Lecture 30 (12/5/25)

Nucleic Acids
- Transcription
- Translation
  - Genetic Code
  - tRNA
  - Protein Biosynthesis

Lipids & Membranes

A. Lipids
1. Roles
2. Classes
   a. Fatty Acids
   b. Fats
   c. Waxes
   d. Membrane lipids
   e. Terpenes (isoprenes)

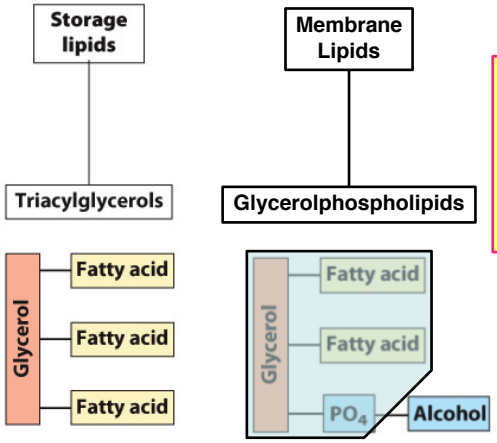
B. Membranes
1. Introduction
2. The 4 S's
   a. Size
   b. Solubility
   c. Shape
   d. Stability
3. Models for Membrane structure
   a. Old Model
   b. Data
   c. Fluid Mosaic Model
   d. Testing the model
4. The Red-Blood Cell Membrane
5. Membrane Asymmetry
   a. transverse
   b. lateral
   c. anchoring
6. Membrane Fluidity

TODAY
• Reading: Ch10, 352-354, 356; 367-369

NEXT
• Reading: Ch11, 370-381
Ch4,6,8,10,14,16,17,18: 118-119, 178,295, 356-359, 530-531, 534-535, 576, 590,613-615, 629, 641-643
Ch 10, 356-360
Ch17, 613-615

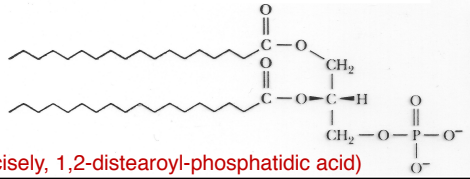
• Homework: #32, #33

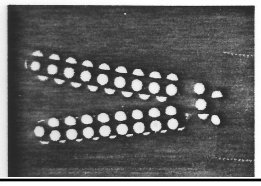
Lipids: Membrane Lipids



Need to know structures and nomenclature:
Fatty acids: palmitate, stearate, oleate, linoleate, α-linolenate, arachadonate
Phospholipids: phosphatidate, sphingosine, PS, PE, PC, SM
Cholesterol

Phosphatidic Acid

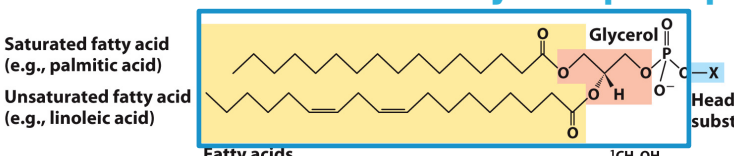




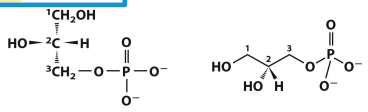
(more precisely, 1,2-distearoyl-phosphatidic acid)

Lipids: Membrane Lipids

General Structure of Glycerophospholipids



1-Palmitoyl-2-linoleoyl-
phosphatidyl-X(name of alcohol)



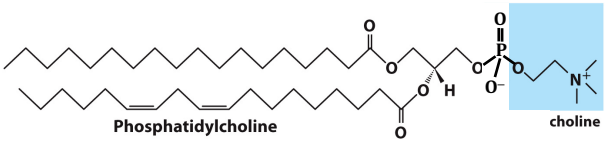
L-Glycerol 3-phosphate (*sn*-glycerol 3-phosphate)

- Primary constituents of animal-cell membranes
- The phosphate group is negatively charged at physiological pH.
- Two fatty acids form ester linkages with the first and second hydroxyl groups of L-glycerol-3-phosphate.
- Unsaturated fatty acids are commonly found connected to C2 of glycerol-3-phosphate.
- The highly polar phosphate group may be further esterified by an alcohol; such substituent groups are called the head groups (another phospho-diester linkage).

