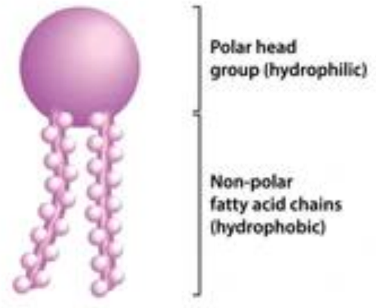
Lipids

Prof. Mamoun Ahram

Lipids

- Lipids are a heterogeneous class of naturally occurring organic compounds that share some properties based on structural similarities, mainly a dominance of nonpolar groups.

- They are Amphipathic.
- They are insoluble in water, but soluble in fat or organic solvents (ether, chloroform, benzene, acetone).
- They are widely distributed in plants & animals.

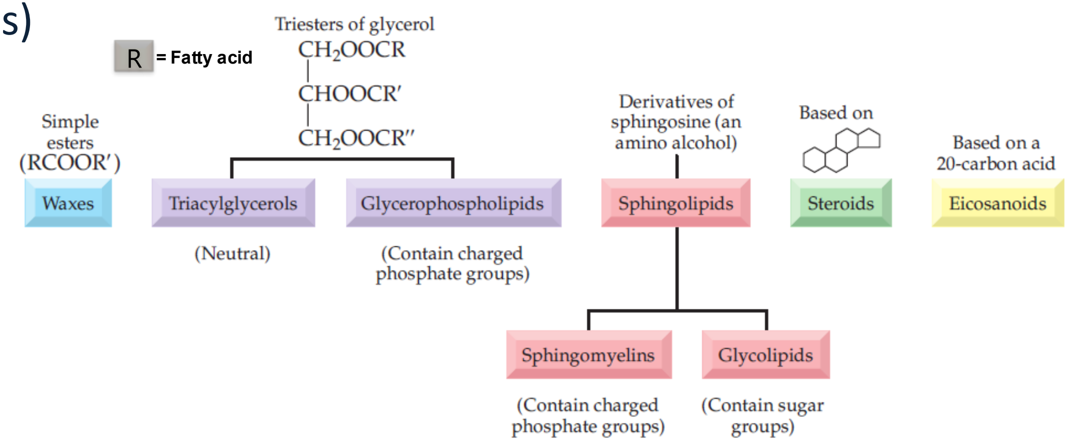


Lipid Functions

- Lipids include:
  - Storage lipids for energy purpose
    - They are storable to unlimited amounts (vs. carbohydrates)
    - They provide a considerable amount of energy to the body (25% of body needs) & provide a high-energy value (more energy per gram vs. carbohydrates & proteins)
  - Structural lipids in membranes
- Signaling molecules, hormone precursors, cofactors, & pigments
- Shock absorbers and thermal insulators

Classes

- Simple lipids (fatty acids, fats, and oils)
- Complex lipids (glycerides , glycerophospholipids, sphingolipids, glycolipids, lipoproteins)
- Derived lipids (waxes, alcohols, eicosanoids)
- Cyclic lipids (steroids)

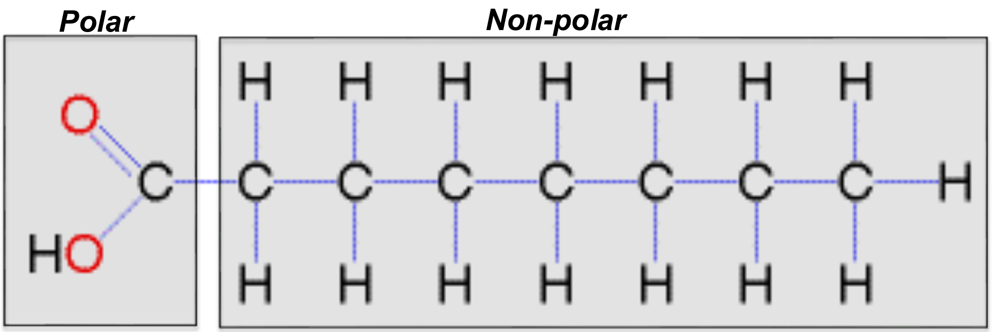


Fatty acids

- Aliphatic mono-carboxylic acids
- Formula: R-(CH_2)n-COOH
- Lengths
  - Physiological (12-24)
  - Abundant (16 and 18)
- Degree of unsaturation
- Amphipathic molecules

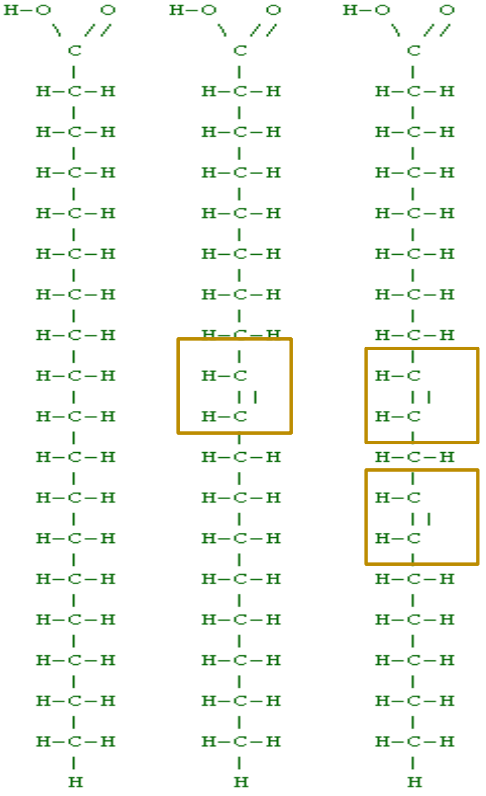
Functions:

- **Building blocks of other lipids**
- **Modification of many proteins (lipoproteins)**
- **Important fuel molecules**
- **Derivatives of important cellular molecules**



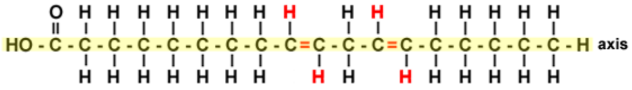
Types of fatty acids

- Saturated fatty acids are those with all of the C-C bonds being single.
- Unsaturated fatty acids are those with one or more double bonds between carbons:
  - Monounsaturated fatty acid: a fatty acid containing one double bond.
  - Polyunsaturated fatty acids contain two or more double bonds.

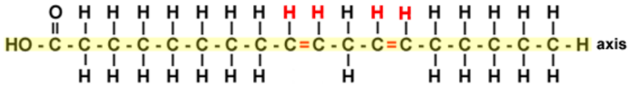


Stearic Acid | Oleic Acid | Linoleic Acid

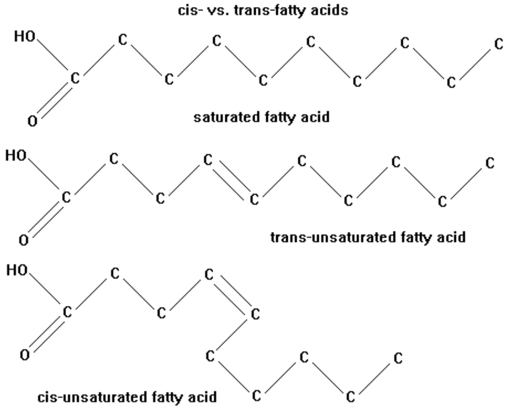
Cis vs. trans bonds

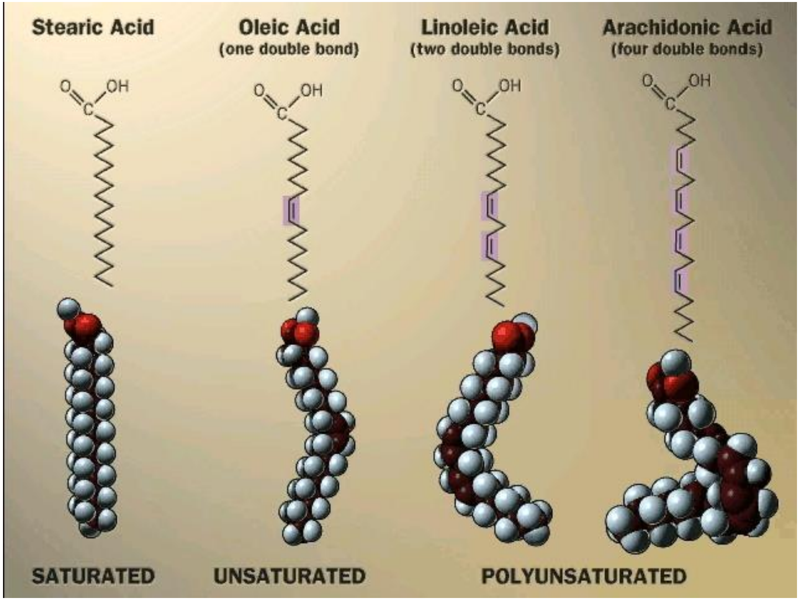


linoleic acid: *trans* configuration (*trans* isomer)



linoleic acid: *cis* configuration (*cis* isomer)



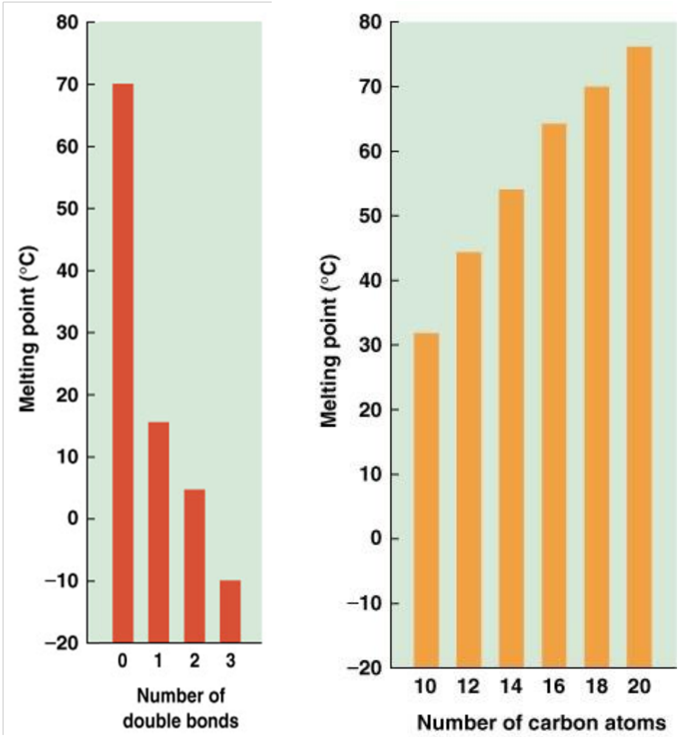


Physiologically:

- **cis isomer predominates**
- **trans is rare**

Properties of fatty acids

- The properties of fatty acids (melting point) are dependent on chain length and degree of saturation.



