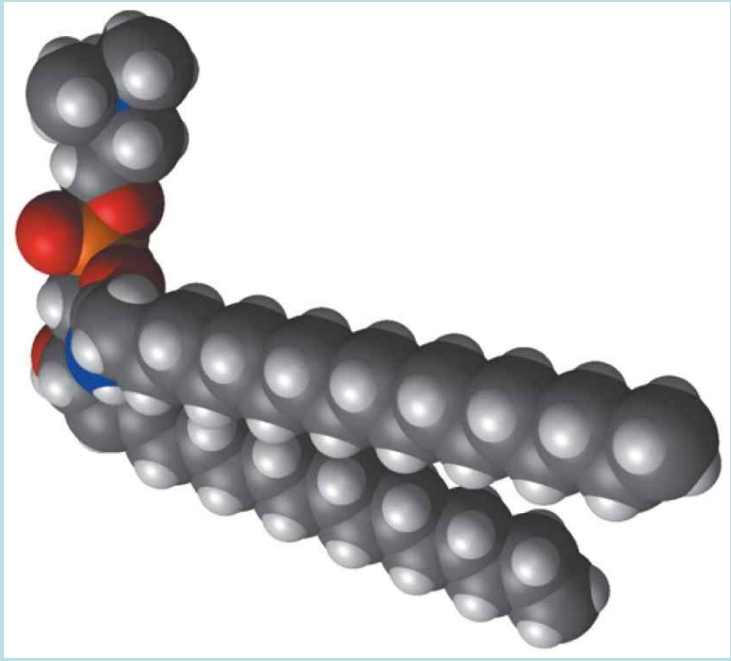
Chapter 10

Lipids



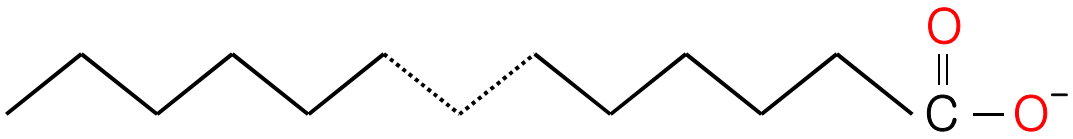
Lipids

- **Fats or Oils:** stored forms of energy
- **Phospholipids, Sterols:** major structural elements of biological membrane
- **Other lipids:** roles as enzyme cofactor, electron carrier, hydrophobic anchor, hormones, intracellular messengers

Storage lipids
Structural lipids in membranes
Lipids as signals, cofactors, and pigments

Storage lipids (derivatives of fatty acids)

Fatty acids: carboxylic acids with hydrocarbon chains (C_4 to C_{36})



Saturated fatty acids
Unsaturated fatty acids

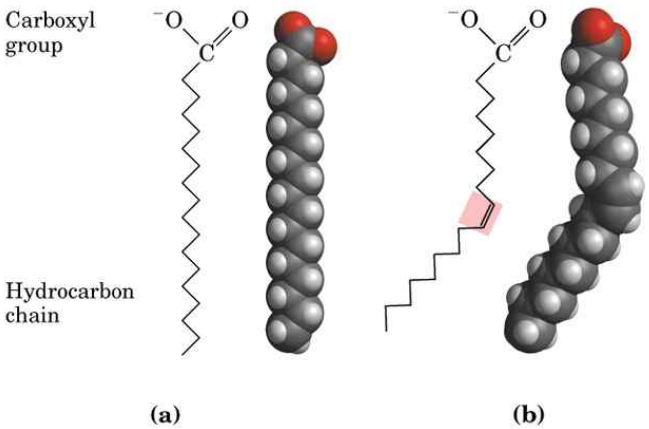


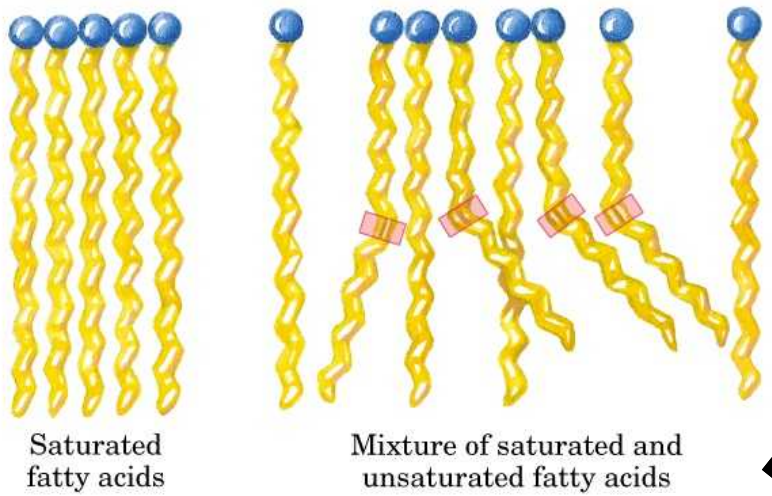
TABLE 10–1 Some Naturally Occurring Fatty Acids: Structure, Properties, and Nomenclature

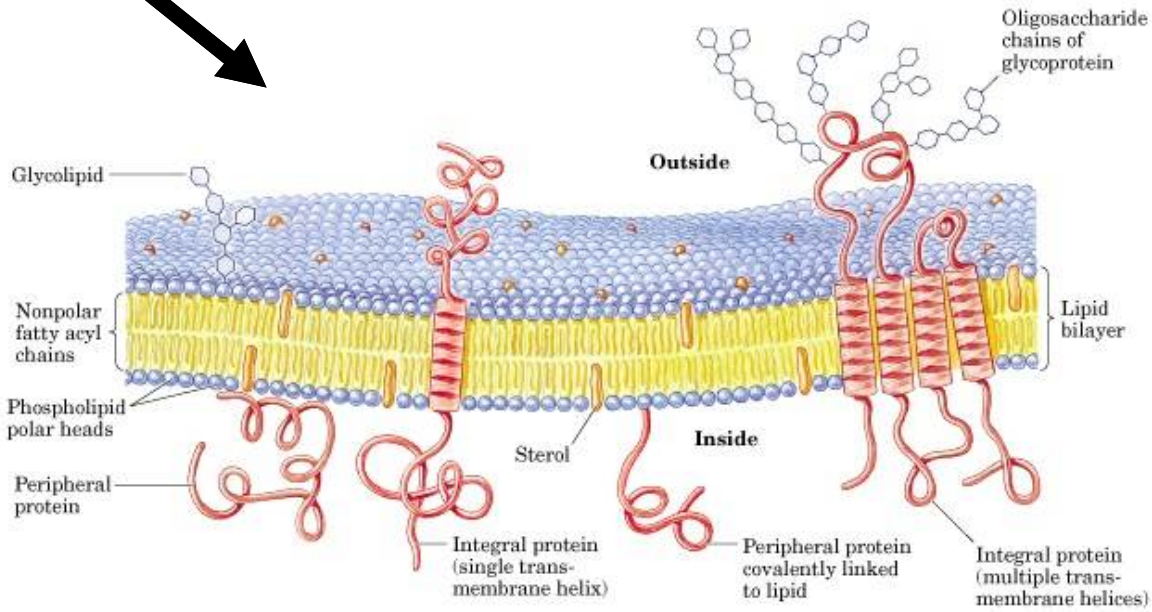
Carbon skeleton	Structure*	Systematic name†	Common name (derivation)	Melting point (°C)	Solubility at 30 °C (mg/g solvent) Water	Benzene
12:0	$CH_3(CH_2)_{10}COOH$	*n*-Dodecanoic acid	Lauric acid (Latin *laurus*, "laurel plant")	44.2	0.063	2,600
14:0	$CH_3(CH_2)_{12}COOH$	*n*-Tetradecanoic acid	Myristic acid (Latin *Myristica*, nutmeg genus)	53.9	0.024	874
16:0	$CH_3(CH_2)_{14}COOH$	*n*-Hexadecanoic acid	Palmitic acid (Latin *palma*, "palm tree")	63.1	0.0083	348
18:0	$CH_3(CH_2)_{16}COOH$	*n*-Octadecanoic acid	Stearic acid (Greek *stear*, "hard fat")	69.6	0.0034	124
20:0	$CH_3(CH_2)_{18}COOH$	*n*-Eicosanoic acid	Arachidic acid (Latin *Arachis*, legume genus)	76.5		
24:0	$CH_3(CH_2)_{22}COOH$	*n*-Tetracosanoic acid	Lignoceric acid (Latin *lignum*, "wood" + *cera*, "wax")	86.0		
16:1(Δ^9)	$CH_3(CH_2)_5CH{=}CH(CH_2)_7COOH$	*cis*-9-Hexadecenoic acid	Palmitoleic acid	1–0.5		
18:1(Δ^9)	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$	*cis*-9-Octadecenoic acid	Oleic acid (Latin *oleum*, "oil")	13.4		
18:2($\Delta^{9,12}$)	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$	*cis*-,*cis*-9,12-Octadecadienoic acid	Linoleic acid (Greek *linon*, "flax")	1–5		
18:3($\Delta^{9,12,15}$)	$CH_3CH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$	*cis*-,*cis*-,*cis*-9,12,15-Octadecatrienoic acid	α-Linolenic acid	−11		
20:4($\Delta^{5,8,11,14}$)	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_3COOH$	*cis*-,*cis*-,*cis*-,*cis*-5,8,11,14-Icosatetraenoic acid	Arachidonic acid	−49.5		

*All acids are shown in their nonionized form. At pH 7, all free fatty acids have an ionized carboxylate. Note that numbering of carbon atoms begins at the carboxyl carbon.

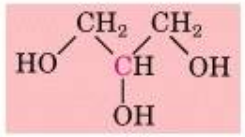
†The prefix *n*- indicates the "normal" unbranched structure. For instance, "dodecanoic" simply indicates 12 carbon atoms, which could be arranged in a variety of branched forms; "*n*-dodecanoic" specifies the linear, unbranched form. For unsaturated fatty acids, the configuration of each double bond is indicated; in biological fatty acids the configuration is almost always cis.

