David L. Nelson and Michael M. Cox

- *LEHNINGER*
- *PRINCIPLES OF BIOCHEMISTRY*
- *Fifth Edition*

CHAPTER 10
Lipids

Lipids

v **Storage Lipids**
Ø Fatty Acids
Ø Triacylglycerols (Energy & Insulation)
Ø Wax

v **Membrane Lipids**
Ø Glycerophospholipids (Phosphoglycerides)
Ø Sphingolipds
Ø Sterols

Fuctions of Lipids

- # Energy Storage: Fats & Oils
- # Structural Component: Phospholipids and sterols
- # Enzyme Cofactors
- # Electron Carriers
- # Light-absorbing Pigments
- # Hydrophobic Anchors
- # Emulsifying Agents
- # Hormones
- # Intracellular Messengers

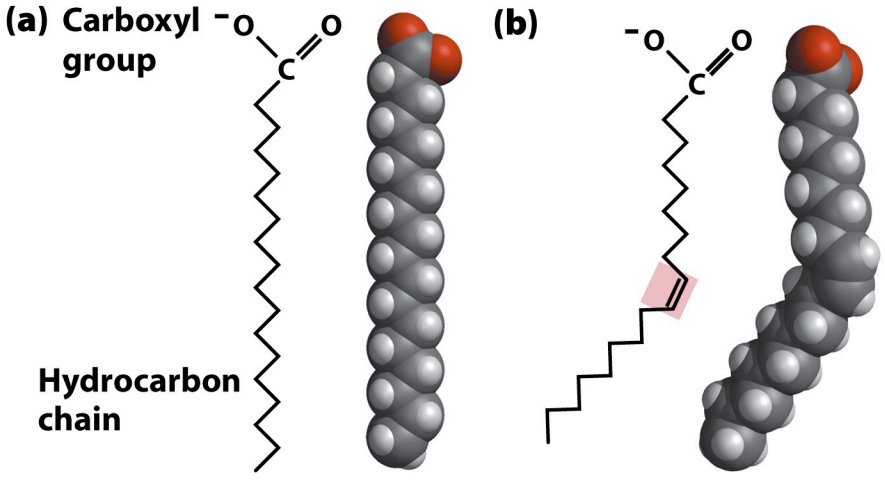

Figure 10-2ab
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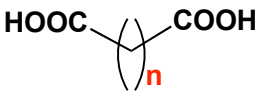
Systematic name	Trivial name	designation	MW	MP (°C)
butanoic	butyric	4	88.1	-7.9
pentanoic	valeric	5		
hexanoic	caproic	6	116.1	-3.4
octanoic	caprylic	8	144.2	16.7
nonanoic	pelargonic	9	158.2	12.5
decanoic	capric	10	172.3	31.6
dodecanoic	lauric	12	200.3	44.2
tetradecanoic	myristic	14	228.4	53.9
hexadecanoic	palmitic	16	256.4	63.1
heptadecanoic	margaric (daturic)	17	270.4	61.3
octadecanoic	stearic	18	284.4	69.6
eicosanoic	arachidic	20	312.5	75.3
docosanoic	behenic	22	340.5	79.9
tetracosanoic	lignoceric	24	368.6	84.2
hexacosanoic	cerotic	26	396.7	88
heptacosanoic	carboceric	27	410.7	
octacosanoic	montanic	28	424.8	
triacontanoic	melissic	30	452.9	
dotriacontanoic	lacceroic	32	481	
tritriacontanoic	ceromelissic (psyllic)	33	495	
tetratriacontanoic	geddic	34	509.1	
pentatriacontanoic	ceroplastic	35	523.1	

Systematic name	Trivial name	designation	MW	MP (°C)
cis-4-decenoic	obtusilic	10:1(n-6)	170.3	
cis-9-decenoic	caproleic	10:1(n-1)	170.3	
cis-5-lauroleic	lauroleic	12:1(n-7)	198.4	
cis-4-dodecenoic	linderic	12:1(n-8)	198.4	
cis-9-tetradecenoic	myristoleic	14:1(n-5)	226.4	
cis-5-tetradecenoic	physeteric	14:1(n-9)	226.4	
cis-4-tetradecenoic	tsuzuic	14:1(n-10)	226.4	
cis-9-hexadecenoic	palmitoleic	16:1(n-7)	254.4	0.5
cis-6-octadecenoic	petroselinic	18:1(n-12)	282.4	30
cis-9-octadecenoic	oleic	18:1(n-9)	282.4	16.2
tr-9-octadecenoic	elaidic	tr18:1(n-9)	282.4	43.7
cis-11-octadecenoic	vaccenic (asclepic)	18:1(n-7)	282.4	39
cis-9-eicosenoic	gadoleic	20:1(n-11)	310.5	25
cis-11-eicosenoic	gondoic	20:1(n-9)	310.5	
cis-11-docosenoic	cetoleic	22:1(n-11)	338.6	
cis-13-docosenoic	erucic	22:1(n-9)	338.6	33.4
cis-15-tetracosenoic	nervonic	24:1(n-9)	366.6	39

Systematic name	Trivial name	designation	MW	MP (°C)
9,12-octadecadienoic	linoleic	18:2(n-6)	280.4	-5
6,9,12-octadecatrienoic	γ-linolenic	18:3(n-6)	278.4	
8,11,14-eicosatrienoic	dihomo-γ-linolenic	20:3(n-6)	306.5	
5,8,11,14-eicosatetraenoic	arachidonic	20:4(n-6)	304.5	-50
7,10,13,16-docosatetraenoic		22:4(n-6)	332.6	
4,7,10,13,16-docosapentaenoic		22:5(n-6)	330.6	
9,12,15-octadecatrienoic	α-linolenic	18:3(n-3)	278.4	-11
6,9,12,15-octadecatetraenoic	stearidonic	18:4(n-3)	276.4	-57
8,11,14,17-eicosatetraenoic		20:4(n-3)	304.5	

Trivial name of dicarboxylic acids



Name	n
oxalic acid	0
malonic acid	1
succinic acid	2
glutaric acid	3
adipic acid	4
pimelic acid	5
suberic acid	6
azelaic acid	7
sebacic acid	8
dodecanedioic acid	10
brassylic acid	11
thapsic acid	14

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 to −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")	−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.