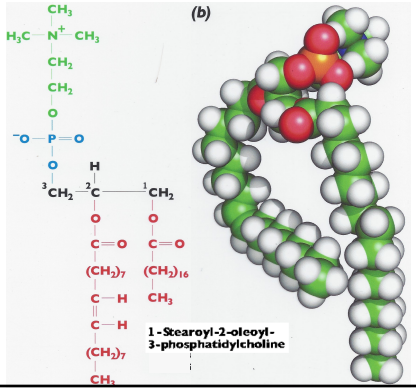
What are these "head groups?"

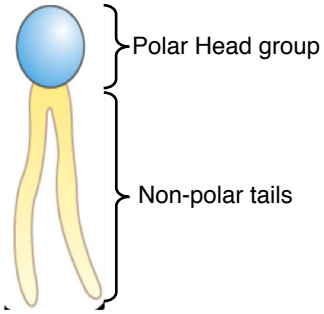
Lipids: Membrane Lipids

Depictions of Glycerophospholipids



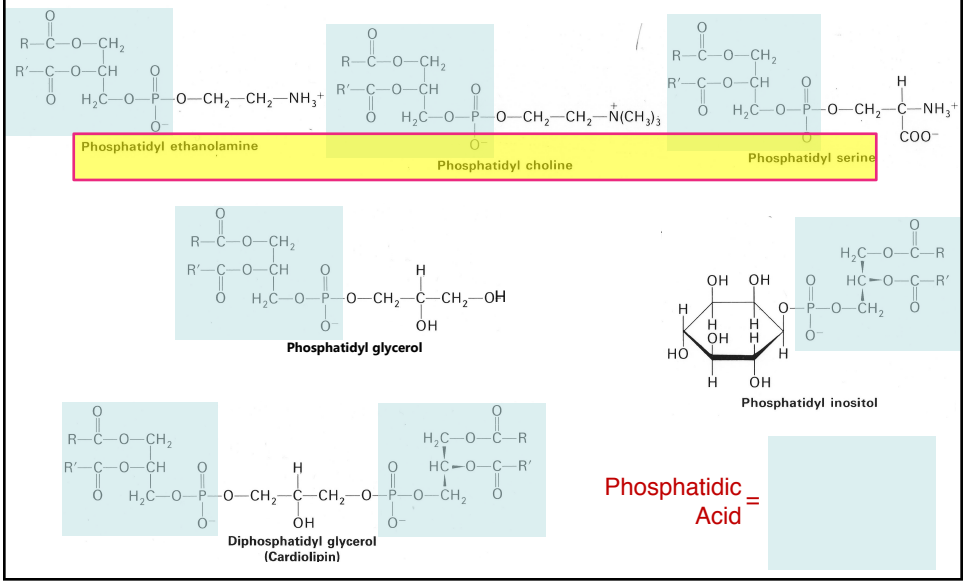
1-Stearoyl-2-linoleoyl-3-phosphatidyl-choline





Lipids: Membrane Lipids

Examples of Glycerophospholipids



Lipids: Membrane Lipids

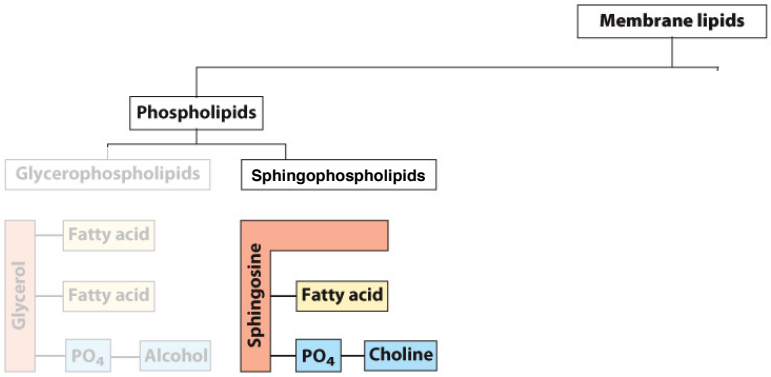
Examples of Glycerophospholipids

Name of glycerophospholipid	Name of X—O	Formula of X	Net charge (at pH 7)
Phosphatidic acid (PA)	—	PA—H	−2
Phosphatidylethanolamine	Ethanolamine	PA	0
Phosphatidylcholine	Choline	PA	0
Phosphatidylserine	Serine	PA	−1
Phosphatidylglycerol	Glycerol	PA	−1
Phosphatidylinositol 4,5-bisphosphate	*myo*-Inositol 4,5-bisphosphate	PA	−4*
Cardiolipin	Phosphatidyl-glycerol	PA	−2

