

# Lecture 5

**BT 203**

**Biochemistry**

**3-0-0-6**

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# Key Concepts

- **What are Lipids?**
- **What are the different types of lipids?**
- **What are fatty acids?**
- **What are the different types of fatty acids?**
- **What are diseases associated with glycoconjugates?**

# LIPIDS

## General Information

- A lipid is an organic substance found in living systems that is **insoluble in water** but is **soluble in organic solvents**
- May contain phosphoric acid, nitrogenous base and carbohydrates
- Lipids vary widely in their structures. They have mostly **carbon, hydrogen** and some have a few **polar atoms/functional groups**

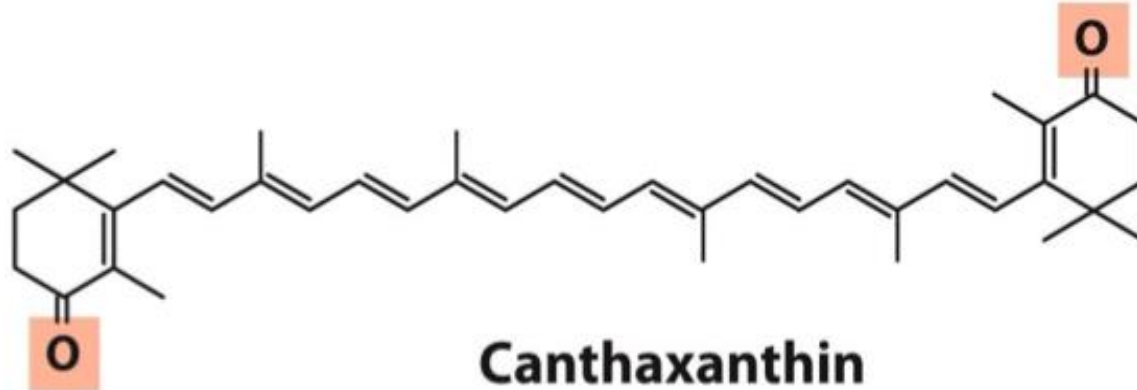
## Bloor's Criteria

- Insoluble in water and soluble in organic solvents such as chloroform, benzene, acetone
- Esters of fatty acids
- Possibility of utilization by living organisms

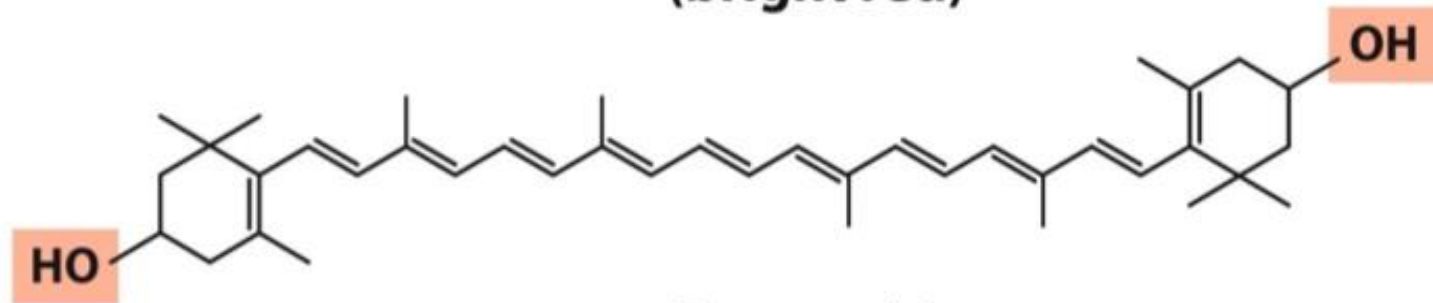
## Biomedical Importance

- Important dietary constituents and acts as a fuel
- Can be stored in the body-in almost unlimited amount
- Insulation
- Building materials
- Essential for neurons and membranes

# LIPIDS AS PIGMENTS



**Canthaxanthin**  
(bright red)



**Zeaxanthin**  
(bright yellow)



# LIPIDS- CLASSIFICATION

## Classification of lipids

### I. Simple Lipids –Esters of fatty acids with various alcohols

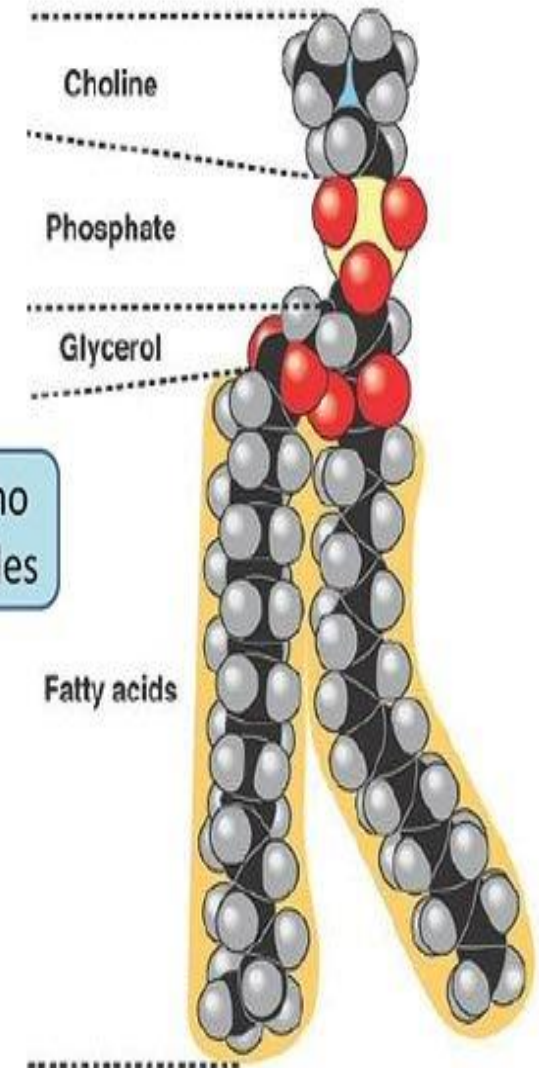
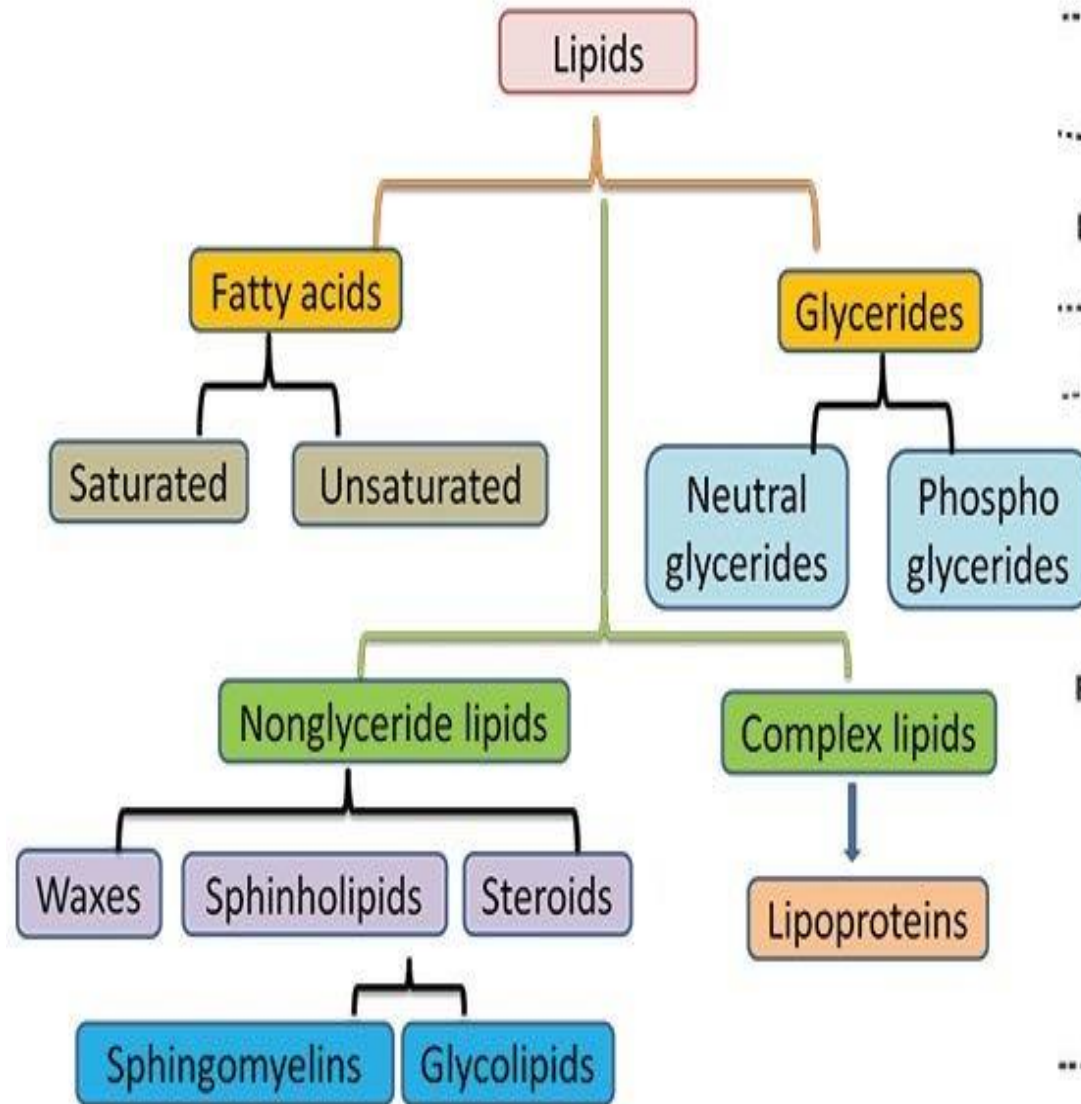
- a. Neutral fats- tri-esters of fatty acids and glycerol
- b. Waxes-mono-hydroxy aliphatic alcohols; Vitamin A and D are palmitic or stearic acids esters