Table 10-1

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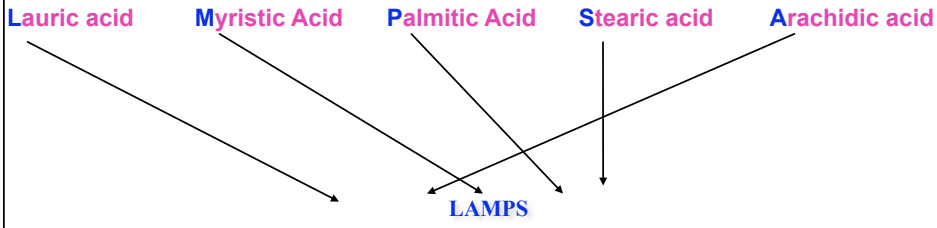
ABCDEFGHIJKL

Lauric acid Myristic Acid Palmitic Acid Stearic acid Arachidic acid



LAMPS

Effect of Unsaturation

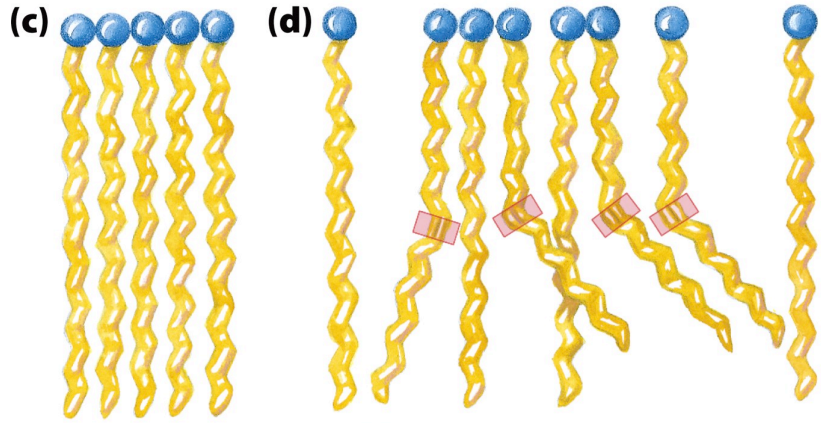


Figure 10-2cd
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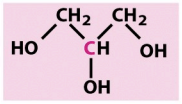
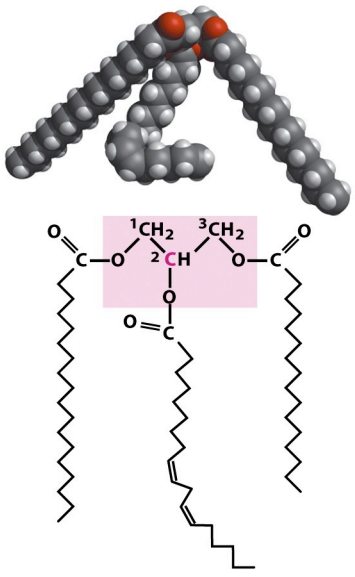
Triacylglycerols (fats, triglycerides)



Glycerol



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

Figure 10-3
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Fatty Acid Components in Fats

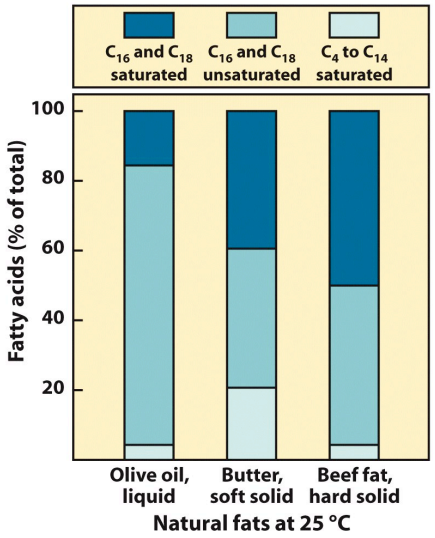

Figure 10-5
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TABLE 10–2 Trans Fatty Acids in Some Typical Fast Foods and Snacks

	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.

Table 10-2
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Wax

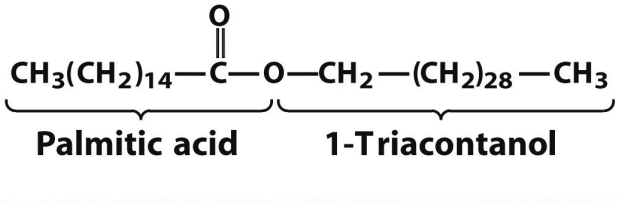

Figure 10-6
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Classes of Storage and Membrane Lipids

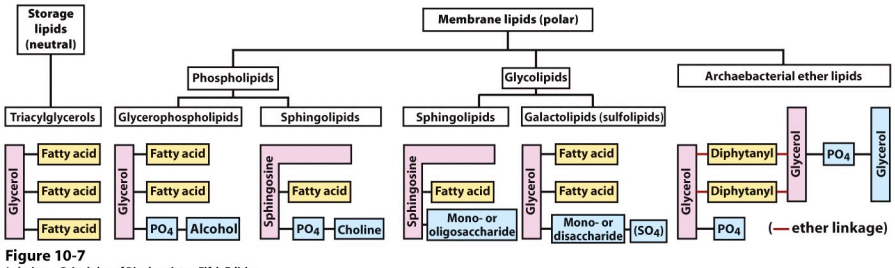

Figure 10-7
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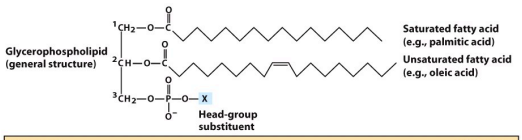
Glycerophospholipids



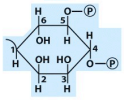
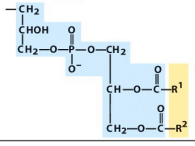
Name of glycerophospholipid	Name of X	Formula of X	Net charge (at pH 7)
Phosphatidic acid	—	—H	−1
Phosphatidylethanolamine	Ethanolamine	$-CH_2-CH_2-\overset{+}{N}H_3$	0
Phosphatidylcholine	Choline	$-CH_2-CH_2-\overset{+}{N}(CH_3)_3$	0
Phosphatidylserine	Serine	$-CH_2-\underset{COO^-}{CH}-\overset{+}{N}H_3$	−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

Figure 10-9
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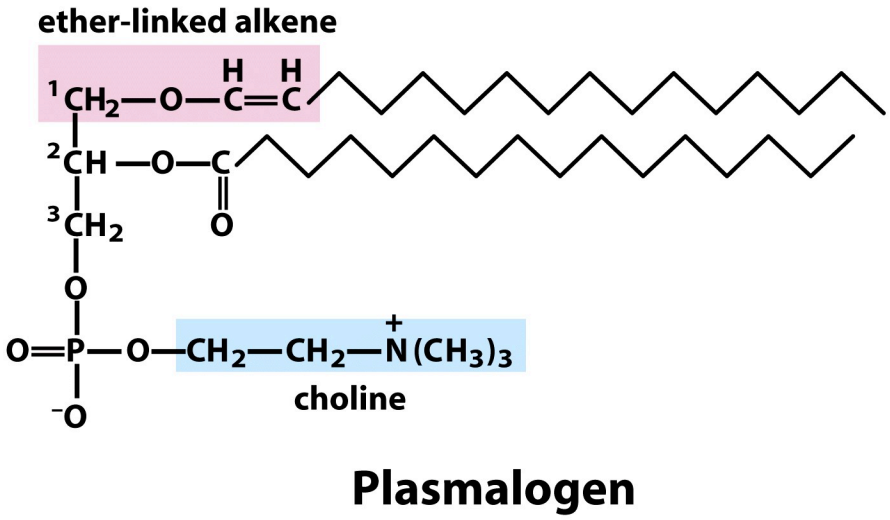

