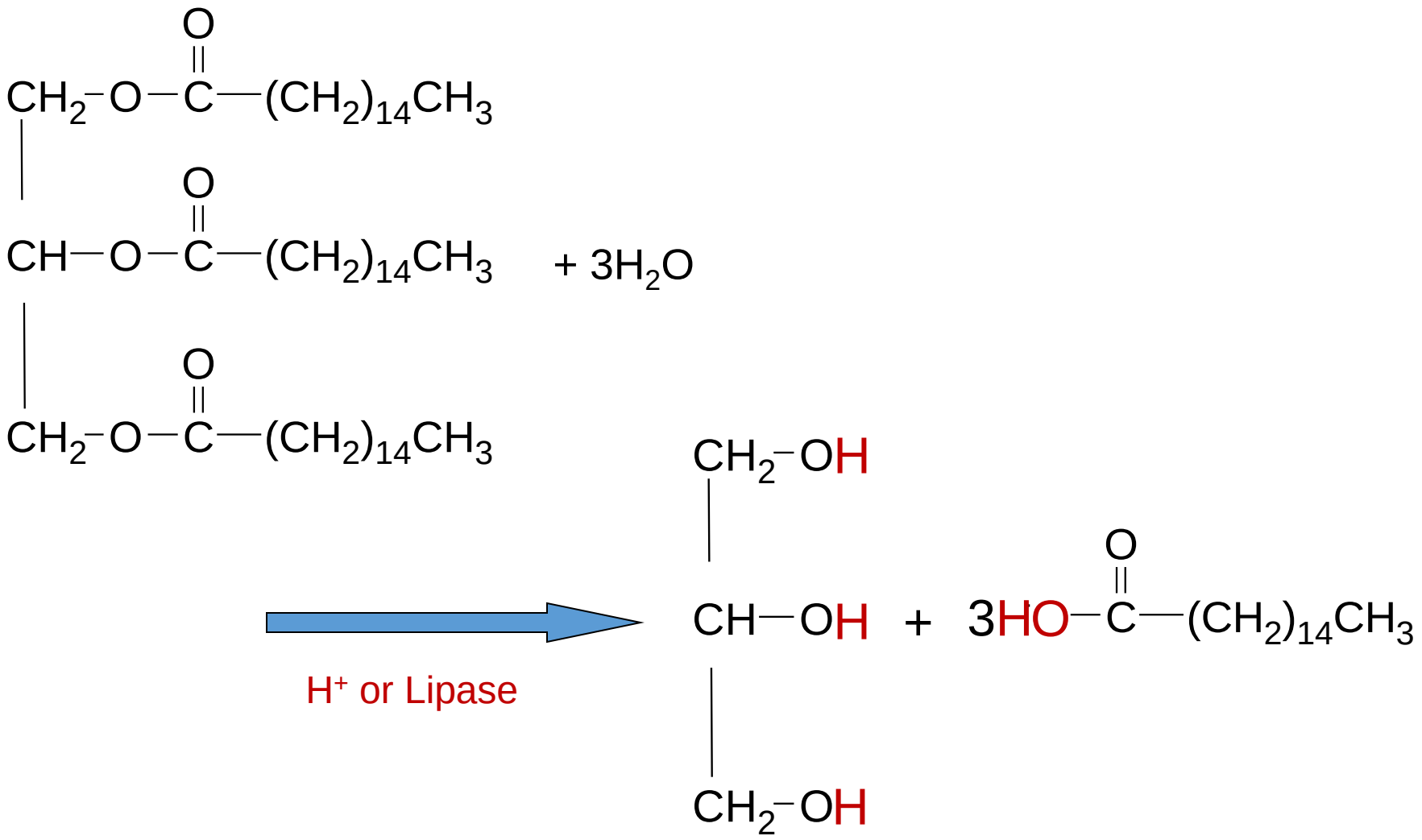
+ $3H_2$ →



glyceryl tristearate
(tristearin)

# 2- Hydrolysis

Triacylglycerols are hydrolysis (split by water) in the presence of strong acid or lipase (digestive enzyme).



