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Fundamentals of Biochemistry

Second Edition

Chapter 9:

Lipids and Biological Membranes

지질이란 넓은 의미로 물에 녹지않고 유기용매에 용해되는 생체고분자를 총칭한다.

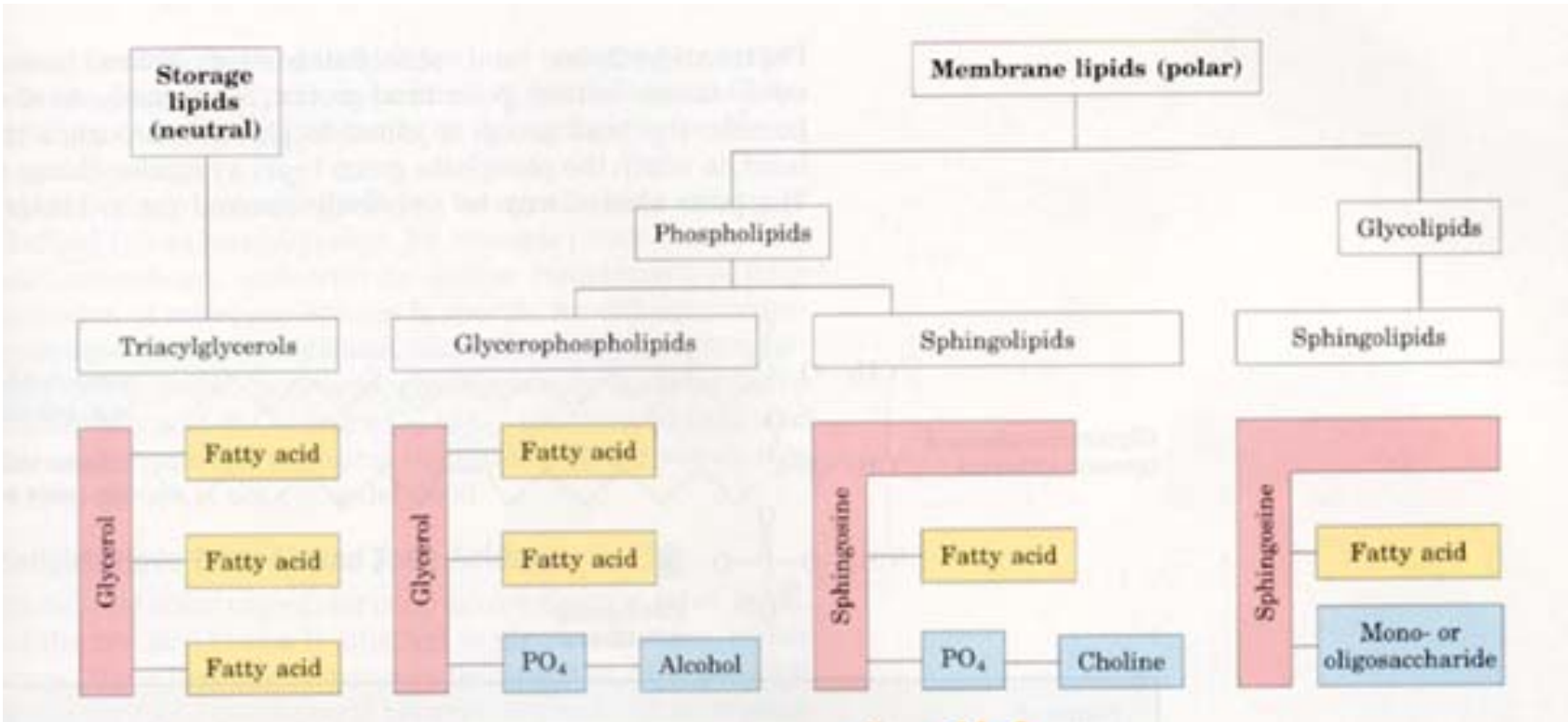
이들은 다른 생체고분자와는 달리 polymer로 존재하지는 않지만 생체막과 같은 구조물을 이룬다.

지질은 몇가지 중요한 생물학적 기능을 가진다:

생체막의 구성성분, 에너지 저장물질, 호르몬을 비롯한 신호전달물질

Lipid classification

Storage lipid: triacylglycerol (neutral molecule)
Membrane lipids: phospholipids + glycolipids (amphiphilic molecule) + cholesterol
hydrophilic---phosphorylated alcohols, sugars
hydrophic moiety---hydrocarbon chain



Fatty acids: carboxylic acids with long-chain hydrocarbon side groups
<14 or >20 are uncommon

Table 9-1 The Common Biological Fatty Acids

Symbol[a]	Common Name	Systematic Name	Structure	mp (°C)
Saturated fatty acids				
12:0	Lauric acid	Dodecanoic acid	$CH_3(CH_2)_{10}COOH$	44.2
14:0	Myristic acid	Tetradecanoic acid	$CH_3(CH_2)_{12}COOH$	52
16:0	Palmitic acid	Hexadecanoic acid	$CH_3(CH_2)_{14}COOH$	63.1
18:0	Stearic acid	Octadecanoic acid	$CH_3(CH_2)_{16}COOH$	69.1
20:0	Arachidic acid	Eicosanoic acid	$CH_3(CH_2)_{18}COOH$	75.4
22:0	Behenic acid	Docosanoic acid	$CH_3(CH_2)_{20}COOH$	81
24:0	Lignoceric acid	Tetracosanoic acid	$CH_3(CH_2)_{22}COOH$	84.2
Unsaturated fatty acids (all double bonds are cis)				
16:1*n*−7	Palmitoleic acid	9-Hexadecenoic acid	$CH_3(CH_2)_5CH{=}CH(CH_2)_7COOH$	−0.5
18:1*n*−9	Oleic acid	9-Octadecenoic acid	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$	13.2
18:2*n*−6	Linoleic acid	9,12-Octadecadienoic acid	$CH_3(CH_2)_4(CH{=}CHCH_2)_2(CH_2)_6COOH$	−9
18:3*n*−3	α-Linolenic acid	9,12,15-Octadecatrienoic acid	$CH_3CH_2(CH{=}CHCH_2)_3(CH_2)_6COOH$	−17
18:3*n*−6	γ-Linolenic acid	6,9,12-Octadecatrienoic acid	$CH_3(CH_2)_4(CH{=}CHCH_2)_3(CH_2)_3COOH$	
20:4*n*−6	Arachidonic acid	5,8,11,14-Eicosatetraenoic acid	$CH_3(CH_2)_4(CH{=}CHCH_2)_4(CH_2)_2COOH$	−49.5
20:5*n*−3	EPA	5,8,11,14,17-Eicosapentaenoic acid	$CH_3CH_2(CH{=}CHCH_2)_5(CH_2)_2COOH$	−54
22:6*n*−3	DHA	4,7,10,13,16,19-Docosohexenoic acid	$CH_3CH_2(CH{=}CHCH_2)_6CH_2COOH$	
24:1*n*−9	Nervonic acid	15-Tetracosenoic acid	$CH_3(CH_2)_7CH{=}CH(CH_2)_{13}COOH$	39

[a]Number of carbon atoms: Number of double bonds. For unsaturated fatty acids, the quantity "*n*−*x*" indicates the position of the last double bond in the fatty acid, where *n* is its number of C atoms, and *x* is the position of the last double-bonded C atom counting from the methyl terminal (ω) end.

Source: Dawson, R.M.C., Elliott, D.C., Elliott, W.H., and Jones, K.M., *Data for Biochemical Research* (3rd ed.), Chapter 8, Clarendon Press (1986).

Table 9-1 Fundamentals of Biochemistry, 2/e

C18 fatty acids

cis double bonds

trans fatty acids?

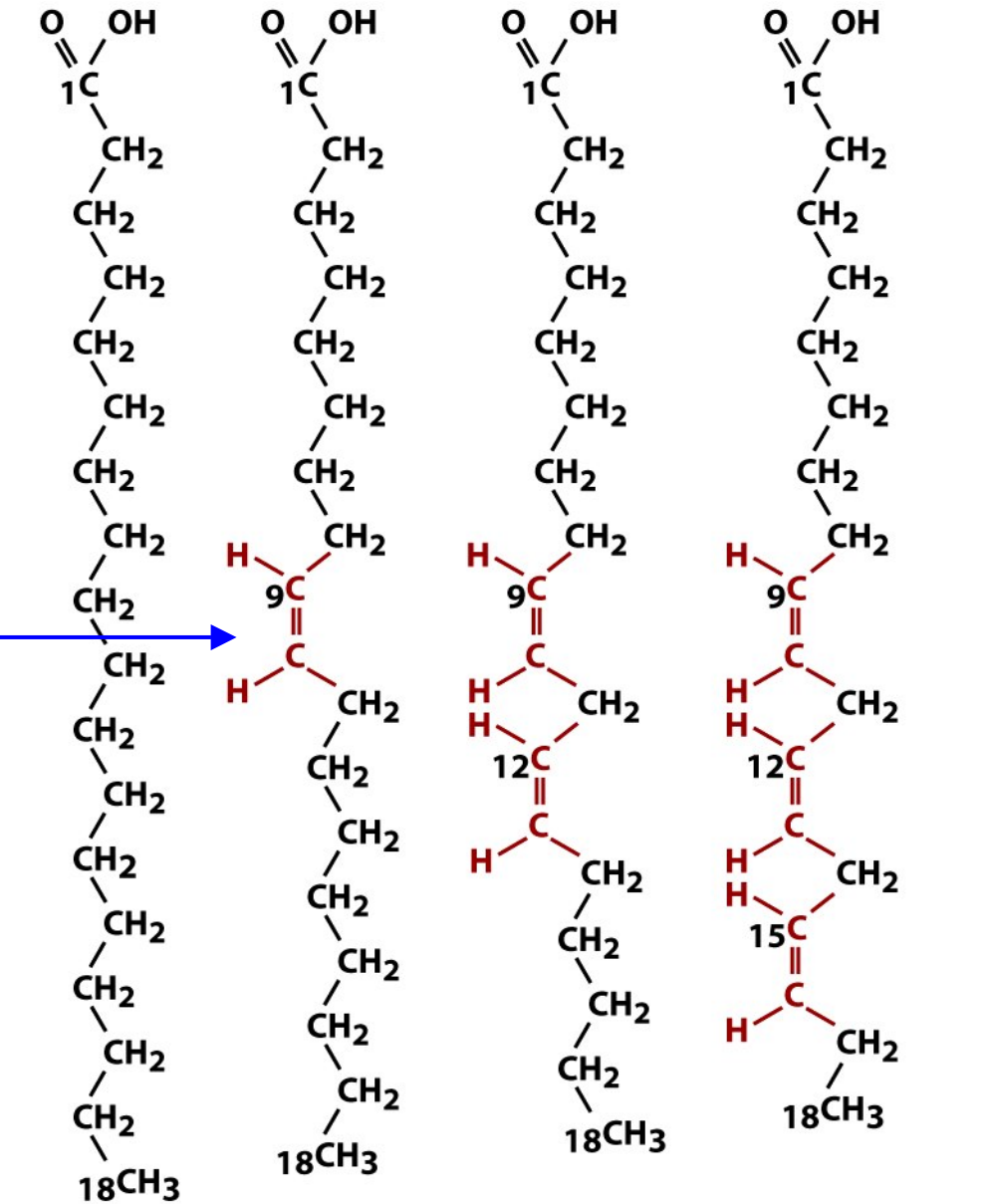


Figure 9-1 Fundamentals of Biochemistry, 2/e

Triacylglycerol

Energy reserve
Survive starvation for 2-3 months

Adipocytes
major synthesis &
storage for triacylglycerols
abundant in subcutaneous layer