Figure 10-10a
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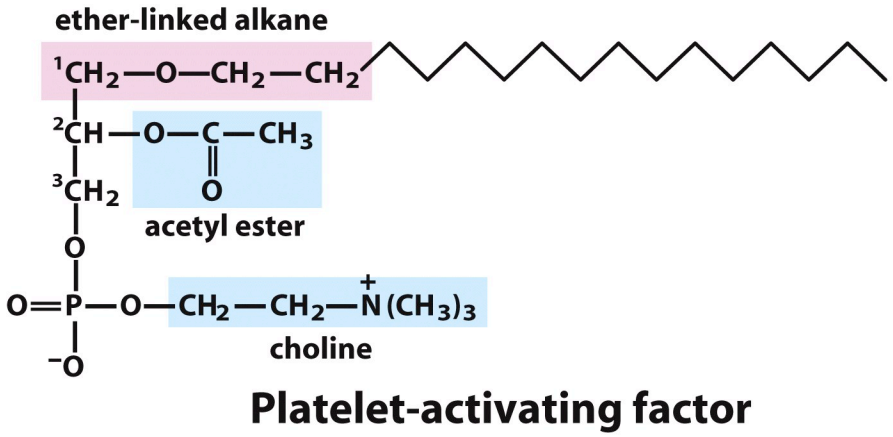

Figure 10-10b
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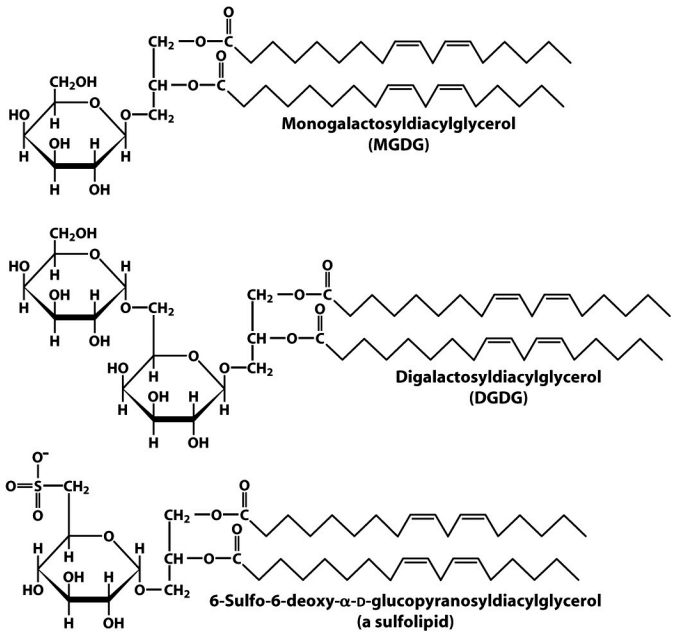

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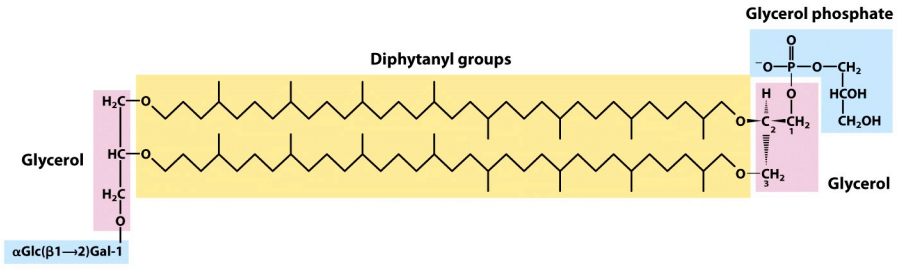

Figure 10-12
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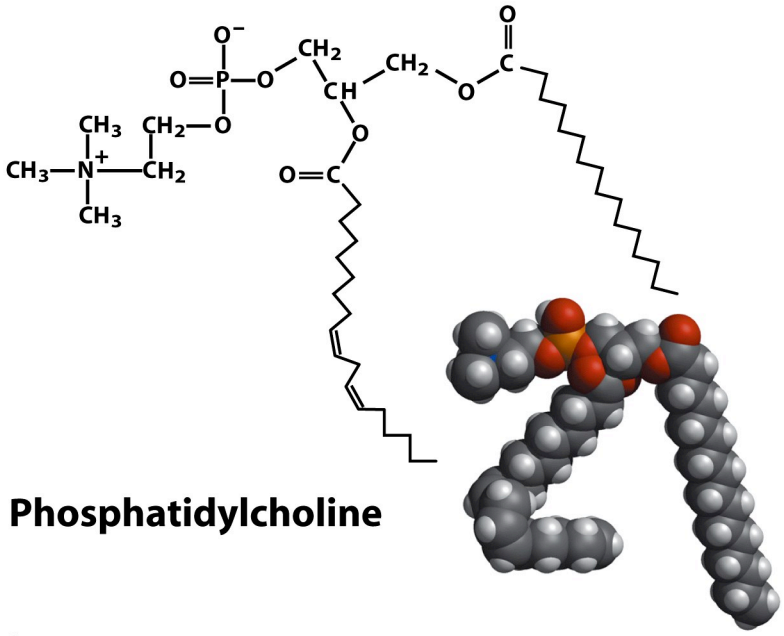

Phosphatidylcholine

Figure 10-14 part 1
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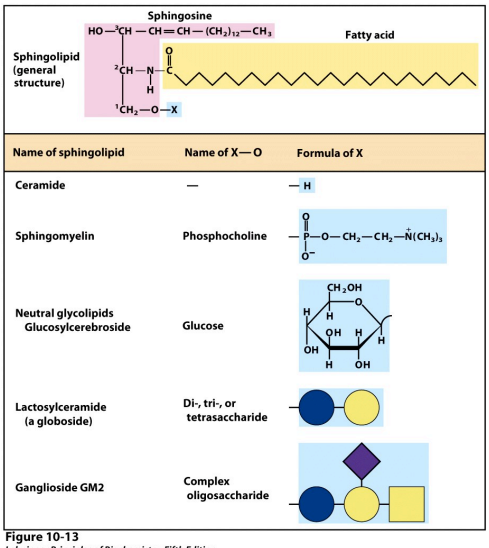
Sphingolipids



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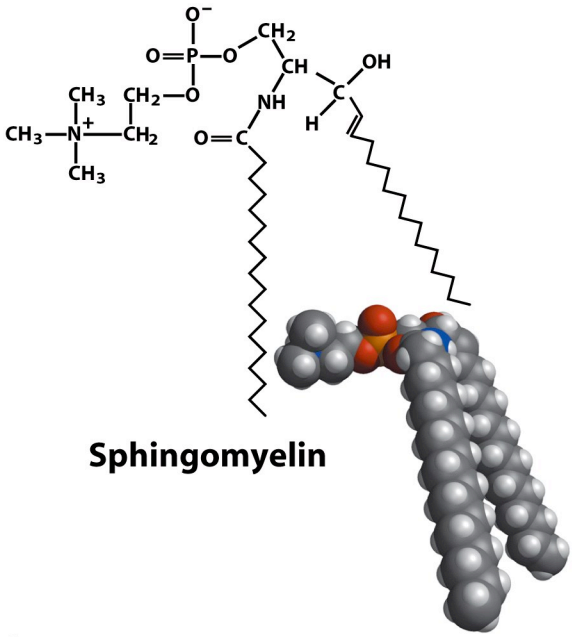