### II. Compound Lipids- Esters of fatty acids

- a. Phospholipids
- b. Glycolipids
- c. Sulpholipids
- d. Aminolipids
- e. Lipoproteins

### III. Derived Lipids

- a. Fatty acids
- b. Mono- and di-acylglycerides
- c. Alcohols



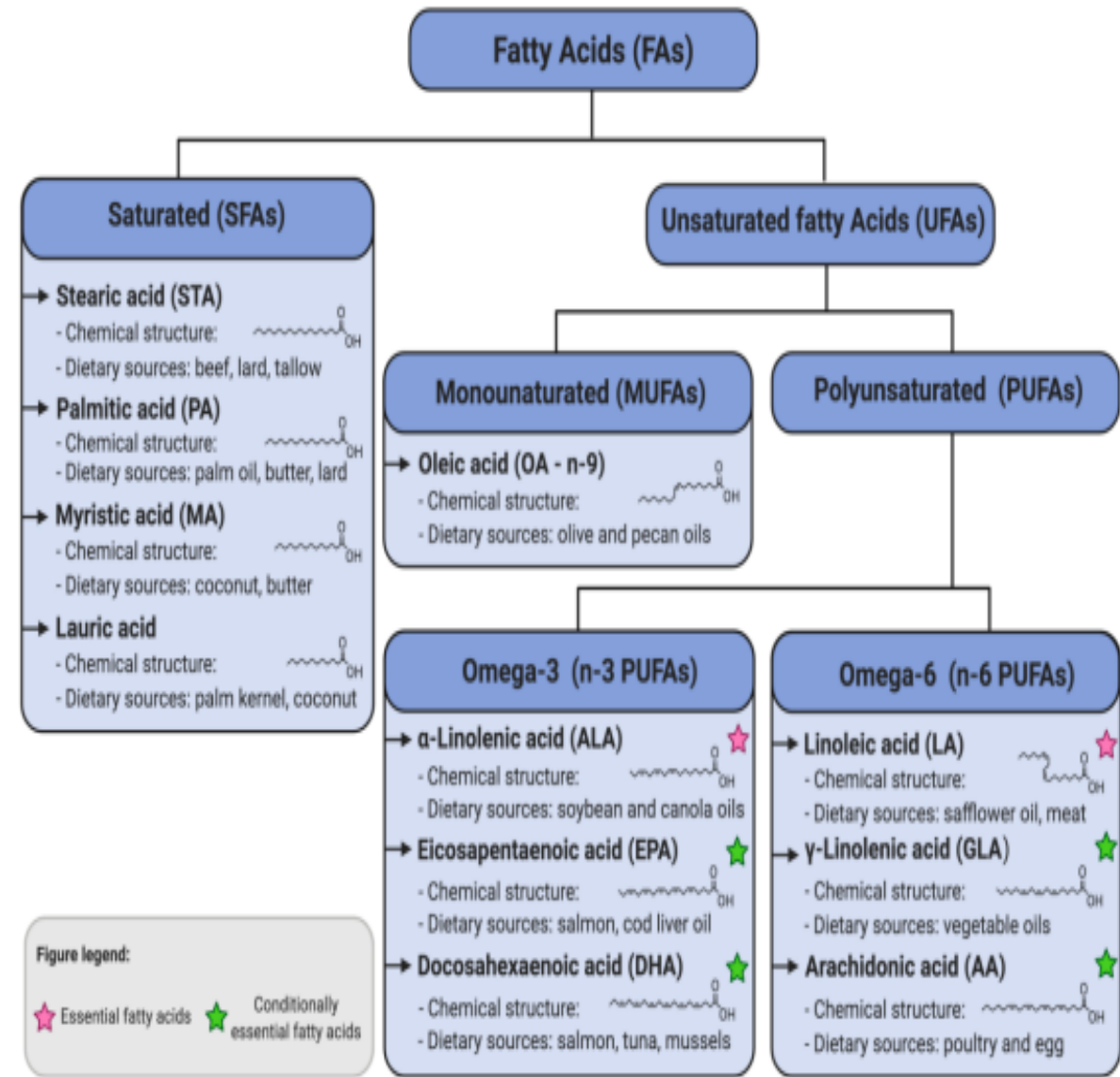
# Derived Lipids

## Fatty Acids (FA)

- Organic acid found in triglycerides
- Obtained from the hydrolysis of fats
- **Mono-carboxylic acid** ranging in chain length from C4 to C24 carbon atoms
- **Amphipathic** molecule