SEM of adipocytes

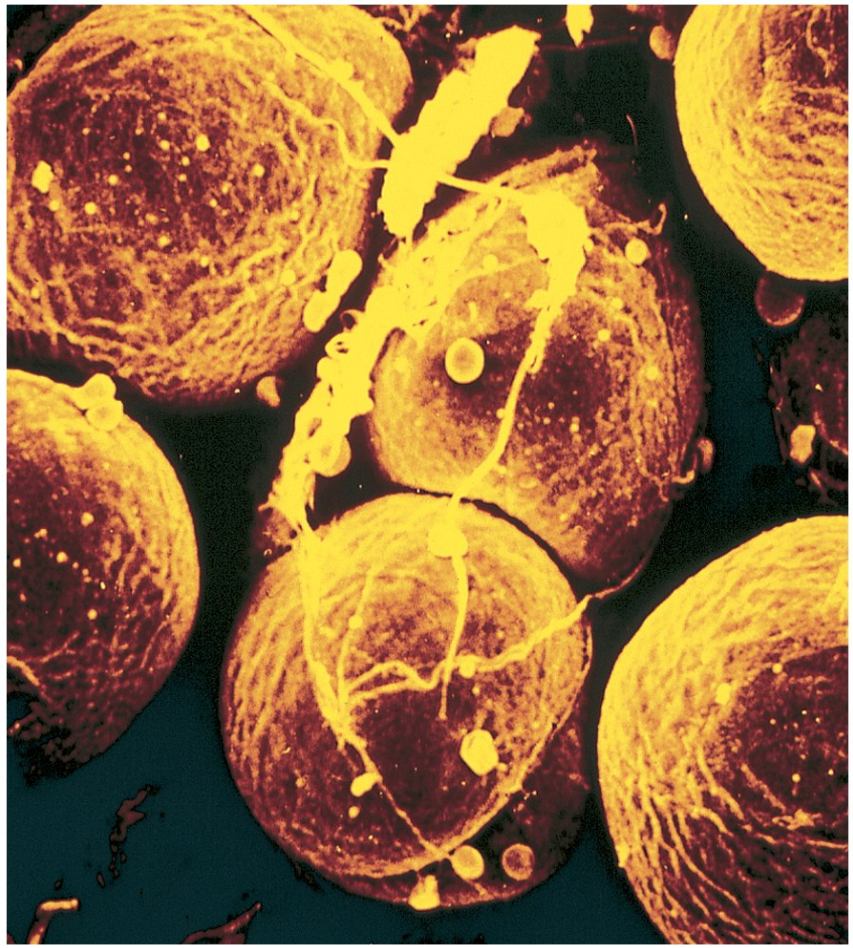
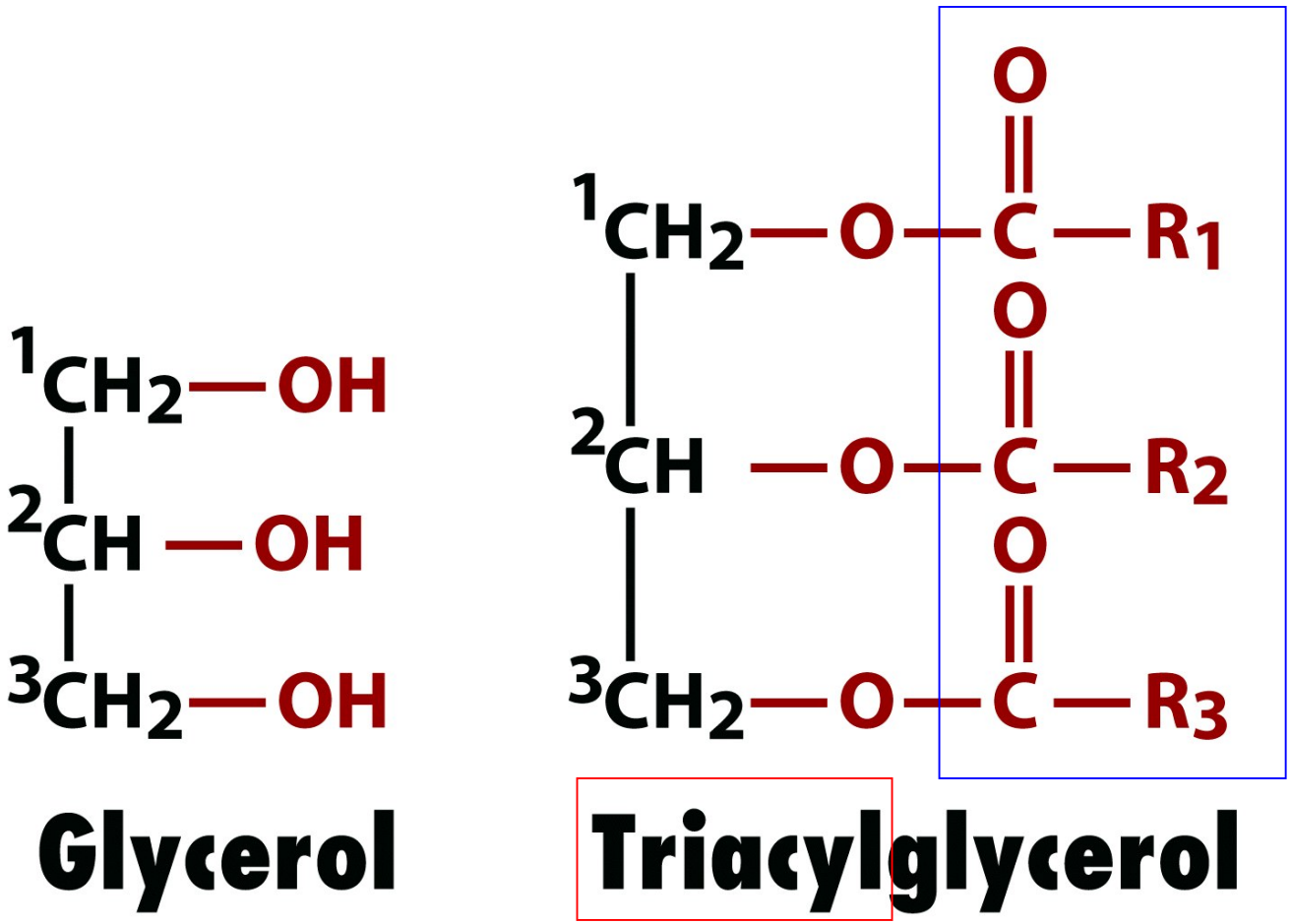


Figure 9-2 Fundamentals of Biochemistry, 2/e



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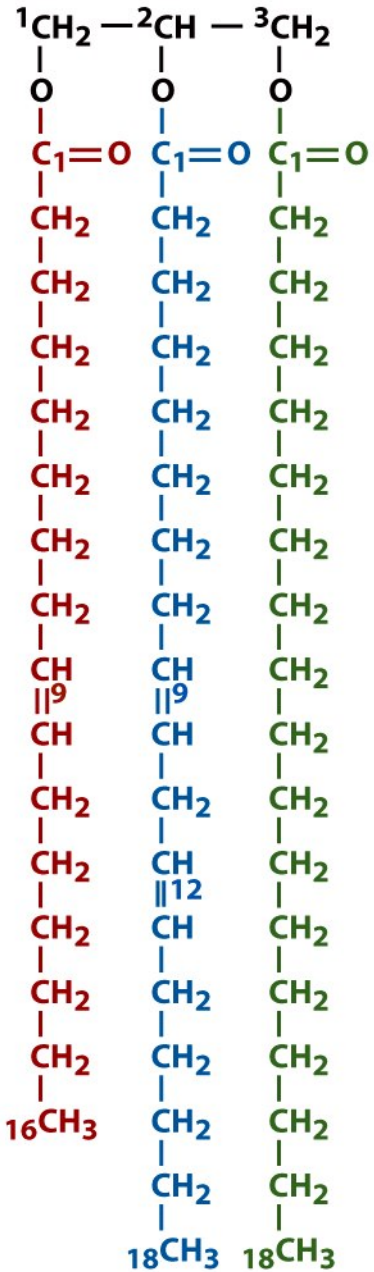


1-Palmitoleoyl-2-linoleoyl-3-stearoyl-glycerol

Unnumbered figure pg 236b Fundamentals of Biochemistry, 2/e

Triacylglycerols are hetereogenous

Two or three different types of fatty acid residues

Plant oils are rich in unsaturated fatty acids

What is difference between fat and oil?