Figure 10-8

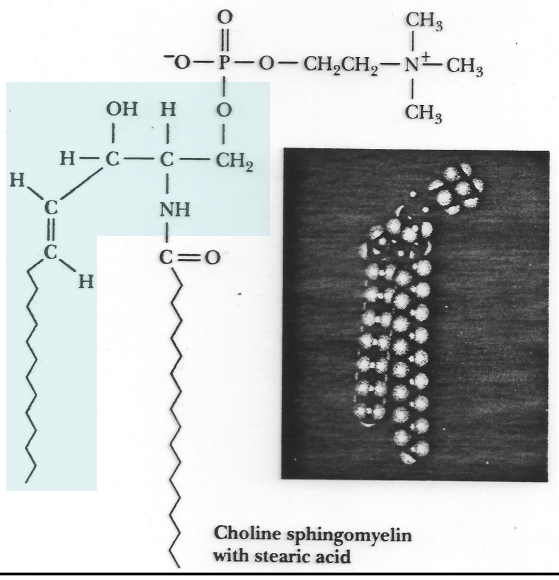
Lipids: Membrane Lipids

Sphingophospholipids



Lipids: Membrane Lipids

Examples of Sphingophospholipids

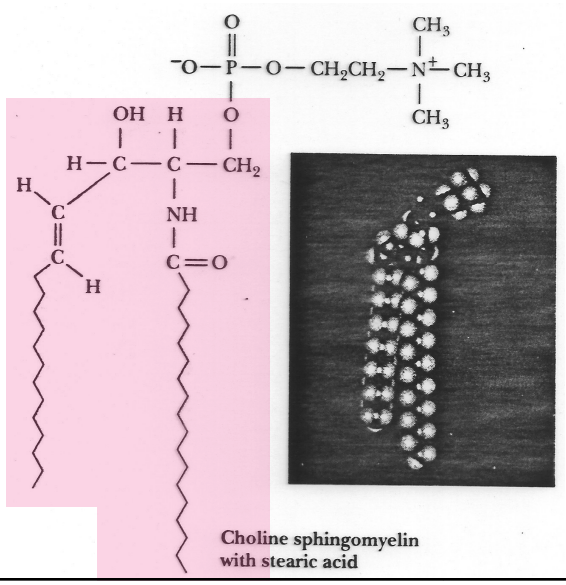


Sphingosine (C18)

- The backbone of sphingolipids is NOT glycerol.
- The backbone of sphingolipids is a C-18 long-chain amino alcohol called sphingosine.

Lipids: Membrane Lipids

Examples of Sphingophospholipids



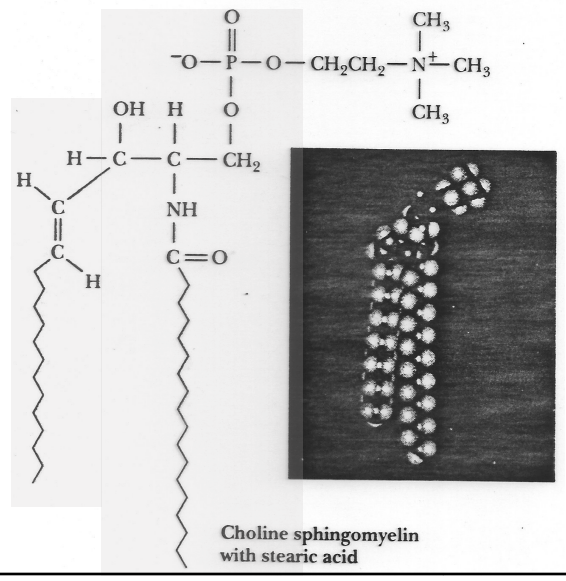
Sphingosine (C18)

Ceramide

- The backbone of sphingolipids is NOT glycerol.
- The backbone of sphingolipids is a C-18 long-chain amino alcohol called sphingosine.
- A fatty acid is joined to sphingosine via an amide linkage, rather than an ester linkage as usually seen in other lipids (hence the name) = ceramide.

Lipids: Membrane Lipids

Examples of Sphingophospholipids



Sphingosine (C18)