## Types of FA

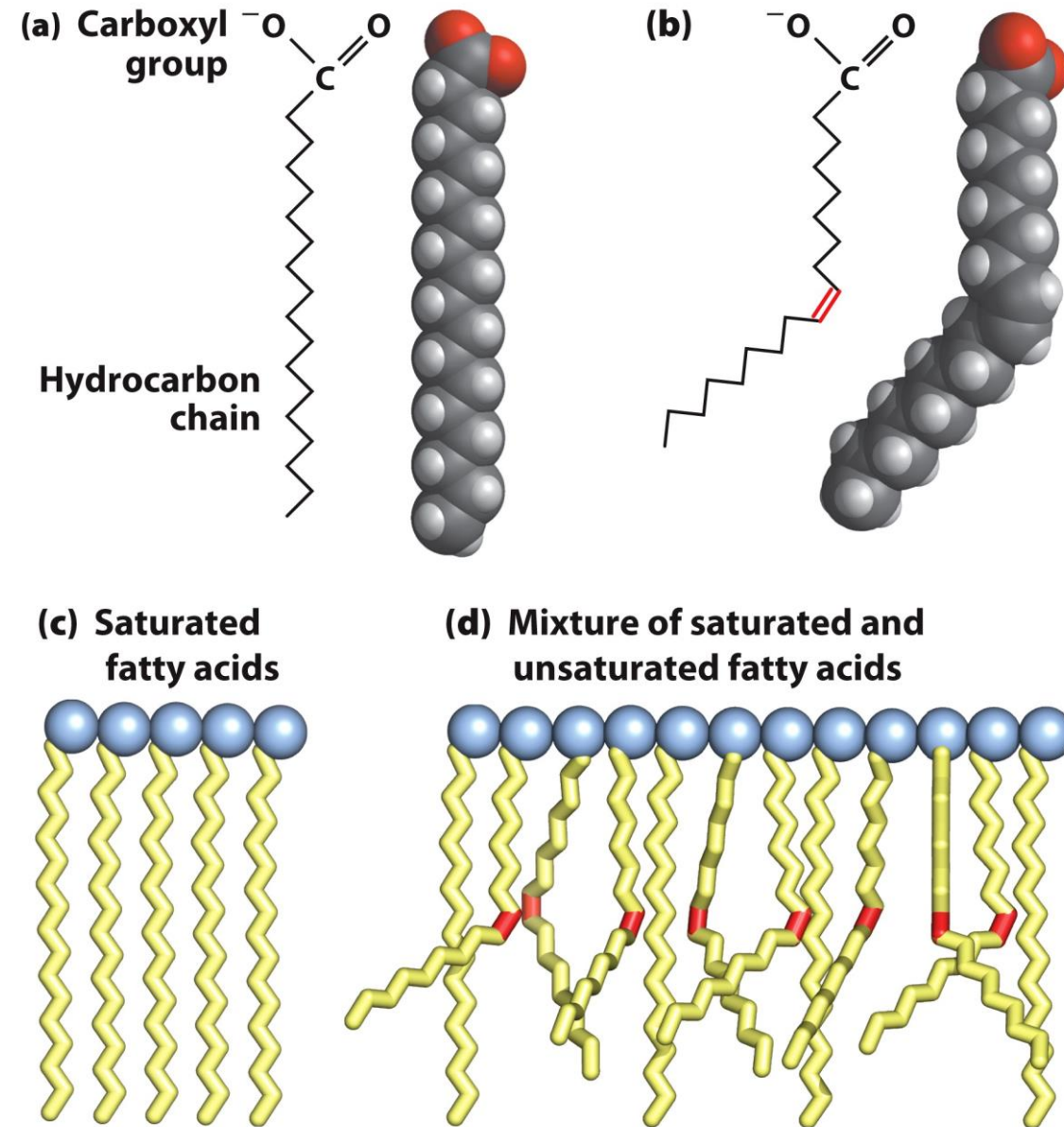
- Depending on Number of carbon atoms – **Odd chain**  
**Even chain**
  - Depending on length of hydrocarbon chains- **Short chain**  
**Medium chain**  
**Long chain**  
**Very long chain**
  - Depending on nature of hydrocarbon chain- **Saturated**  
**Unsaturated**  
**Branched**  
**Hydroxy**
- Almost all natural unsaturated fatty acids have cis stereochemistry in C=C's.
  - Small amounts of trans are produced in stomachs of ruminating animals by partial enzymatic hydrogenation of polyunsaturated fats, and thus are present in small amounts in milk and butter





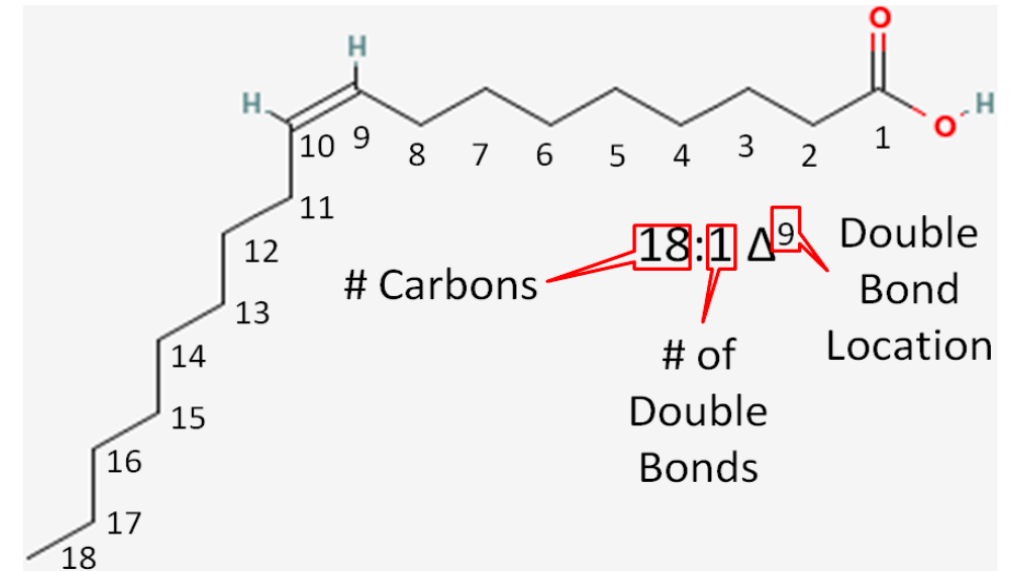
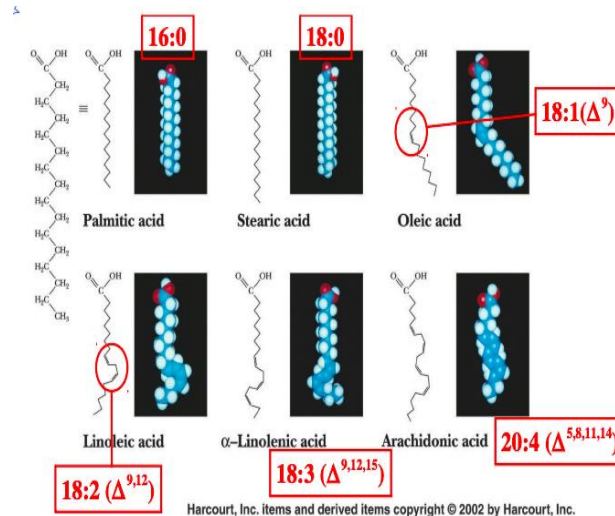
# Properties of fatty acids