Glycerophospholipid

major lipid components of biological membranes

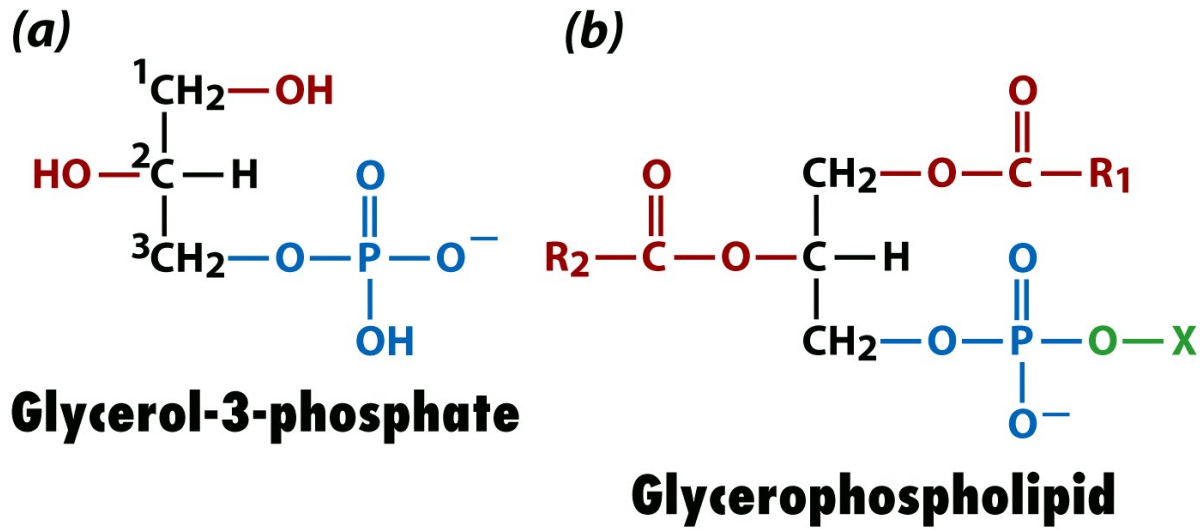
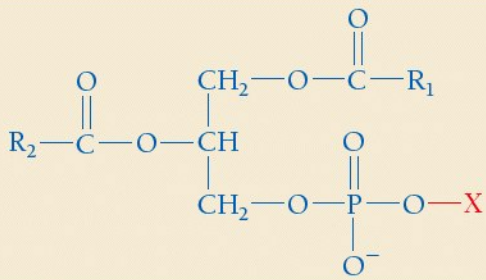


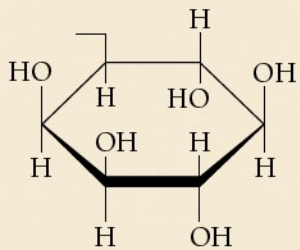
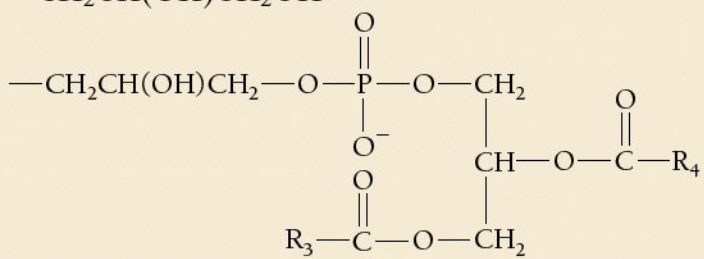
Figure 9-3 Fundamentals of Biochemistry, 2/e

R1: C16-18 saturated

R2: C16-20 unsaturated

Table 9-2 The Common Classes of Glycerophospholipids



Name of X—OH	Formula of −X	Name of Phospholipid
Water	—H	Phosphatidic acid
Ethanolamine	$-CH_2CH_2NH_3^+$	Phosphatidylethanolamine
Choline	$-CH_2CH_2N(CH_3)_3^+$	Phosphatidylcholine (lecithin)
Serine	$-CH_2CH(NH_3^+)COO^-$	Phosphatidylserine
myo-Inositol		Phosphatidylinositol
Glycerol	$-CH_2CH(OH)CH_2OH$	Phosphatidylglycerol
Phosphatidylglycerol		Diphosphatidylglycerol (cardiolipin)

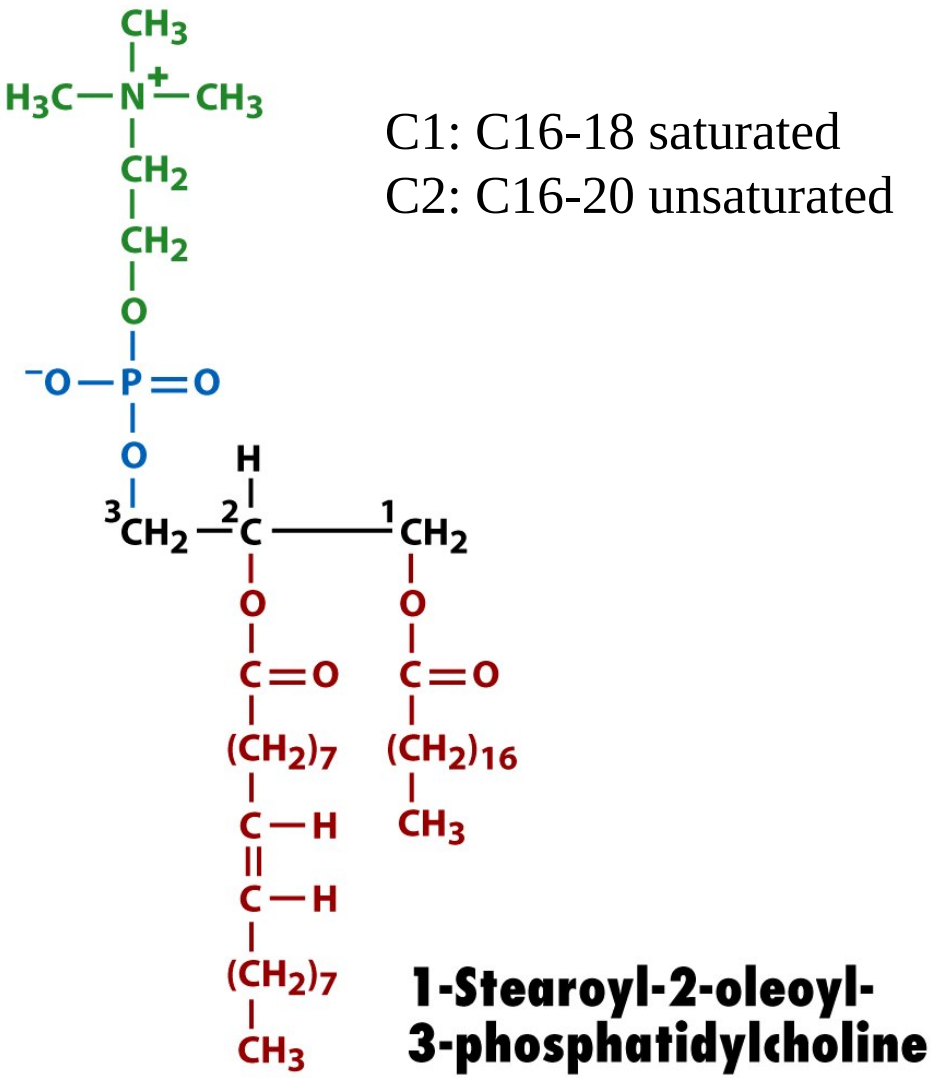


Figure 9-4a Fundamentals of Biochemistry, 2/e

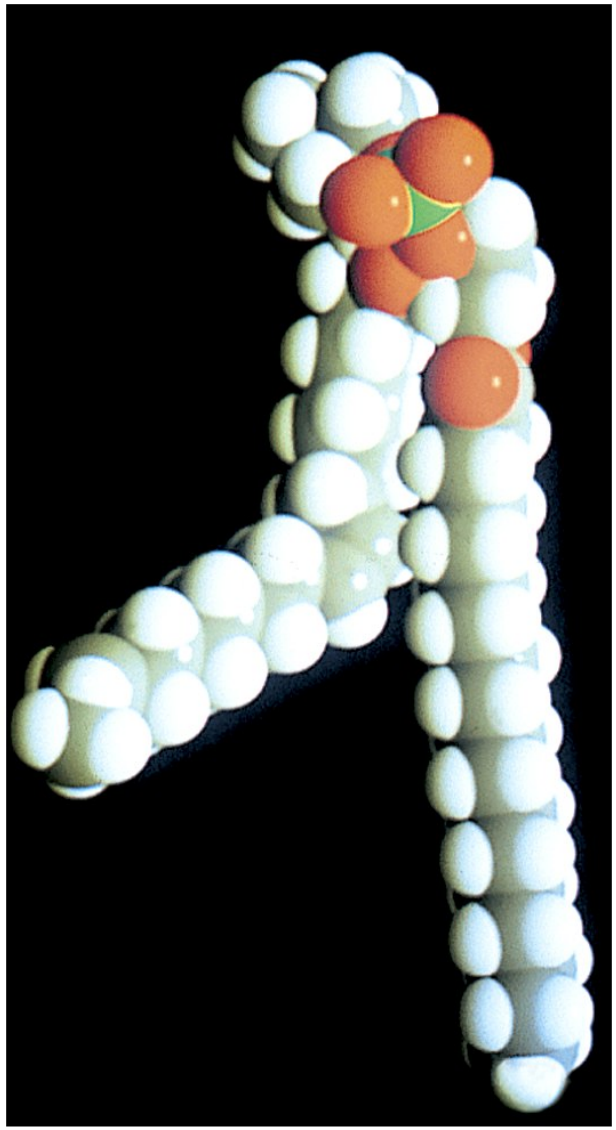


Figure 9-4b Fundamentals of Biochemistry, 2/e

Glycerophospholipids are hydrolyzed by phospholipases

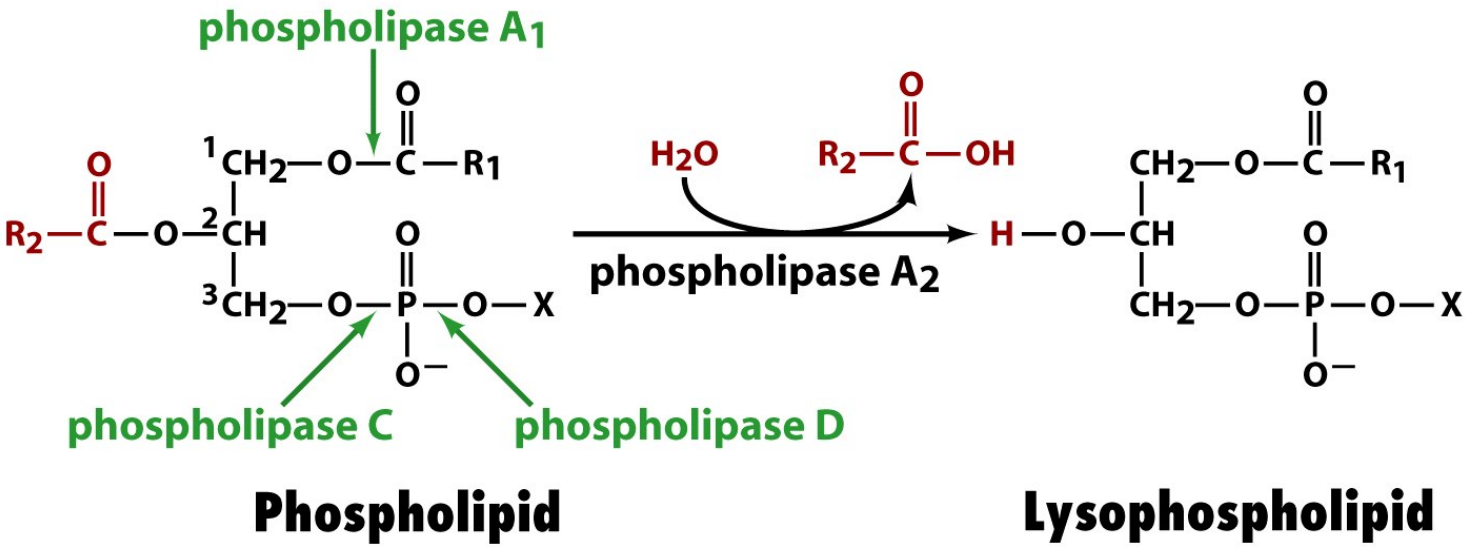


Figure 9-5 Fundamentals of Biochemistry, 2/e

Bee and snake venoms are phospholipase A2
Lysophospholipids: powerful detergent disrupting cell membranes