Properties of saturated fatty acids

Short chain F.A. (2-4)	Medium-chain F.A. (6-10)	Long chain F.A. (12-20)
They are liquid in nature	Solids at room temperature	Solids at room temperature
Water-soluble	Water-soluble	Water-insoluble
Volatile at RT	Non-volatile at RT	Non-volatile
Acetic and butyric acids	Caprylic, caproic, & capric acids	Palmitic and stearic acids

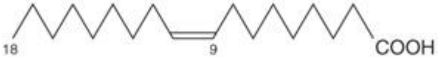
Greek number prefix

Number	prefix	Number	prefix	Number	prefix
1	Mono-	5	Penta-	9	Nona-
2	Di-	6	Hexa-	10	Deca-
3	Tri-	7	Hepta-	20	Eico-
4	Tetra-	8	Octa-		

Naming of a fatty acid

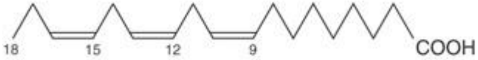
- Alkane to oic
  - Octadecane (octa and deca) is octadecanoic acid
    - One double bond = octadecenoic acid
    - Two double bonds = octadecadienoic acid
    - Three double bonds = octadecatrienoic acid
- Designation of carbons and bonds
  - 18:0 = a C18 fatty acid with no double bonds
    - stearic acid (18:0); palmitic acid (16:0)
  - 18:2 = two double bonds (linoleic acid)
- Designation of the location of bonds
  - Δn: The position of a double bond
    - cis-Δ9: a cis double bond between C 9 and 10
    - trans-Δ2: a trans double bond between C 2 and 3

Palmitoleic acid (ω7, 16:1, Δ^{9})

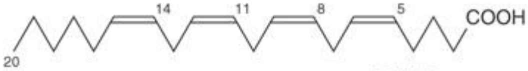


Oleic acid (ω9, 18:1, Δ^{9})

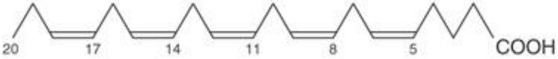
***Linoleic acid (ω6, 18:2, $\Delta^{9,12}$)**



***α-Linolenic acid (ω3, 18:3, $\Delta^{9,12,15}$)**



***Arachidonic acid (ω6, 20:4, $\Delta^{5,8,11,14}$)**

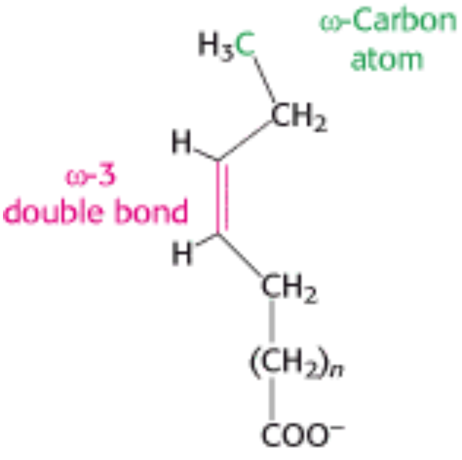


Eicosapentaenoic acid (ω3, 20:5, $\Delta^{5,8,11,14,17}$)

Number of carbons	Number of double bonds	Common name	Systematic name	Formula
14	0	Myristate	n-Tetradecanoate	$CH_3(CH_2)_{12}COO^-$
16	0	Palmitate	n-Hexadecanoate	$CH_3\,(CH_2)\,_{14}COO$-
18	0	Stearate	n-Octadecanoate	$CH_3(CH2)\,_{16}COO$-
18	1	Oleate	cis-Δ^9-Octadecenoate	$CH_3(CH_2)\,_7CH{=}CH(CH_2)\,_7COO$-
18	2	Linoleate	cis,cis-Δ^9,Δ^{12}-Octadecadienoate	$CH_3(CH_2)_4CH{=}CHCH_2CH(CH_2)_7COO$-
18	3	Linolenate	all-cis-Δ^9,Δ^{12},Δ^{15}-Octadecatrienoate	$CH_3CH_2(CH{=}CHCH_2)_3(CH_2)_6COO$-
20	4	Arachidonate	all-cis-Δ^5,Δ^8,Δ^{11},Δ^{14}-Eicosatetraenoate	$CH_3(CH_2)_4\,(CH{=}CHCH_2)_4(CH_2)_2\,COO$-

Another way of naming

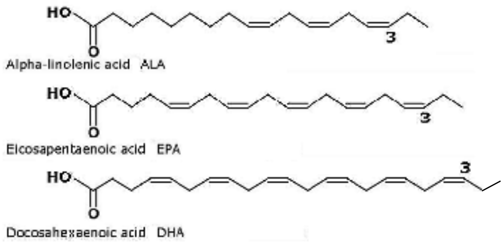
- (ω)-C: distal methyl C as #1



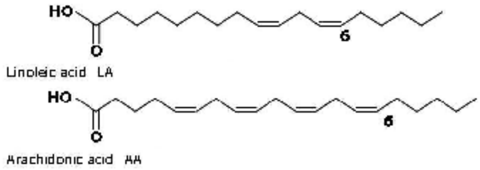
An ω-3 fatty acid

Per softgel		
Organic Flaxseed Oil (Linseed Oil)		400mg
Pure Fish Oil		400mg
Starflower Oil (Borage Oil)		400mg
typically providing:		
Alpha Linolenic Acid (ALA)	Omega-3	200mg
Docosahexaenoic Acid (DHA)	Omega-3	48mg
Eicosapentaenoic Acid (EPA)	Omega-3	72mg
Gamma Linolenic Acid (GLA)	Omega-6	88mg
Linoleic Acid (LA)	Omega-6	204mg
Oleic Acid	Omega-9	168mg

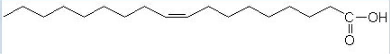
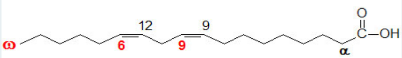
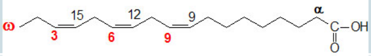
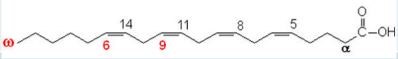
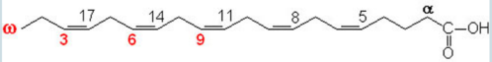
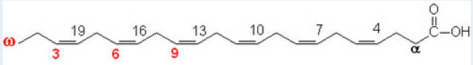
Omega-3 fatty acids



Omega-6 fatty acids



- **Essential FAs:**
  - **Linoleic acid: precursor of arachidonates**
  - **Linolenic acid: precursor of EPA and DHA**

Numerical Symbol	Common Name and Structure	Comments
$18:1^{\Delta 9}$	Oleic acid 	Omega-9 monounsaturated
$18:2^{\Delta 9,12}$	Linoleic acid 	Omega-6 polyunsaturated
$18:3^{\Delta 9,12,15}$	α-Linolenic acid (ALA) 	Omega-3 polyunsaturated
$20:4^{\Delta 5,8,11,14}$	Arachidonic acid 	Omega-6 polyunsaturated
$20:5^{\Delta 5,8,11,14,17}$	Eicosapentaenoic acid (EPA) 	Omega-3 polyunsaturated (fish oils)
$22:6^{\Delta 4,7,10,13,16,19}$	Docosahexaenoic acid (DHA) 	Omega-3 polyunsaturated (fish oils)

Derived fatty acids: Waxes & Eicosanoids

Waxes

$$\underbrace{CH_3(CH_2)_{14}-\overset{\overset{\displaystyle O}{\|}}{C}}_{\text{Palmitic acid}}-\underbrace{O-CH_2-(CH_2)_{28}-CH_3}_{\text{Triacontanol}}$$

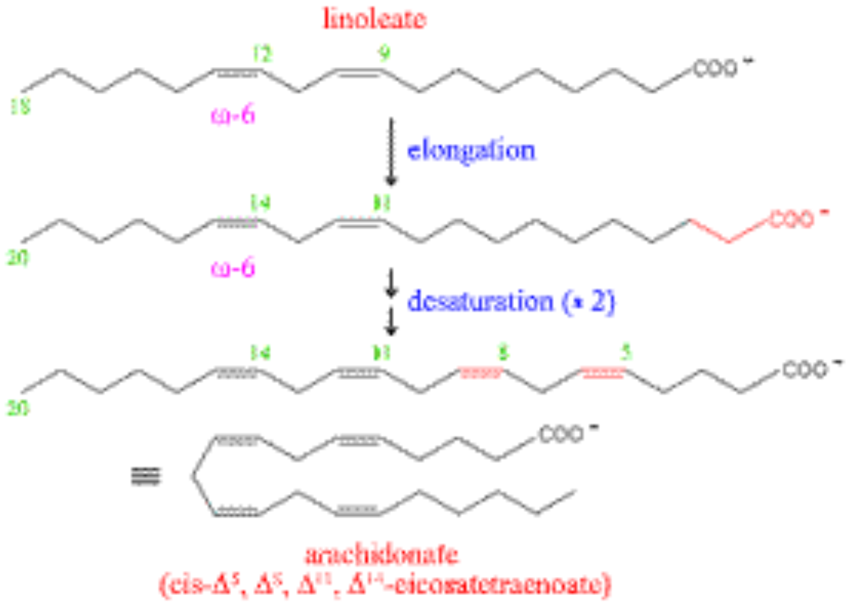
- Solid simple lipids containing a monohydric alcohol (C16 ~ C30, higher molecular weight than glycerol) esterified to long-chain fatty acids (C14 ~ C36).
  - Example: palmitoyl alcohol
- Insoluble in water
- Not easily hydrolyzed (fats) & indigestible
- Very resistant to rancidity
- No nutritional value
- External coating of plant leaves that prevent loss of water

Type	Structural Formula	Source	Uses
Beeswax	$CH_3(CH_2)_{14}-\overset{\overset{O}{\|}}{C}-O-(CH_2)_{29}CH_3$	Honeycomb	Candles, shoe polish, wax paper
Carnauba wax	$CH_3(CH_2)_{24}-\overset{\overset{O}{\|}}{C}-O-(CH_2)_{29}CH_3$	Brazilian palm tree	Waxes for furniture, cars, floors, shoes
Jojoba wax	$CH_3(CH_2)_{18}-\overset{\overset{O}{\|}}{C}-O-(CH_2)_{19}CH_3$	Jojoba	Candles, soaps, cosmetics

Do not memorize the structures but study them

Arachidonate

all *cis*-$\Delta^5,\Delta^8,\Delta^{11},\Delta^{14}$-eicosatetraenoate, $CH_3(CH_2)_4(CH=CHCH_2)_4(CH_2)_2COO^-$



Eicosanoids

- "eicosa" is Greek for "20"
- **Eicosanoids** are active lipids that function as "local hormones"
- They are derived from the 20-carbon arachidonate.
- They consist primarily of:
  - the prostaglandins (including prostacyclins) and thromboxanes, which are synthesized by cyclooxygenases
  - leukotrienes and lipoxins, which are synthesized from lipooxygenases.