The packing of fatty acids into stable aggregates

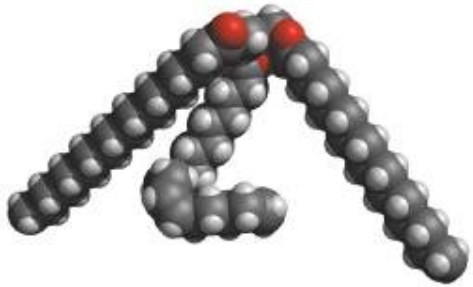


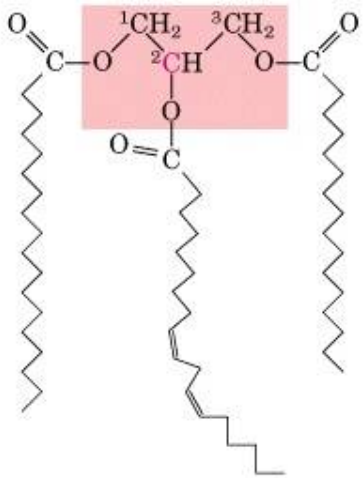


Triacylglycerols (triglycerides, fats)



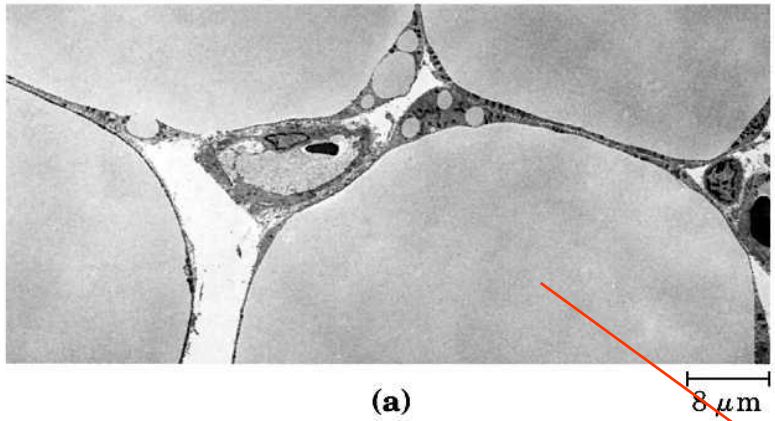
Glycerol





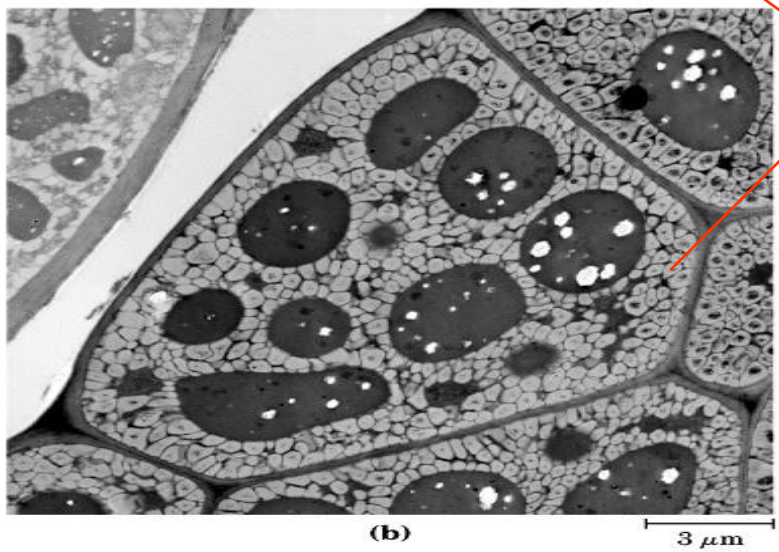
1-Stearoyl, 2-linoleoyl, 3-palmitoyl glycerol,
a mixed triacylglycerol

provide stored energy and insulation
(hydrolyzed by **lipases**)



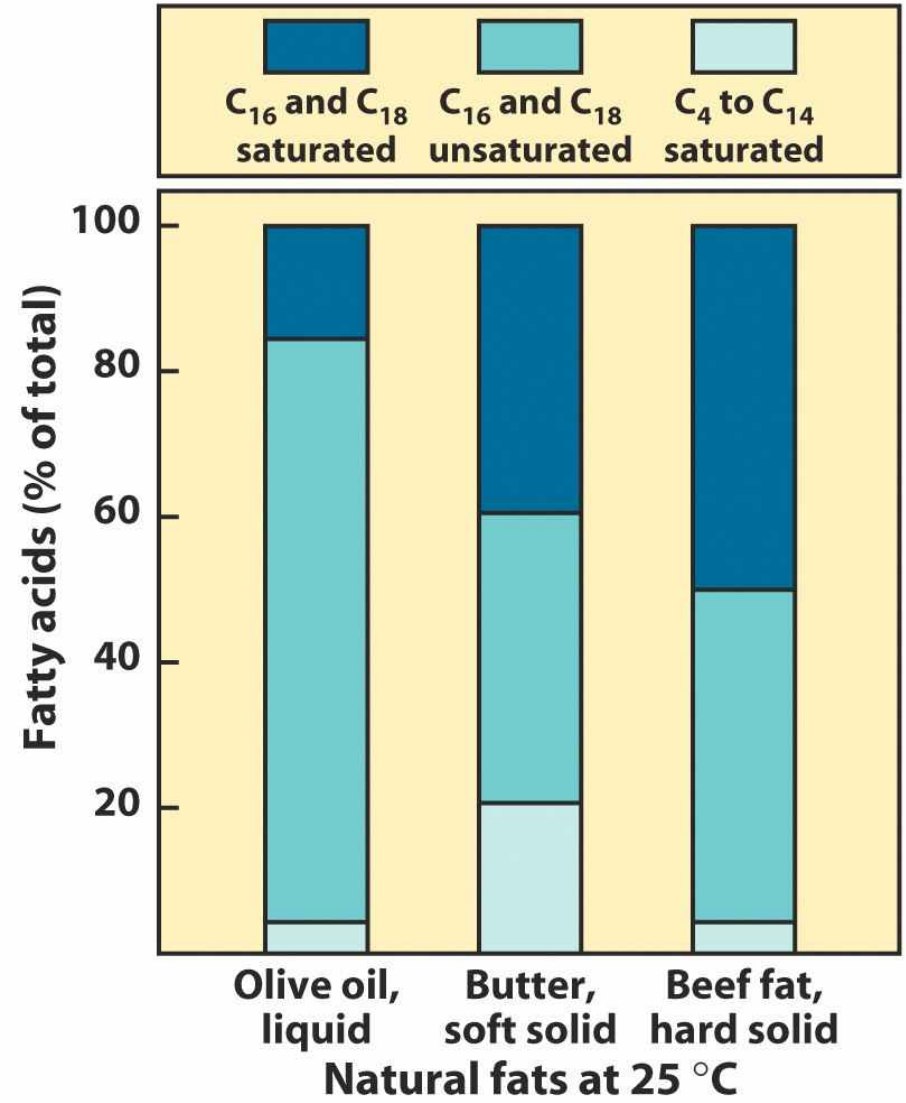
adipocytes

fat



seed

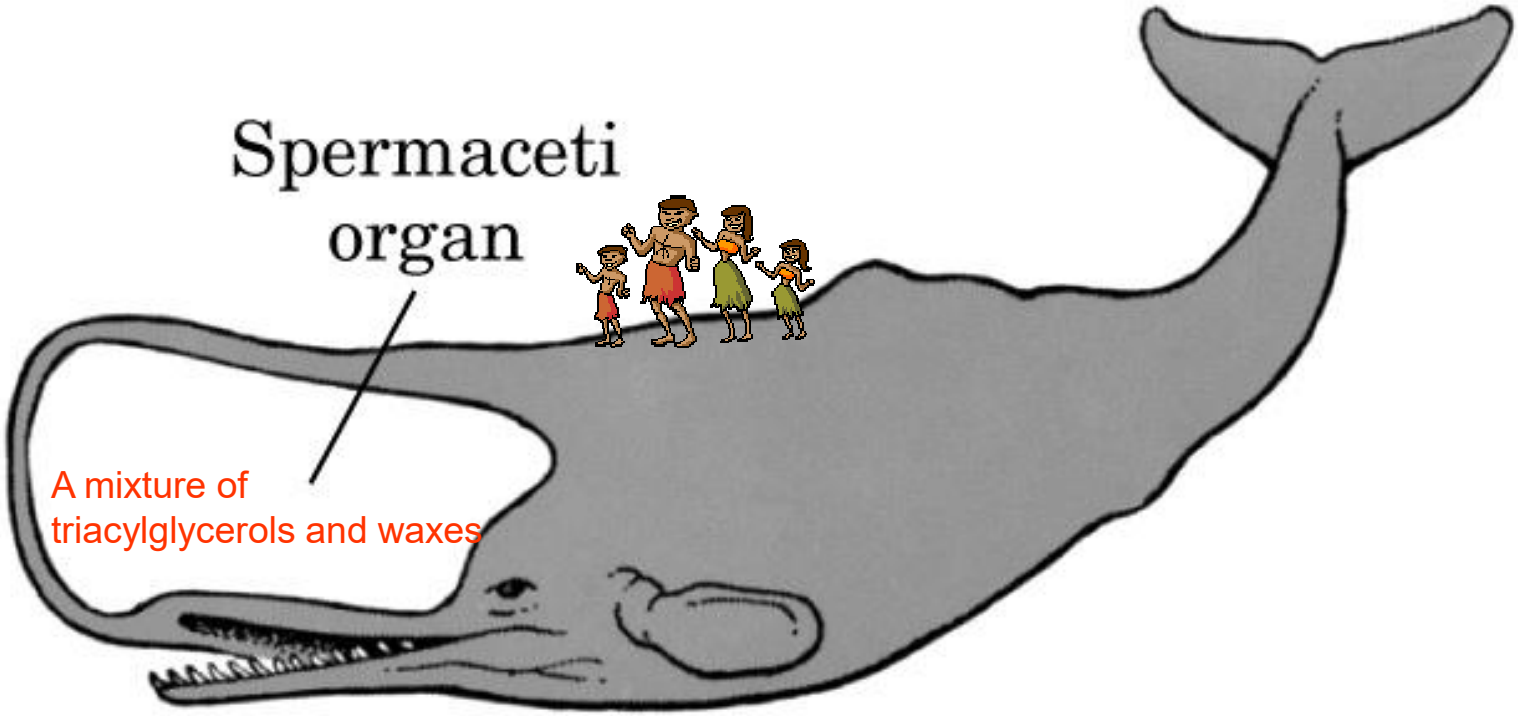
Many food contain triacylglycerol

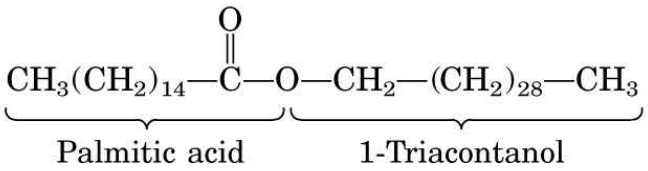


Using triacylglycerol as stored fuels:

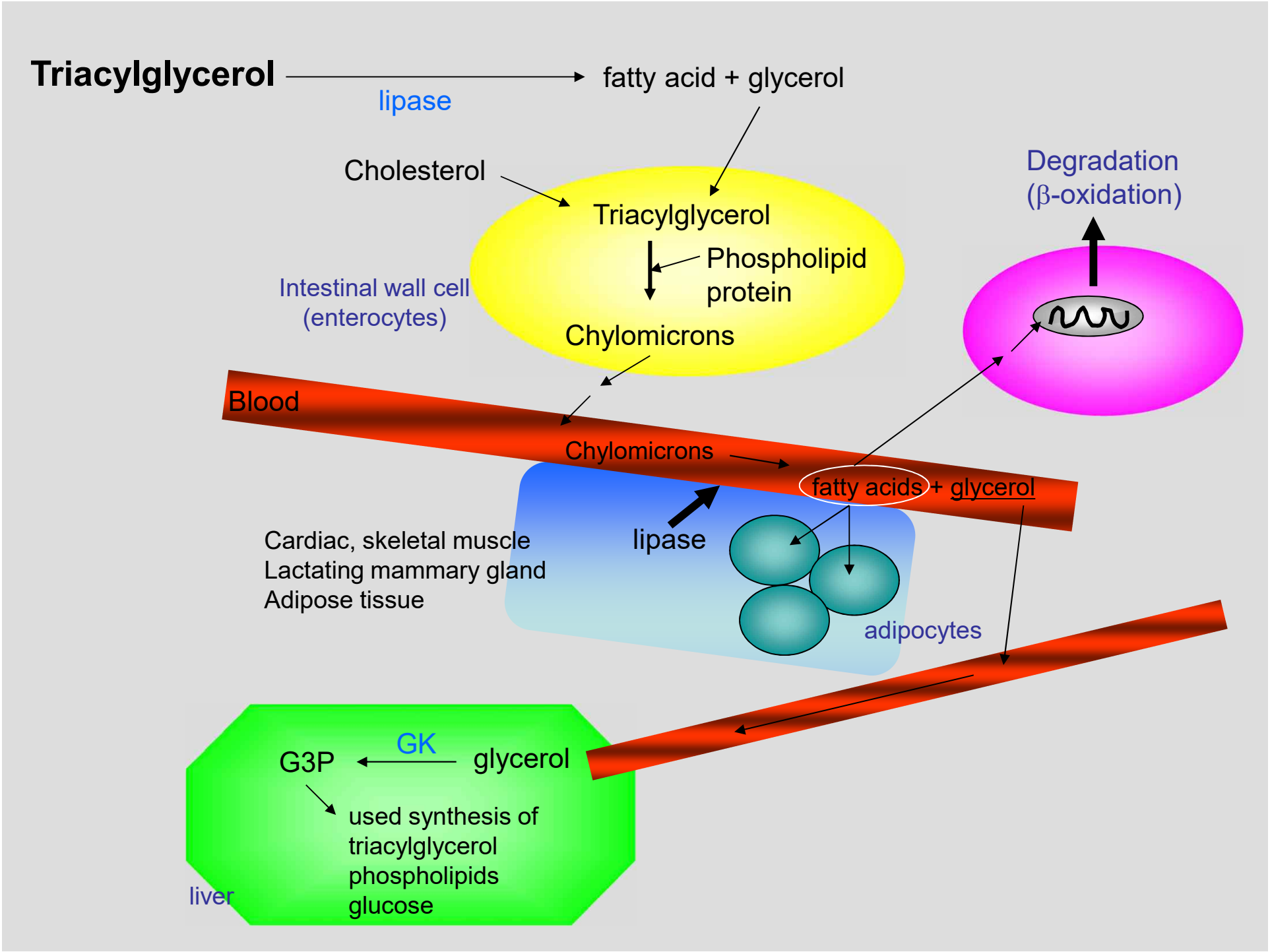
(1) More reduced than those of sugars
(2) Hydrophobic and unhydrated

Sperm whale

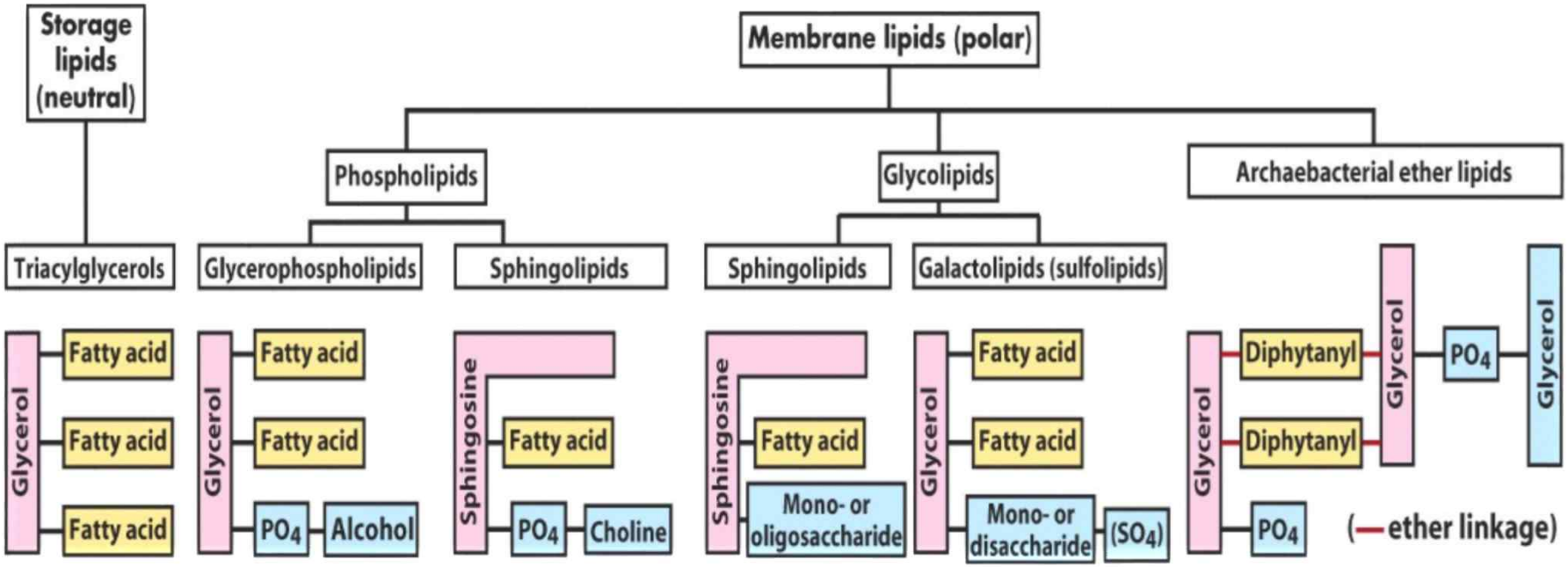




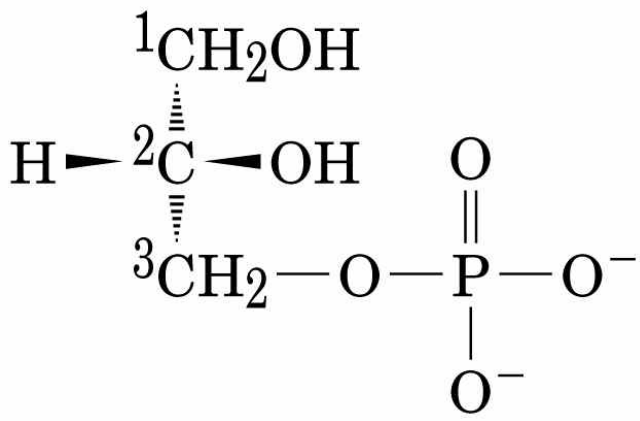
(a)


Triacylglycerol
lipase
fatty acid + glycerol
Cholesterol
Triacylglycerol
Phospholipid
protein
Chylomicrons
Intestinal wall cell
(enterocytes)
Degradation
(β-oxidation)
Blood
Chylomicrons
fatty acids + glycerol
lipase
Cardiac, skeletal muscle
Lactating mammary gland
Adipose tissue
adipocytes
GK
G3P
glycerol
used synthesis of
triacylglycerol
phospholipids
glucose
liver

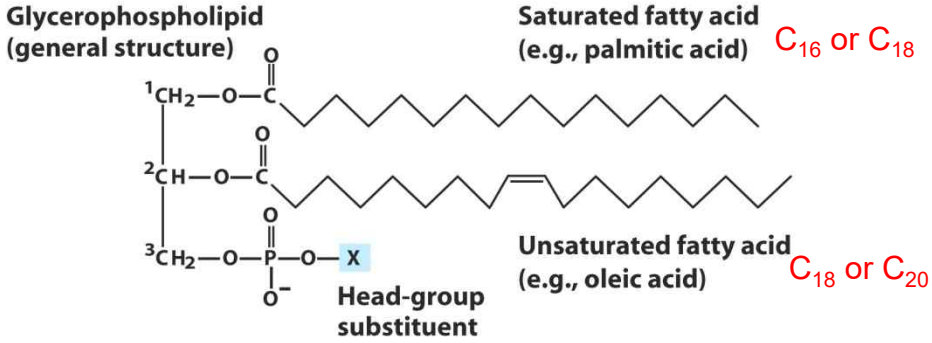
Structural lipids in membrane

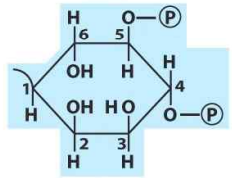
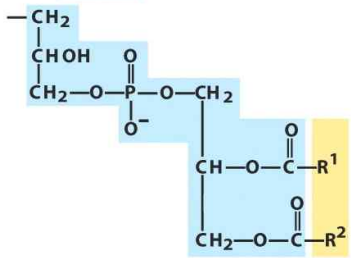