Model of phospholipase A2 and a glycerophospholipid

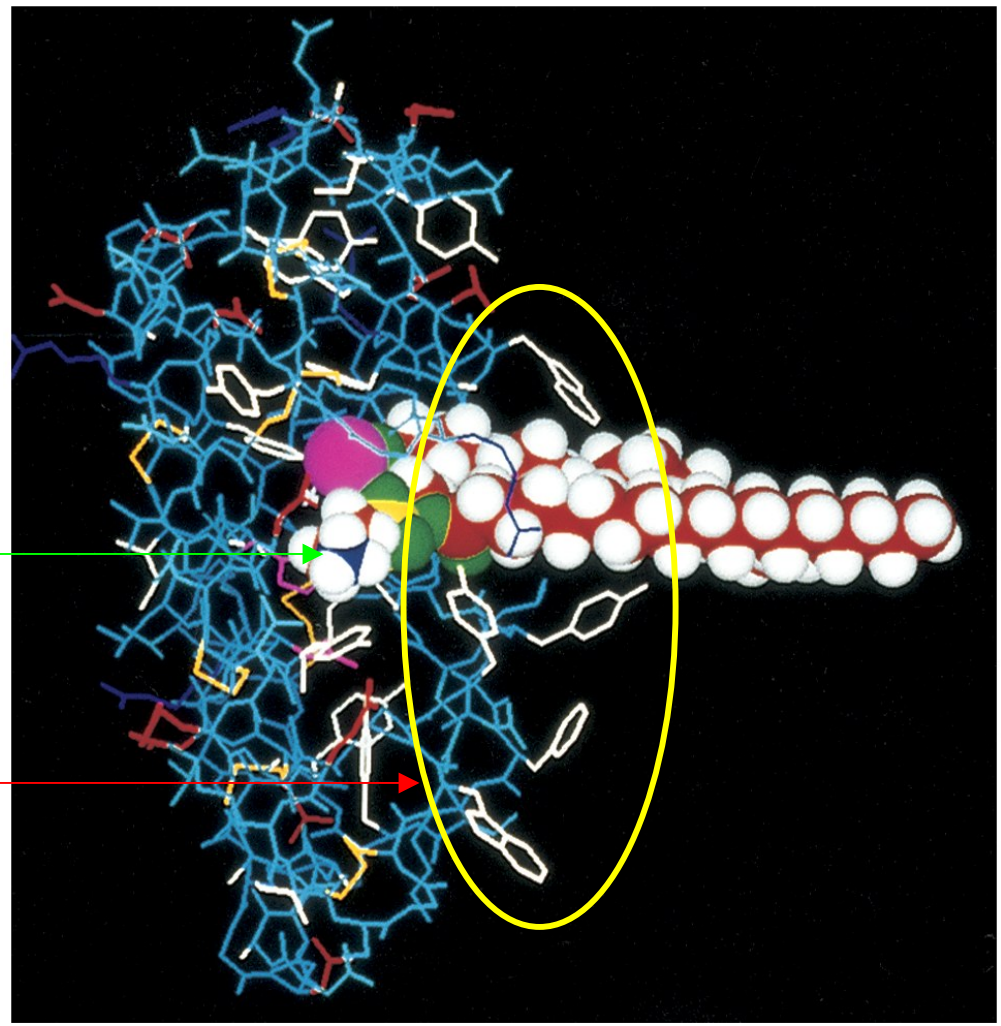


Figure 9-6 Fundamentals of Biochemistry, 2/e

Hydrolyzed products serve as inter- and extracellular molecules

Lysophosphatidic acid (1-acylglycerol-3-phosphate)

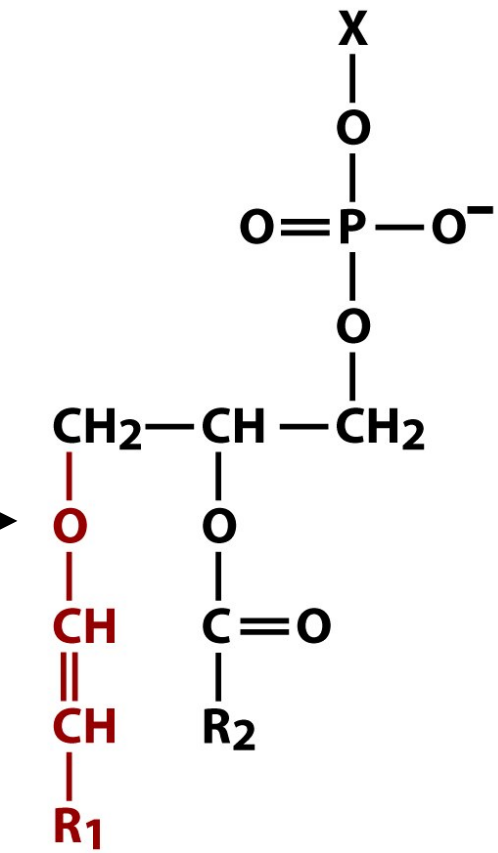
stimulate cell growth for wound healing

1,2-diacylglycerol

activate protein kinase (p771, Fig.21-22)

Plasmalogen: ether linkage glycerophospholipid

Ether linkage

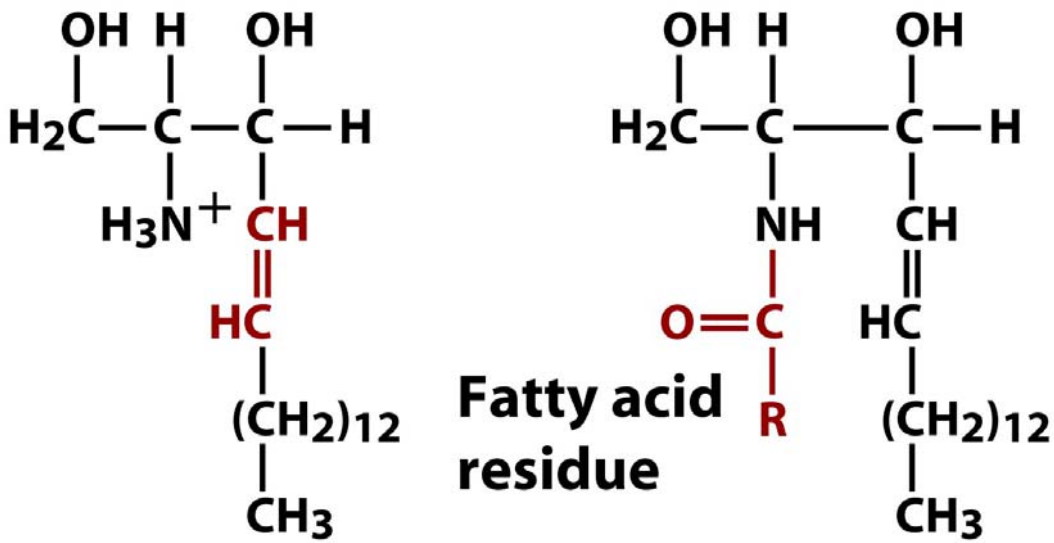


A plasmalogen

Unnumbered figure pg 240a Fundamentals of Biochemistry,

Sphingolipids

Synthesized from palmitoyl CoA and serine (p667, Fig. 19-36)



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N-acyl fatty acid derivative of sphingoshine

Sphingomyelins: the most common sphingolipids

rich in myelin sheath surrounding nerve cell axons

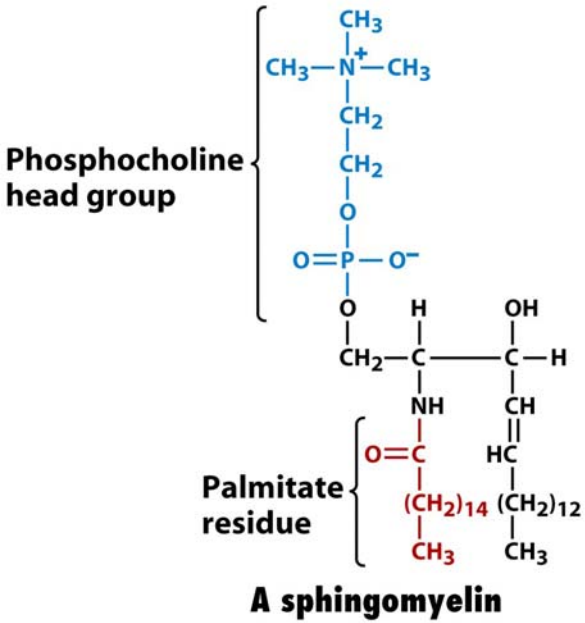

Figure 9-7a Fundamentals of Biochemistry, 2/e
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Figure 9-7b Fundamentals of Biochemistry, 2/e