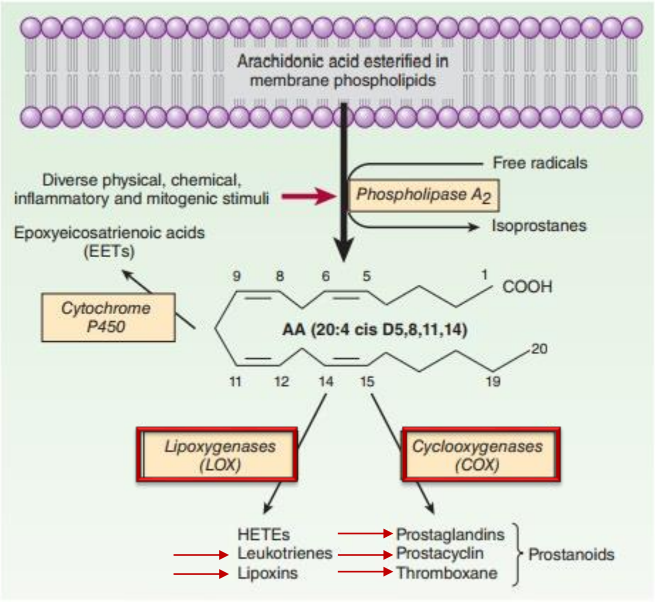
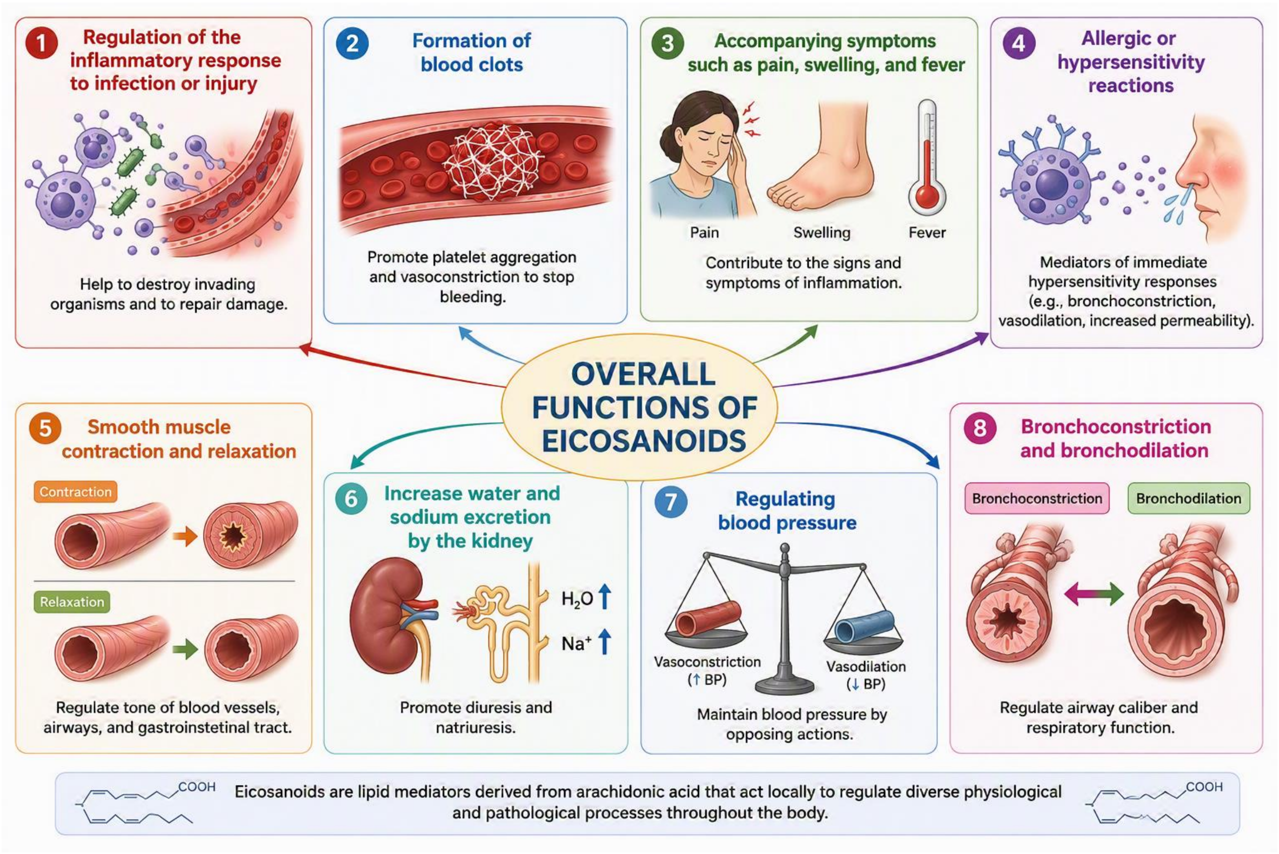


FIGURE 18–1 Pathways of arachidonic acid (AA) release and metabolism.

Overall functions

- Regulation of the inflammatory response to infection or injury
  - to destroy invading organisms and to repair damage
- Formation of blood clots
- Accompanying symptoms such as pain, swelling, and fever
- Allergic or hypersensitivity reactions
- Smooth muscle contraction and relaxation
- Increase water and sodium excretion by the kidney
  - regulating blood pressure.
- Bronchoconstriction and bronchodilation



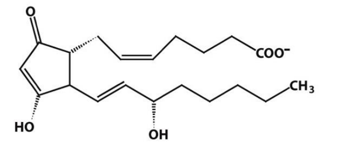
OVERALL FUNCTIONS OF EICOSANOIDS
1 Regulation of the inflammatory response to infection or injury
Help to destroy invading organisms and to repair damage.
2 Formation of blood clots
Promote platelet aggregation and vasoconstriction to stop bleeding.
3 Accompanying symptoms such as pain, swelling, and fever
Pain
Swelling
Fever
Contribute to the signs and symptoms of inflammation.
4 Allergic or hypersensitivity reactions
Mediators of immediate hypersensitivity responses (e.g., bronchoconstriction, vasodilation, increased permeability).
5 Smooth muscle contraction and relaxation
Contraction
Relaxation
Regulate tone of blood vessels, airways, and gastroinstetinal tract.
6 Increase water and sodium excretion by the kidney
H_2O ↑
Na^+ ↑
Promote diuresis and natriuresis.
7 Regulating blood pressure
Vasoconstriction (↑ BP)
Vasodilation (↓ BP)
Maintain blood pressure by opposing actions.
8 Bronchoconstriction and bronchodilation
Bronchoconstriction
Bronchodilation
Regulate airway caliber and respiratory function.
COOH
Eicosanoids are lipid mediators derived from arachidonic acid that act locally to regulate diverse physiological and pathological processes throughout the body.
COOH

Eicosanoids and their functions

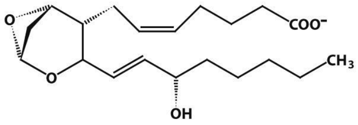
They control cellular function in response to injury

- Prostaglandins (20 carbons, internal 5-carbon ring)
  - Induction of inflammation
  - Inhibition of platelet aggregation
    - Inhibition of blood clotting
- Thromboxanes (20 carbons, internal 6-carbon ring with oxygen)
  - Constriction of smooth muscles
  - Induction of platelet aggregation
- Leukotrienes (20 carbons, 4 double bonds, 3 are conjugated (a triene))
  - Constriction of smooth muscles
    - Asthma
- Lipoxins
  - Inhibitors of inflammation

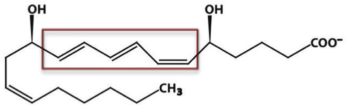
Neither memorize the specific functions nor the structures



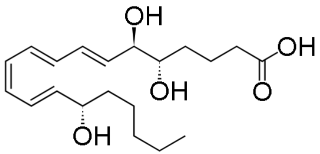
Prostaglandin E_2



Thromboxane A_2 (TXA_2)

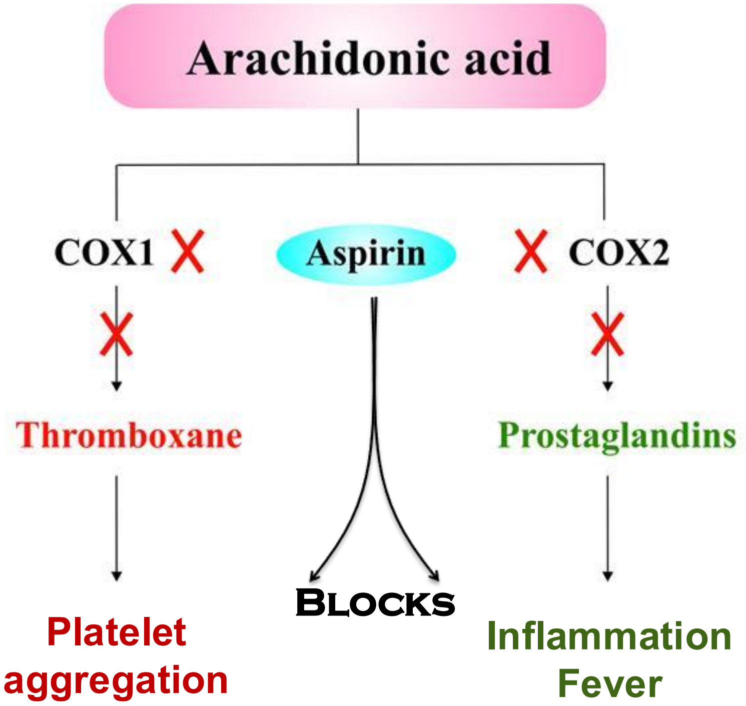


Leukotriene B_4



Lipoxins

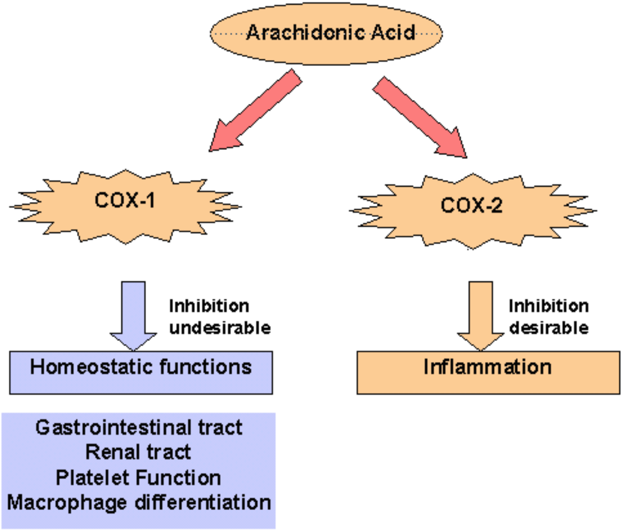
Aspirin is good



COX: Cyclooxygenase

Targets of Aspirin

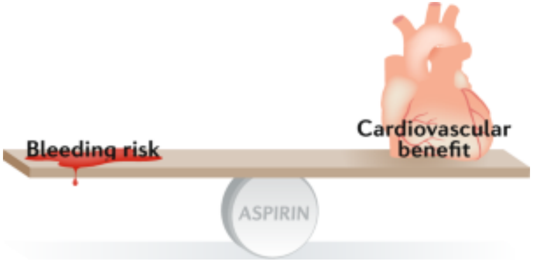
- Cyclooxygenase is present in three forms in cells, COX-1, COX-2, and COX-3.
- Aspirin targets both, but COX-2 should only be the target.

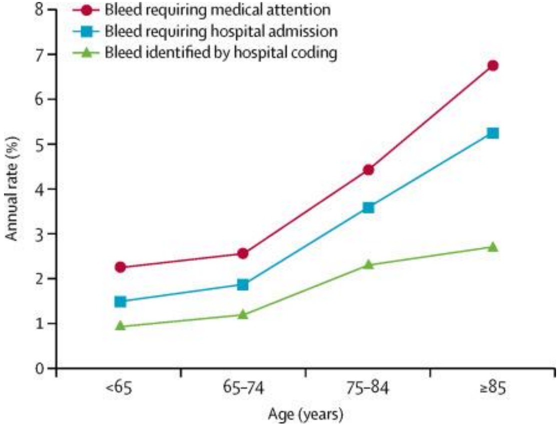


Aspirin can be bad

Cardiovascular disease vs. bleeding

- Aspirin also causes excessive bleeding among the elderly.