- Saturated fatty acids pack tightly and form more rigid, organized aggregates
- Unsaturated chains bend and pack in a less ordered way, with greater potential for motion
- Membrane fluidity determined by **temperature** and the **degree of fatty acid unsaturation** of phospholipids
- Certain bacteria can modulate fatty acid unsaturation in response to temperature



# Nomenclature of fatty acids

- Number of carbon atoms
- “Oic” being the substitute
- ✓ Saturated fatty acids end in “anoic” e.g. octanoic acid
- ✓ Unsaturated fatty acids end in “enoic” e.g. octadecenoic acid



	common name	IUPAC name	melting point (C°)
16:0	palmitate	hexadeconoate	63
16:1 $\Delta^9$	palmitoleate	cis- $\Delta^9$ -hexadeconoate	-0.5
18:0	stearate	octadeconoate	70
18:1 $\Delta^9$	oleate	cis- $\Delta^9$ - octadeconoate	13
18:2 $\Delta^{9,12}$	linoleate	cis- $\Delta^{9,12}$ - octadeconoate	-9
18:3 $\Delta^{9,12,15}$	linolenate	cis- $\Delta^{9,12,15}$ - octadeconoate	-17
20:0	arachidate	eicosanoate	75
20:4 $\Delta^{5,8,11,14}$	arachindonate	cis- $\Delta^{5,8,11,14}$ -eicosatetraenoate	-49

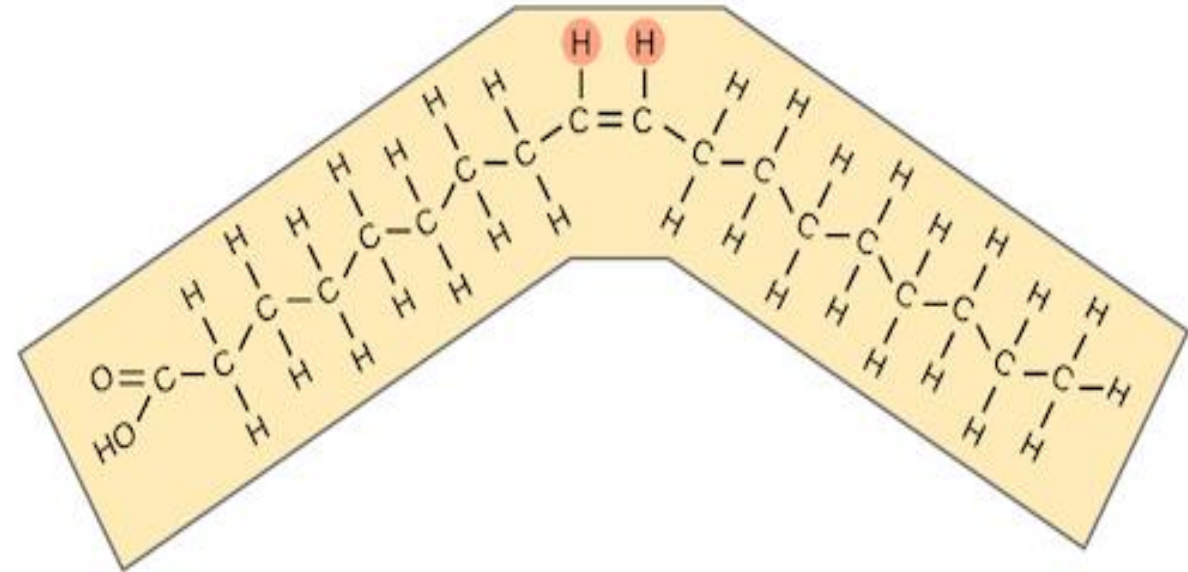
Number of carbon atoms	18
Number of double bonds	1
Number of carbons from the carboxylic acid end to the first double bond	9
Name: 18:9() cis-9-octadecenoic acid	



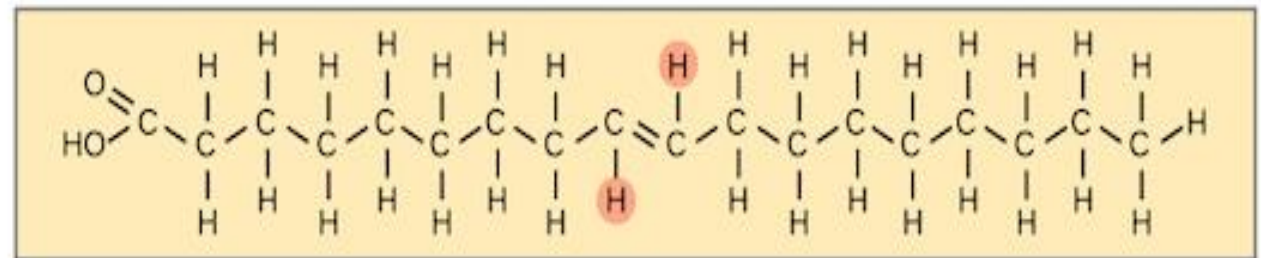
# Configuration of Unsaturated fatty acids

- ✓ Unsaturated fatty acids contain **double bonds**
- ✓ Exists in either **cis-** or **trans-** configuration
- ✓ **Cis-configuration:** The two hydrogen atoms associated with the double bond are present on the same side causing the kink
- ✓ **Trans-configuration:** The two hydrogen atoms associated with the double bond are present on the different side

Cis oleic acid



Trans oleic acid



# Food is tasty???

- Trans fatty acids form by partial dehydrogenation of unsaturated fatty acids
  - Done to increase shelf life or stability at high temperature of oils used in cooking (especially deep frying)
- A **trans double bond** allows a given fatty acid to adopt an extended conformation
- Trans fatty acids can pack more regularly and show **higher melting points** than cis forms
- **Consuming trans fats increases risk of cardiovascular disease**
  - Avoid deep-frying partially hydrogenated vegetable oils
  - Current trend: reduce trans fats in foods (Wendy's, KFC).

**TABLE 10–2** Trans Fatty Acids in Some Typical Fast Foods and Snacks

	Trans fatty acid content	
	In a typical serving (g)	As % of total fatty acids
French fries	4.7–6.1	28–36
Breaded fish burger	5.6	28
Breaded chicken nuggets	5.0	25
Pizza	1.1	9
Corn tortilla chips	1.6	22
Doughnut	2.7	25
Muffin	0.7	14
Chocolate bar	0.2	2

Source: Adapted from Table 1 in Mozaffarian, D., Katan, M.B., Ascherio, P.H., Stampfer, M.J., & Willet, W.C. (2006). Trans fatty acids and cardiovascular disease. *N. Engl. J. Med.* 354, 1604–1605.

Note: All data for foods prepared with partially hydrogenated vegetable oil in the United States in 2002.