# Metabolism of tricaylglycerols

- Humans store energy as triacylglycerols in adipose cells below the surface of the skin, in the breast area, and surrounding internal organs.

- The number of adipose cells is constant; weight gained or lost causes them to swell or shrink, but not decrease or increase in number.

- To metabolize triacylglycerols for energy, the esters are hydrolyzed by enzymes called lipases.

- Complete metabolism of a triacylglycerol yields $CO_2$, $H_2O$, and a great deal of energy.

# 3- Saponification (Basic Hydrolysis)

- Is the process of forming “soaps”  (salts of fatty acids).

- Is the reaction of a fat with a strong base (NaOH).

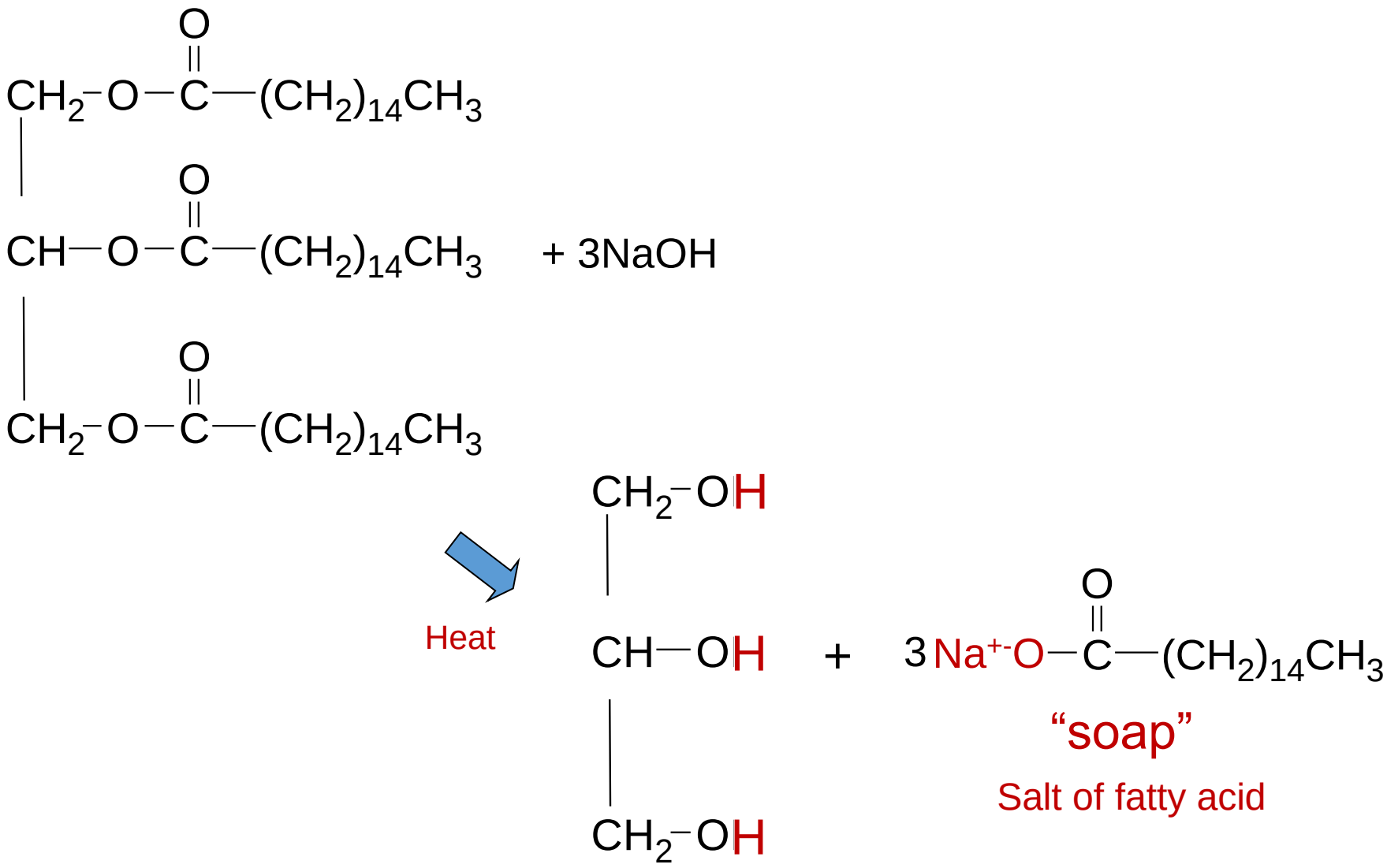
- Splits triacylglycerols into glycerol and the salts of fatty acids.