Figure 10-14 part 2
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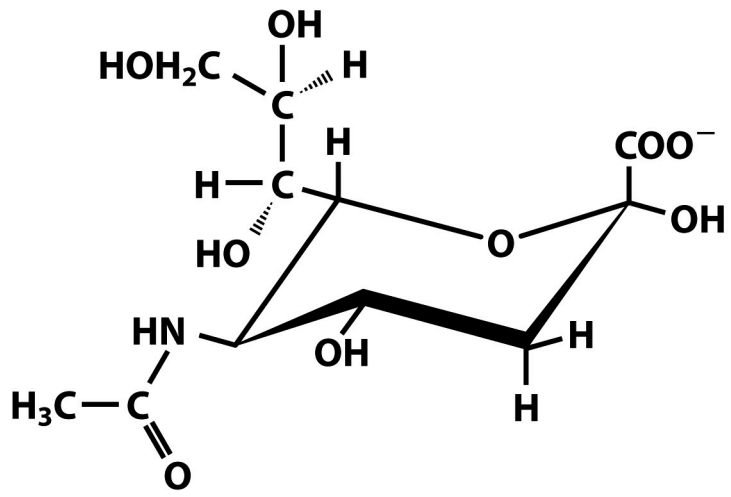

***N*-Acetylneuraminic acid (a sialic acid) (Neu5Ac)**

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Blood Groups

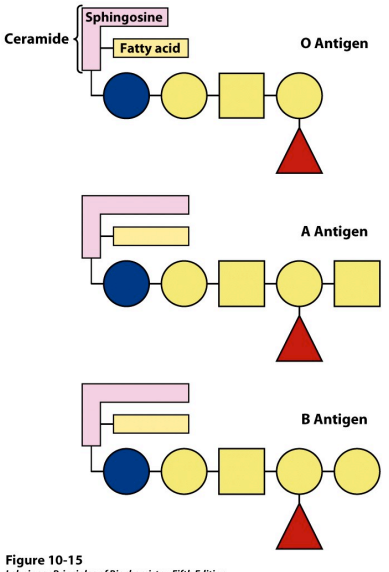

Figure 10-15
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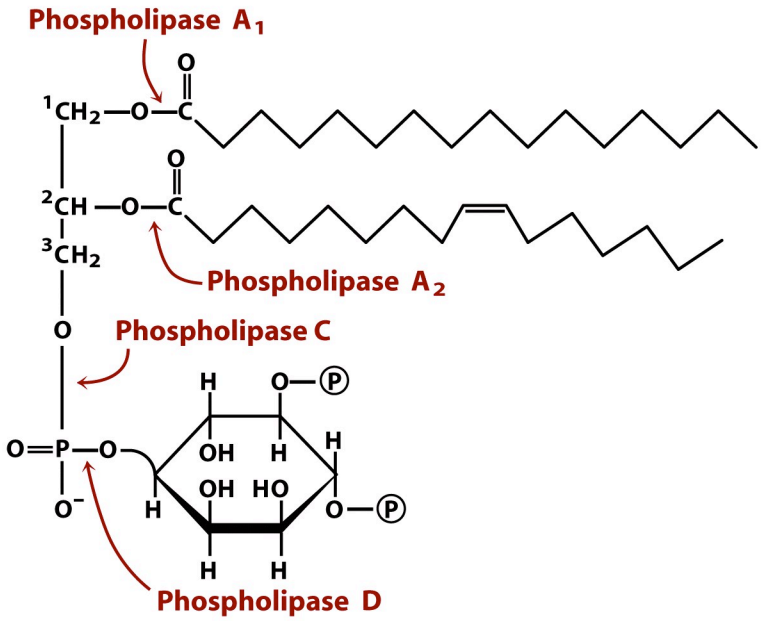

Figure 10-16
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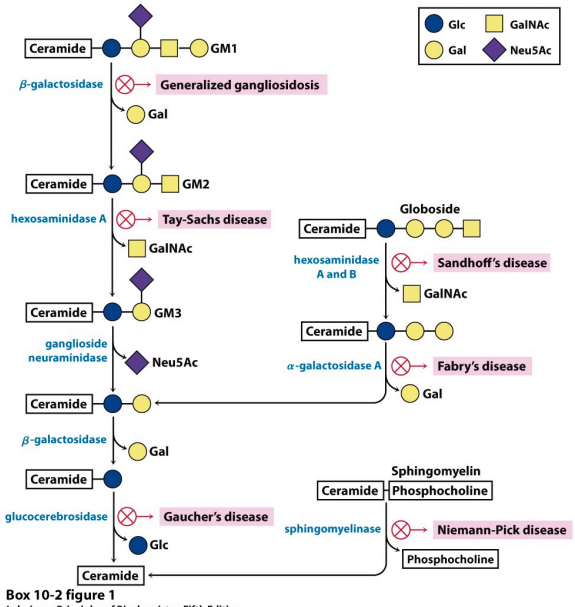
Lipids related dieseases



Box 10-2 figure 1
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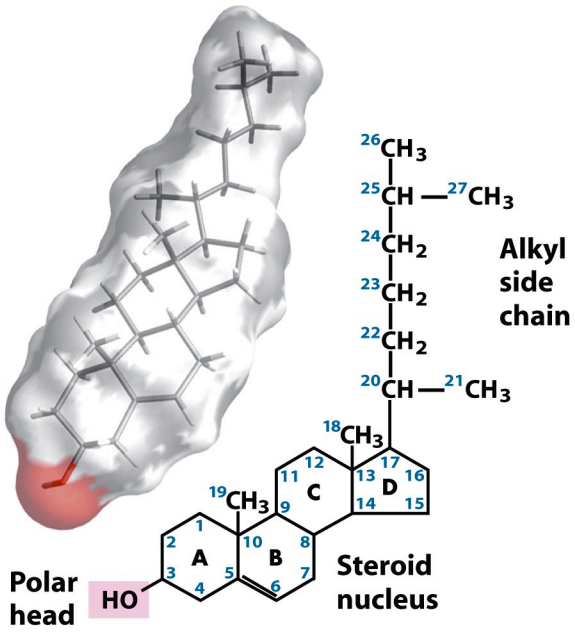

Figure 10-17
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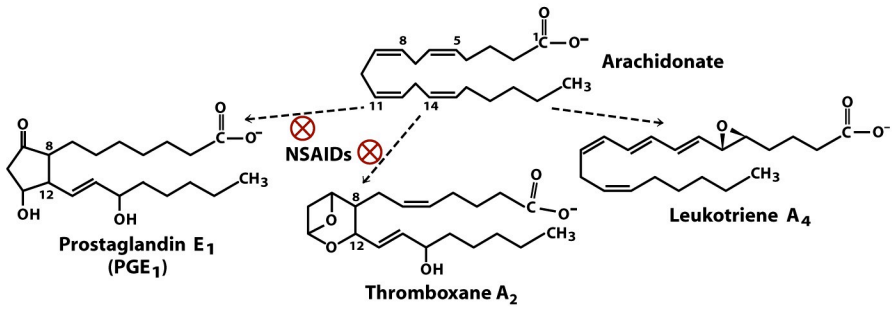