Ceramide

Sphingomyelin

- The backbone of sphingolipids is NOT glycerol.
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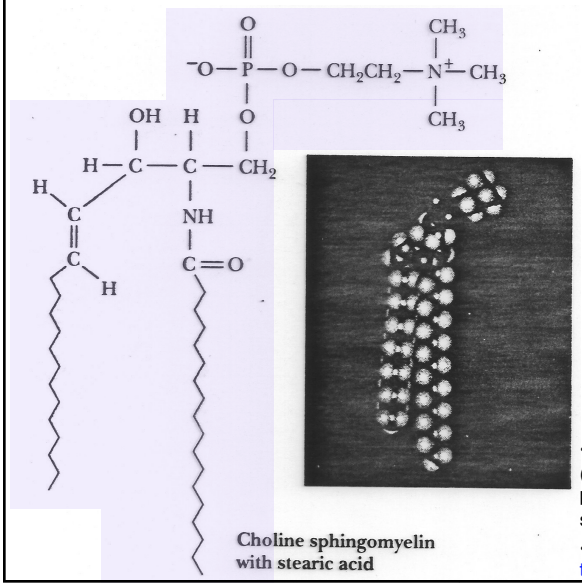
- A fatty acid is joined to sphingosine via an amide linkage, rather than an ester linkage as usually seen in other lipids (hence the name) = ceramide.
- A polar phosphate group is connected to ceramide by a phospho-ester linkage = sphingomyelin.

Lipids: Membrane Lipids

Examples of Sphingophospholipids



Sphingosine (C18)

Ceramide

Sphingomyelin

Choline Sphingomyelin

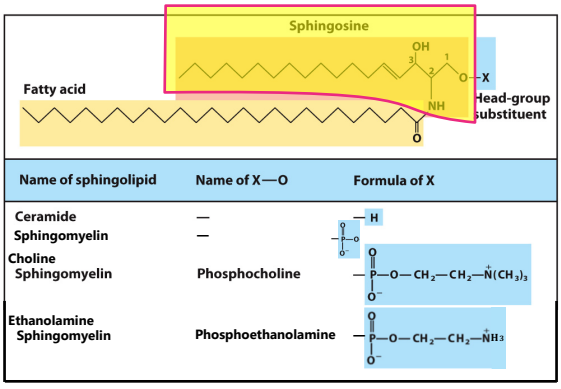
- The backbone of sphingolipids is NOT glycerol.
- The backbone of sphingolipids is a C-18 long-chain amino alcohol called sphingosine.
- A fatty acid is joined to sphingosine via an amide linkage, rather than an ester linkage as usually seen in other lipids (hence the name) = ceramide.
- A polar phosphate group is connected to ceramide by a phospho-ester linkage = sphingomyelin.
- A polar alcohol is connected by another phospho-ester linkage = Choline sphingomyelin or Ethanolamine sphingomyelin

•Choline Sphingomyelin = Ceramide (sphingosine + amide-linked fatty acid) + phosphocholine attached to the C1-alcohol of sphingosine

•Sphingomyelin is abundant in myelin sheath that surrounds some nerve cells in animals.

Lipids: Membrane Lipids

Sphingophospholipids



Lipids: Membrane Lipids

Sphingomyelin is Structurally Similar to Phosphatidylcholine

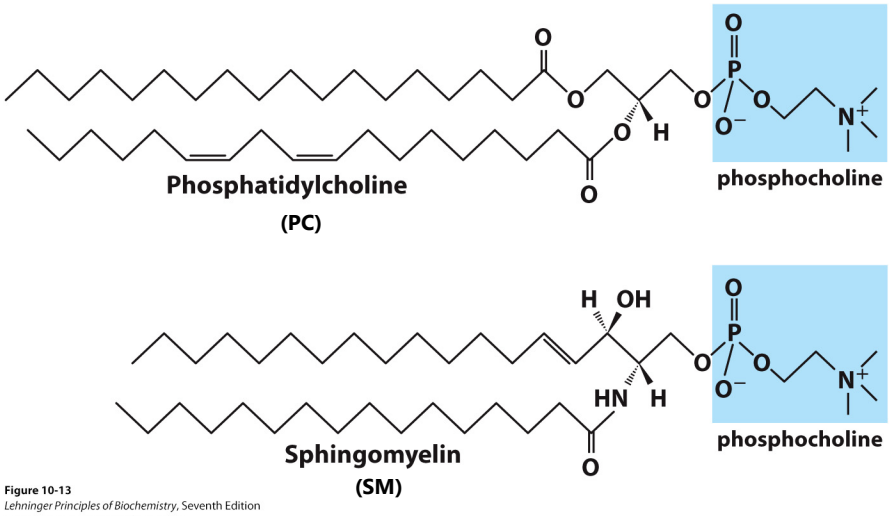
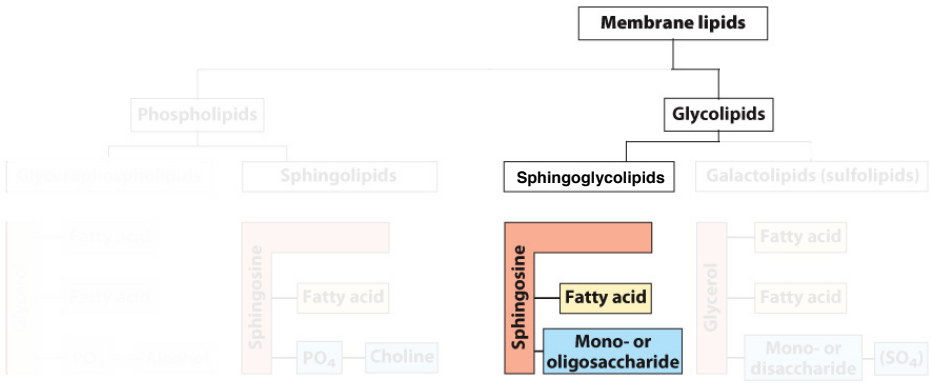