Glycerophospholipids (phosphoglycerides)

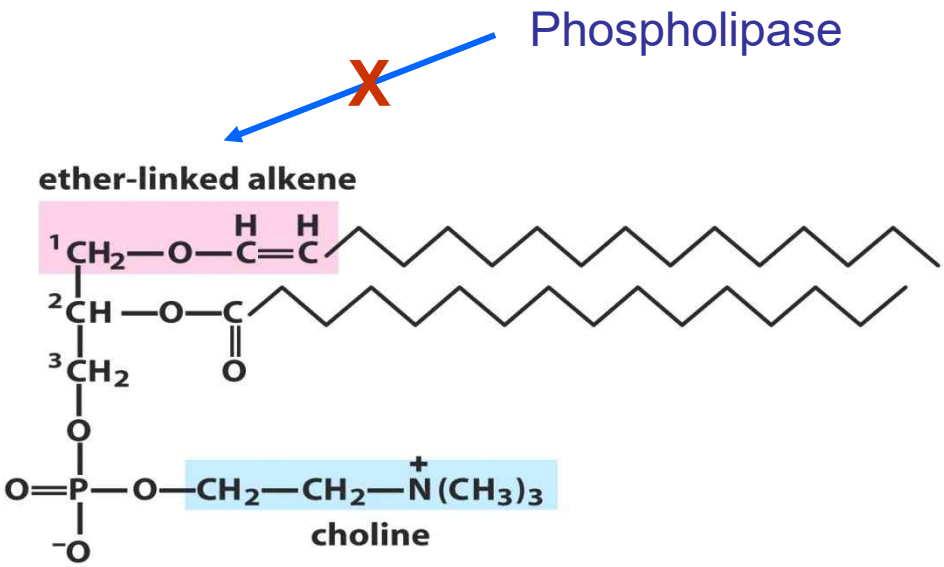


Glycerol 3-Phosphate

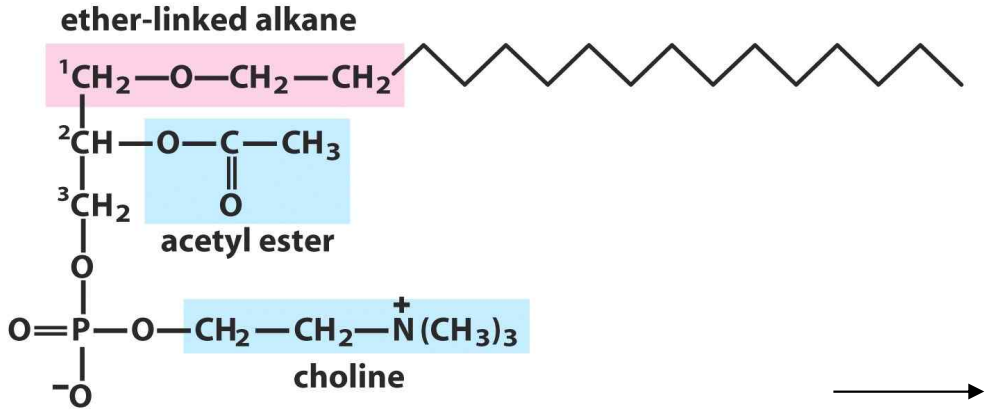


Name of glycerophospholipid	Name of X	Formula of X	Net charge (at pH 7)
Phosphatidic acid	—	—H	−1
Phosphatidylethanolamine	Ethanolamine	$-CH_2-CH_2-\overset{+}{N}H_3$	0
Phosphatidylcholine	Choline	$-CH_2-CH_2-\overset{+}{N}(CH_3)_3$	0
Phosphatidylserine	Serine	$-CH_2-\underset{COO^-}{CH}-\overset{+}{N}H_3$	−1
Phosphatidylglycerol	Glycerol	$-CH_2-\underset{OH}{CH}-CH_2-OH$	−1
Phosphatidylinositol 4,5-bisphosphate	*myo*-Inositol 4,5-bisphosphate		−4
Cardiolipin	Phosphatidyl-glycerol		−2

Some phospholipids have ether-linked fatty acids



Plasmalogen (~ 50% of heart phospholipids in vertebrate)

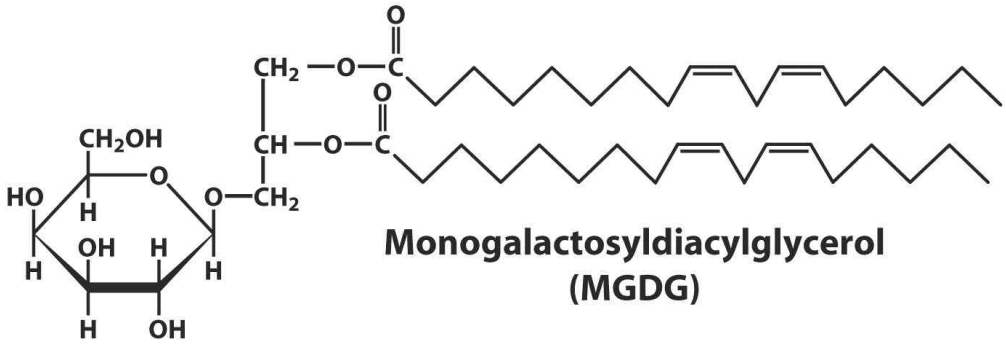


Platelet-activating factor → Platelet aggregation
Serotonin release

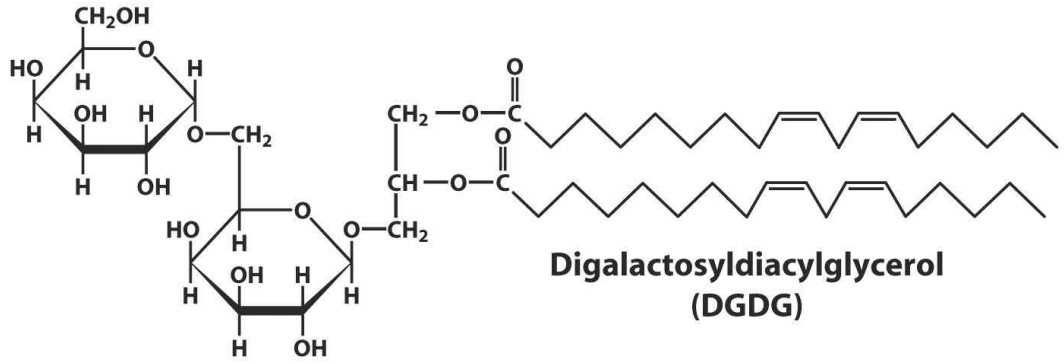
Galactolipids & Sulfolipids

predominate in plant cells

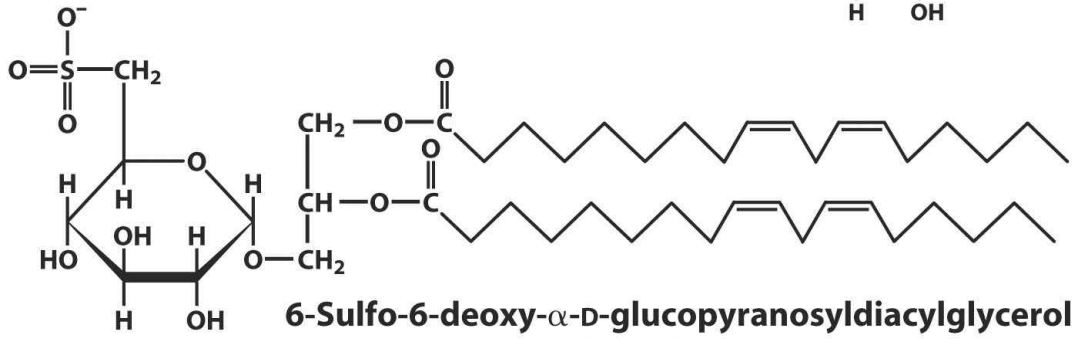
localized in the thylakoid membranes of chloroplasts



Monogalactosyldiacylglycerol (MGDG)

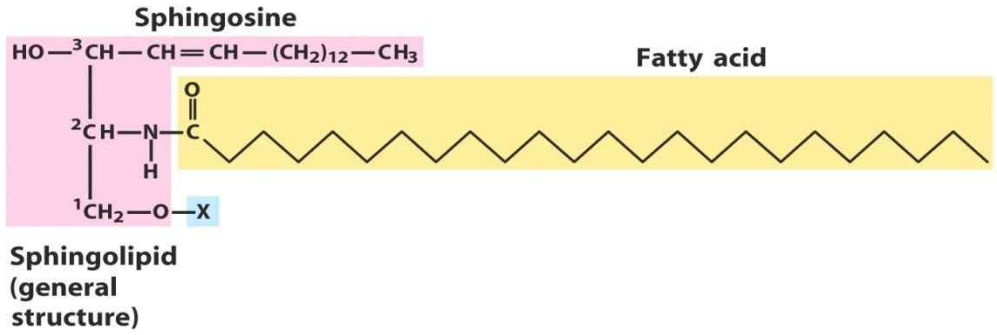


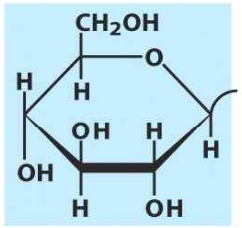
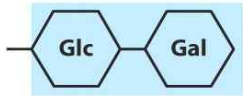
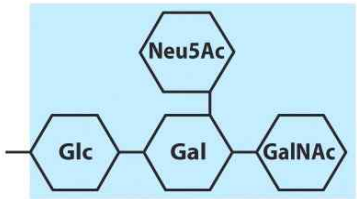
Digalactosyldiacylglycerol (DGDG)