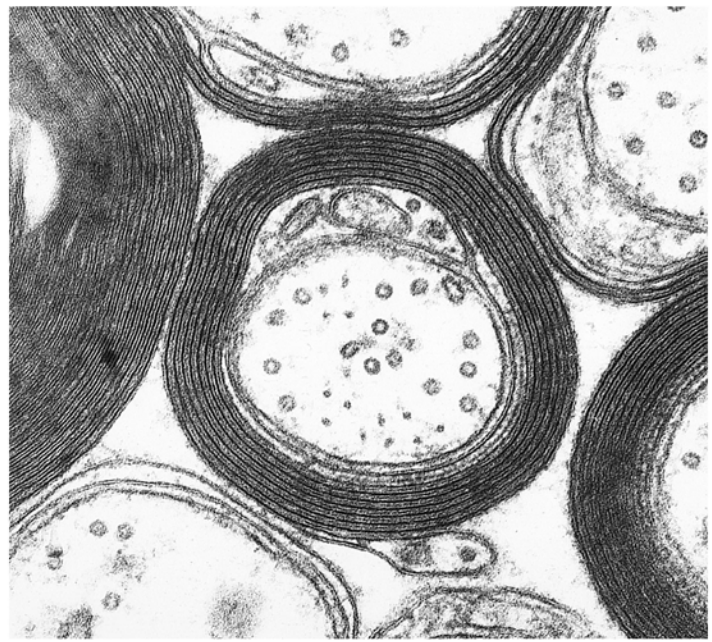


Figure 9-8 Fundamentals of Biochemistry, 2/e

Glycolipids

Cerebrosides: sphingolipids with single sugar residues

glucocerebrosides, galactocerebrosides

Gangliosides: the most complex glycosphingolipids

rich in brain lipids

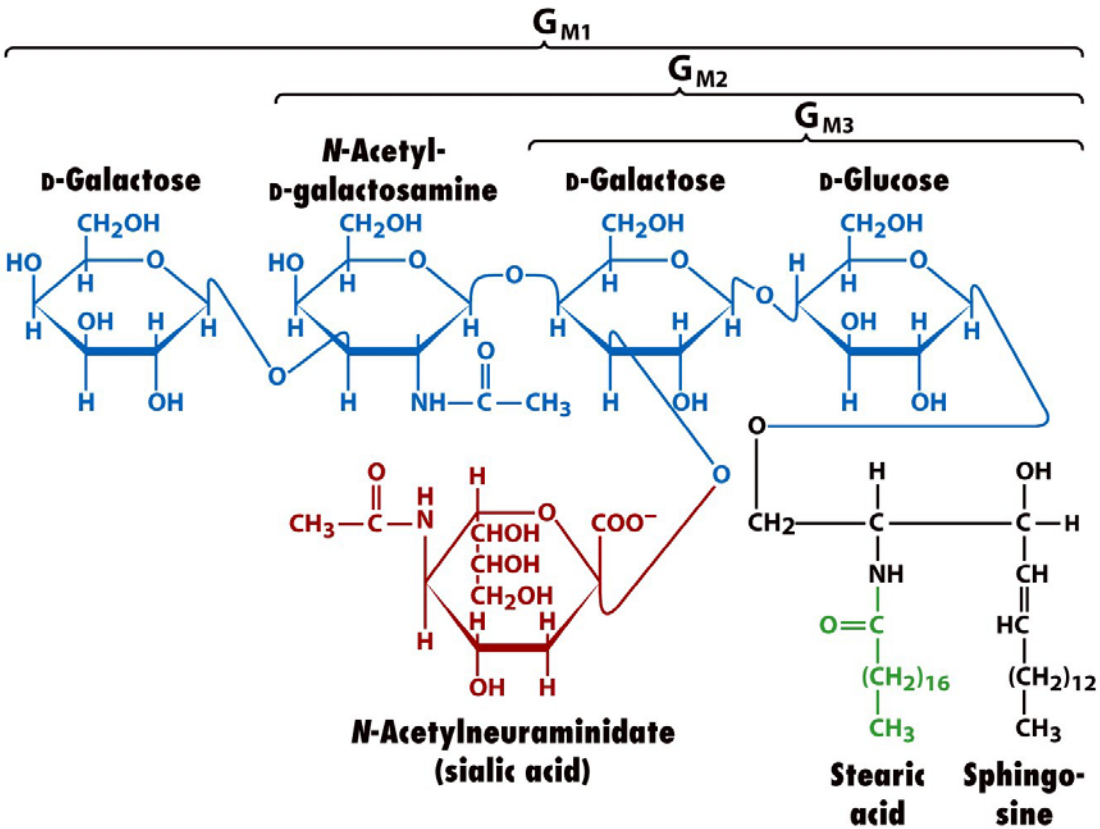


Figure 9-9a Fundamentals of Biochemistry, 2/e

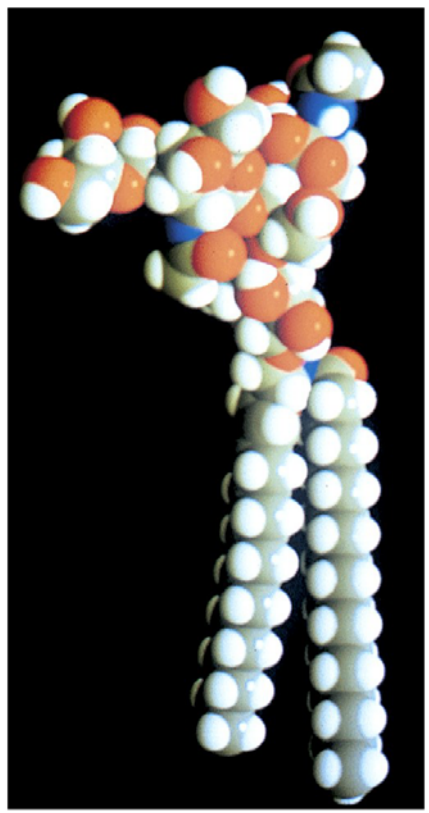


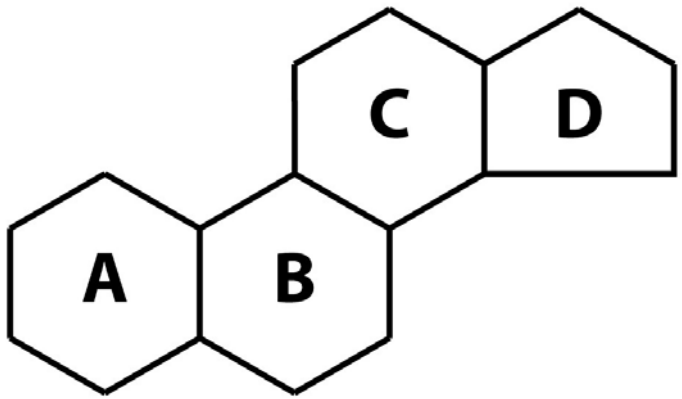
Figure 9-9b Fundamentals of Biochemistry, 2/e

Function of ganglosides

Specific receptors for hormones
Specific determinants of cell-cell recognition
Important for the growth and differentiation of tissues
Disorders in breakdown: sphinolipid storage diseases

Steroids

derivatives of 4 fused-ring compound



Cyclopentanoperhydrophenanthrene

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Cholesterol

- The most abundant steroid in animals
- A major component of animal membrane
- Metabolic precursor of steroid hormones
- Cholesterl esters: storage form

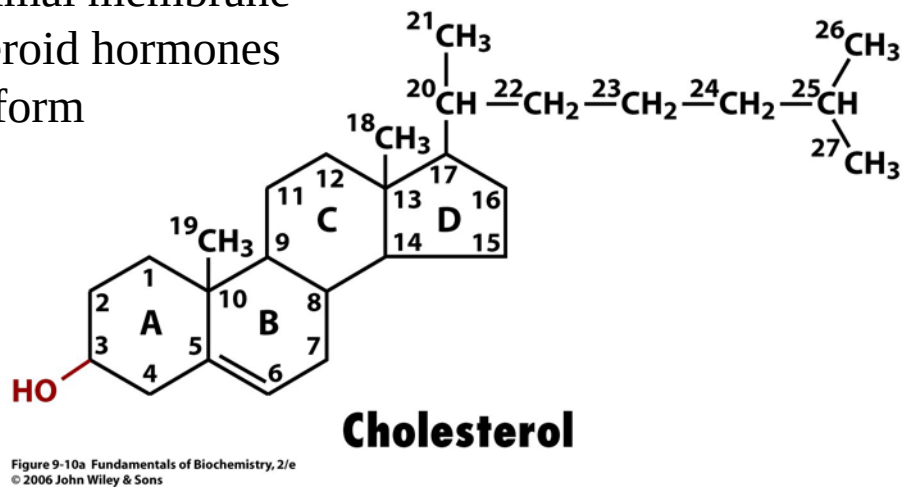

Figure 9-10a Fundamentals of Biochemistry, 2/e
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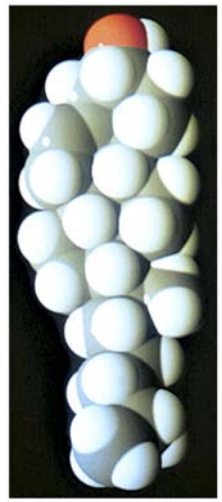
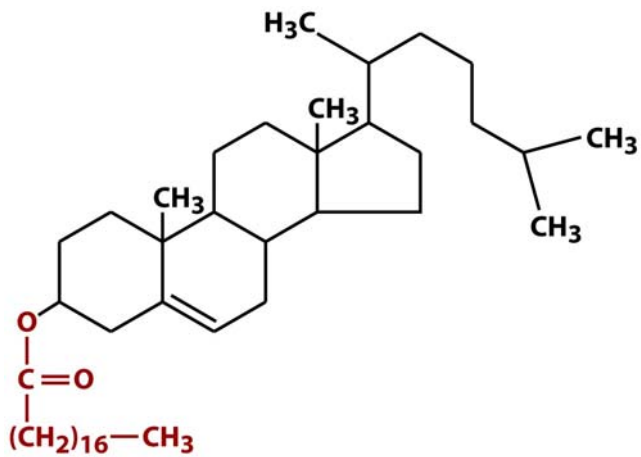


Figure 9-10b Fundamentals of Biochemistry, 2/e



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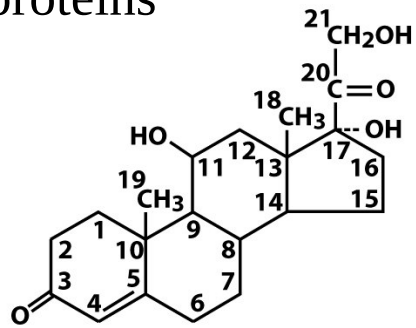
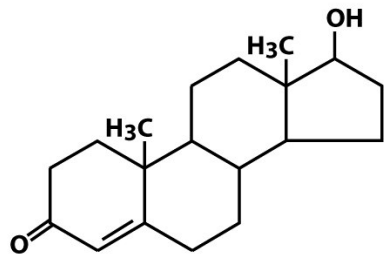
Classification of steroid hormones