Figure 10-13
Lehninger Principles of Biochemistry, Seventh Edition

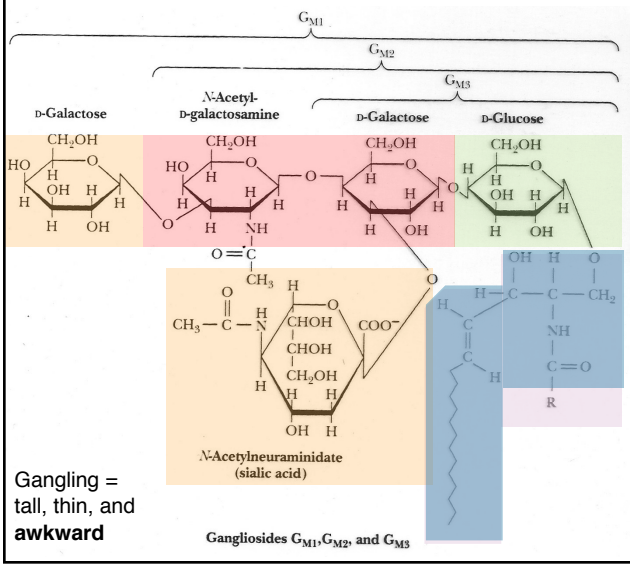
Lipids: Membrane Lipids

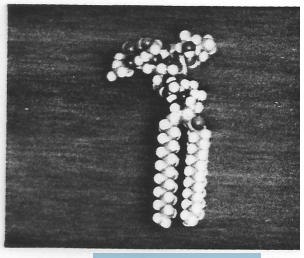
Sphingoglycolipids



Lipids: Membrane Lipids

Sphingoglycolipids





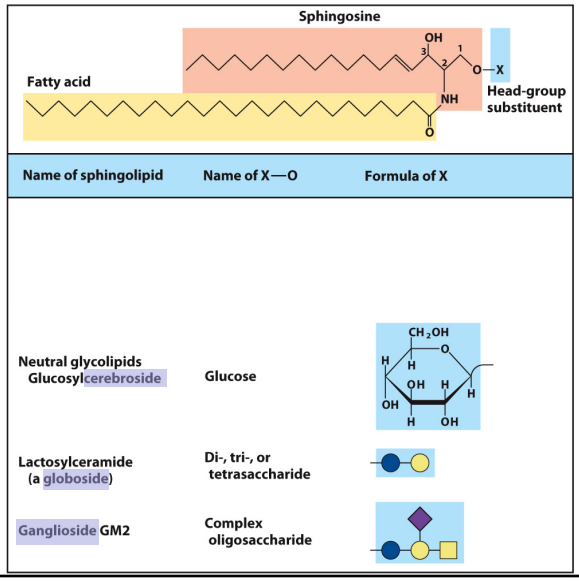
Sphingosine
Ceramide
Cerebroside
Globoside
Ganglioside

Gangling = tall, thin, and **awkward**

Figure 9.14 The structures of several important gangliosides. Also shown is a space-filling model of ganglioside G_{M1}.