Age-specific risks, severity, time course, and outcome of bleeding on long-term antiplatelet treatment after vascular events: a population-based cohort study

Linxin Li*, Olivia C Geraghty*, Ziyah Mehta, Peter M Rothwell, on behalf of the Oxford Vascular Study

Interpretation In patients receiving aspirin-based antiplatelet treatment without routine PPI use, the long-term risk of major bleeding is higher and more sustained in older patients in practice than in the younger patients in previous trials, with a substantial risk of disabling or fatal upper gastrointestinal bleeding. Given that half of the major bleeds in patients aged 75 years or older were upper gastrointestinal, the estimated NNT for routine PPI use to prevent such bleeds is low, and co-prescription should be encouraged.

Celebrex

- A newer generation of drugs targets COX2.
  - Be cautious with Celebrex
  - Vioxx (from the same family) was withdrawn from the market
    - caused heart failure

Cardiovascular Risk

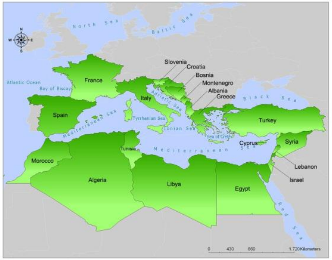
- CELEBREX may cause an increased risk of serious cardiovascular thrombotic events, myocardial infarction, and stroke, which can be fatal. All NSAIDs may have a similar risk. This risk may increase with duration of use. Patients with cardiovascular disease or risk factors for cardiovascular disease may be at greater risk. (See **WARNINGS** and **CLINICAL TRIALS**).

- CELEBREX is contraindicated for the treatment of peri-operative pain in the setting of coronary artery bypass graft (CABG) surgery (see **WARNINGS**).

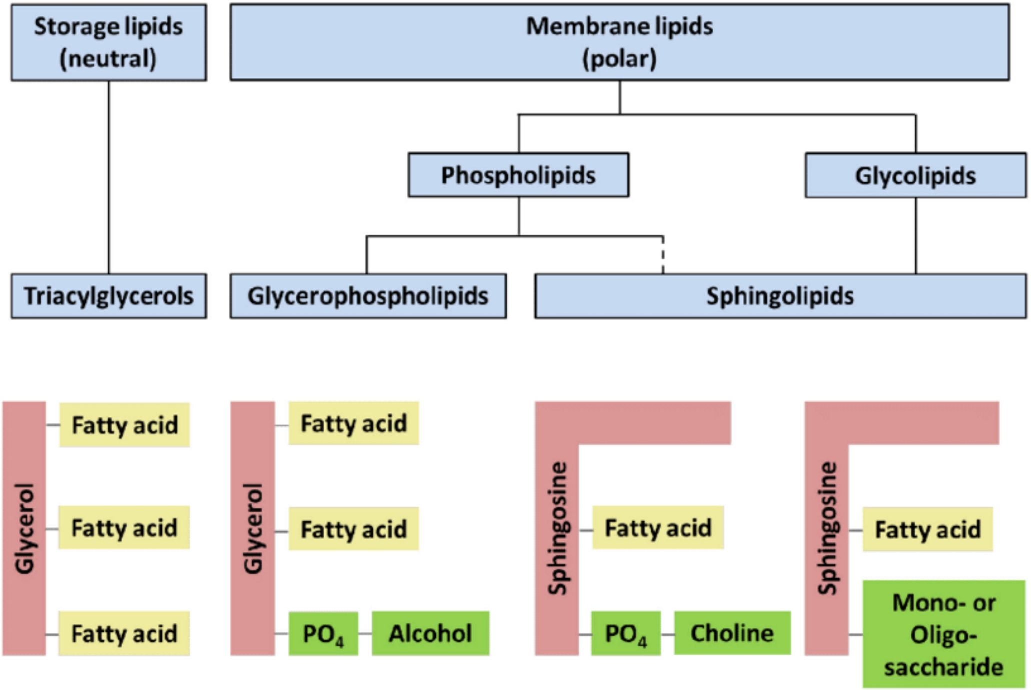
Omega fatty acids

- Omega-3 fatty acids
  - α-linolenic acid → eicosapentaenoic acid (EPA) → docosahexaenoic acid (DHA)
    - They reduce inflammatory reactions.
- Omega-6 fatty acids:
  - Arachidonic acid
- Omega-9 fatty acids
  - Oleic acid
    - It reduces cholesterol in the circulation.

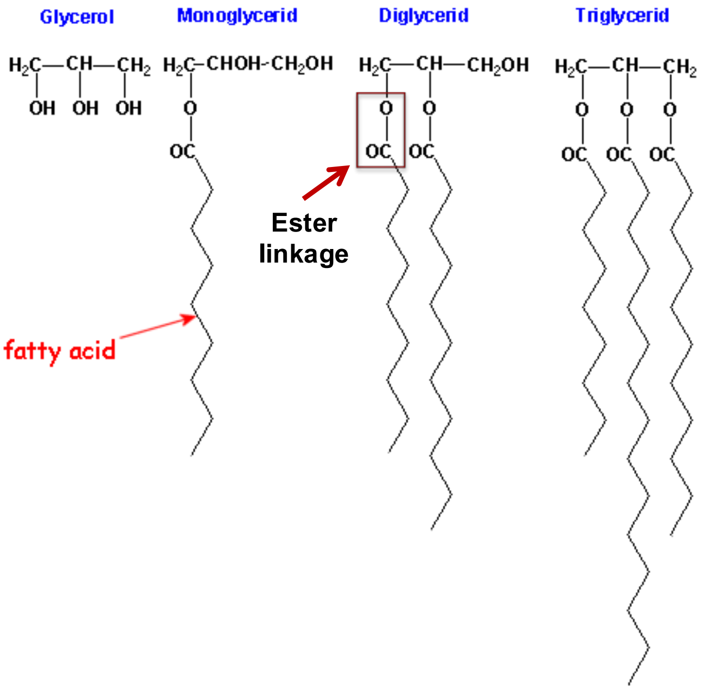
Healthy mediterranean food



Complex lipids


Storage lipids (neutral)
Membrane lipids (polar)
Phospholipids
Glycolipids
Triacylglycerols
Glycerophospholipids
Sphingolipids
Glycerol
Fatty acid
Fatty acid
Fatty acid
Glycerol
Fatty acid
Fatty acid
PO_4
Alcohol
Sphingosine
Fatty acid
PO_4
Choline
Sphingosine
Fatty acid
Mono- or Oligo-saccharide

Triglycerides



Types of glycerides

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)

Glycerol unit

Palmitic acid unit

Oleic acid unit

Linolenic acid unit

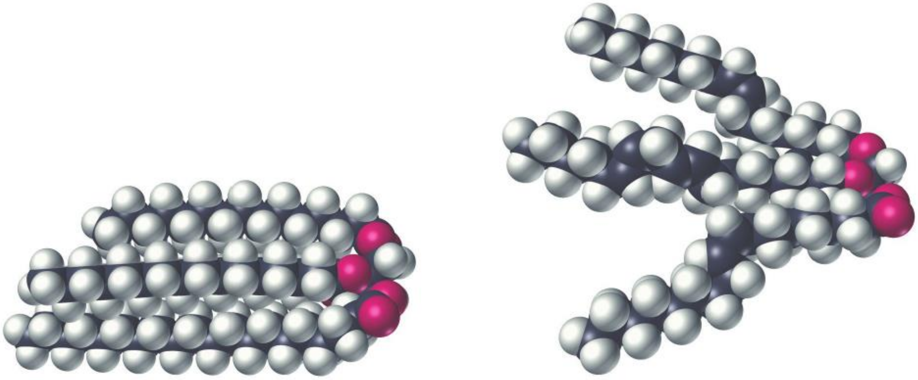
$$\begin{array}{l} CH_2OCO(CH_2)_{14}CH_3 \\ | \\ CHOCO(CH_2)_7CH{=}CH(CH_2)_7CH_3 \\ | \\ CH_2OCO(CH_2)_7(CH{=}CHCH_2)_3CH_3 \end{array}$$

Glyceryl palmitooleolinolenate
(a mixed triglyceride;
a polyunsaturated oil)

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

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.

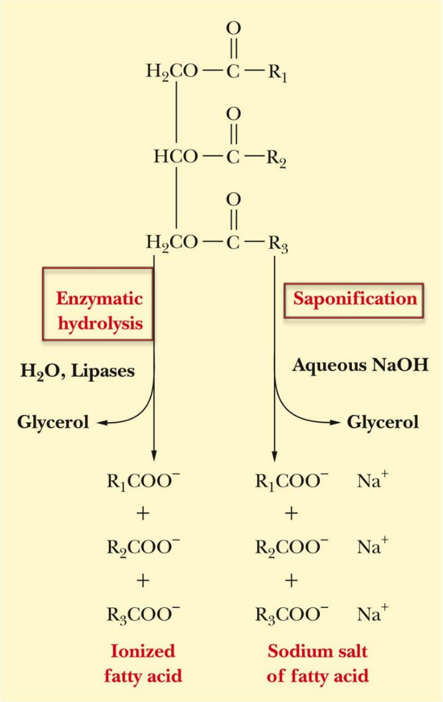


A fat An oil

Saponification

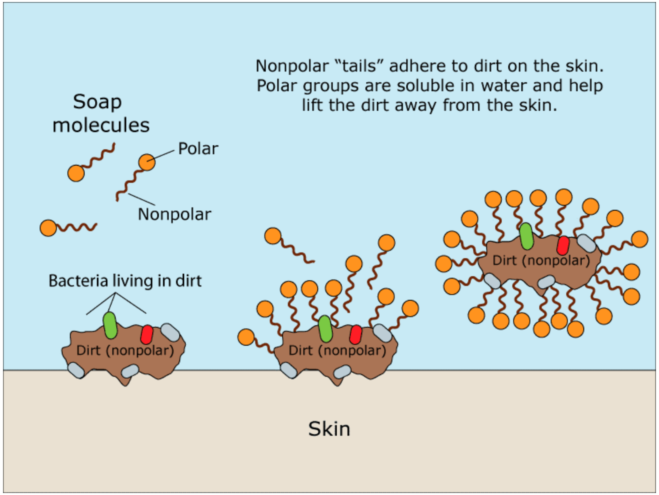
- Hydrolysis: steam, acid, enzyme (e.g., lipase of pancreas)

- Saponification: Alkaline hydrolysis produces salts of fatty acids (soaps). Soaps cause emulsification of oily material.



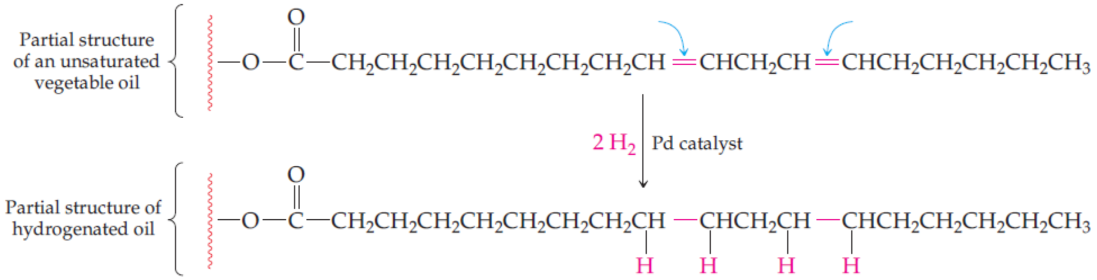
How does soap work?