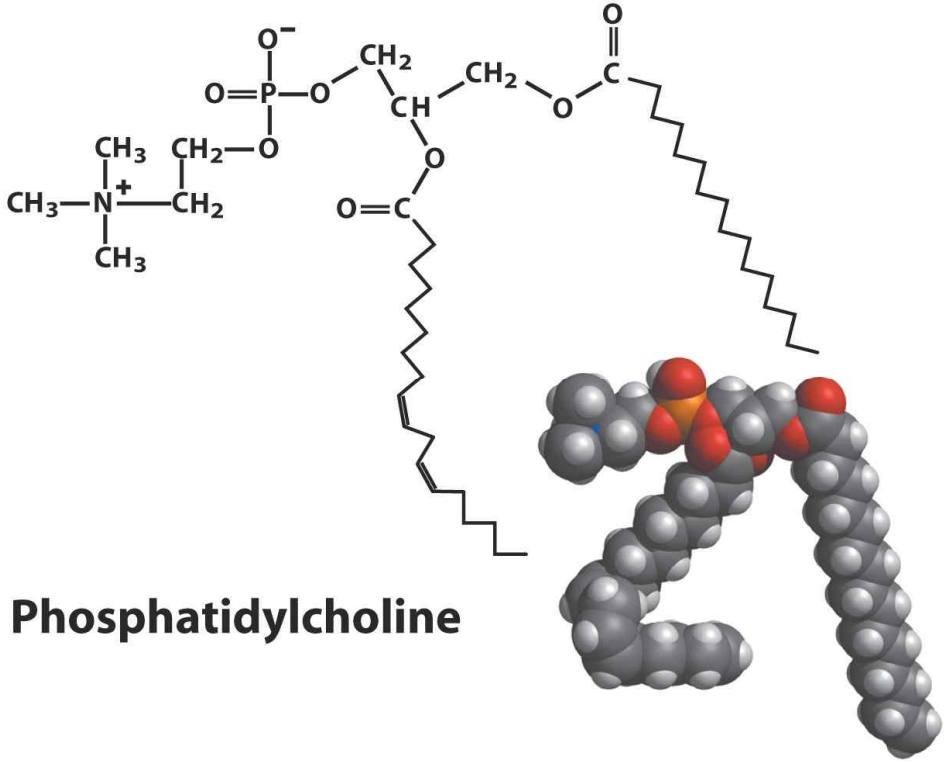
6-Sulfo-6-deoxy-α-D-glucopyranosyldiacylglycerol (a sulfolipid)

Sphingolipids

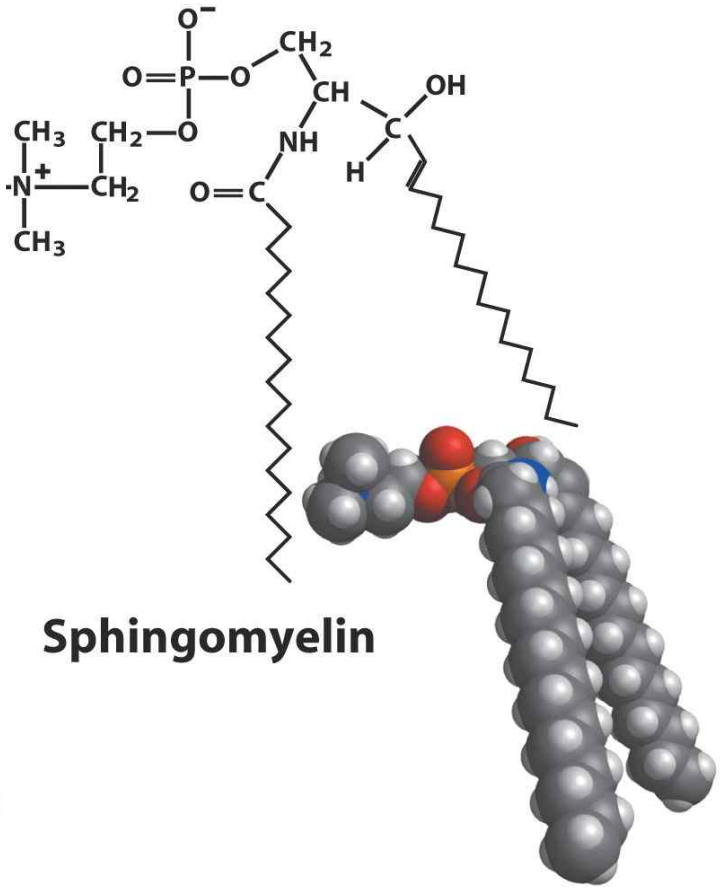


Name of sphingolipid	Name of X	Formula of X
Ceramide	—	— H
Sphingomyelin	Phosphocholine	— P(=O)(O⁻)—O—CH_2—CH_2—$N^+(CH_3)_3$
Neutral glycolipids Glucosylcerebroside	Glucose	
Lactosylceramide (a globoside)	Di-, tri-, or tetrasaccharide	
Ganglioside GM2	Complex oligosaccharide	