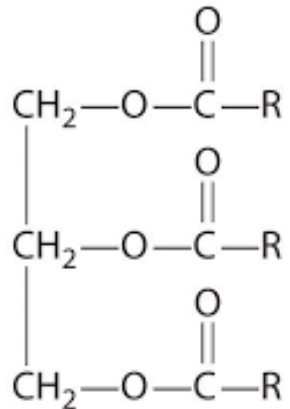
# Simple Lipids

Simple lipids are **esters of fatty acids with alcohol**

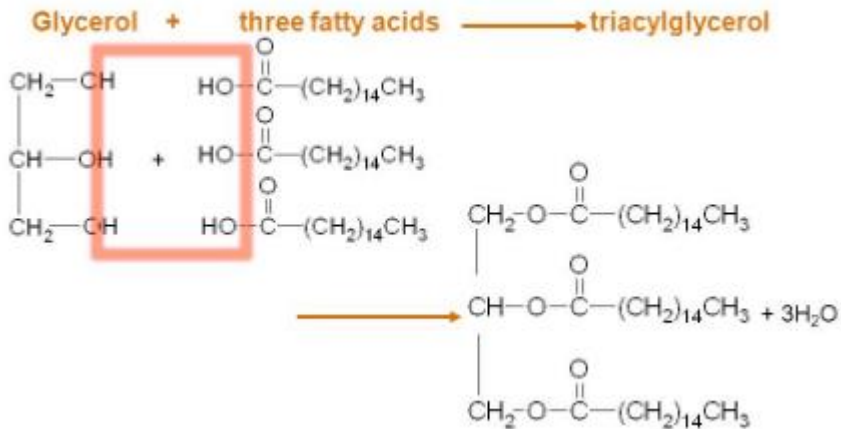
1. **Fats and oils**: esters of fatty acid with glycerol
2. **Waxes**: esters of fatty acids with high molecular weight monohydric alcohol



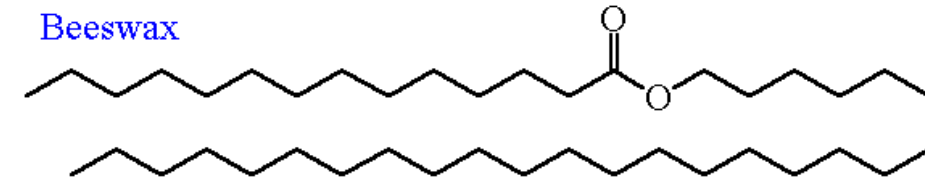
Waxes



General structure of a triacylglycerol

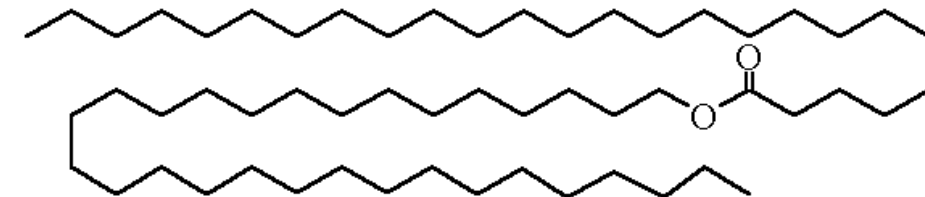


Beeswax



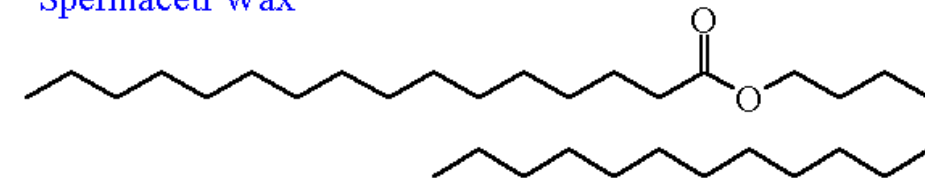
Ceryl Myristate

Carnauba Wax



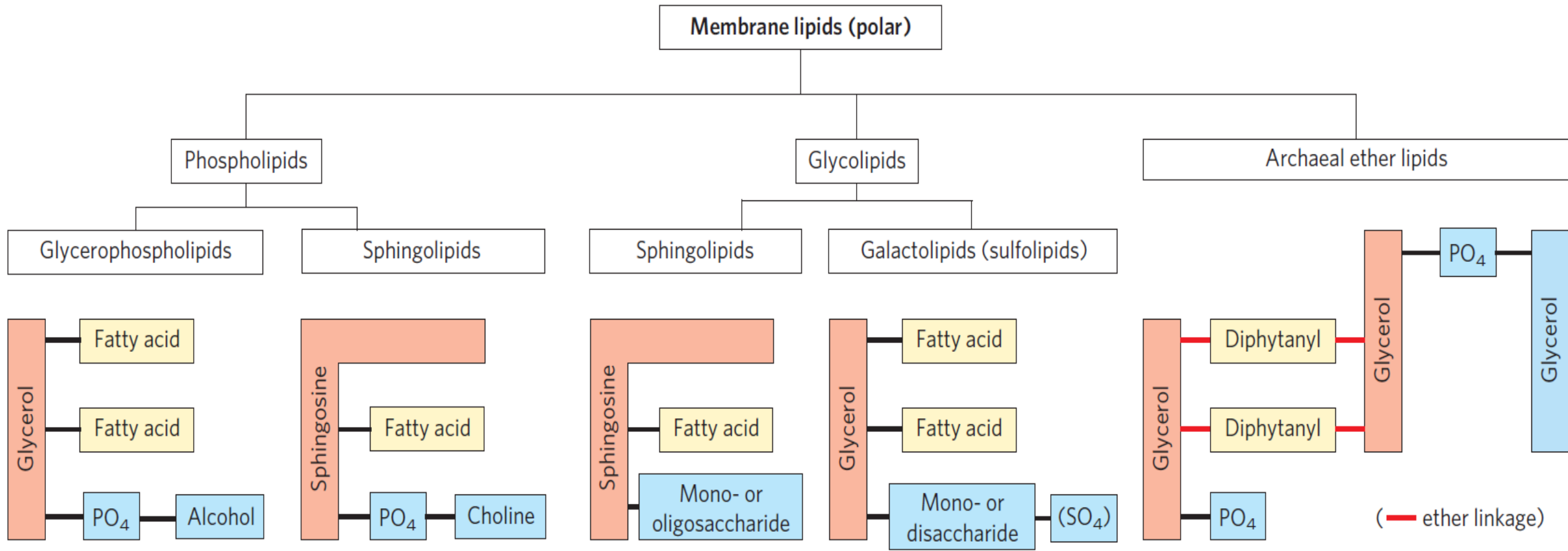
Myricyl Cerotate

Spermaceti Wax



Cetyl Palmitate

# Compounds Lipids (Membrane Lipids)

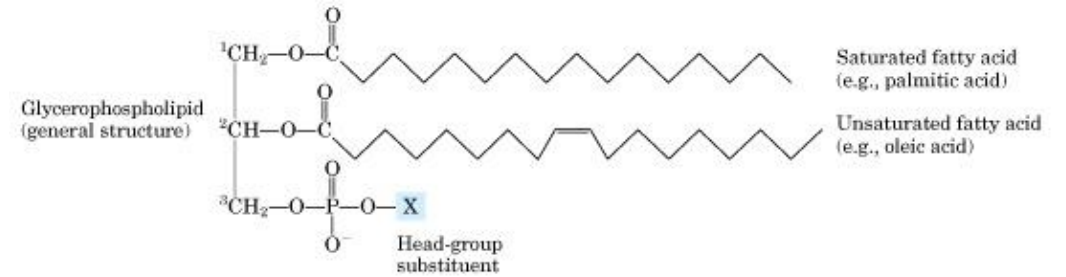




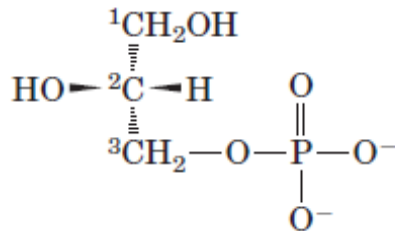
# Glycerophospholipids

## ✓ Phosphatidic acid derivatives

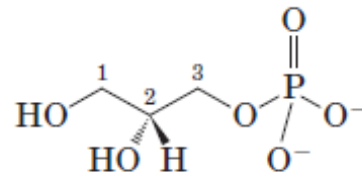
- ✓ **Structure-** Two fatty acids are attached in ester linkage to the first and second carbons of glycerol, and a highly polar or charged group is attached through a phosphodiester linkage to the third carbon
- ✓ Diacylglycerols linked to a polar alcohol by a phosphodiester bond
- ✓ The fatty acids vary within each group, but usually are sat'd C16/18 at C1, and unsat'd C18/20 at C2
- ✓ Note: the charge on the alcohol may be positive, negative, or neutral