Figure 10-18
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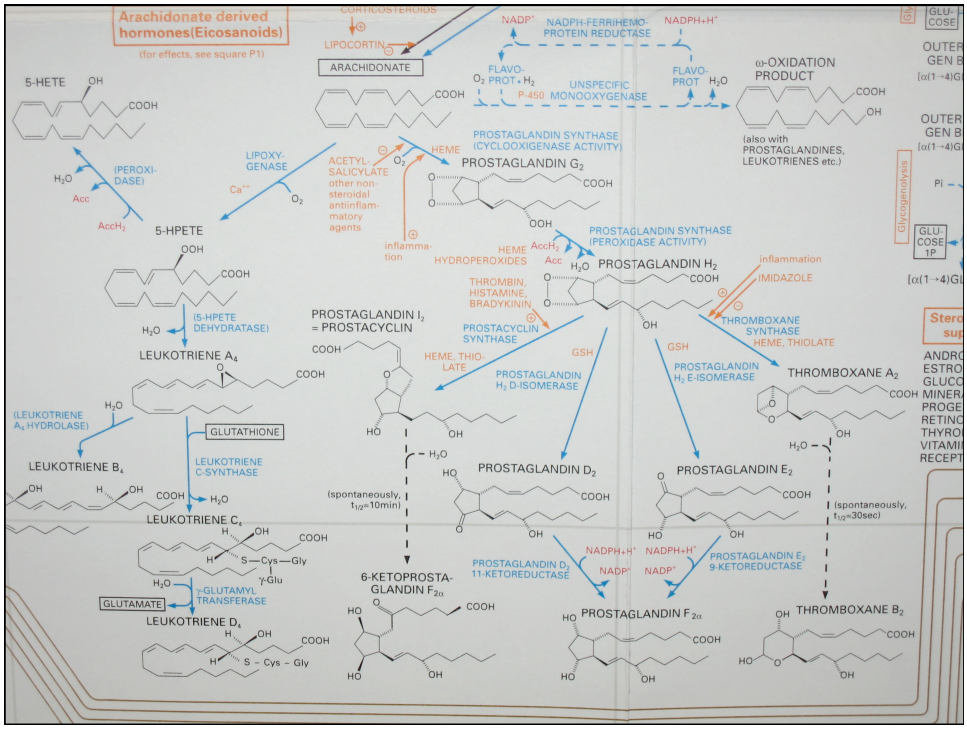

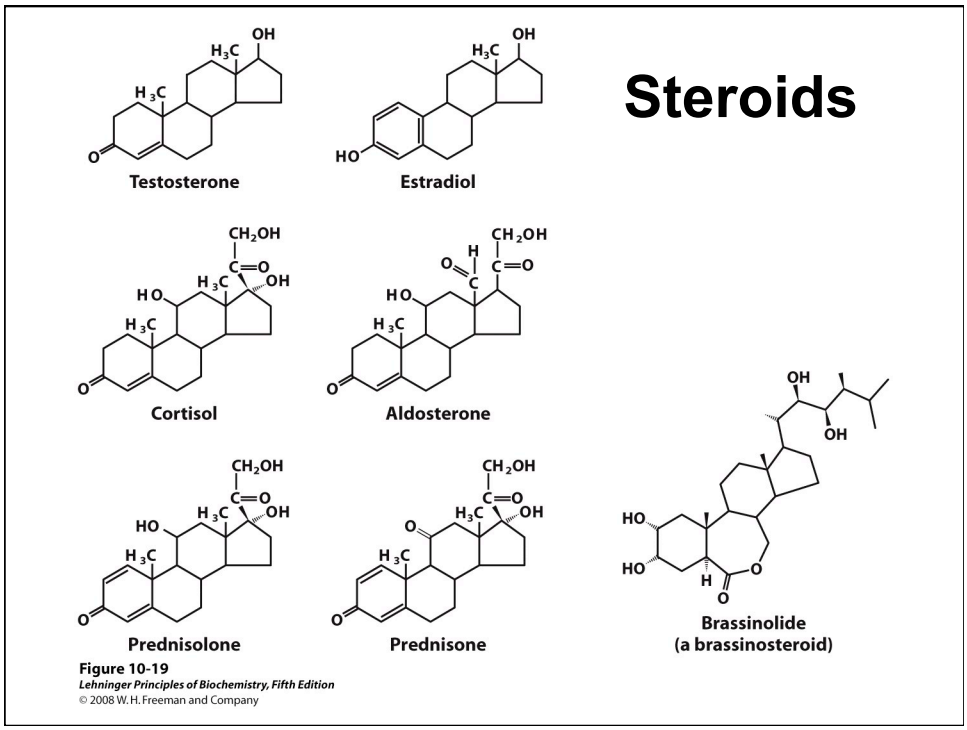

Figure 10-19
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TABLE 10–3 Eight Major Categories of Biological Lipids

Category	Category code	Examples
Fatty acids	FA	Oleate, stearoyl-CoA, palmitoylcarnitine
Glycerolipids	GL	Di- and triacylglycerols
Glycerophospholipids	GP	Phosphatidylcholine, phosphatidylserine, phosphatidylethanolamine
Sphingolipids	SP	Sphingomyelin, ganglioside GM2
Sterol lipids	ST	Cholesterol, progesterone, bile acids
Prenol lipids	PR	Farnesol, geraniol, retinol, ubiquinone
Saccharolipids	SL	Lipopolysaccharide
Polyketides	PK	Tetracycline, aflatoxin B_1

Table 10-3
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Vitamins

- Vitamins are essential, noncaloric nutrients.
- Vitamins are needed in very small amounts.
- Our bodies cannot synthesize vitamins; they are obtained entirely from our diet or from vitamin supplements.
- A healthy diet containing fresh vegetables, fruits, whole grains and complete protein sources provides the recommended daily amount of vitamins and minerals.
- Vitamins are divided into two classes: water soluble and fat soluble.
- A vitamin's class determines how it is absorbed into the bloodstream and transported, whether it can be stored in the body, and how easily it is lost from the body.

Vitamin A

- Vitamin A is present in mild, eggs, and liver and in the form of beta-carotene, found in vegetable sources. Beta-carotene is converted to vitamin A once inside the body.
- Vitamin A is involved in vision and is required for proper growth in children.
- Lack of vitamin A leads to night blindness.

Retinol and derivatives

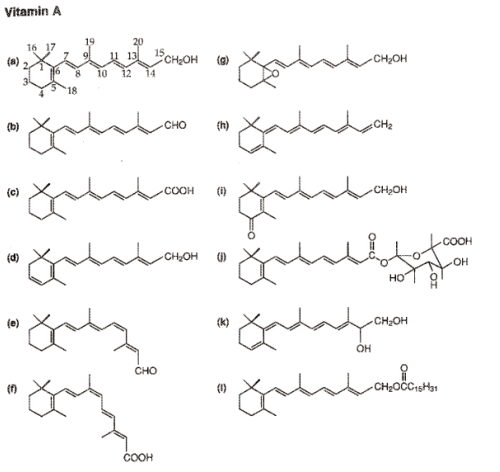


Fig. 1 Formulas for retinol and its derivatives. All are all-trans isomers except as noted. (a) retinol, (b) retinal, (c) retinoic acid, (d) 3,4-didehydroretinol, (e) 11-*cis* retinal, (f) 9-*cis* retinoic acid, (g) 5,6-epoxyretinol, (h) *retro* anhydroretinol, (i) 4-oxoretinol, (j) retinoyl β-glucuronide, (k) 14-hydroxy-4,14-*retro* retinol, (l) retinyl palmitate.