- 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.



Hydrogenation

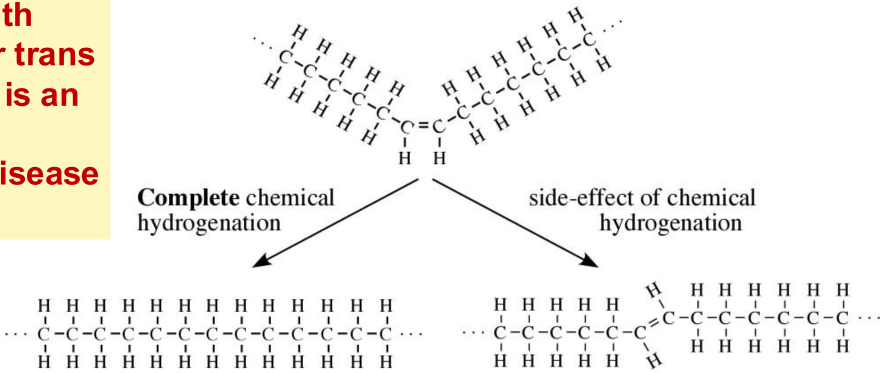
- The carbon-carbon double bonds in vegetable oils can be hydrogenated to yield saturated fats in the same way that any alkene can react with hydrogen to yield an alkane.



Trans fat

- 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).



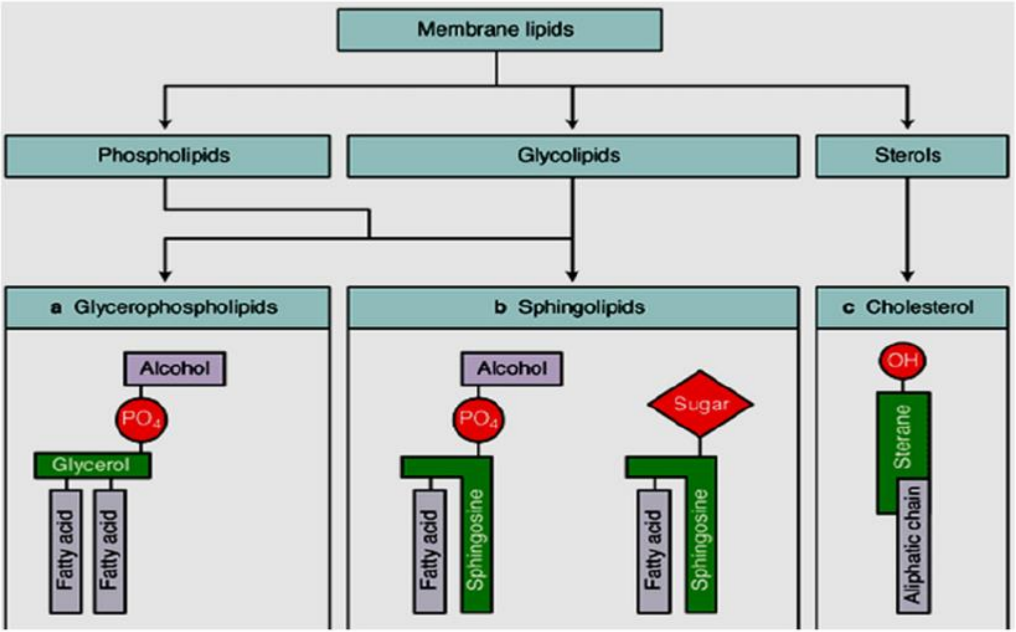
Double bond in the ***trans*** configuration

Example: margarine

- 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.

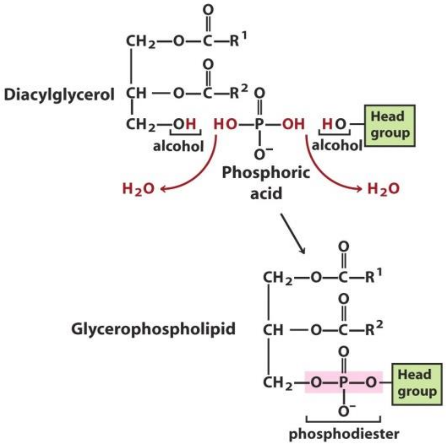
Membrane lipids

The most prevalent class of lipids in membranes is the <u>glycerophospholipids</u>



Phospholipids (phosphoacylglycerols)

- Phosphatidic acids
- Phosphatidylcholine (lecithin)
  - Most abundant membrane lipid
- Cephalins
  - Phosphatidylethanolamine
  - Phosphatidylserine
    - abundant in brain
- Phosphatidylinositol
  - sends messages across cell membranes
- Cardiolipin
- Plasmalogens

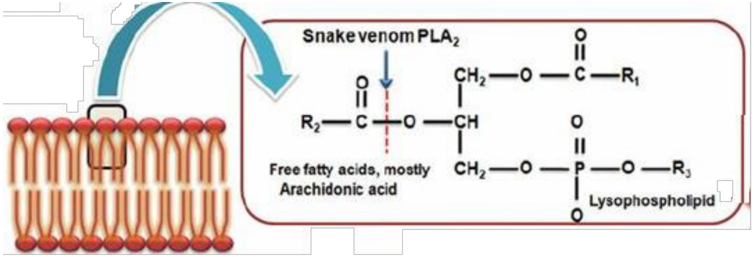


Phosphatidic acid	—	$-H$
Phosphatidylethanolamine	Ethanolamine	$-CH_2-CH_2-\overset{+}{N}H_3$
Phosphatidylcholine	Choline	$-CH_2-CH_2-\overset{+}{N}(CH_3)_3$
Phosphatidylserine	Serine	$-CH_2-\underset{COO^-}{CH}-\overset{+}{N}H_3$

Glycerophospholipids - Lecithins

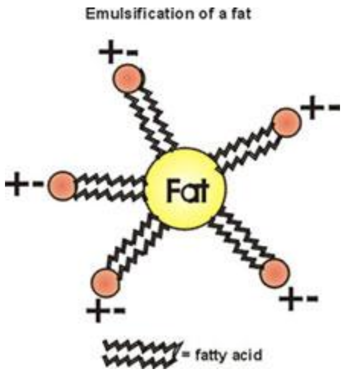
- Snake venom contains an enzyme called lecithinase, specifically phospholipase A2, which hydrolyzes polyunsaturated fatty acids and converts lecithin into lysolecithin.
  - hemolysis of RBCs

Phosphatidylcholine **Choline** $-CH_2-CH_2-\overset{+}{N}(CH_3)_3$



Emulsification

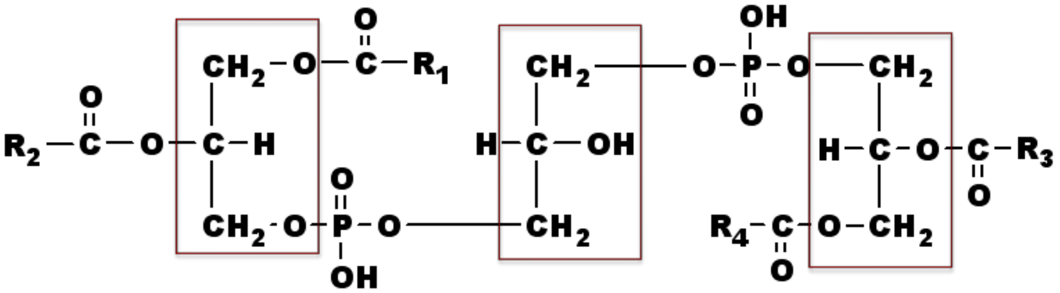
- Because of their amphipathic nature, they act as emulsifying agents, that is substances that can surround nonpolar molecules and keep them in suspension in water.



Glycerophospholipids - Cardiolipins

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

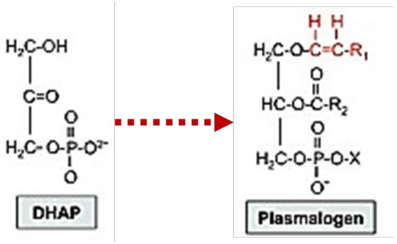
Do not memorize the structures but study them

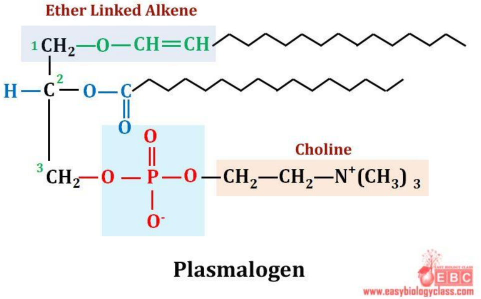


Cardiolipin

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:
  - 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

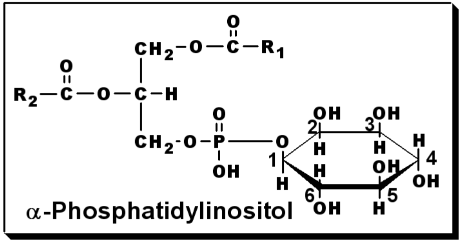




Glycerophospholipids - Inositides

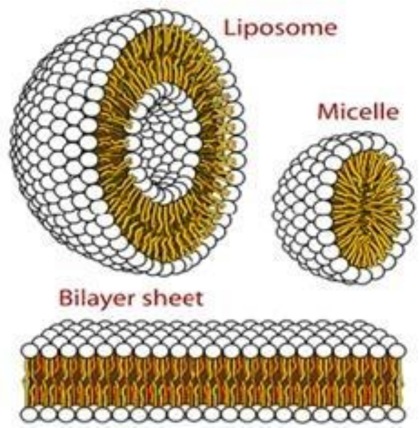
- Phosphatidyl inositol
- Cyclic sugar alcohol (inositol)
- Structure: glycerol, saturated FA, unsaturated FA, phosphoric acid, & inositol
- Source: Brain tissues

- Functions:
  - Major component of the cell membrane
  - Signalling molecules are produced upon hydrolysis

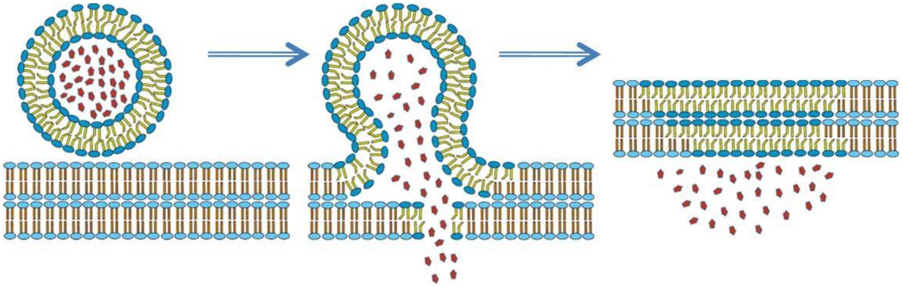


α-Phosphatidylinositol

The different structures of phospholipids

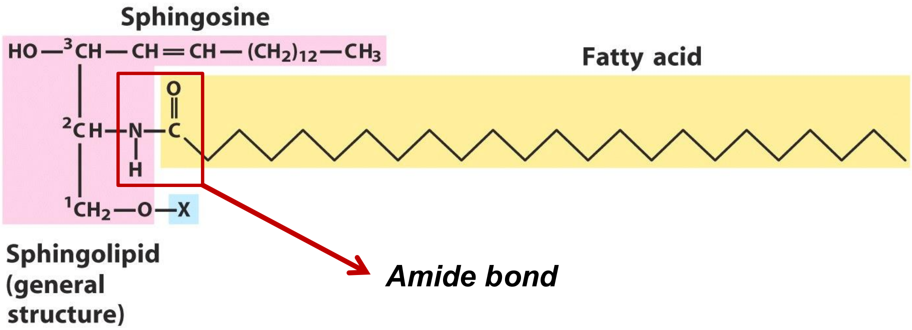


Uses of liposomes: delivery



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.