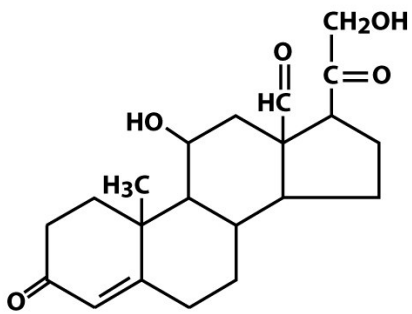
- Glucocorticoids: cortisol
- Mineralocorticoids: aldosterone
- Sex hormones: androgens, estrogens
- Insoluble and transported by proteins



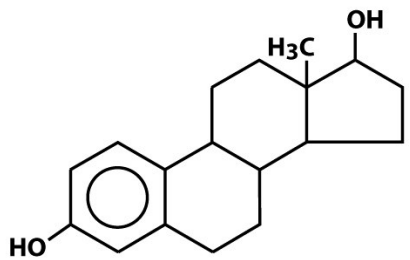
Cortisol (hydrocortisone)
(a glucocorticoid)



Testosterone
(an androgen)



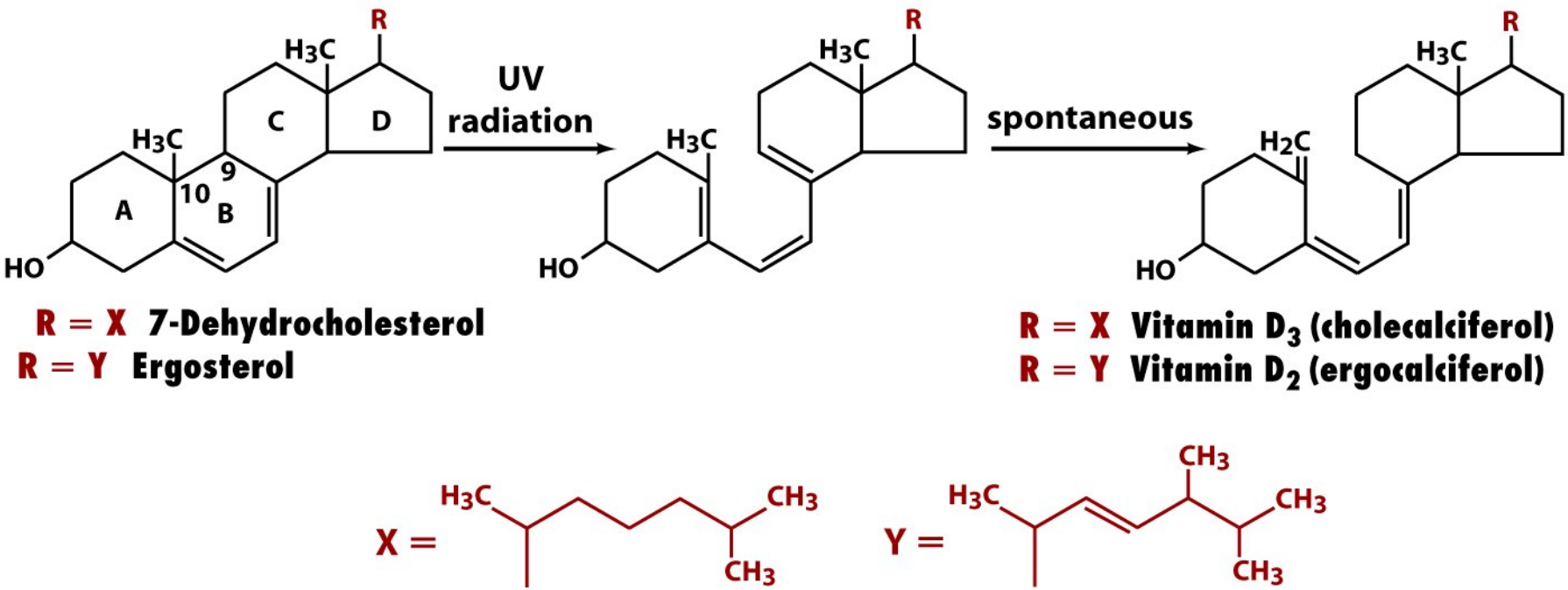
Aldosterone
(a mineralocorticoid)



β-Estradiol
(an estrogen)

Figure 9-11 Fundamentals of Biochemistry, 2/e

Vitamin D: steroid B ring is disrupted between C9 and C10



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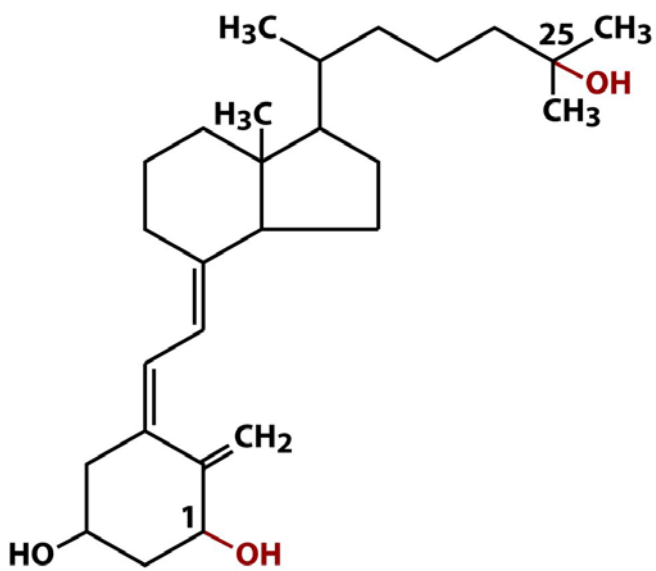
Vit D2, D3 (inactive forms)

Hydroxylation at
C25 (liver)
C1 (kidney)



1α,25-Dihydroxycholecalciferol

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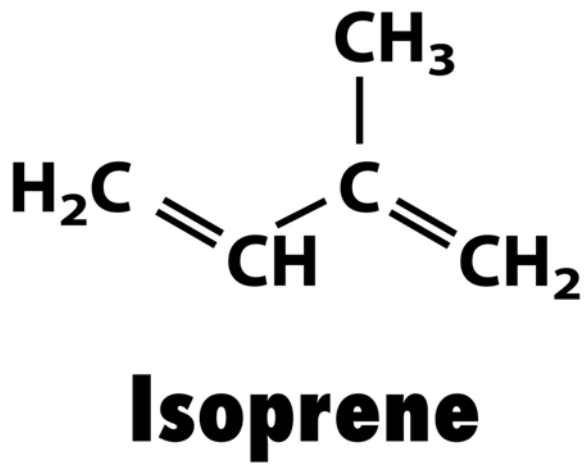
Increase serum [Ca^{++}] by promoting intestinal absorption of dietary Ca^{++}
Deposition of Ca^{++} in bone and teeth
Diseases due to deficiency and excess intake

Other lipids that are not components of membranes

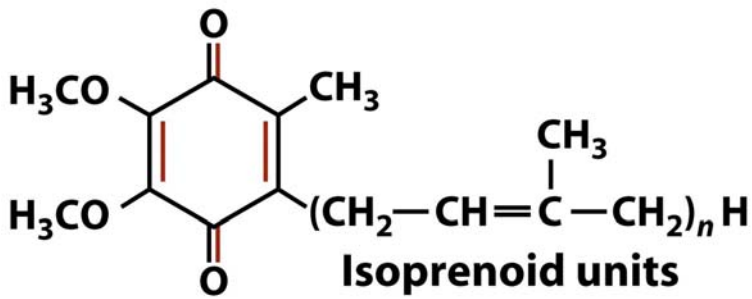
- Mostly are isoprenoids (built from isoprene units)
  - Ubiquinone (coenzyme Q)
  - Fat soluble vitamins: retinol, vitamin K, vitamin E
- Other less common are eicosanoids (C20 compounds)
  - prostaglandins, prostacyclins, thromboxanes, leukotrienes, lipoxins



Isoprene

Isoprenoid compounds

Rich in plant, fungi, bacteria
Called terpenoids (>25,000)
Pigments
Molecular signals (hormones & pheromones)
Defensive agents



Coenzyme Q (CoQ) or ubiquinone

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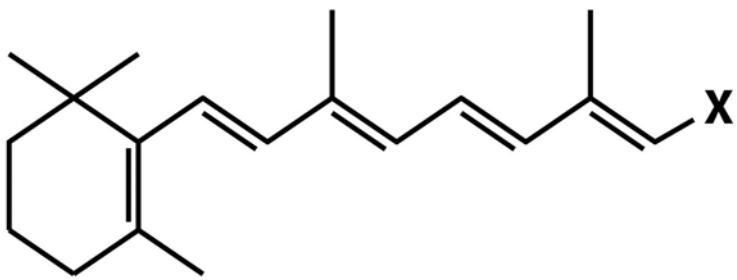
Electron carrier in mitochondrial membarne
n=10 in mammalian



X = CH_2OH Retinol (vitamin A)
X = CHO Retinal

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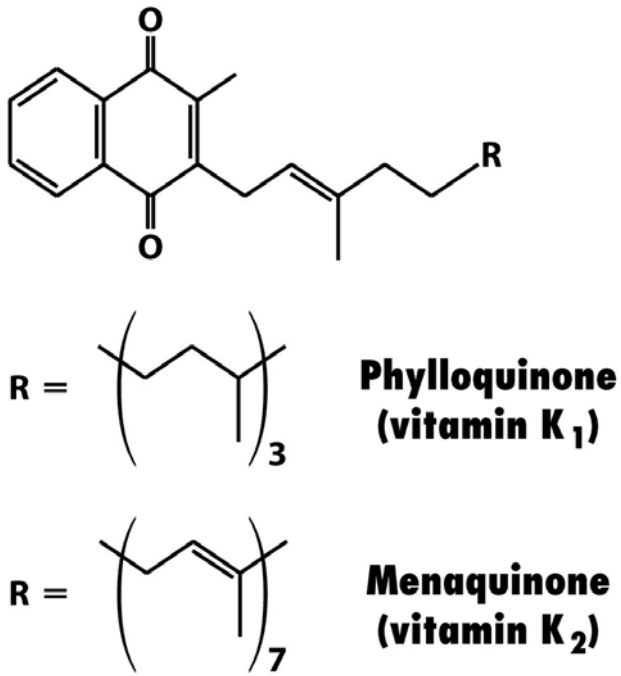
Derived mainly from plant β-carotene
Retinol (vit A)
Retinal: eye's photoreceptor
Retinoic acid: hormone like actions