- With KOH or the oils that are polyunsaturated gives softer soaps (liquid soaps).

- Soaps are typically made from tallow (from cows or sheep), coconut oil, or palm oil.

- All soaps work in the same way, but have different properties depending on the lipid source, length of C chain, and degree of unsaturation.

# 3- Saponification (Basic Hydrolysis)



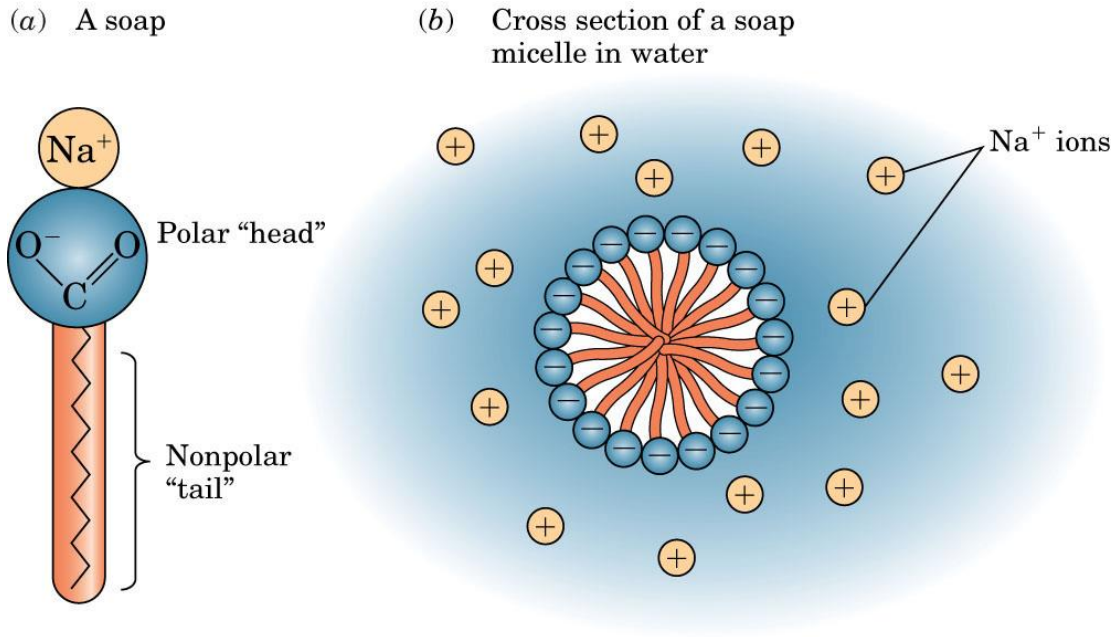
# Soaps

Hydrophobic part: nonpolar

Hydrophilic part: polar (remains in contact with environment)