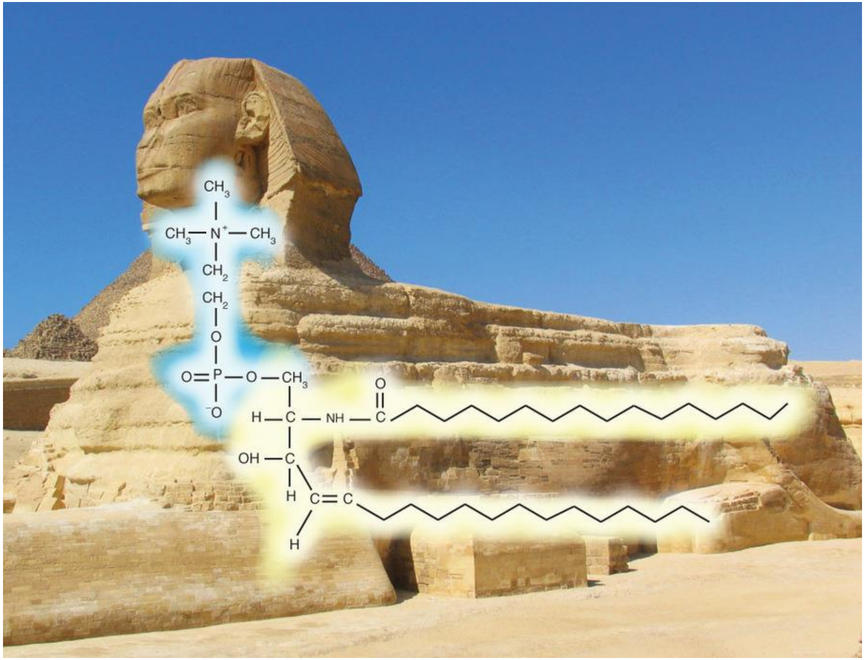


Mysterious lipids

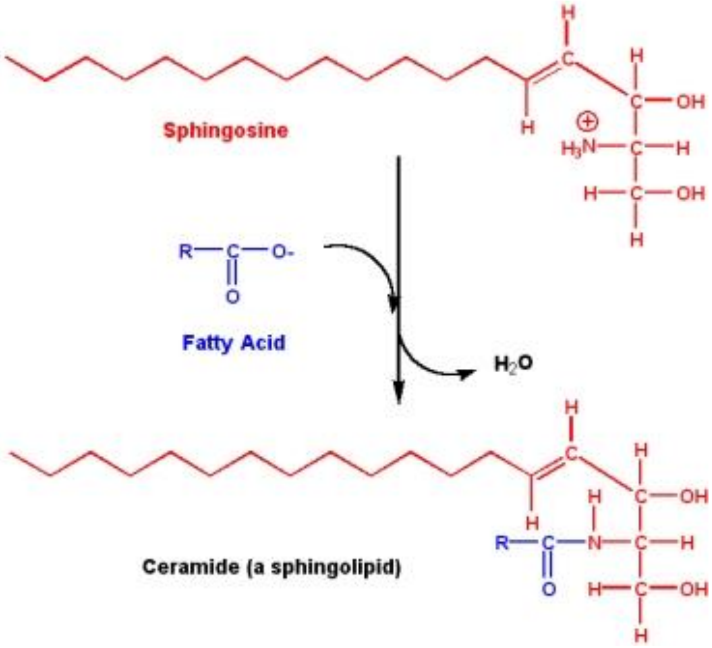
***Sphynx* → *sph*ingolipids**

<u>Trivia</u>

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



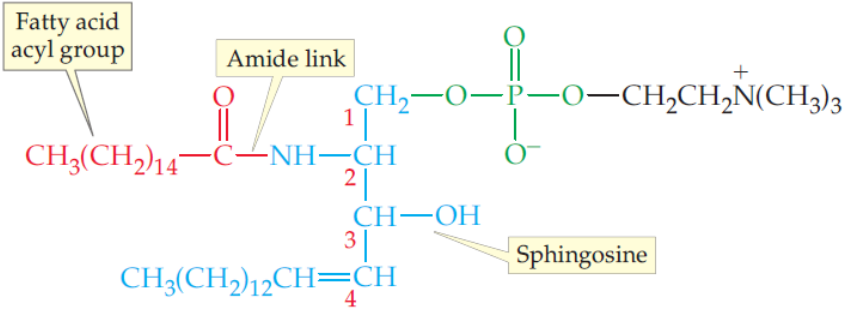
Ceramide



Sphingosine
H
C
H
C
OH
H
H_3N
C
H
H
C
OH
H
R
C
O-
O
Fatty Acid
H_2O
H
C
H
C
OH
H
H
R
C
N
C
H
O
H
C
OH
H
Ceramide (a sphingolipid)

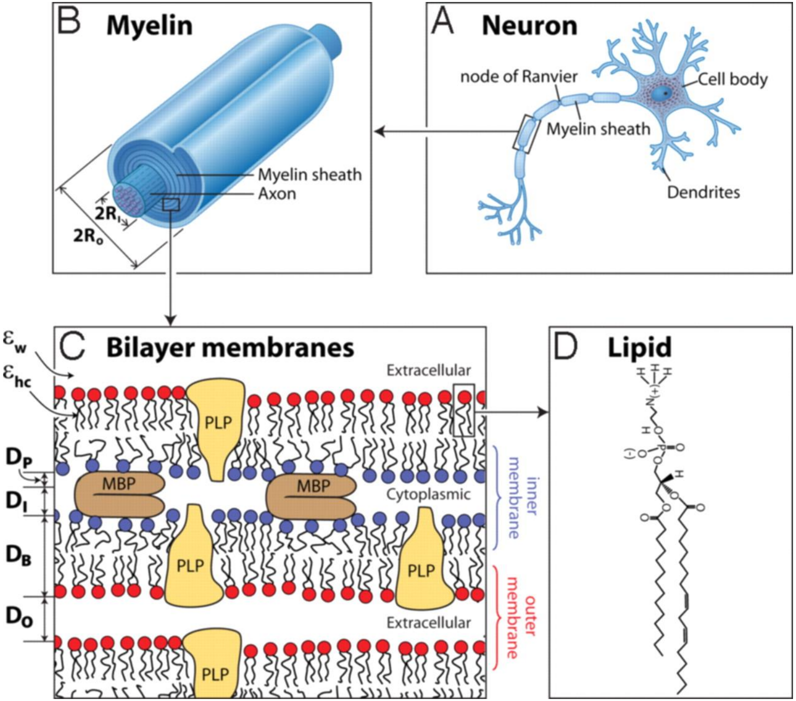
Types of sphingolipids

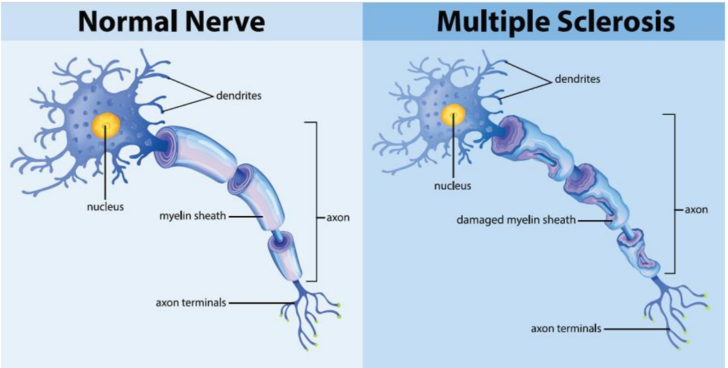
- The sphingolipids are divided into two subcategories:
  - Sphingomyelin
    - It is a sphingolipid that is a major component of the coating around nerve fibers.
    - The group attached to C1 is a phosphocholine
  - Glycosphingolipid (or glycolipids)



A sphingomyelin (a sphingolipid)

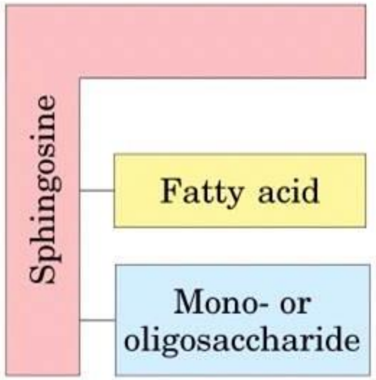
Zooming into the myelin





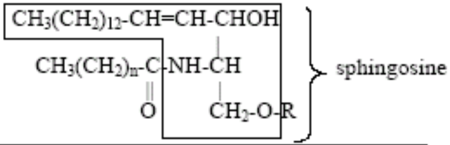
Glycolipids

- Sphingolipids can also contain carbohydrates attached at C-1 and these are known as glycolipids.
- Glycolipids are present on cell membranes and act as cell surface receptors that can function in cell recognition (e.g., pathogens) and chemical messengers.
- There are three types of glycolipids:
  - Cerebrosides
  - Globosides
  - Gangliosides



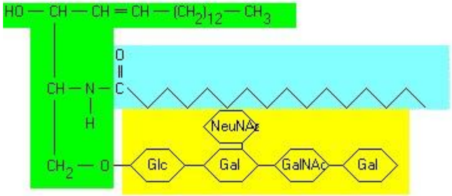
Glycolipids

- Cerebrosides: the simplest glycolipids, contain a single hexose (galactose or glucose).
- Globosides and gangliosides are more complex glycolipids.
- Both contain glucose, galactose, and N-acetylgalactosamine, but gangliosides must also contain sialic acid.

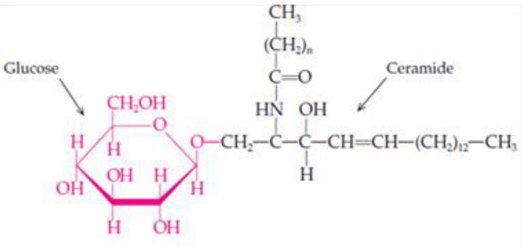


glycolipids

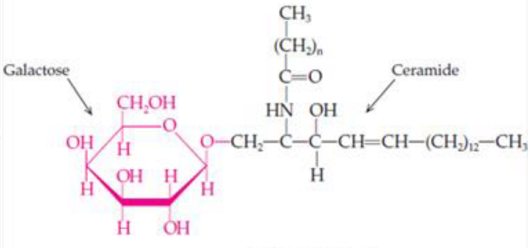
Sphingolipid type	R group
Ceramide	H
Sphingomyelin	phosphocholine
Cerebroside	monosaccharide (galactose or glucose)
Globoside	two or more sugars (galactose, glucose, N-acetylglucosamine
Ganglioside	three or more sugars including at least one sialic acid



Gangliosides are bound by cholera toxin in the human intestine facilitating its endocytosis into the cells.