Glycosphingolipids



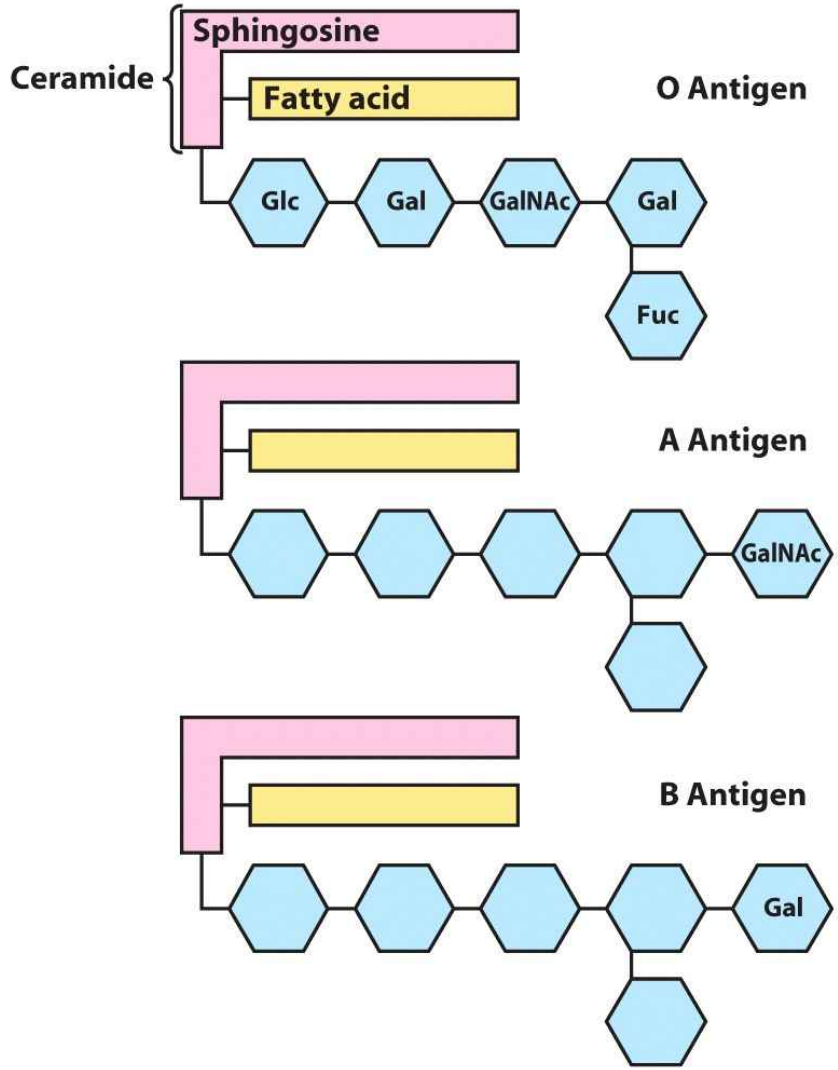
Phosphatidylcholine



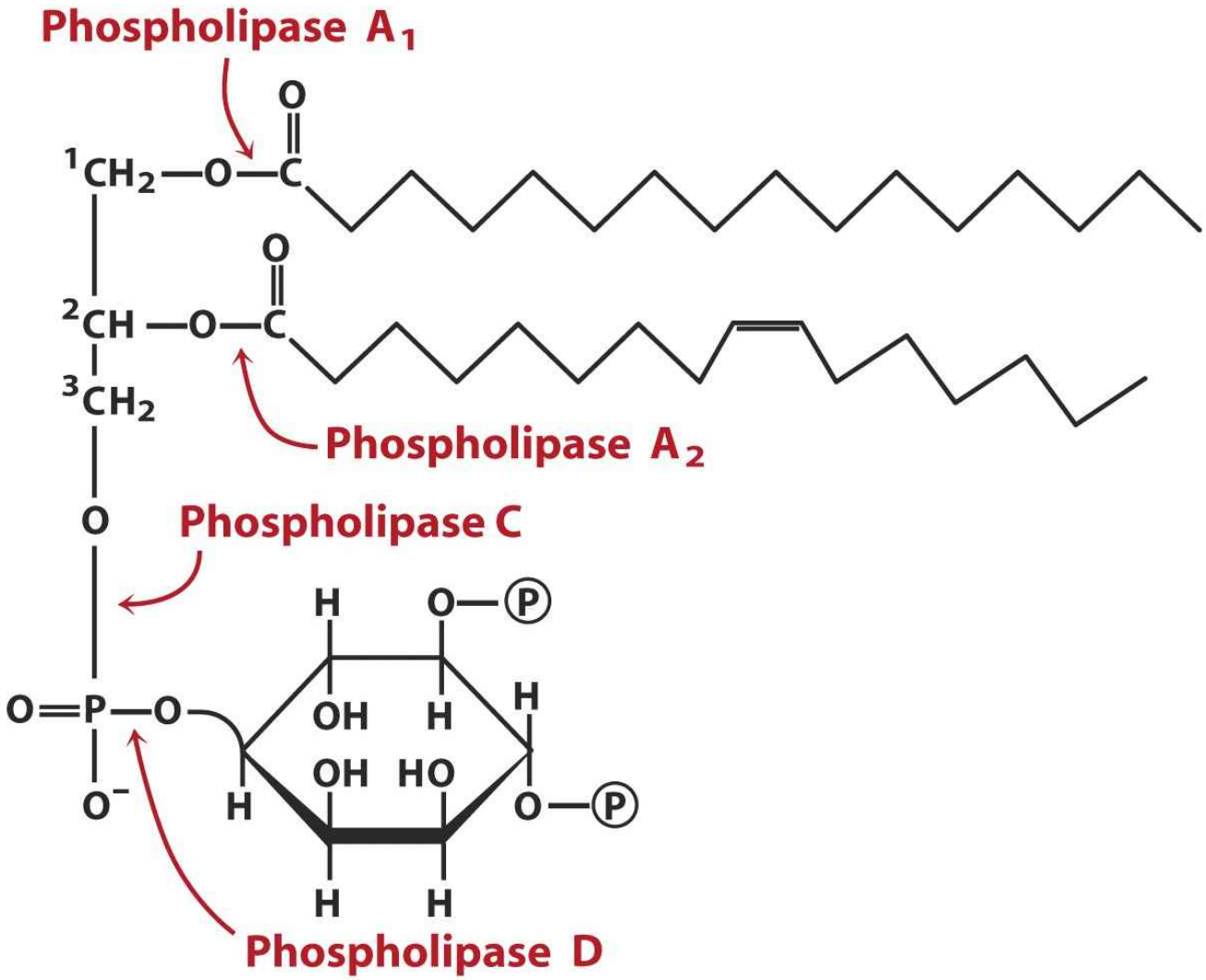
Sphingomyelin

Sphingolipids at cell surface are sites of biological recognition

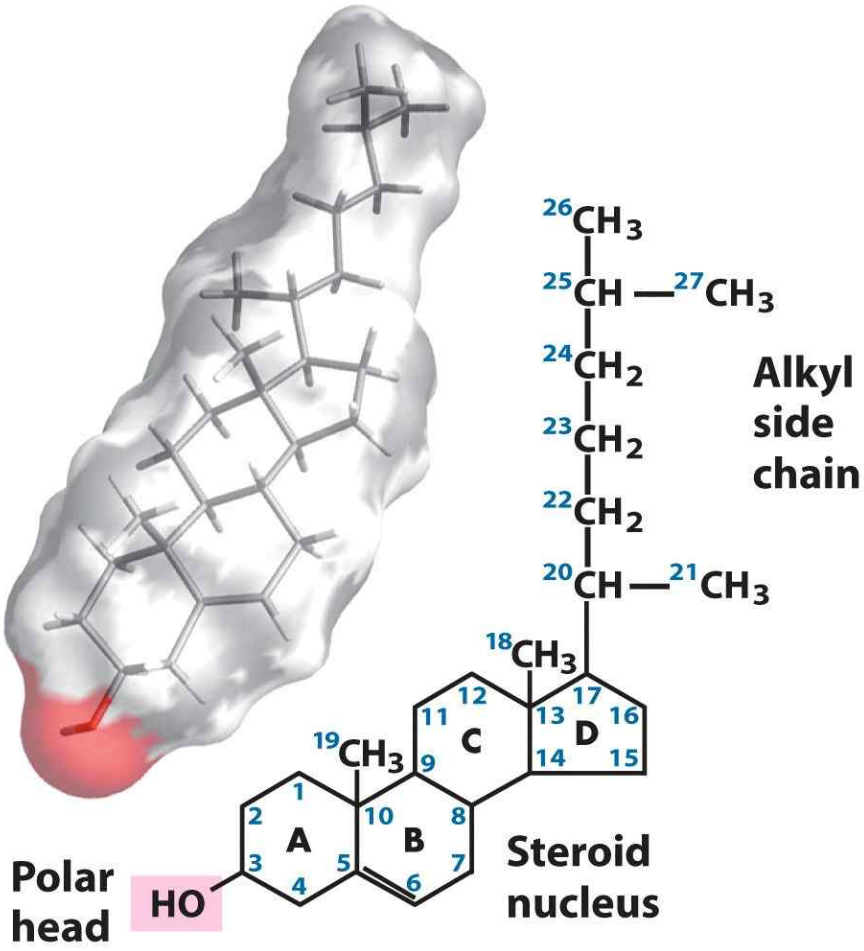
Glycosphingolipids as determinants of blood groups