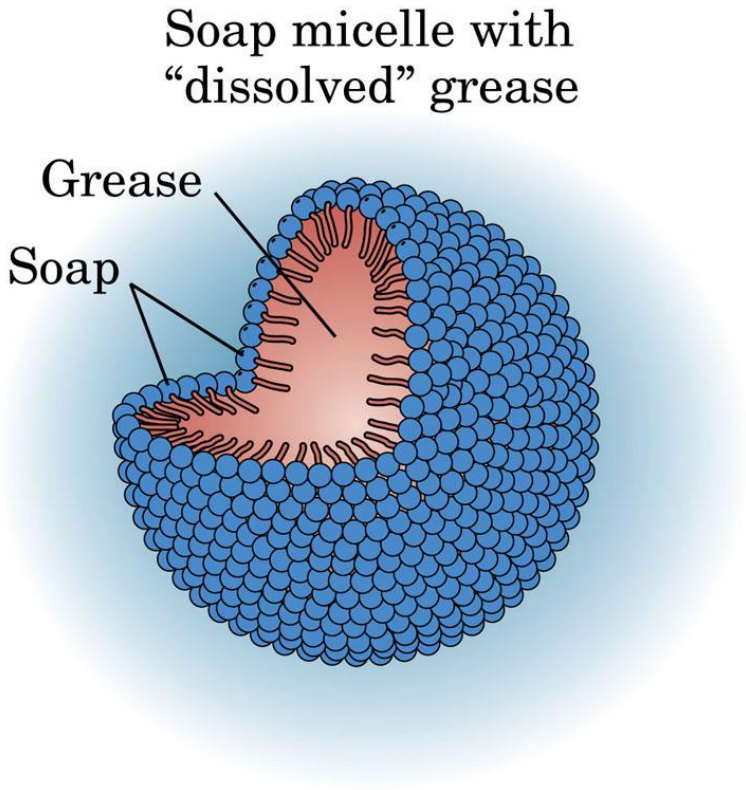

**Sodium soaps**



# Soaps

When soap is mixed with dirt (grease, oil, and …), soap micelles "dissolve" these nonpolar, water-insoluble molecules.

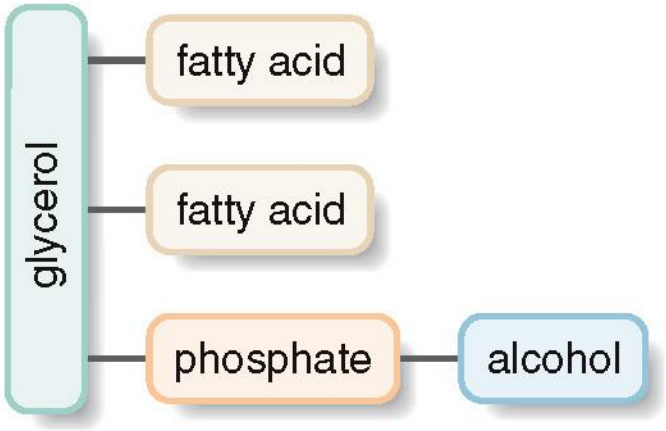
The soap molecule has two different ends, one that is hydrophilic (polar head) that binds with water and the other that is hydrophobic (non-polar hydrocarbon tail) that binds with grease and oil



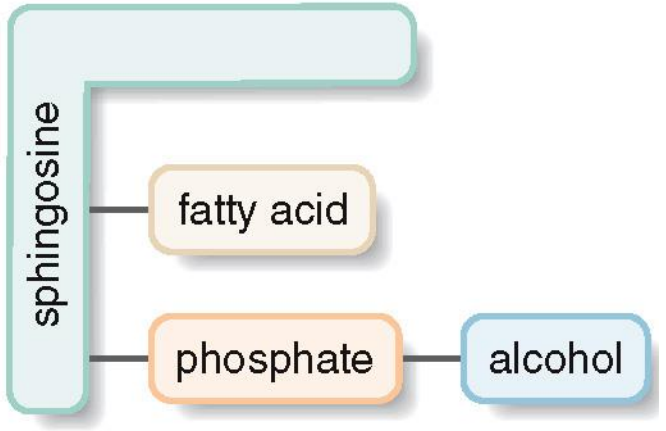
# phospholipids

Phospholipids are lipids that contain a P atom.

Two common types:




**phosphoacylglycerol**



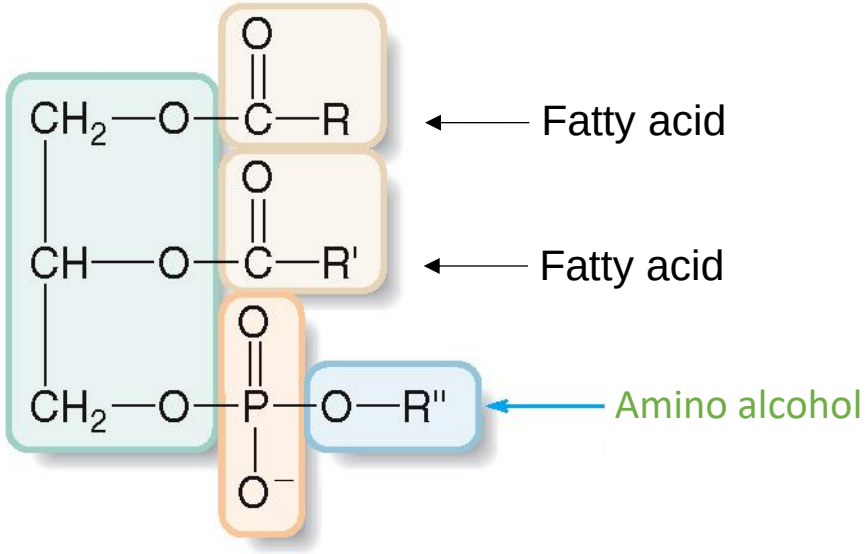

**sphingomyelin**

# phospholipids

## 1. Phosphoacylglycerols:

They are the main component of most cell membranes.

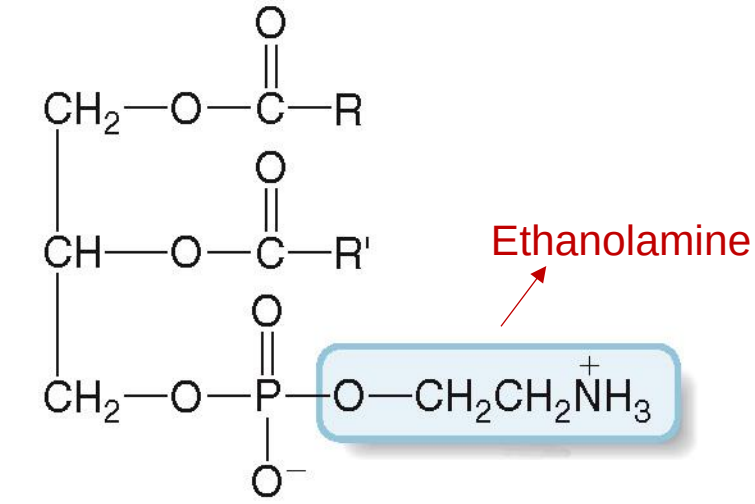
Structurally, they resemble a triacylglycerol, except the third fatty acid has been replaced with a phosphodiester bonded to an alcohol.



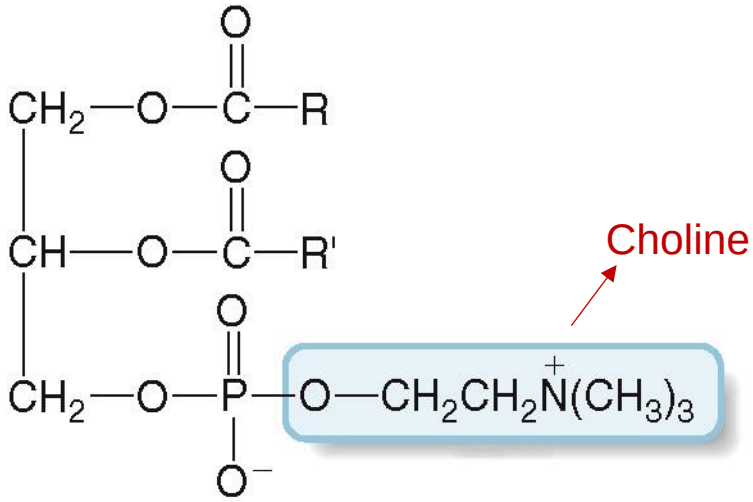
# phospholipids

## 1. Phosphoacylglycerols:

There are two types of phosphoacylglycerols:




**cephalin**
(phosphatidylethanolamine)

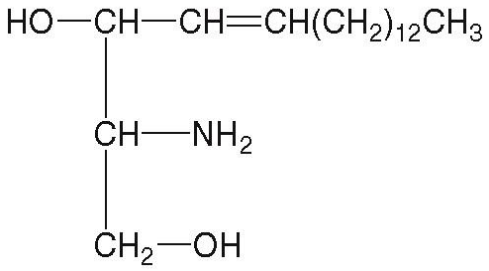



**lecithin**
(phosphatidylcholine)

# phospholipids

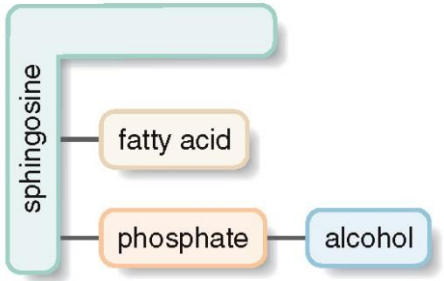
2. Sphingomyelins: They differ in two ways:

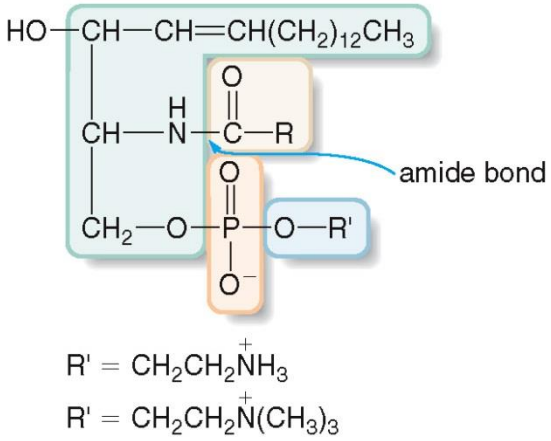
1. They do not contain a glycerol backbone, they have a sphingosine backbone instead.