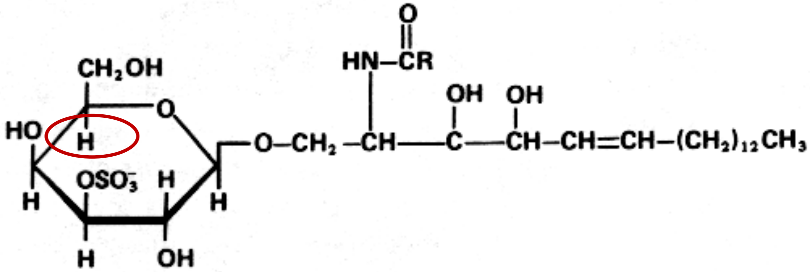
Glucocerebroside

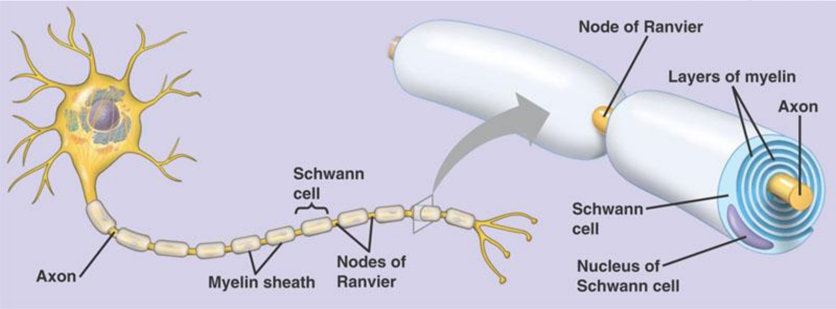


Galactocerebroside

Sulfatides

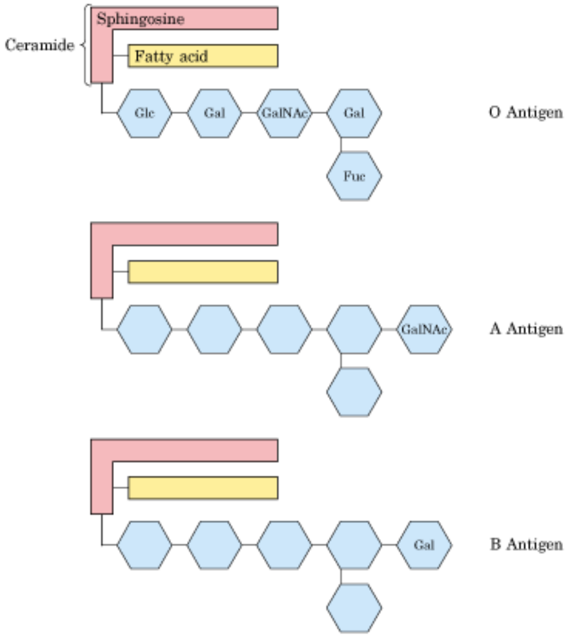
- Synthesized from galactocerebroside
- Abundant in brain myelin



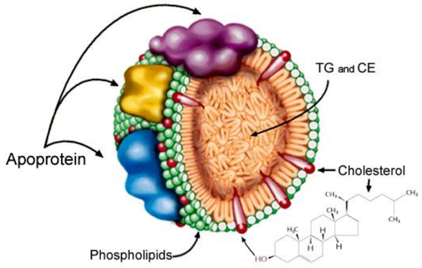


Sphingolipids and blood groups

- Sphingolipids serve in intercellular communication and as the antigenic determinants of the ABO blood groups.
- Some are used as receptors by viruses and bacterial toxins.



Lipoproteins



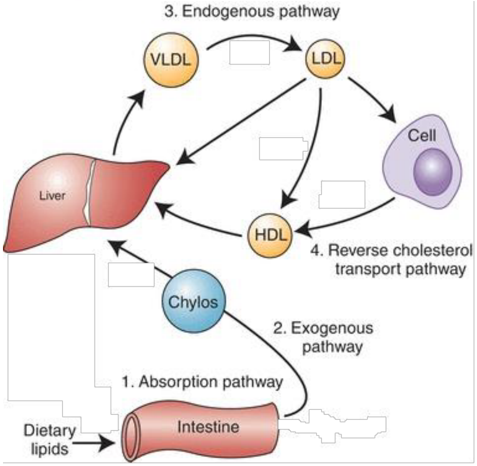
Function: transport of different types of lipids (cholesterol, cholesterol esters, phospholipids & triacylglycerols) in blood plasma.

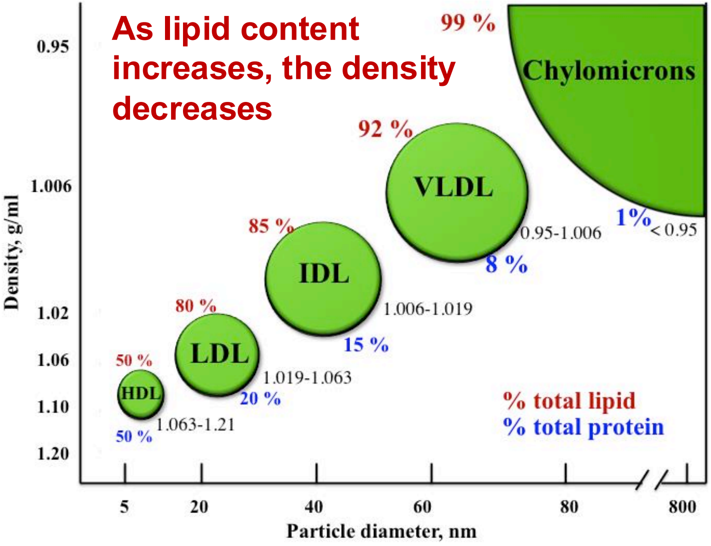
VLDL: very low-density lipoprotein

LDL: low-density lipoprotein

IDL: intermediate-density lipoprotein

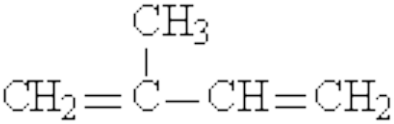
HDL: high-density lipoprotein





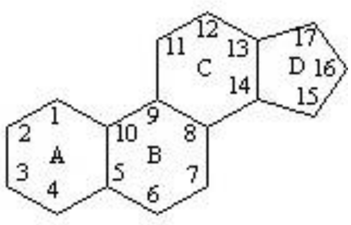
Steroids

The precursor



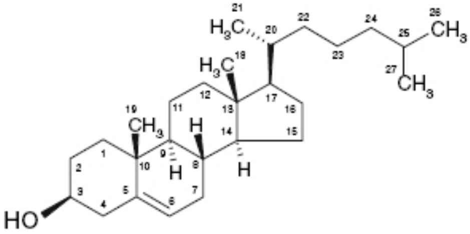
Isoprene

The nucleus



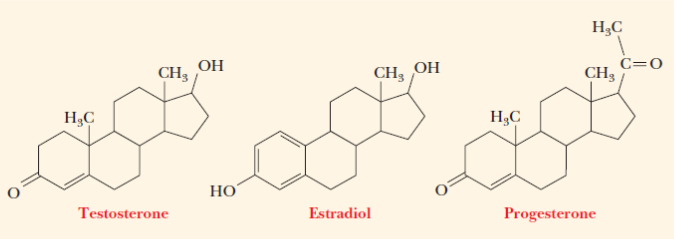
Steroid nucleus

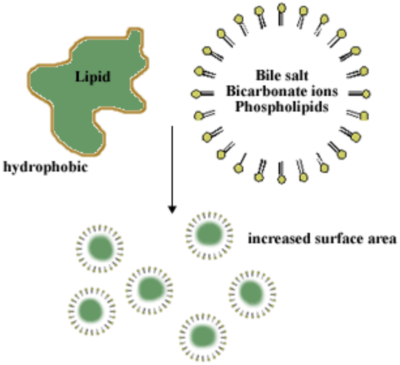
The most common steroid

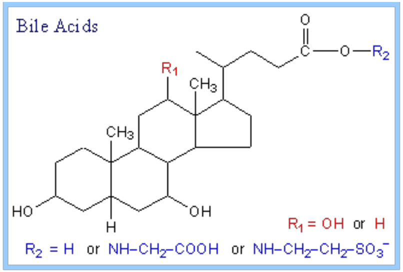


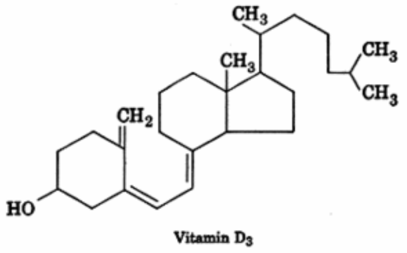
Products of cholesterol

- Hormones
  - Sex hormones (androgens,. estrogens, progestins)
- Vitamin D
- Bile acids (intestinal absorption of fat)



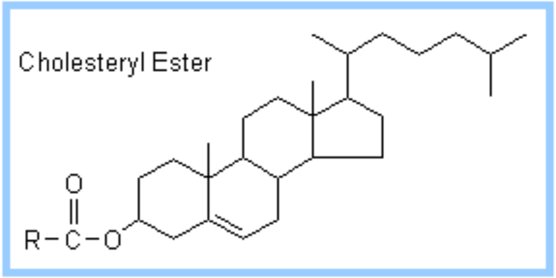


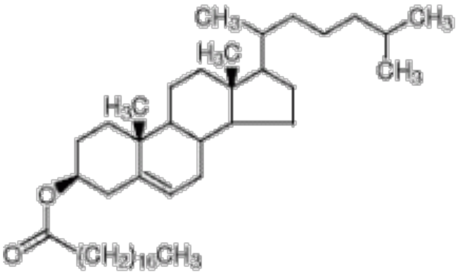




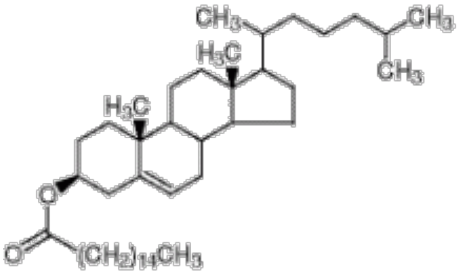
Cholesterol esters

- A cholesterol with a fatty acid attached at (-OH) of C3

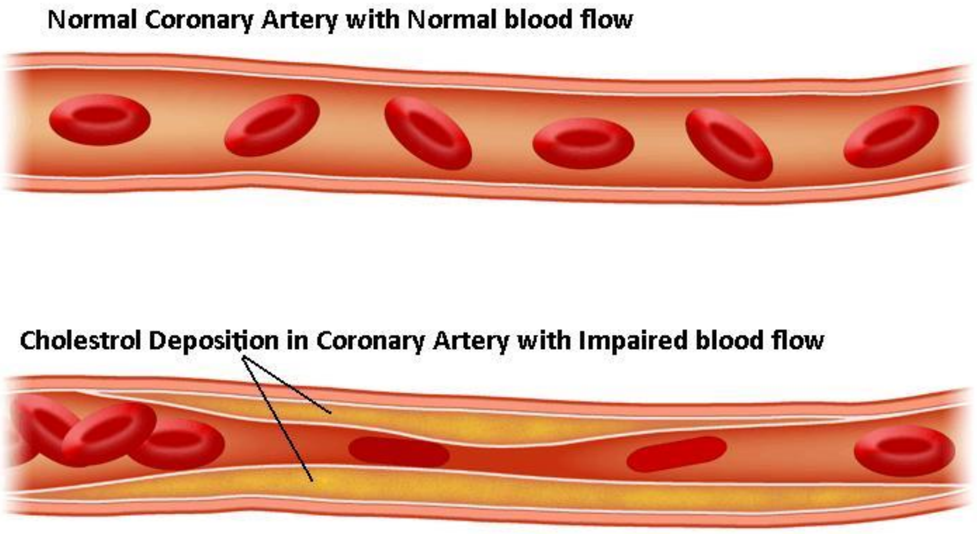




Name the molecules?