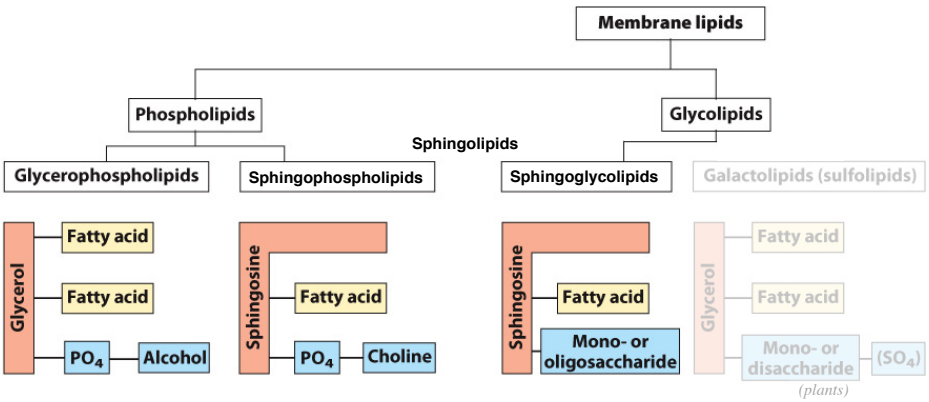
Lipids: Membrane Lipids

Sphingoglycolipids



Lipids: Membrane Lipids

Classification of Membrane Lipids

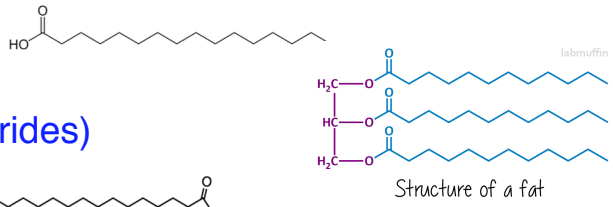


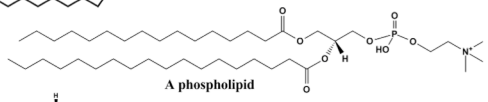
Lipids: Classes

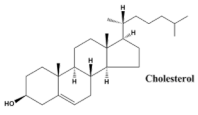
Biological molecules that are characterized by low solubility in water, that is, are relatively hydrophobic.

Classes of Lipids They have a high hydrocarbon content

1. Fatty acids
2. Fats (triglycerides)
3. Waxes
4. Membrane Lipids
5. Isoprenes



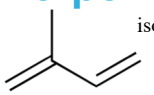




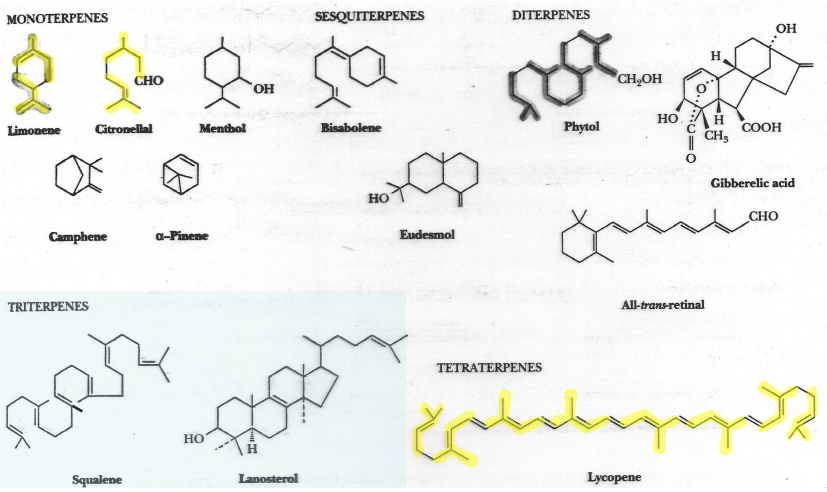
Lipids: Membrane Lipids

Cholesterol & Terpenes (Isoprenes)

2 x isoprene = terpene



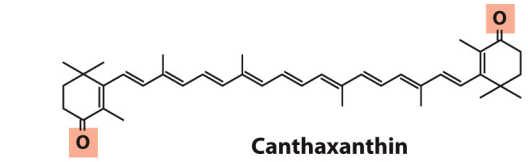
C5



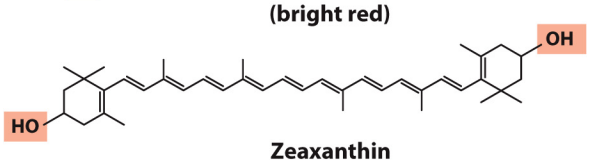
Lipids: Membrane Lipids

Cholesterol & Terpenes (Isoprenes)

Lipids Can Provide Pigment



Canthaxanthin (bright red)



Zeaxanthin (bright yellow)