sphingosine

2. They do not contain an ester; their single fatty acid is bonded to the backbone by an amide bond.

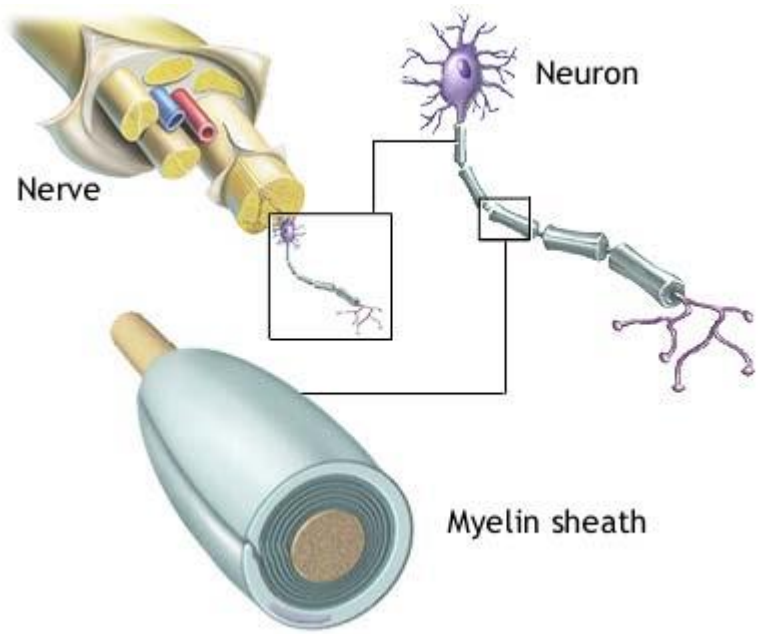


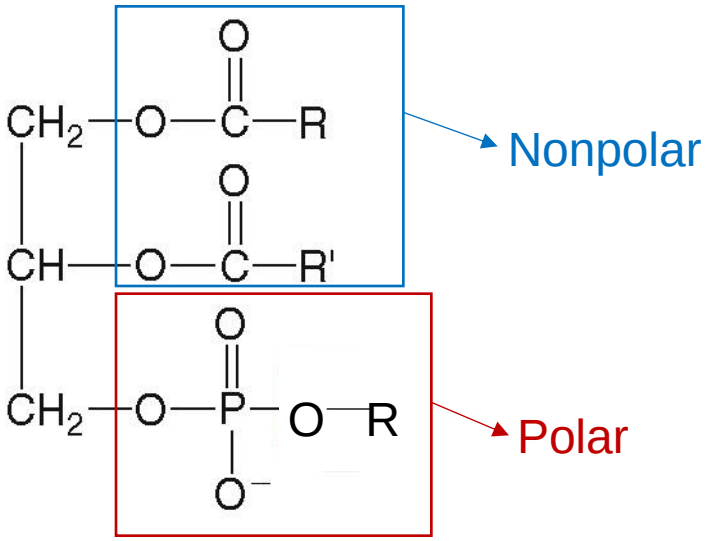
# phospholipids

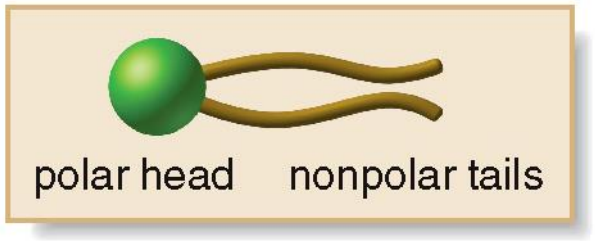
## 2. Sphingomyelins:

The myelin sheath, the coating that surrounds nerve cells, is rich in sphingomyelins.



# phosphoacylglycerols

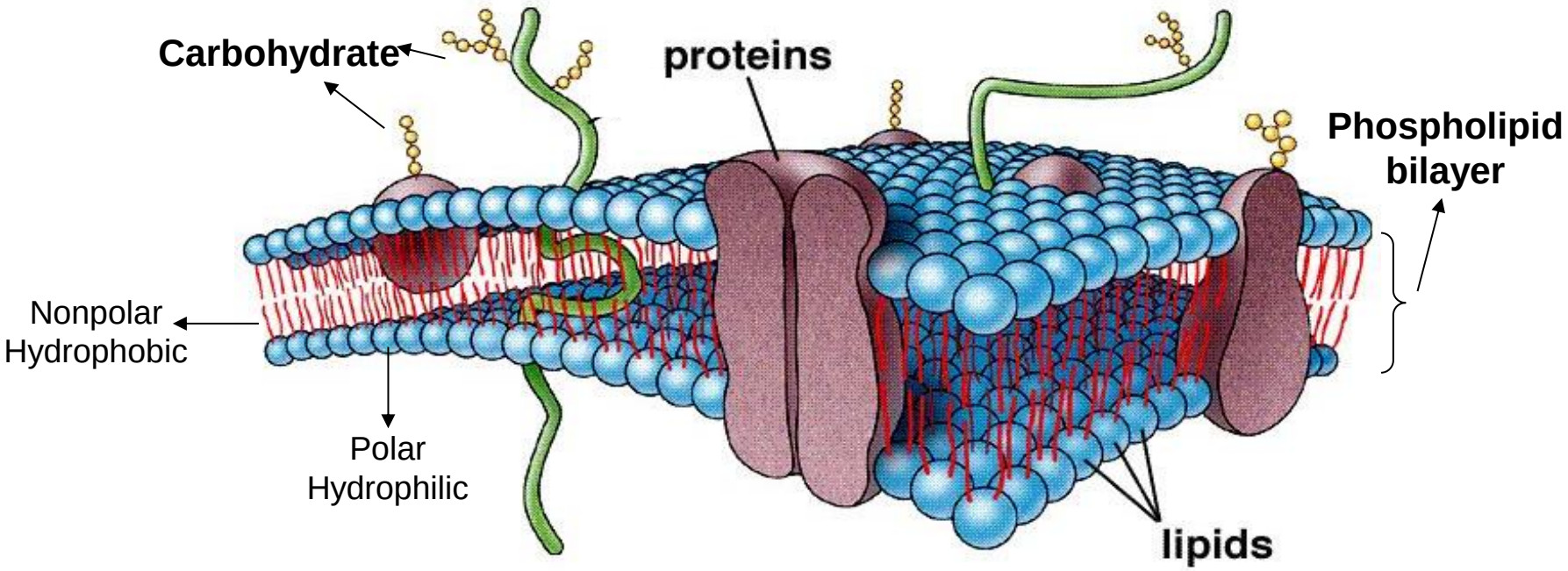



**Interact with both polar and nonpolar substances.**

1. Most abundant lipids in cell membranes (semipermeable).
2. Combine with less polar triglycerides and cholesterol to make them soluble.