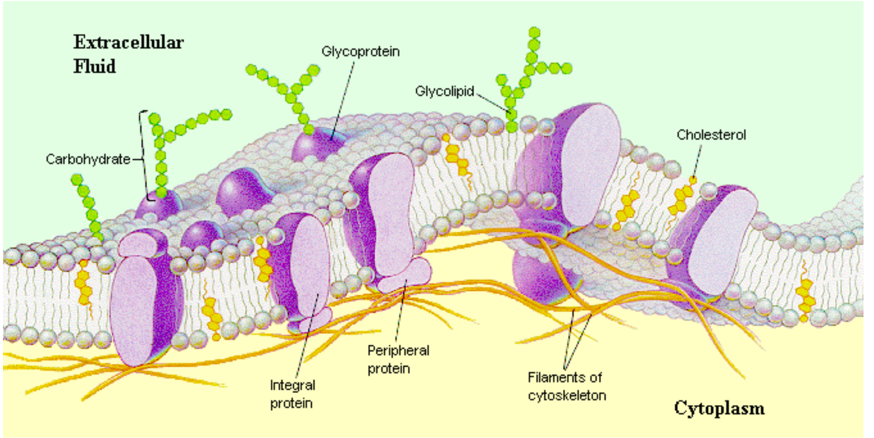


Atherosclerosis



Cell membranes

- The membrane is hypothesized in a model known as the fluid mosaic model.
- Components: 45% lipid, 45% protein and 10% carbohydrate
- They exist side by side without forming some other substance of intermediate nature.

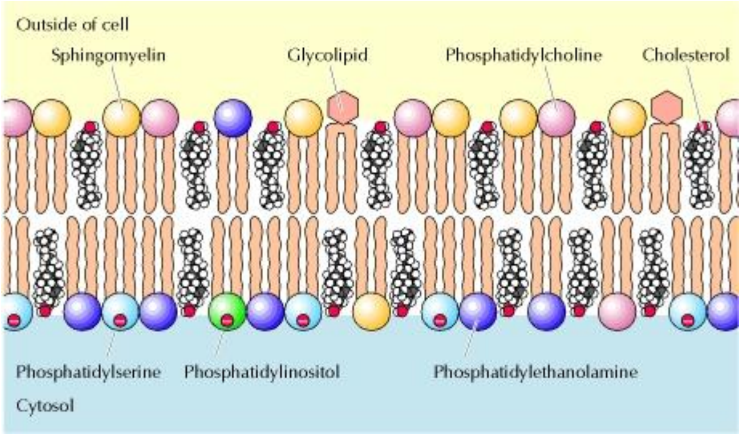


Phospholipids

- The outer: phosphatidylcholine, sphingomyelin, and glycolipids(cell recognition)
- The inner: phosphatidylethanolamine, phosphatidylserine, and phosphatidylinositol (signaling)

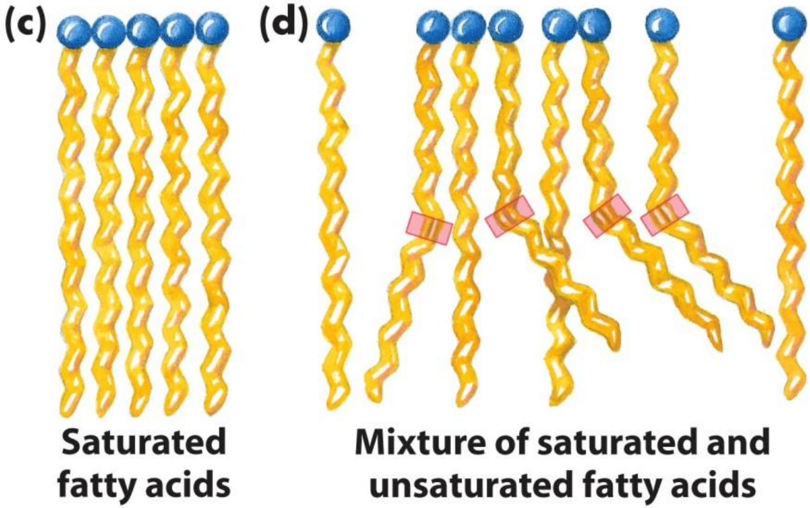
Cholesterol is distributed in both leaflets

Animal cells vs. plant cells vs. prokaryotic cells



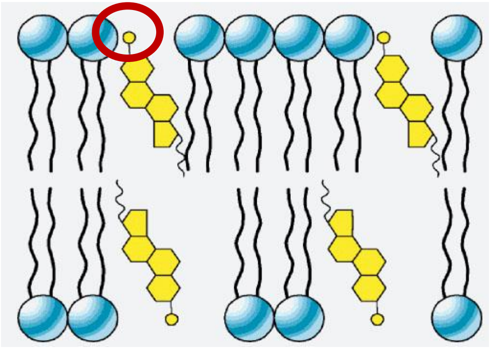
Fatty acids and membrane fluidity

- Saturated fatty acids have straight hydrocarbon tails, allowing them to pack closely together, creating a rigid membrane.
- Unsaturated fatty acids have kinks in their tails due to double bonds, preventing tight packing and increasing membrane fluidity.

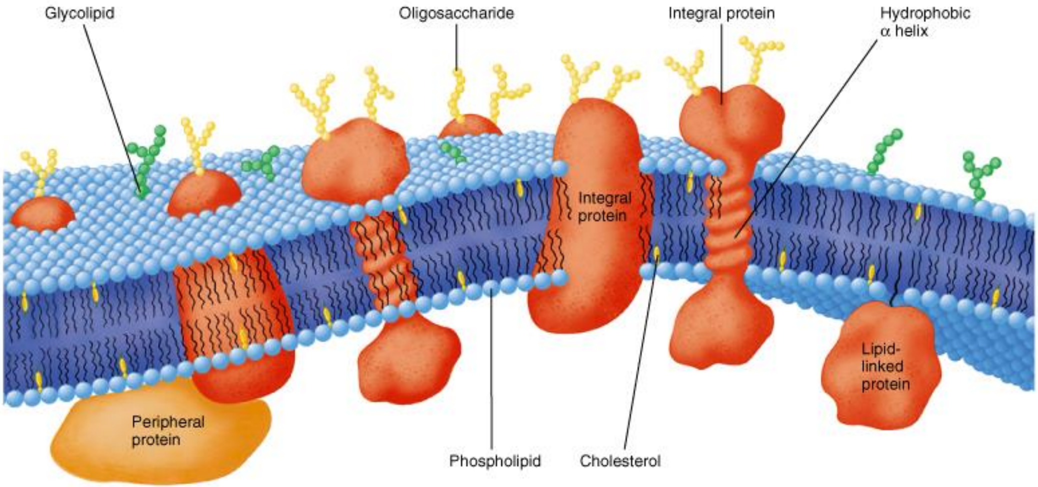


Cholesterol and membrane fluidity

- The presence of cholesterol and the cis unsaturated fatty acids in the membrane prevents the hydrophobic chains from packing too closely together, allowing free membrane proteins and lipid molecules to move laterally in the plane of the leaflet, making the membrane a dynamic environment.
- Cholesterol can also stabilize the fluidic membranes by increasing interactions between the fatty acids of phospholipids through hydrophobic interactions with the cholesterol ring structure.
- Note the significance of cholesterol at low and high temperatures.



Membrane proteins

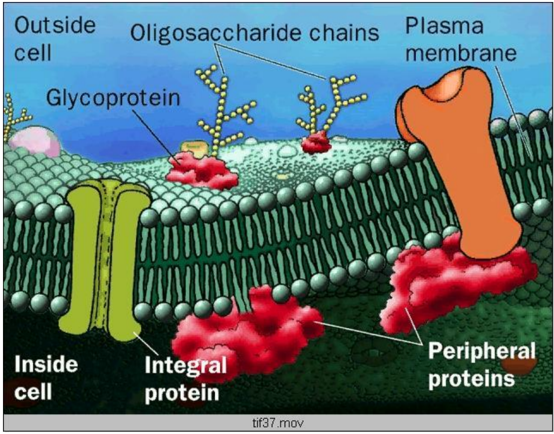


Types of membrane proteins

- Peripheral proteins:
  - are associated with the exterior of membranes via noncovalent interactions
- Integral membrane proteins:
  - anchored into membrane via hydrophobic regions
- Lipid-anchored:
  - associated via a lipid group

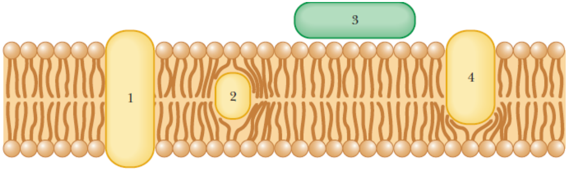
Peripheral membrane proteins

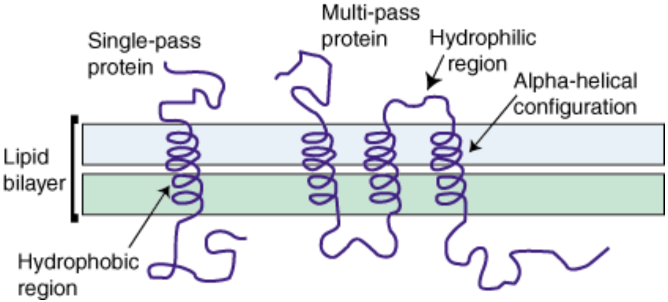
- They are associated with membranes but do not penetrate the hydrophobic core of the membrane.
  - They can be associated with integral membrane proteins.
- They are not strongly bound to the membrane and can be removed without disrupting the membrane structure.
  - Treatment with mild detergent



Integral membrane proteins

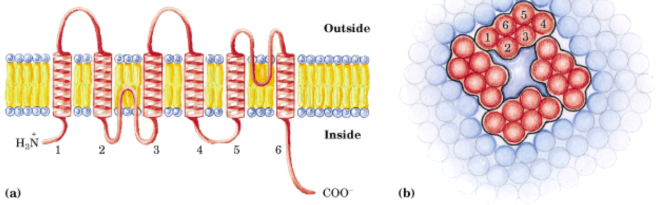
The integral membrane proteins can be associated with the lipid bilayer in several ways.





The membrane integral domains are:
1. Single or multiple
2. α-helix (human) or β-sheet (bacteria)

Some can form channels.



Structure-function of Membranes

- Transport:
  - Membranes are impermeable barrier
  - Proteins can be carriers or channels
- Signaling
  - Protein receptors and small molecules (some can be lipids themselves)
- Catalysis
  - Enzymes