Dr. Dan Sudia/Science Source

Richard Day/VIREO

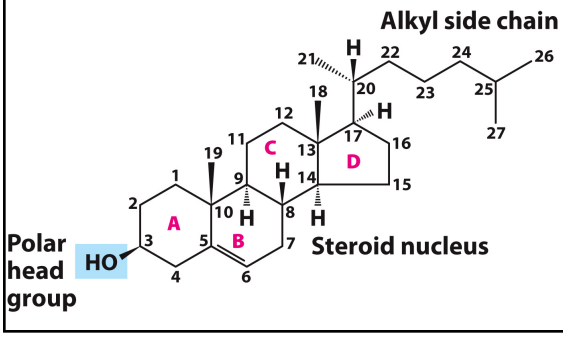
Figure 10-23
Lehninger Principles of Biochemistry, Seventh Edition

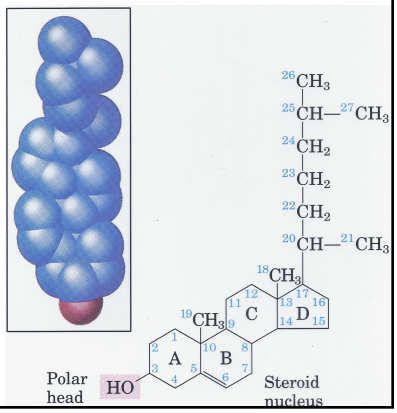
Lipids: Membrane Lipids

Cholesterol & Terpenes (Isoprenes)

- Cholesterol
  - Tri-terpene
  - steroid nucleus: four fused rings (lanosterol)
  - hydroxyl group (polar head) in the A-ring
  - various nonpolar side chains
- The tetracycle structure of Cholesterol is almost planar.

Need to Know: Structure, numbering

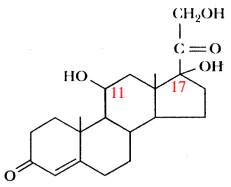




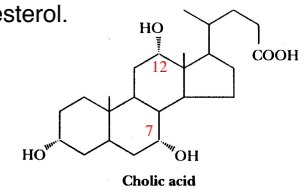
Lipids: Membrane Lipids

Cholesterol & Terpenes (Isoprenes)

- Cholesterol and related sterols are present in the membranes of most eukaryotic cells.
  - modulate fluidity and permeability
  - thicken the plasma membrane
  - no sterols in most bacteria
- Mammals obtain cholesterol from food or synthesize it *de novo* in the liver.
- Cholesterol, bound to proteins, is transported to tissues via blood vessels.
  - When in excess, cholesterol in low-density lipoproteins (LDLs) tends to deposit and clog arteries
- Bile acids and many hormones are derivatives of cholesterol.

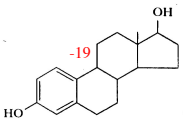

Cortisol

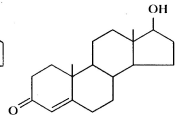
A Metabolic Hormone
(made by adrenal gland)

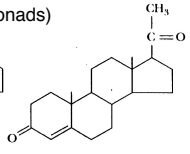

Cholic acid

A Bile Acid
(made by liver)

Sex Hormones
(made by the gonads)


Estradiol


Testosterone


Progesterone

Lipids: Membrane Lipids

Table 19.4
Lipid Compositions of Membranes

Source	Lipid Composition[a] (% of total lipids)								
	Cholesterol	PC	SM	PE	PI	PS	PG	DPG	Glycolipids
Rat Liver									
Plasma membrane	30	18	14	11	4	9	—	—	—
Rough endoplasmic reticulum	6	55	3	16	8	3	—	—	—
Inner mitochondrial membrane	3	45	3	25	6	1	2	18	—
Nuclear membrane	10	55	3	20	7	3	—	—	—
Golgi	8	40	10	15	6	4	—	—	—
Lysosomes	14	25	24	13	7	—	—	5	—
Rat Brain Myelin	22	11	6	14	—	7	—	—	21
Rat Erythrocyte	24	31	9	15	2	7	—	—	3
***E. coli* Plasma Membrane**	0	0	—	80	—	—	15	5	—

[a]PC = phosphatidylcholine; SM = sphingomyelin; PE = phosphatidylethanolamine; PI = phosphatidylinositol; PS = phosphatidylserine; PG = phosphatidylglycerol; DPG = diphosphatidylglycerol (cardiolipin).