# Cell Membrane



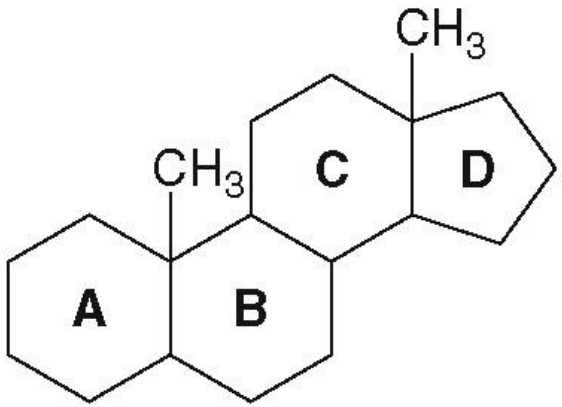

Semipermeable: selected nutrients can enter and waste products can leave.

Fluid mosaic model

# Steroids

Steroids have:

- A steroid nucleus which is 4 carbon rings.
- Attached groups that make the different types of compounds.
- No fatty acids.

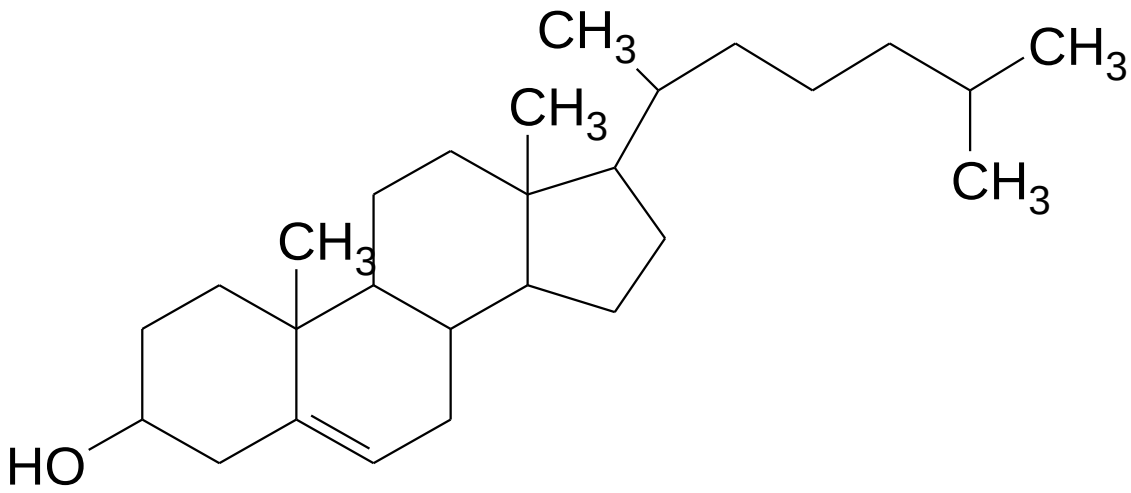



steroid skeleton
(steroid nucleus)

# Cholesterol

Cholesterol:

- Is the most abundant steroid in the body.
- Insoluble in water (need a water soluble carrier).
- Has methyl $CH_3$- groups, alkyl chain, and -OH attached to the steroid nucleus.



# Cholesterol

Cholesterol:

- Is obtained from meats, milk, and eggs.
- Is synthesized in the liver from fats, carbohydrates and proteins.
- Is needed for cell membranes, brain and nerve tissue, steroid hormones, and Vitamin D.
- Clogs arteries when high levels form plaque (because it is insoluble in blood).
- No cholesterol in vegetable and plants.



At artery clogged by cholesterol plaque



Gallstones form in gallbladder

# Lipoproteins

VLDL: very-low-density lipoprotein → Triglycerides and Cholesterol

LDL: low-density lipoprotein (bad Cholesterol) → Cholesterol

HDL: high-density lipoprotein (good Cholesterol) → Cholesterol

Recommended levels are: HDL > 40 mg/dL, LDL < 100 mg/dL, total serum cholesterol < 200 mg/dL.

Chylomicrons → Triglycerides and Cholesterol