Name of glycerophospholipid	Name of X	Formula of X	Net charge (at pH 7)
Phosphatidic acid	—	—H	-1
Phosphatidylethanolamine	Ethanolamine	—CH <sub>2</sub> —CH <sub>2</sub> —NH <sub>3</sub> <sup>+</sup>	0
Phosphatidylcholine	Choline	—CH <sub>2</sub> —CH <sub>2</sub> —N <sup>+</sup> (CH <sub>3</sub> ) <sub>3</sub>	0
Phosphatidylserine	Serine	—CH <sub>2</sub> —CH(NH <sub>3</sub> <sup>+</sup> )—COO <sup>-</sup>	-1
Phosphatidylglycerol	Glycerol	—CH <sub>2</sub> —CH(OH)—CH <sub>2</sub> —OH	-1
Phosphatidylinositol 4,5-bisphosphate	<i>myo</i> -Inositol 4,5-bisphosphate		-4
Cardiolipin	Phosphatidylglycerol		-2



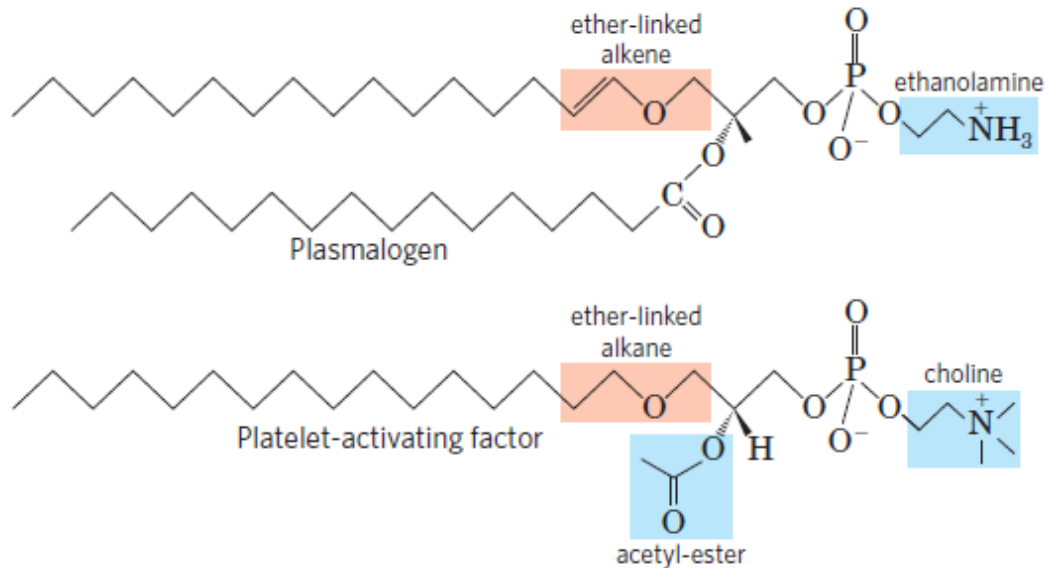
L-Glycerol 3-phosphate (*sn*-glycerol 3-phosphate)





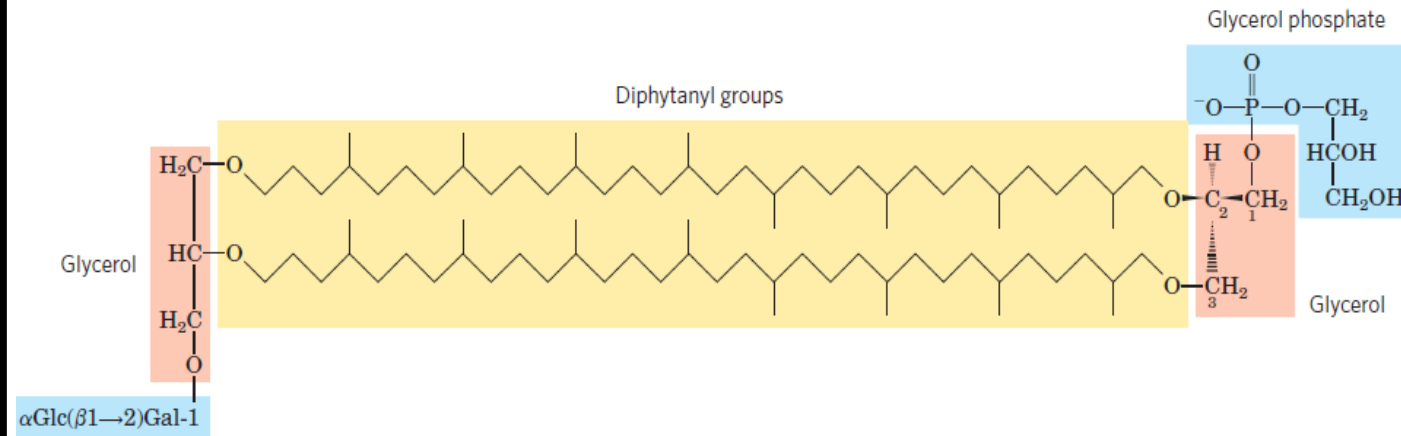
## Unique Glycerophospholipids

## Ether Glycerophospholipids



- ✓ One of the two acyl chains is attached to glycerol in ether
- ✓ Plasmalogens- Heart lipids (double bond between C-1 and C-2 linkage )
- ✓ Platelet activating factor