Phospholipids and Sphingolipids are degraded in lysosome

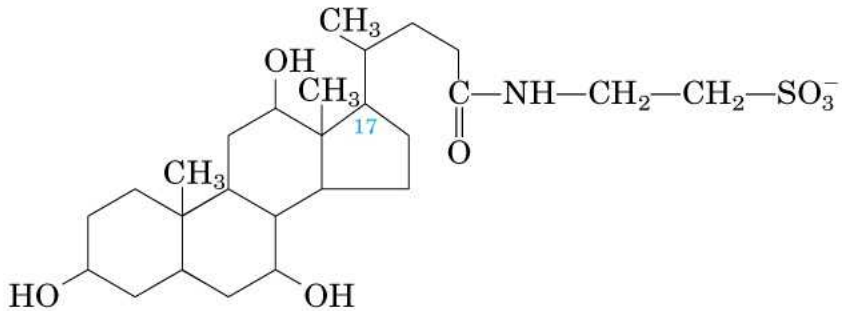


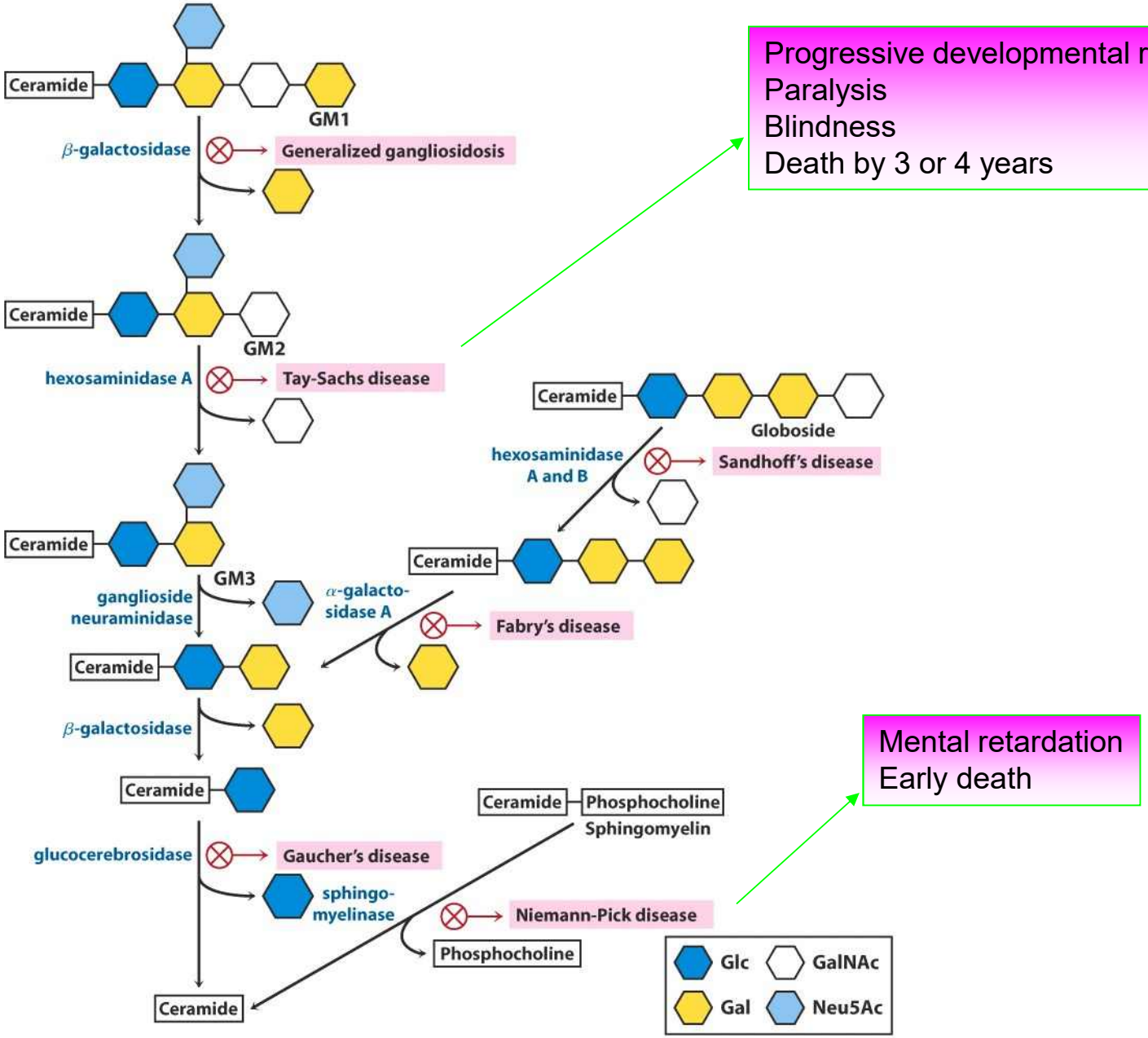
Sterols have four fused carbon rings



Cholesterol

- Membrane components (memb. fluidity)
- Steroid hormone
- Bile acids

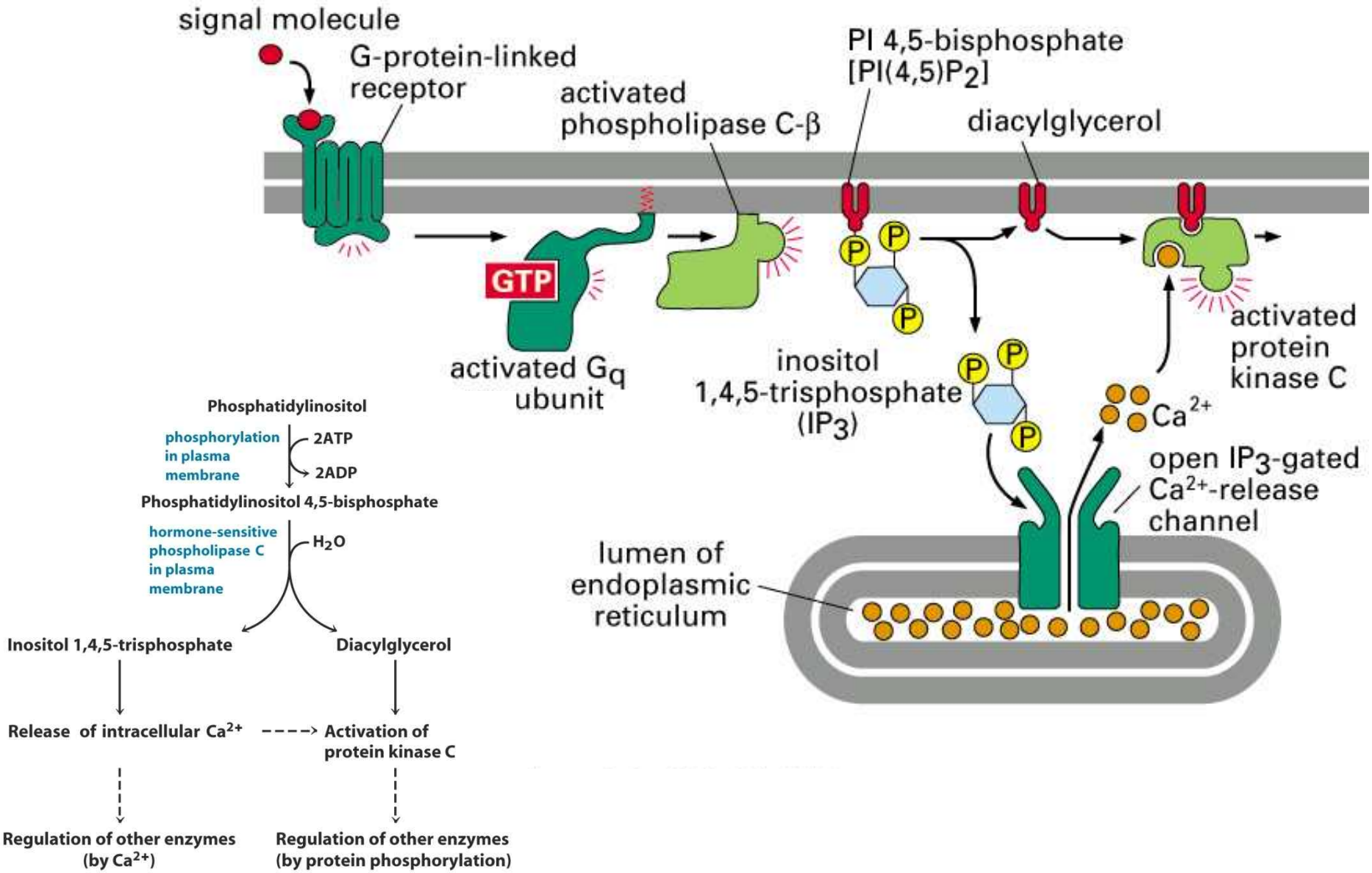




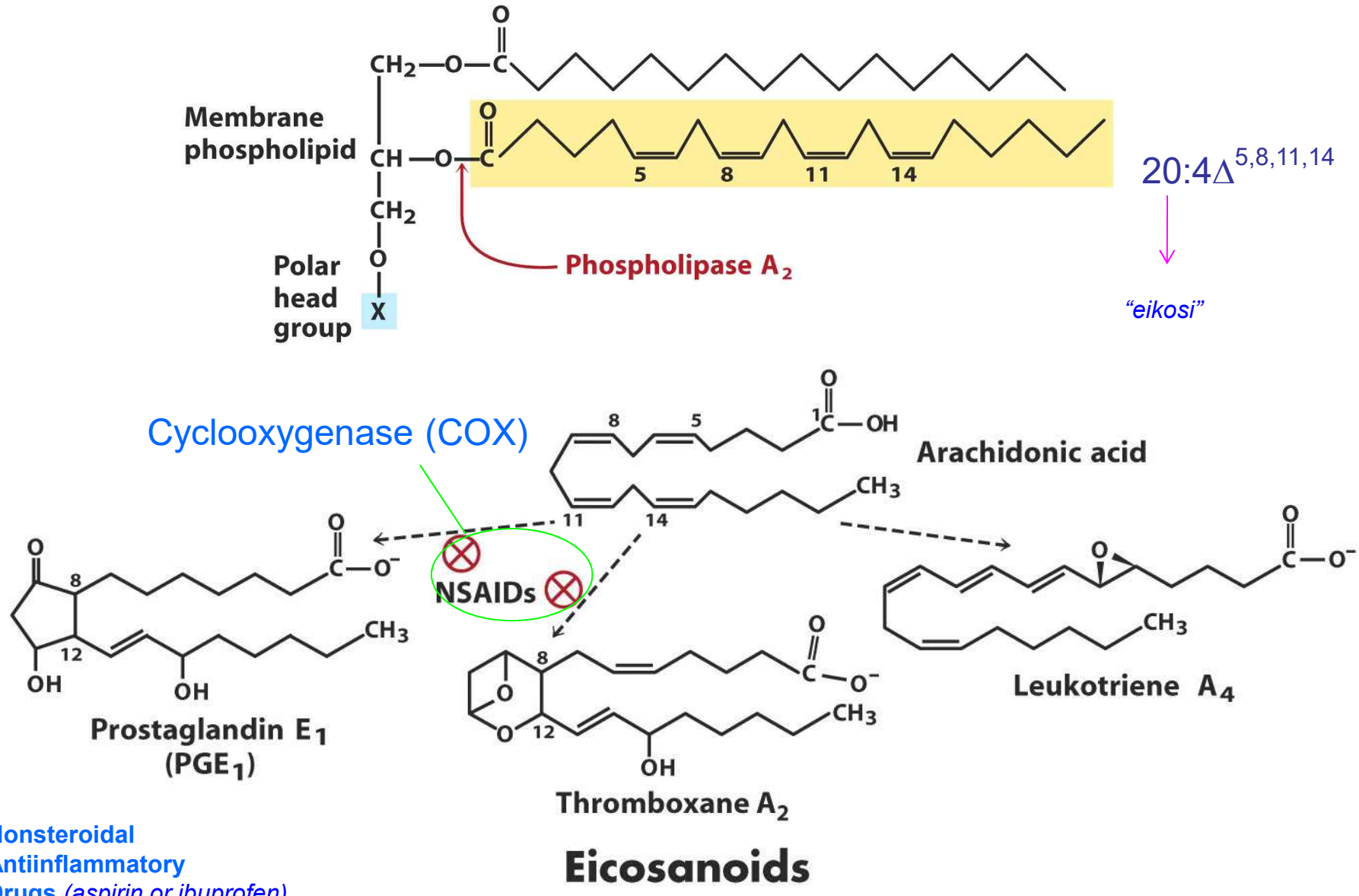
Progressive developmental retardation
Paralysis
Blindness
Death by 3 or 4 years

Mental retardation
Early death

Lipids as signals, cofactors, and pigments



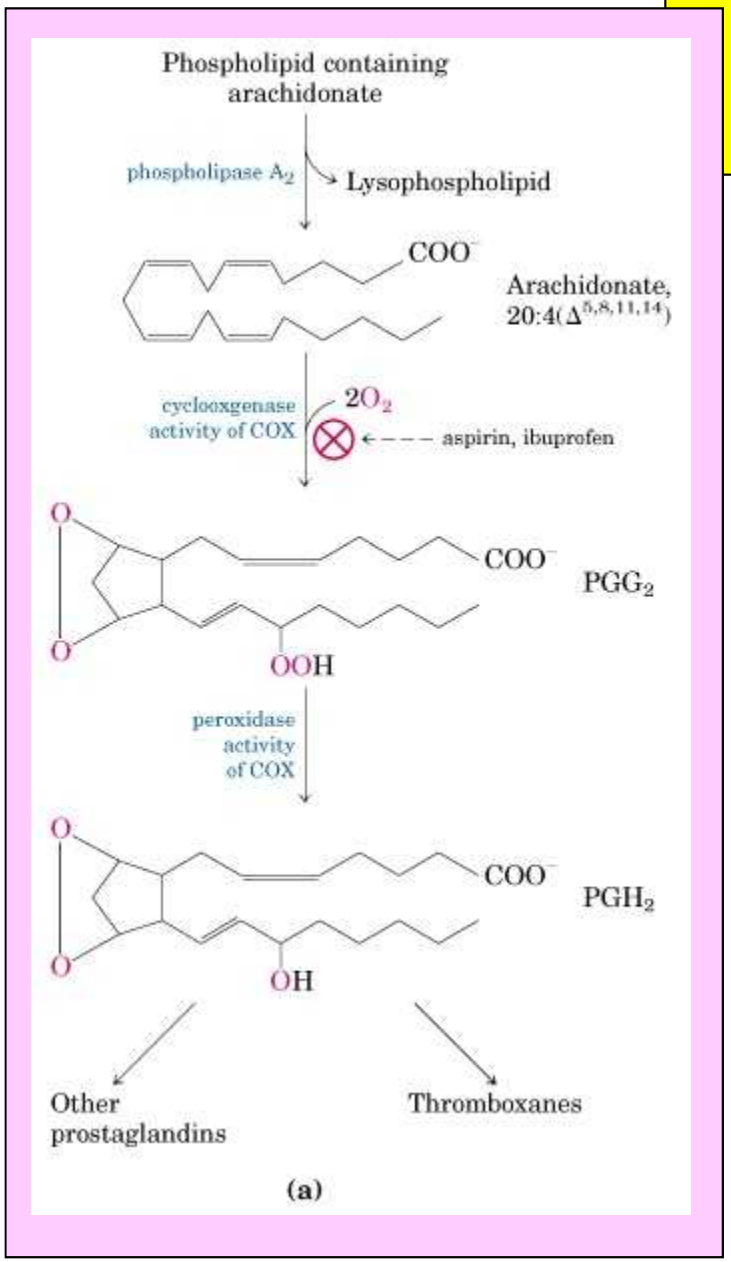
Eicosanoids carry messages to nearby cells