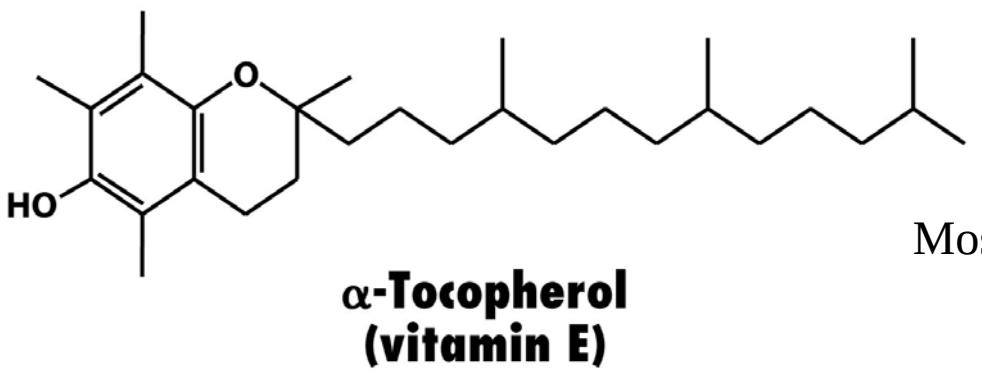


Unnumbered figure pg 246b Fundamentals of Biochemistry, 2/e

Synthesized by
- plant (phylloquinone)
- bacteria (menaquinone)

Animal is supplied by intestinal bacteria (50%)

Blood coagulation
- carboxylation of Glu in the proteins



Unnumbered figure pg 246c Fundamentals of Biochemistry, 2/e

Most abundant member is α-tocopherol
- Incorporated into cell membrane
- Function as antioxidant

Eicosanoids from arachidonic acid

Act at very low conc and locally
Tissue dependent products
Varity of function
- pain and fever
- blood pressure
- blood coagulation
- reproduction

Opposite actions
- thromboxane & prostacyclin

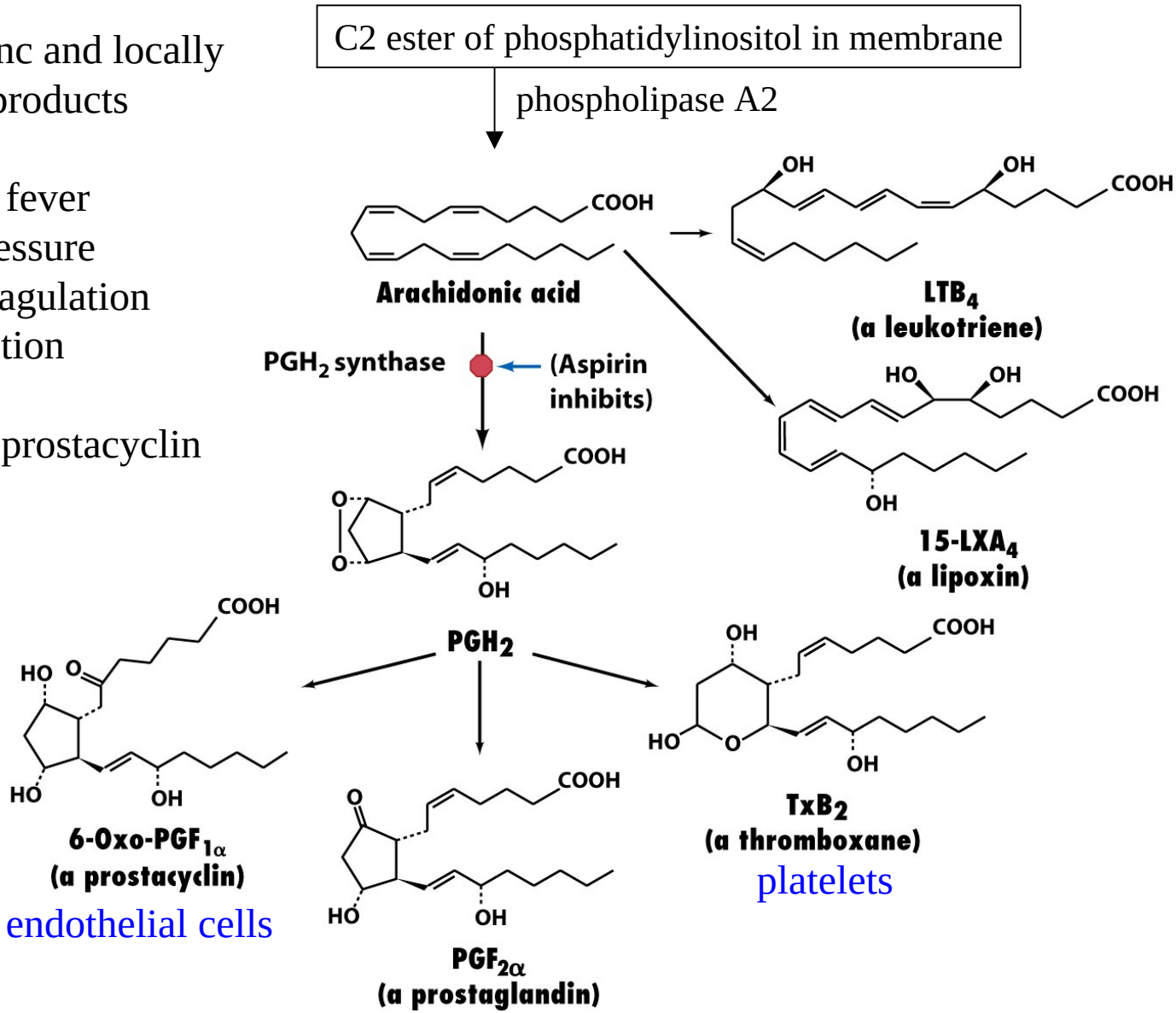


Figure 9-12 Fundamentals of Biochemistry, 2/e

Lipid bilayers

Avoid unfavorable contact with water
Micelles and bilayers

Fatty acids form micelles

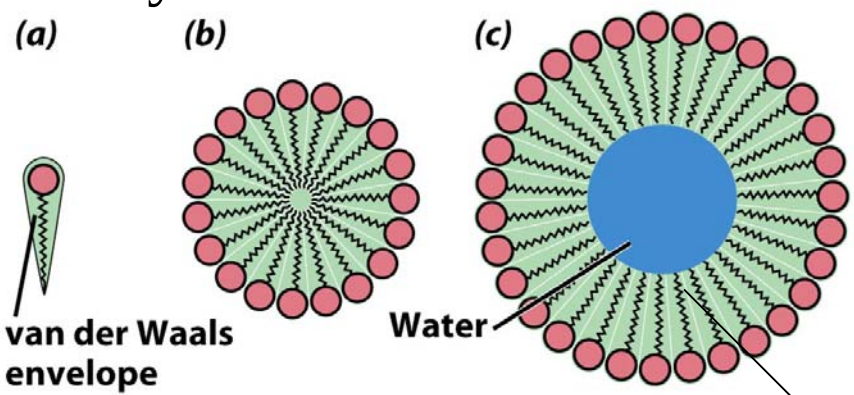


Figure 9-13 Fundamentals of Biochemistry, 2/e
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Unfavorable water-filled center