Vitamins

Table 10.1 Properties of the water-soluble vitamins

Water-soluble vitamin	Major roles	Deficiency symptoms	Significant sources
(a) Thiamine (B_1)	Nerve function, energy generation, supports normal appetite	Edema, enlarged heart, heart damage, weakened muscles, paralysis	Pork, whole and enriched grains, legumes, sunflower seeds
(b) Riboflavin (B_2)	Energy generation, supports normal vision and skin health	Light sensitivity, skin inflammation and lesions	Liver, milk, yogurt, whole and enriched grains, leafy greens
(c) Niacin (B_3)	Energy generation, supports skin health, supports nervous and digestive systems	Diarrhea; inflammation of mouth, gums, and tongue; dermatitis; fatigue; depression	All protein-containing foods, especially chicken, beef, tuna, milk, eggs; enriched grains, peanuts
(d) Pantothenic acid (B_5)	Energy metabolism	Nausea, headache, fatigue, insomnia	Liver, mushrooms, whole grains, avocados, broccoli
(e) Pyridoxine (B_6)	Fat metabolism, helps to make red blood cells	Headache, anemia, nausea, smooth tongue, cracks at corners of mouth, dermatitis, muscle disruption	Meat, fish, poultry, whole grains, legumes, leafy greens, seeds

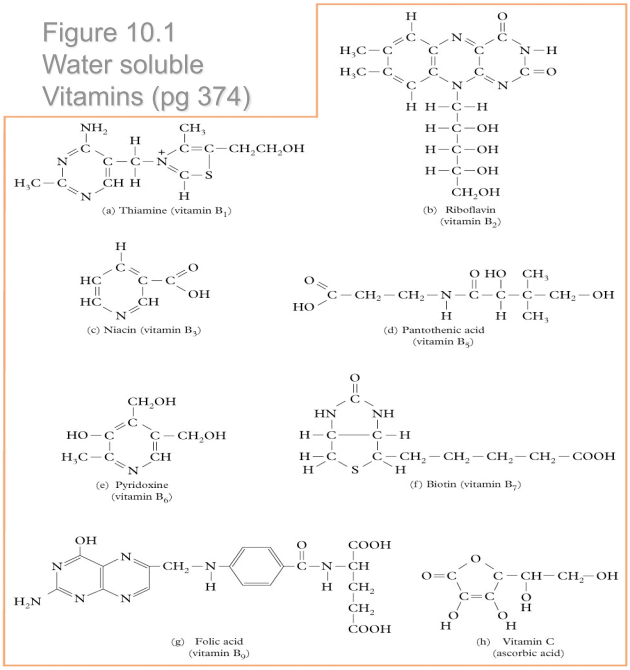
Vitamins

Table 10.1 Properties of the water-soluble vitamins

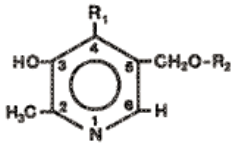
Water-soluble vitamin	Major roles	Deficiency symptoms	Significant sources
(f) Biotin (B_7)	Coenzyme in glucose production and fat synthesis	Dermatitis, depression, hair loss, loss of appetite, nausea	Organ meats, fish, egg yolks, whole grains, soybeans
(g) Folic acid (B_9)	Synthesis of RNA and DNA, new cell formation	Anemia (large cell type), impaired growth, diarrhea, frequent infections, smooth tongue, depression, confusion, weakness	Liver, leafy greens, legumes, seeds
Vitamin B_{12}	Coenzyme in folic acid metabolism, nerve function, new cell synthesis	Pernicious anemia, anemia, degeneration of nerve function, smooth tongue, fatigue, hypersensitive skin	Animal products including cheese, milk, eggs
(h) Vitamin C	Collagen synthesis, antioxidant, amino acid metabolism, immune system support, assists in wound healing, iron absorption	Anemia (small cell type), bleeding gums, loosened teeth, muscle degeneration, fragile bones	Citrus fruit, strawberries, greens, broccoli

*Letters refer to the structures shown in Figure 10.1. The structure of vitamin B_{12} is very complex, so we have not illustrated it.

Figure 10.1
Water soluble
Vitamins (pg 374)



Vitamin B_6



PN ; R_1 = CH_2OH PNP ; R_2 = $PO_3^=$
PM ; R_1 = CH_2NH_2 PMP ; R_2 = $PO_3^=$
PL ; R_1 = CHO PLP ; R_2 = $PO_3^=$

Fig. 1 Structure of B_6 vitamers.

Vitamin B_{12}

Cobalamin

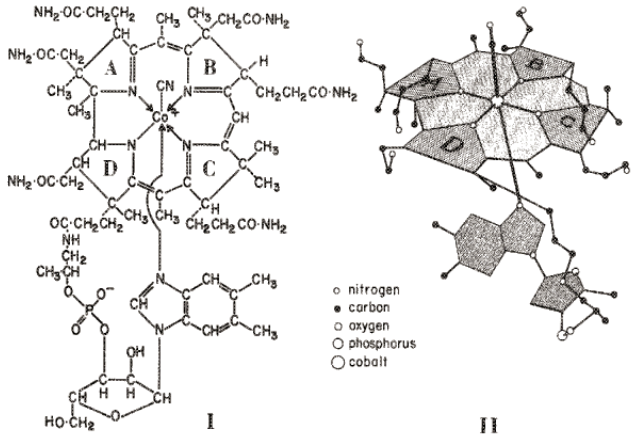


Fig. 1 Cobalamin. **I**, chemical structures of cyanocobalamin. **II**, semidiagrammatic representation of three-dimensional structure showing relations of planar and nucleotide moieties. Hydrogen atoms and a number of oxygen atoms are omitted.

Vitamin B_2

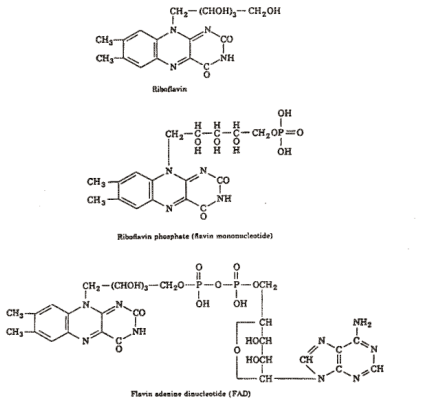


Fig. 1 Structural formulas of riboflavin, flavin mononucleotide (riboflavin-5′-phosphate, FMN) and flavin adenine dinucleotide (FAD).

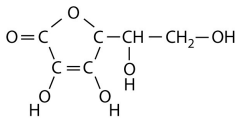
Vitamins

1. Vitamin C and members of the vitamin B family are water soluble.

- Water soluble vitamins are absorbed directly into the bloodstream where they travel freely.
- They are not stored in the tissues to any great amount so are not toxic. Excess amounts are secreted in the urine.
- Water soluble vitamins are diminished in foods cooked in water.