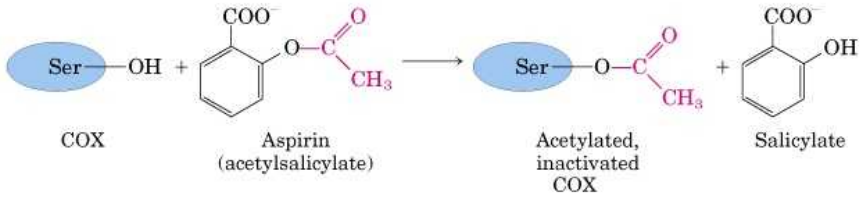


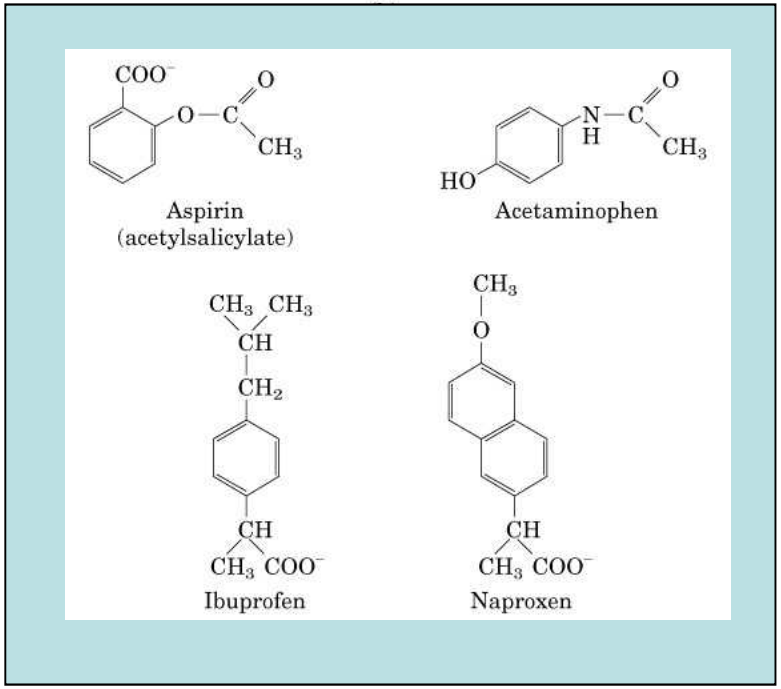
Nonsteroidal Antiinflammatory Drugs *(aspirin or ibuprofen)*

Cyclooxygenase (COX)
(Prostaglandin H_2 synthase)

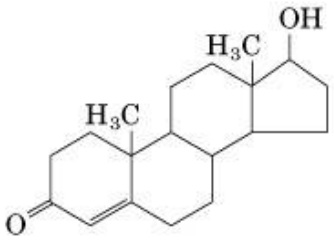
COX-1, COX-2



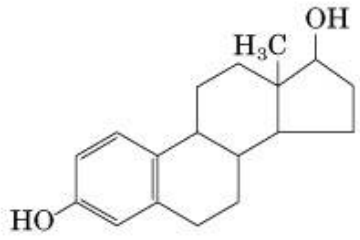




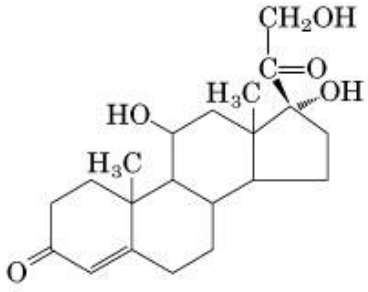
Steroid hormones derived from cholesterol



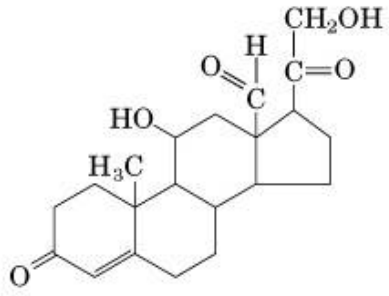
Testosterone



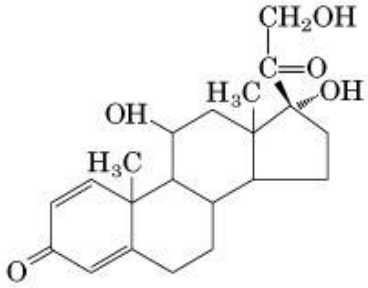
Estradiol



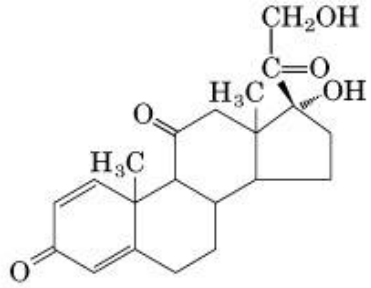
Cortisol



Aldosterone

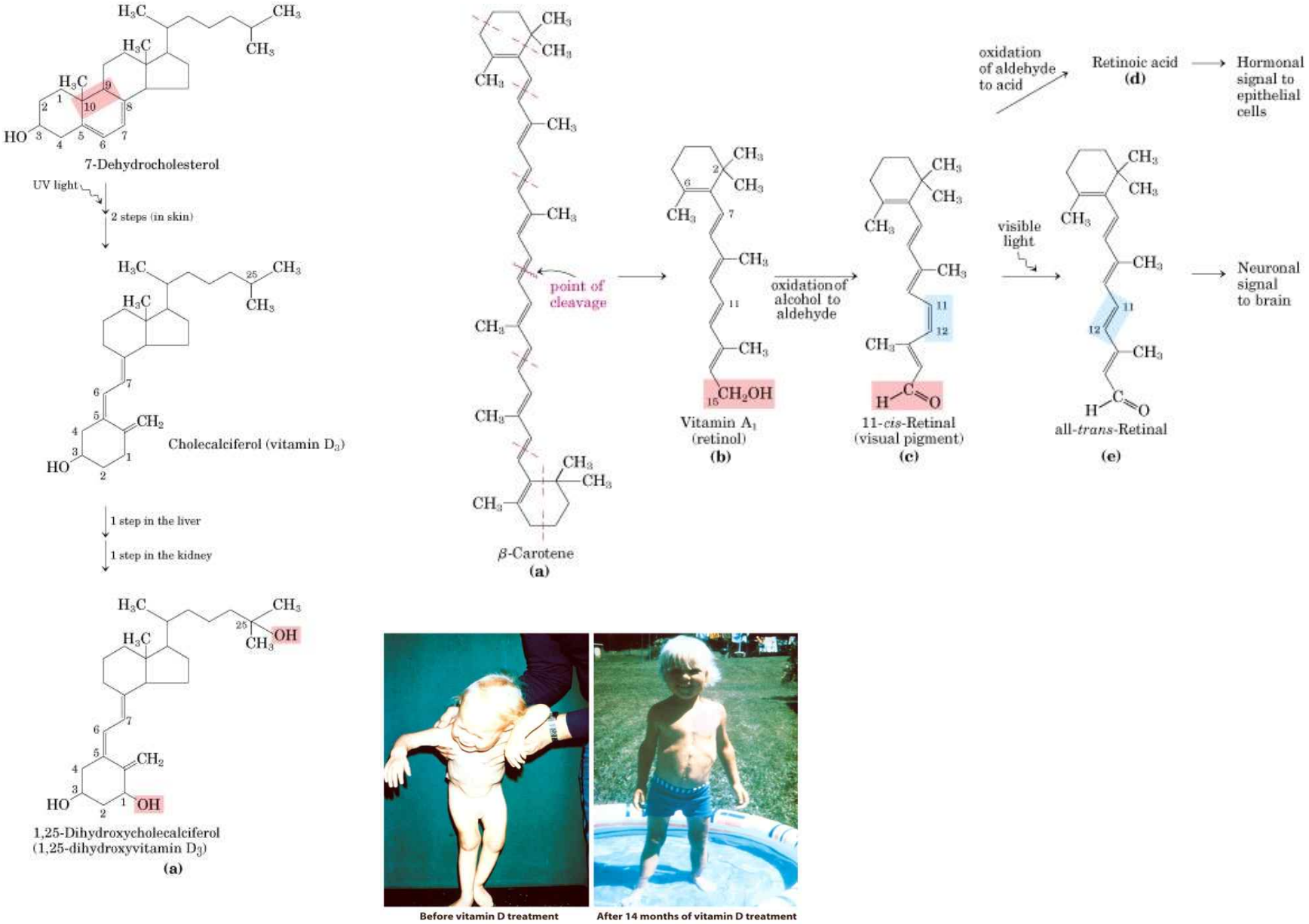


Prednisolone



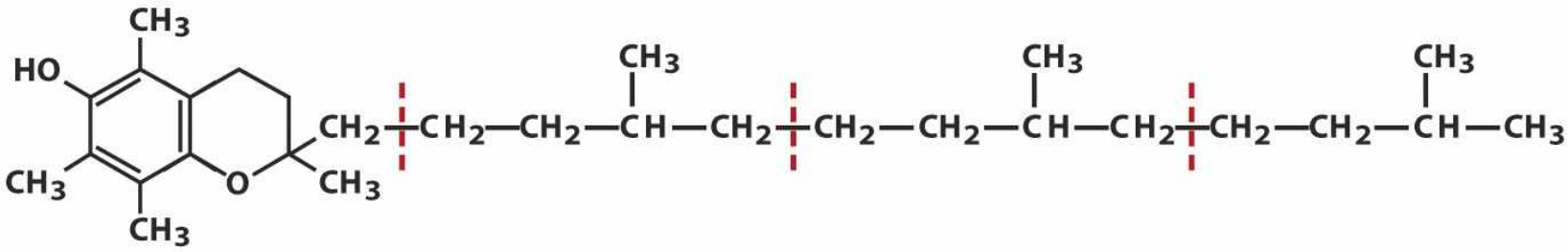
Prednisone

Vitamin A and D are hormone precursors



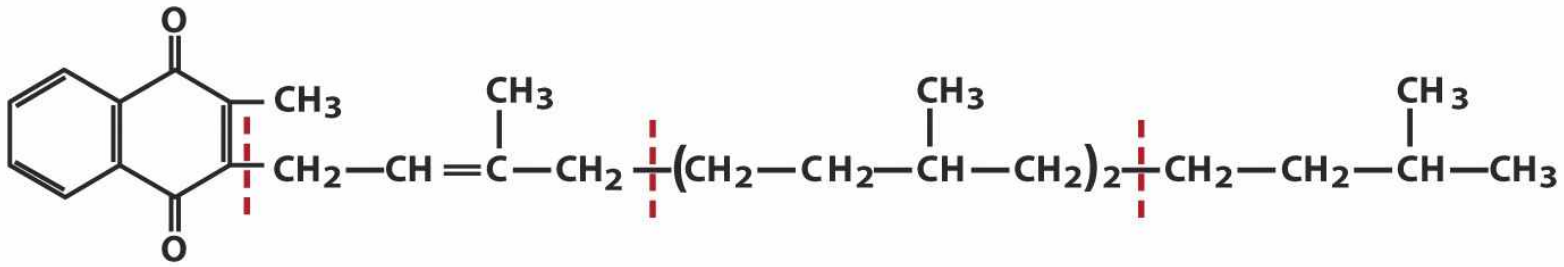
Before vitamin D treatment

After 14 months of vitamin D treatment



(a)

Vitamin E: an antioxidant



(b)

Vitamin K_1: a blood-clotting cofactor (phylloquinone)