## Archaea Membranes



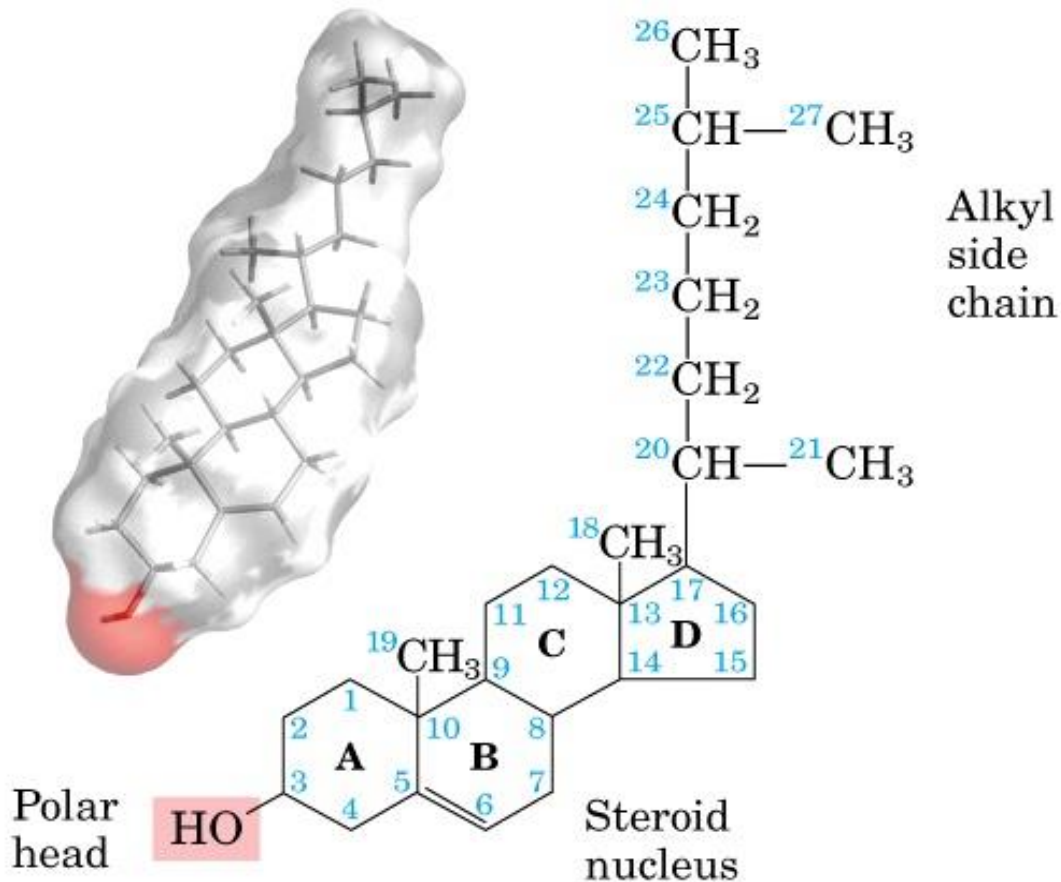
- ✓ Archaea live in ecological niches with extreme conditions
- ✓ Membrane lipids containing long-chain (32 carbons) branched hydrocarbons linked at each end to glycerol
- ✓ Linkages are through ether bonds, which are much more stable to hydrolysis at low pH and high temperature
- ✓ Glycerol dialkyl glycerol tetraethers (GDGTs)

# Sphingolipids

- ✓ Derivatives of long-chain amino alcohol sphingosine
- ✓ **Ceramide** (headgroup = H) is the parent of all sphingolipids
- ✓ **Sphingomyelins** - polar headgroup (phospholipids)
  - phosphocholine
  - phosphoethanolamine
- ✓ **Glycosphingolipids** – sugars, no phosphate (Neutral)
  - **cerebrosides** (1 sugar + ceramide)
  - **globosides** (2 sugars or more + ceramide)
- ✓ **Gangliosides**- oligosaccharide headgroups (Charged)
  - with one or more sialic acid residues

Name of sphingolipid	Name of X—O	Formula of X
Ceramide	—	—H
Sphingomyelin	Phosphocholine	
Neutral glycolipids Glucosylcerebroside	Glucose	
Lactosylceramide (a globoside)	Di-, tri-, or tetrasaccharide	
Ganglioside GM2	Complex oligosaccharide	

# Sterols: Structural Lipids, Hormone Precursors, and Detergents



✓ Structural lipids present in the membranes of most eukaryotic cells

✓ **Structure-** Steroid nucleus, consisting of four fused rings, three with six carbons and one with five.

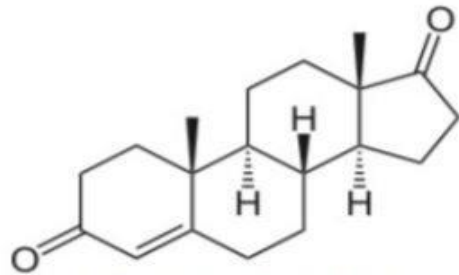
## Cholesterol

- The most fundamental and famous steroid is cholesterol
- Have a **structural role** in most eukaryotic membranes
- Hormone derivatives regulate gene expression
- Sterols in other species: **stigmasterol** in plants and **ergosterol** in fungi

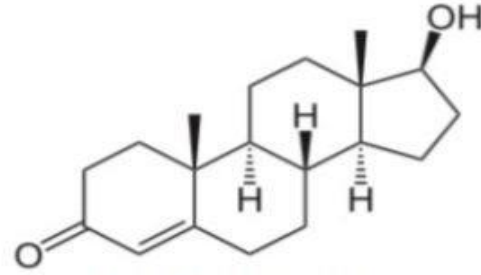
# Important steroids in body

- **Androgens** These are "male sex hormones" that regulate the development of the male reproductive system and the secondary sexual characteristics in males.
- **Progesterone, estrone, and estradiol** These are "female sex hormones" that regulate the development of the female reproductive system and are responsible for the maintenance of secondary sexual characteristics in females.
- **Aldosterone** This steroid controls water and electrolyte balances.
- **Cortisone** This compound is involved in metabolism and in controlling inflammation.
- **Bile salts** Facilitates the digestion of certain lipids and the absorption of fat-soluble vitamins.
- **Vitamin D** An important steroid that controls calcium absorption and deposition in the bone. Recent research also suggests that vitamin D plays a fundamental role in the prevention of many cancers. High consumption of vitamin D and sun exposure appear to reduce cancer risk.