Vitamins

- Vitamin C is water soluble because it contains many hydroxyl groups.



(h) Vitamin C
(ascorbic acid)

- Vitamin C is required for the production of collagen, an important connective tissue.
- A deficiency of vitamin C results in the disease, scurvy, characterized by skin lesions and tooth loss.
- Vitamin C is found in fresh fruits and vegetables, especially citrus fruits.

Vitamins

- A deficiency of vitamin C leads to the disease scurvy, characterized by skin lesions and tooth loss.
- Vitamin C is an antioxidant and is also involved in the body's immune response against infection.
- Many people ingest large amounts of vitamin C to try to ward off colds. Its effectiveness is inconclusive and people are advised to refrain from taking massive doses of vitamin C.
- The other water soluble vitamins are all members of the B family.
- The B vitamins all act as coenzymes, molecules that cannot be synthesized by the body but are required for the activity of certain enzymes.

Vitamin C

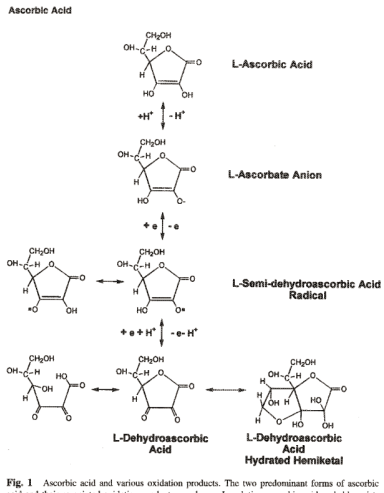


Fig. 1 Ascorbic acid and various oxidation products. The two predominant forms of ascorbic acid and their associated oxidation products are shown. In solution, ascorbic acid probably exists as the hydrated hemiketal.

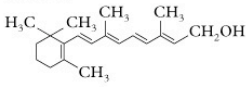
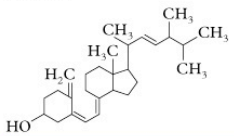
Fat Soluble Vitamins

2. Vitamins A, D, E, and K are fat soluble.

- The fat soluble vitamins are carried by fat-transporting proteins in the blood.
- Fat soluble vitamins can accumulate in fatty tissue, so levels of fat soluble vitamins can build up to toxic doses if mega-doses are taken.
- Fat soluble vitamins may be missing from the diet for weeks since reserves are generally stored in the fatty tissues.

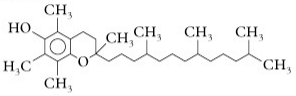
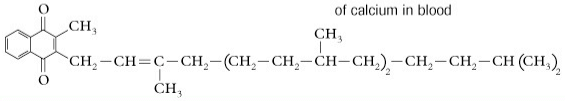
Vitamins

Table 10.2 Properties of fat-soluble vitamins

Fat-soluble vitamin	Major roles	Deficiency symptoms	Significant sources
Vitamin A 	Vision, growth, reproduction, immune function, cell development, bone and tooth growth	Night blindness, impaired growth, anemia, diarrhea, frequent infections	Liver, fortified milk, cheese, eggs, orange-colored fruits and vegetables, leafy greens, broccoli
Vitamin D 	Absorption of calcium and phosphorus, bone maintenance	In children, misshapen bones and retarded growth; in adults, softening of bones, lax muscles	Tuna, salmon, fish oils, fortified milk, egg yolk, butter, margarine, cereals; synthesized in the body with help of sunlight

Vitamins

Table 10.2 Properties of fat-soluble vitamins

Fat-soluble vitamin	Major roles	Deficiency symptoms	Significant sources
Vitamin E 	Antioxidant, protects cell membranes	Breakdown of red blood cells, anemia, nerve damage	Egg yolks, leafy greens, whole grain products, wheat germ, nuts, seeds, corn oil, safflower oil, soybean oil
Vitamin K 	Syntheses of blood-clotting proteins, regulation of calcium in blood	Hemorrhaging	Beef liver, egg yolk, legumes, leafy greens, cabbage family; synthesized by bacteria in digestive tract

Vitamin D

- Vitamin D can be made in the body by the action of UV light on the skin. It is routinely added to milk as a vitamin supplement.
- Vitamin D is involved in the uptake of calcium through the intestinal wall.
- Vitamin D deficiency leads to a disease called rickets.

Interchange between Vitamin Ds

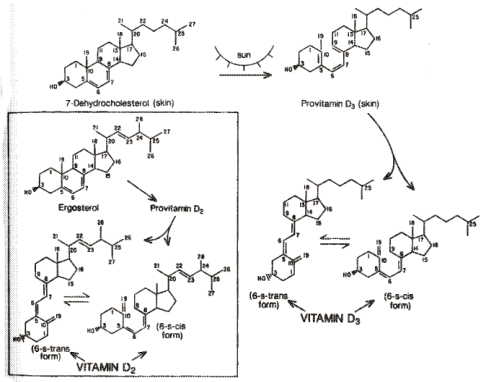


Fig. 1 Chemistry and irradiation pathway for production of vitamin D_3 (a natural process) and vitamin D_2 (a commercial process). In each instance the provitamin, with a $\Delta 5,\Delta 7$ conjugated double-bond system in the B ring, is converted to the *seco*-B previtamin, with the 9,10 carbon–carbon bond broken. Then the previtamin D thermally isomerizes to the "vitamin" form, which contains a system of three conjugated double bonds. In solution vitamin D is capable of assuming a large number of conformations due to rotation about the 6,7 carbon–carbon bond of the B ring. The 6-*s*-cis conformer (the steroid-like shape) and the 6-*s*-trans conformer (the extended shape) are presented for both vitamin D_2 and vitamin D_3.

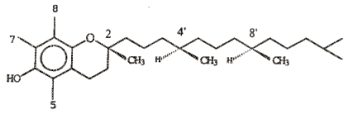
Vitamin D_3 metabolites

Fig. 5 Summary of the metabolic transformations of vitamin D_3. Shown here are the structures of all known chemically characterized vitamin D_3 metabolites.

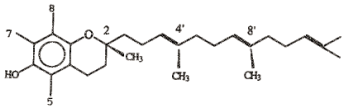
Vitamin E

- Vitamin E is an antioxidant.
- It is present in eggs, vegetable oil, nuts, and other fatty plant based foods.
- A deficiency of vitamin E leads to scaly skin, sterility and decay of muscle tissue.
- When O_2 is used by the body, small amounts of highly reactive molecules called free radicals are formed.
- Free radicals damage living cells by disrupting cell membranes. They are also damaging to proteins and DNA.
- Vitamin E and other antioxidants prevent this damage from happening.

Tocopherols



Toco Structure



Tocotrienol Structure

Position of methyls	Toco structure	Tocotrienol structure
5,7,8	α-Tocopherol (α-T)	α-Tocotrienol (α-T-3)
5,8	ß-Tocopherol (ß-T)	ß-Tocotrienol (ß-T-3)
7,8	γ-Tocopherol (γ-T)	γ-Tocotrienol (γ-T-3)
8	δ-Tocopherol (δ-T)	δ-Tocotrienol (δ-T-3)

Fig. 1 Structural formula of tocopherols.