Phospholipids form bilayers

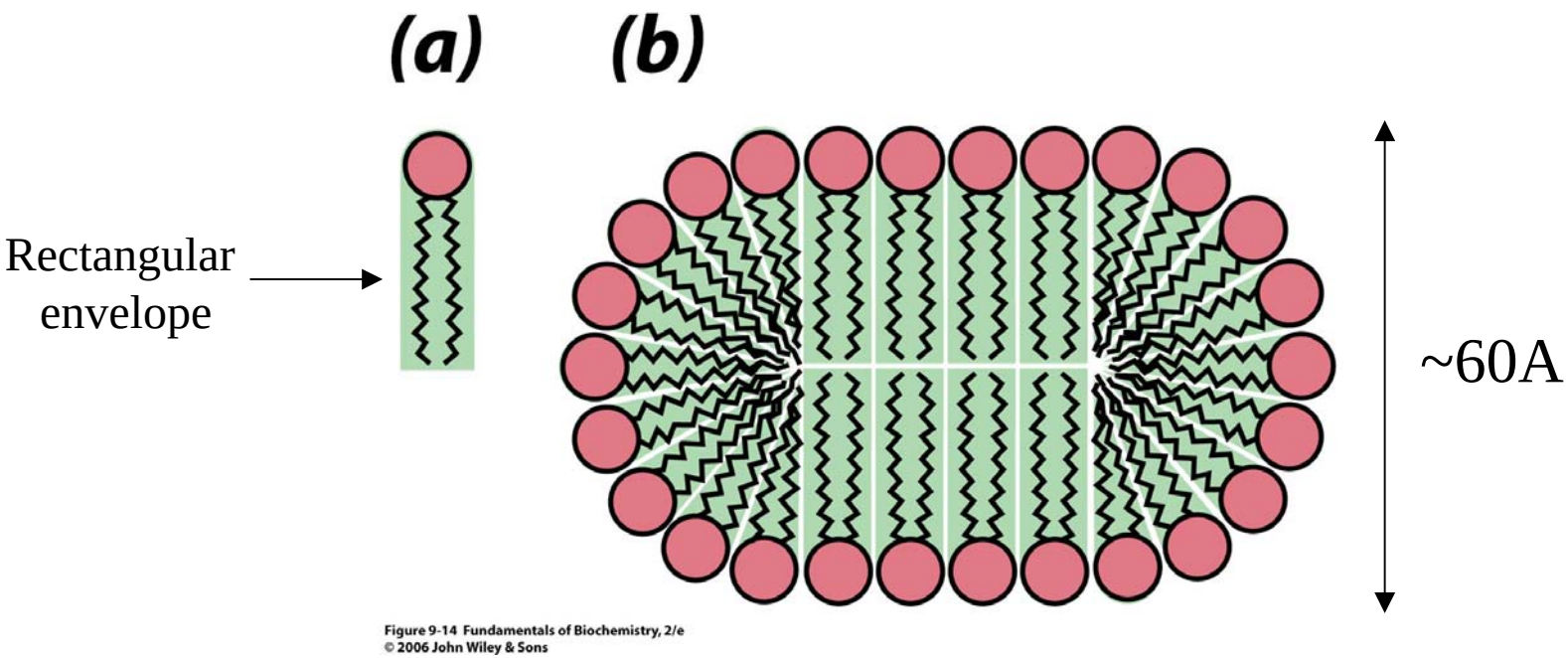

Figure 9-14 Fundamentals of Biochemistry, 2/e

Liposome: hollow bilayer

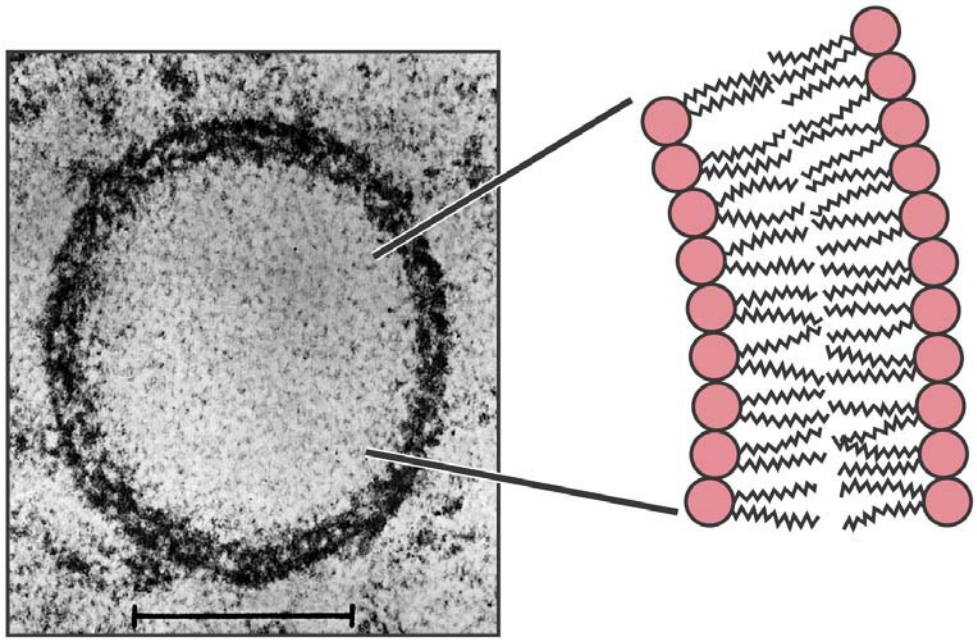

Figure 9-15 Fundamentals of Biochemistry, 2/e

Models of biological membranes
Vehicles for drug delivery: fusion with the plasma membrane

Lipid mobility

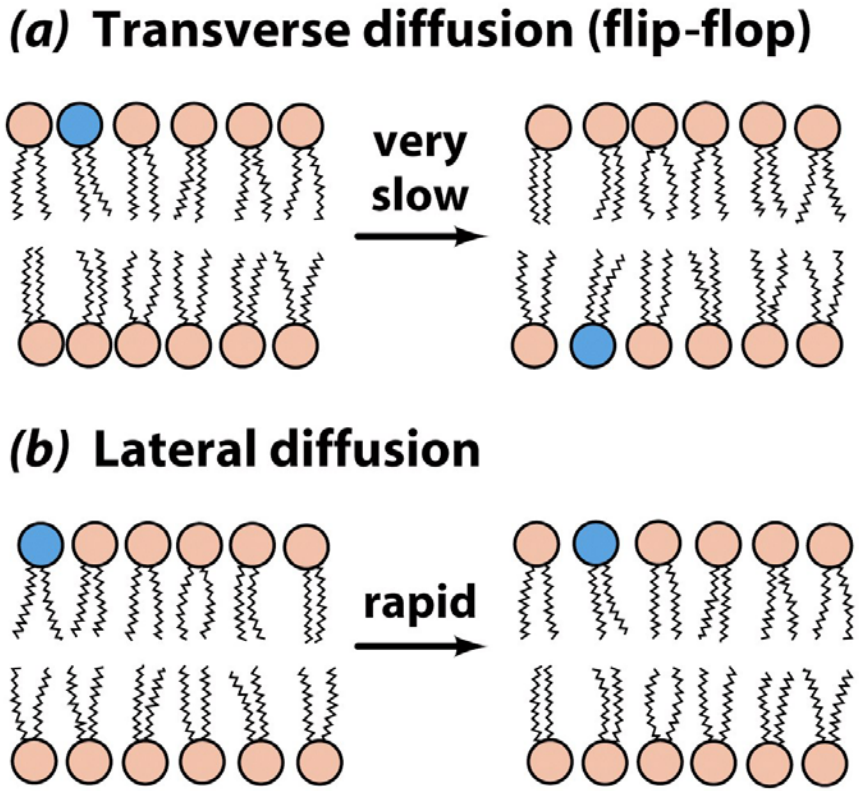

Figure 9-16 Fundamentals of Biochemistry, 2/e

Dynamics of lipid bilayer

Constant motion due to free rotation around the C-C bonds
Viscosity of light machine oil

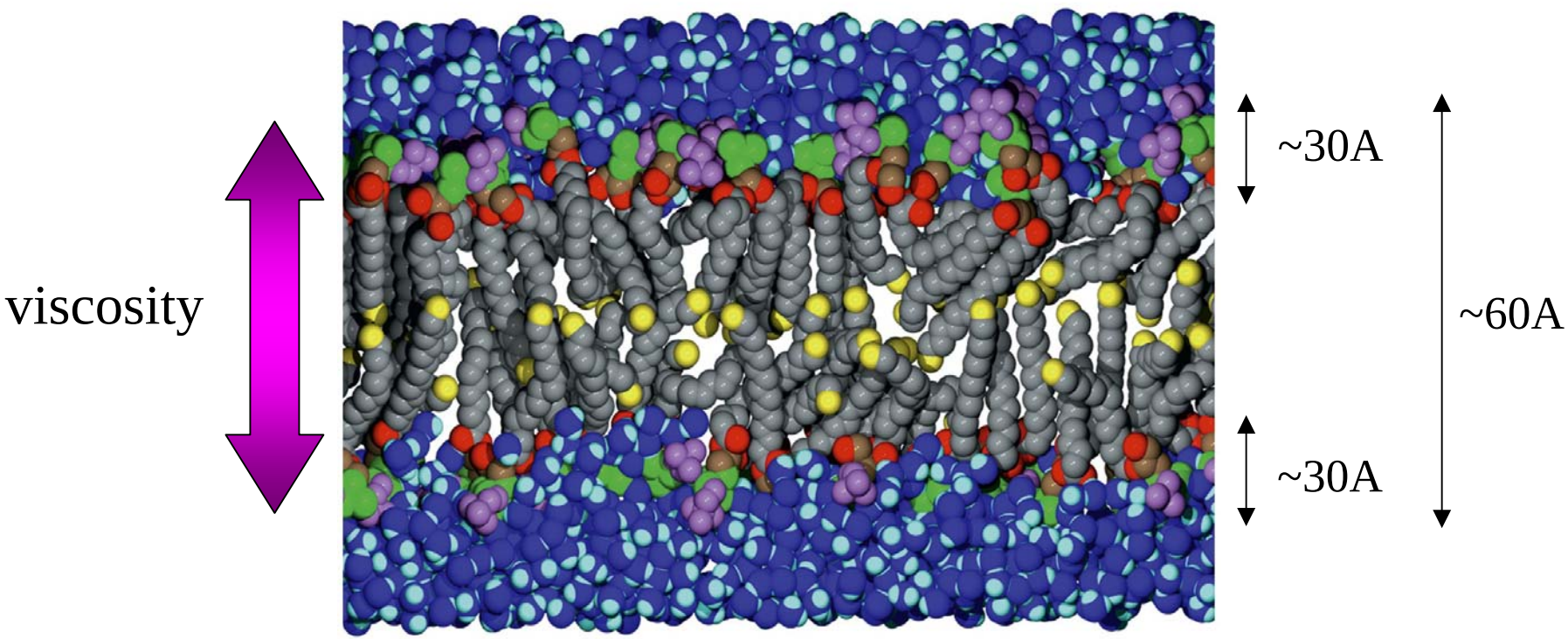

Figure 9-17 Fundamentals of Biochemistry, 2/e

The fluidity is temperature-dependent

Transition temperature: 10~40C

constant level of fluidity: modification of fatty acid compositions

Cholesterol is a membrane plasticizer

decreases membrane fluidity & broaden the range of transition temp

liquid crystal

gel-like solid

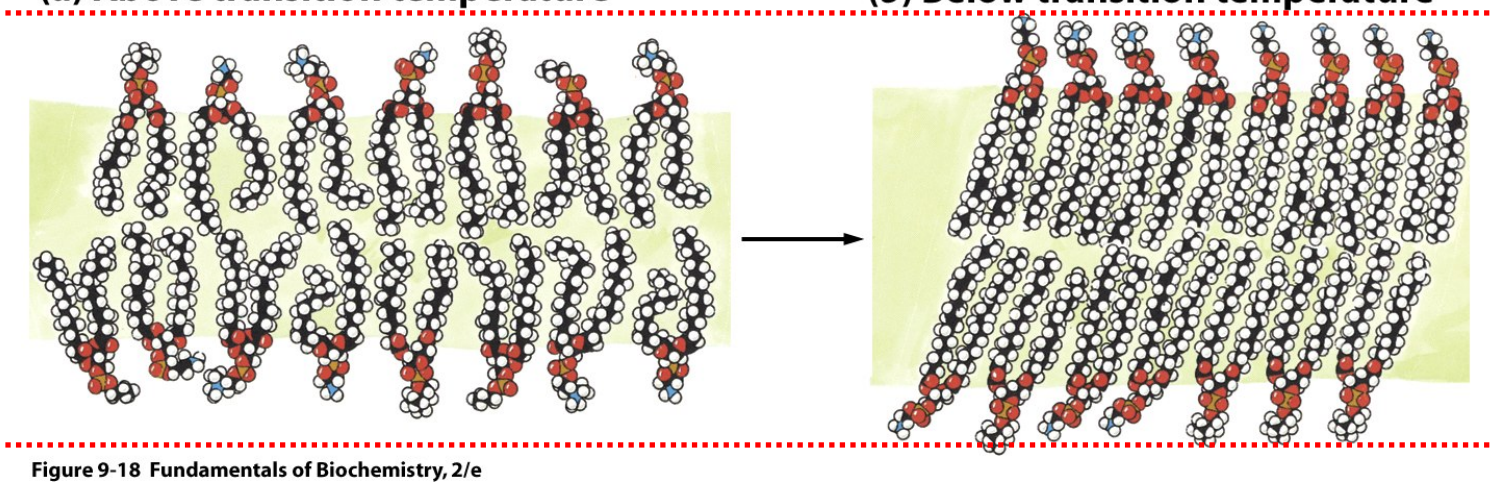

Figure 9-18 Fundamentals of Biochemistry, 2/e