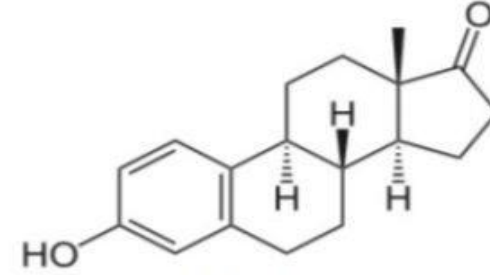
# Important steroids in body



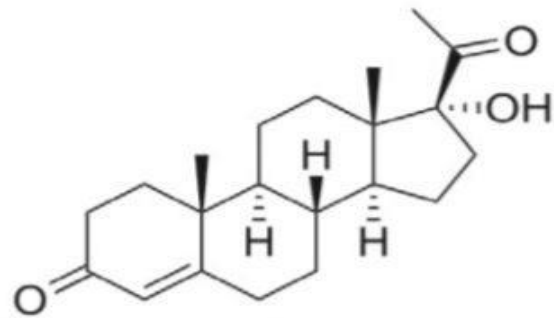
androstenedione



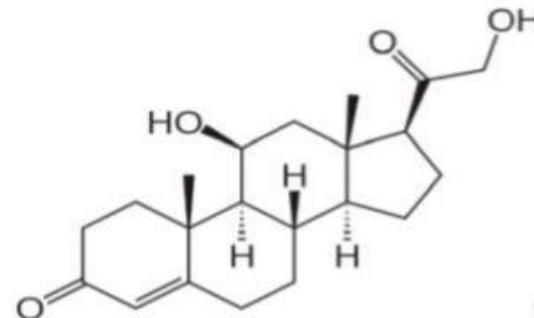
testosterone



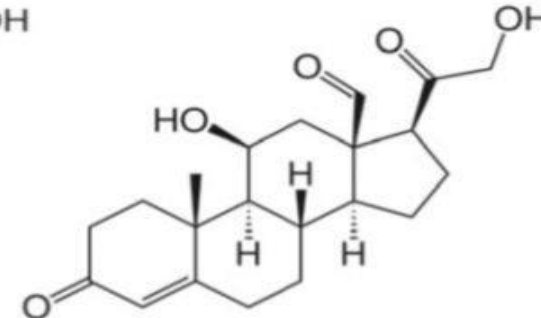
estrone



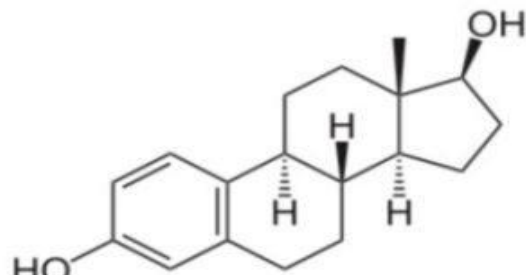
17 $\alpha$ -hydroxyprogesterone



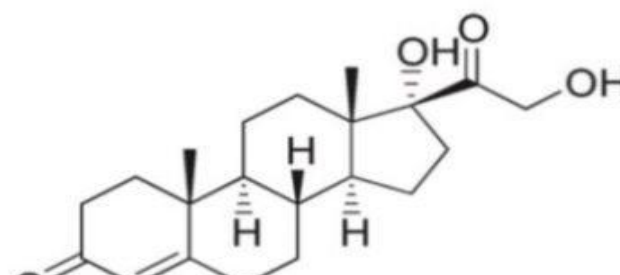
corticosterone



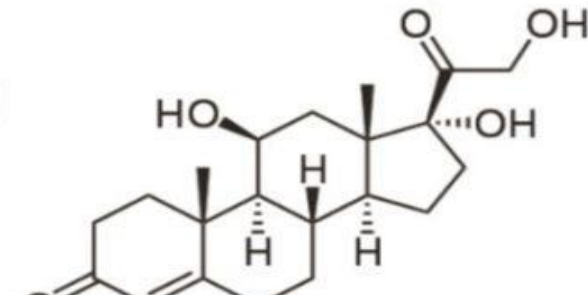
aldosterone



estradiol



11-deoxycortisol



cortisol

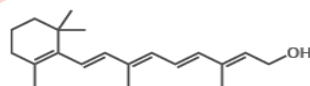


# VITAMINS

## THE CHEMICAL STRUCTURES OF VITAMINS

Vitamins are the essential nutrients that our body needs in small amounts. More specifically, an organic compound is defined as a vitamin when it is required by an organism, but not synthesised by that organism in the required amounts (or at all). There are thirteen recognised vitamins.

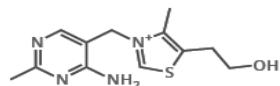
### VITAMIN A



**RETINOL**  
active form in mammalian tissues

Important for eyesight. Also strengthens immune system and keeps skin and linings of parts of the body healthy.

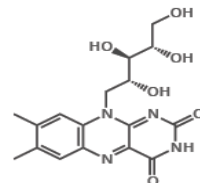
### VITAMIN B1



**THIAMIN**  
can also occur in pyrophosphate ester form

Used to keep nerves & muscle tissue healthy. Also important for processing of carbohydrates and some proteins.

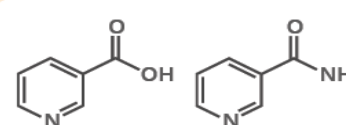
### VITAMIN B2



**RIBOFLAVIN**  
excess turns urine bright yellow

Important for body growth, red blood cell production, and keeping the eyes healthy. Also helps processing of carbohydrates.

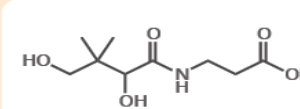
### VITAMIN B3



**NICOTINIC ACID**  
niacin is collective name for these compounds

Helps with digestion and digestive system health. Also helps with the processing of carbohydrates.

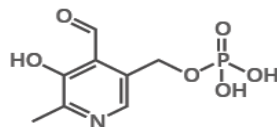
### VITAMIN B5



**PANTOTHENIC ACID**  
also occurs in pyrophosphate ester form

Important for manufacturing red blood cells and maintaining a healthy digestive system. Also helps process carbohydrates.

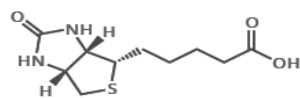
### VITAMIN B6



**PYRIDOXAL PHOSPHATE**  
active form in mammalian tissues

Helps make some brain chemicals; needed for normal brain function. Also helps make red blood cells and immune system cells.

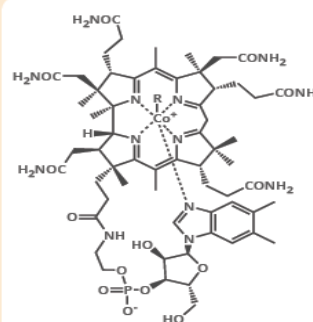
### VITAMIN B7



**BIOTIN**  
produced by intestinal bacteria

Needed for metabolism of various compounds. Often recommended for strengthening hair, but evidence is variable.

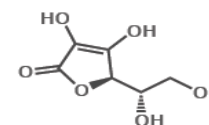
### VITAMIN B12



**COBALAMIN**  
usually contains CN as the R group

Important for the nervous system, for making red blood cells, and helps in the production of DNA and RNA.

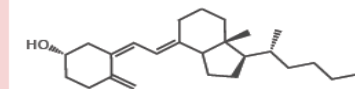
### VITAMIN C



**ASCORBIC ACID**  
deficiency can cause scurvy

Important for a healthy immune system; helps produce collagen, used to make skin and other tissues. Also helps wound healing.

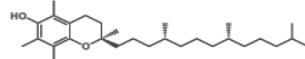
### VITAMIN D



**CHOLECALCIFEROL**  
natural form; different form used in supplements

Important for bone health and maintaining the immune system function. May also have a preventative role in cancers.

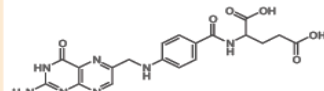
### VITAMIN E



**ALPHA-TOCOPHEROL**  
group includes tocopherols & tocotrienols

An antioxidant that helps prevent damage to cells and may have a preventative role in cancer. Also helps make red blood cells.

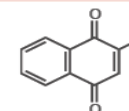
### VITAMIN B9



**FOLIC ACID**  
found as tetrahydrofolate in food

Important for brain function & mental health. Aids production of DNA & RNA. Important when tissues are growing quickly.

### VITAMIN K



**MENADIONE**  
all K vitamins are menadiene or derivatives

Helps blood clot properly, & plays a key role in bone health. Newborns receive vitamin K injections to prevent bleeding.

### Key

Vitamins can be divided broadly into two classes.

- WATER-SOLUBLE VITAMINS**  
These vitamins are not stored in the body. As such, generally, they are required more frequently than the fat-soluble vitamins.
- FAT-SOLUBLE VITAMINS**  
These vitamins are stored in the liver and fatty tissues until required. As such, they can be harmful if too much is taken in.



# Summary

- ✓ Lipids- water insoluble compounds, storage and membrane lipids
- ✓ Fatty acids and their classifications
- ✓ Relevance of fatty acids in biological systems
- ✓ Membrane proteins and their classifications
- ✓ Glycerophospholipids
- ✓ Sphingolipids
- ✓ Sterols- Cholesterol and its analogues
- ✓ Biological relevance of different steroids present in human body
- ✓ Vitamins and its significance