Vitamin E

Vitamin E

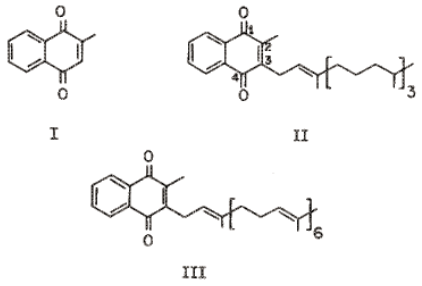
Table 1 Vitamin E Compounds

Vitamin	Trivial name	Chemical name
α-Tocopherol	5,7,8-Trimethyltocol	2,5,7,8-Tetramethyl-2-(4′,8′,12′-trimethyltridecyl)-6-chromanol
β-Tocopherol	5,8-Dimethyltocol	2,5,8-Trimethyl-2-(4′,8′,12′-trimethyltridecyl)-6-chromanol
γ-Tocopherol	7,8-Dimethyltocol	2,7,8-Trimethyl-2-(4′,8′,12′-trimethyltridecyl)-6-chromanol
δ-Tocopherol	8-Monomethyltocol	2,8-Dimethyl-2-(4′,8′,12′-trimethyltridecyl)-6-chromanol
α-Tocotrienol	5,7,8-Trimethyl tocotrienol	2,5,7,8-Tetramethyl-2-(4′,8′,12′-trimethyltridecyl)-6-chromanol
β-Tocotrienol	5,8-Dimethyl tocotrienol	2,5,8-Trimethyl-2-(4′,8′,12′-trimethyltridecyl)-6-chromanol
γ-Tocotrienol	7,8-Dimethyl tocotrienol	2,7,8-Trimethyl-2-(4′,8′,12′-trimethyltridecyl)-6-chromanol
δ-Tocotrienol	8-Monomethyl tocotrienol	2,8-Dimthyl-2-(4′,8′,12′-trimethyltridecyl)-6-chromanol

Vitamin K

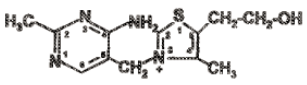
- Vitamin K is required to make the proteins involved in blood clotting. A routine injection of vitamin K is given to newborn infants.

Vitamin K

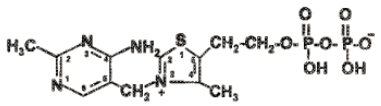


I II III

Thiamine



Thiamine



Thiamine pyrophosphate

Fig. 1 Structural formulas of thiamine and thiamine pyrophosphate.

Folic Acids

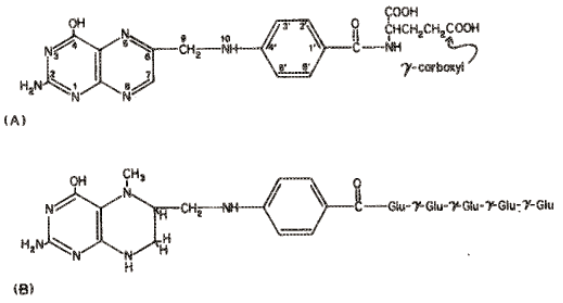


Fig. 1 Structure of (A) folic acid (PteGlu) and (B) 5-methyl-tetrahydrofolate pentaglutamate (5-Methyl-$H_4PteGlu_5$). Although folic acid is not naturally occurring, it is readily transported and reduced to the natural forms of the vitamin. One-carbon substituents can be at the N-5 and/or N-10 positions of the reduced folate molecule.

Table 1. Recommended Dietary Allowances of Vitamins for Healthy Adults

Age (Years)	Vit. A (μg)	Vit. C (mg)	Vit. D (μg)	Vit. E (μg)	Vit. K (μg)	Vit. B1 (mg)	Vit. B2 (mg)	Vit. B6 (mg)	Folate (μg)
Males									
19-30	900	90	5	15	120	1.2	1.3	1.3	400
31-50	900	90	5	15	120	1.2	1.3	1.3	400
51-70	900	90	10	15	120	1.2	1.3	1.7	400
> 70	900	90	10	15	120	1.2	1.1	1.7	400
Females									
19-30	700	75	5	15	90	1.1	1.1	1.3	400
31-50	700	75	5	15	90	1.1	1.1	1.3	400
51-70	700	75	10	15	90	1.1	1.1	1.5	400
> 70	700	75	15	15	90	1.1	1.1	1.5	400
Pregnant	770	70	5	15	75-90	1.4	1.1	1.9	600
Nursing	1300	95	5	19	75-90	1.4	1.1	2.0	500

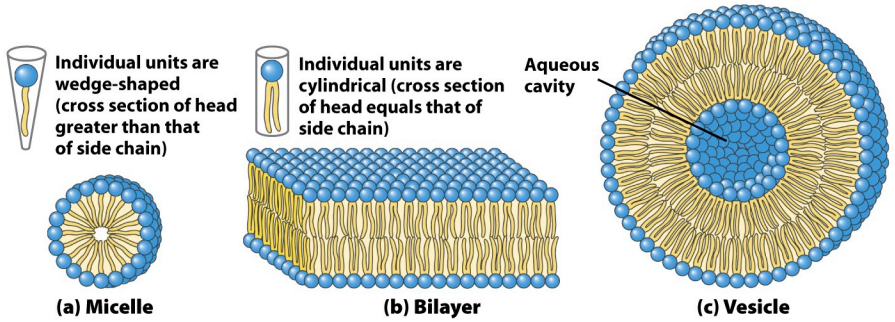


Figure 11-4
Lehninger Principles of Biochemistry, Fifth Edition

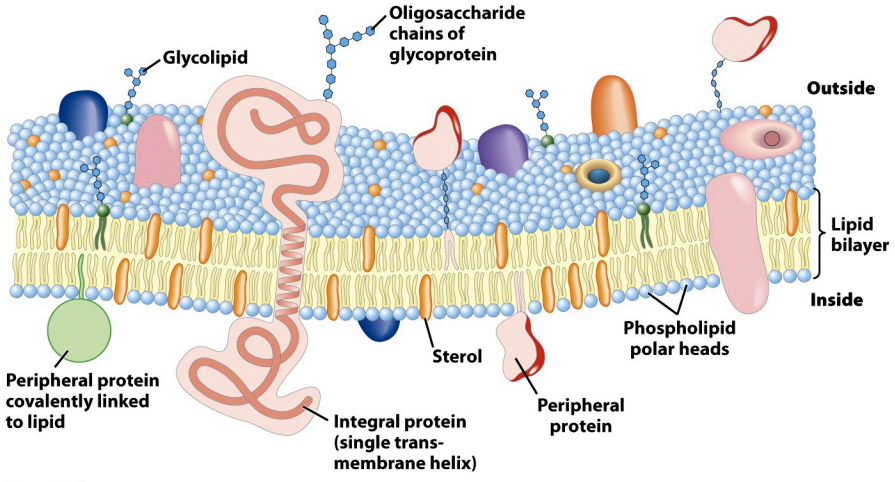


Figure 11-3
Lehninger Principles of Biochemistry, Fifth Edition