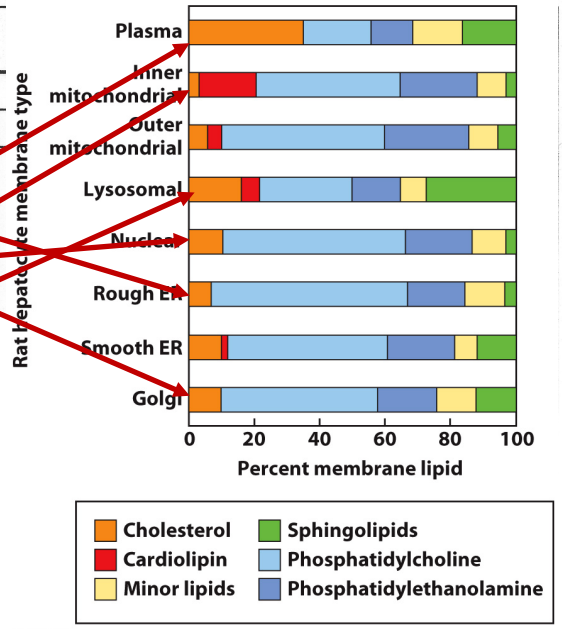
Source: Adapted from M. K. Jain and R. C. Wagner, *Introduction to Biological Membranes*, John Wiley & Sons, New York, 1980.

*This is the mung bean and the PM contains a large fraction of phosphatidic acid (21%). From Yoshida *et al*. (1986) *Plant Physiol* **82**:807

Lipids: Membrane Lipids

Table 19.4
Lipid Compositions of Membranes

Source	Cholesterol
Rat Liver	
Plasma membrane	30
Rough endoplasmic reticulum	6
Inner mitochondrial membrane	3
Nuclear membrane	10
Golgi	8
Lysosomes	14



Lipids: Membranes

Lipids: Membranes

- All cells have a cell membrane, which separates the cell from its surrounding.
- Eukaryotic cells have various internal membranes that divide the internal space into compartments (i.e., organelles).
- Membranes are complex lipid-based structures that form stable, dynamic, pliable "sheets"/barriers
- Membranes are composed of a variety of lipids and proteins

Lipids: Membrane Proteins

TABLE 11-1 Major Components of Plasma Membranes in Various Organisms

	Components (% by weight)				
	Protein	Phosphlipid	Sterol	Sterol type	Other lipids
Human myelin sheath	30	30	19	Cholesterol	Galactolipids, plasmalogens
Mouse liver	45	27	25	Cholesterol	—
Maize leaf	47	26	7	Sitosterol	Galactolipids
Yeast	52	7	4	Ergosterol	Triacylglycerols, steryl esters
Paramecium (ciliated protist)	56	40	4	Stigmasterol	—
E. coli	75	25	0	—	—

Note: Values do not add up to 100% in every case because there are components other than protein, phospholipids, and sterol; plants, for example, have high glycolipid content.

Membrane Composition Is
Highly Variable in Different Organisms…
and different organelles

Lipids: Membranes

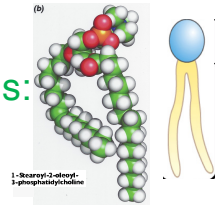
The 4 S's

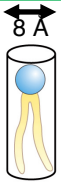
Size
Shape
Solubility
Stability

Lipids: Membranes

Size

Phospholipids:



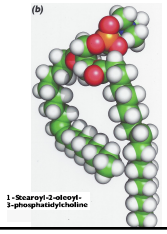


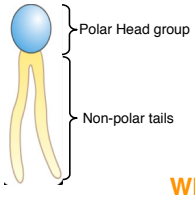
Individual units are cylindrical (cross section of head equals that of side chain).

Membranes:

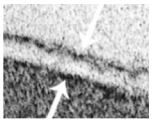
40-60 Å

Shape





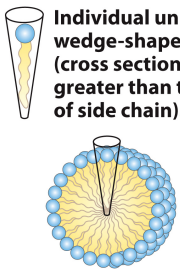
It has a "trilaminar" structure as seen in the EM



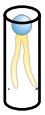
What are the consequences of this shape?

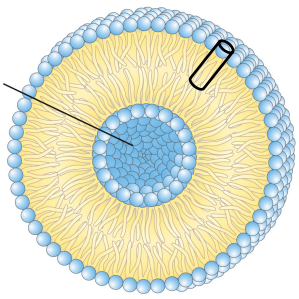
Lipids: Membranes

Shape



Micelle





Vesicle

- Two major structures are observed:
  - –Bilayers/vesicles
  - –micelles
- Structures formed depend on:
  - type of lipid
  - Concentration

What is this concentration dependence?

- Both form spontaneously in aqueous solution and are stabilized by noncovalent forces, especially hydrophobic effect due to amphipathic molecules: large polar head & tail
  - –Examples that form micelles: fatty acids, sodium dodecyl sulfate
  - –Examples that form bilayers: phospholipids, glycolipids
- Micelles are composed of a few dozen to a few thousand lipid molecules.

Lipids: Membranes

The 4 S's

Size

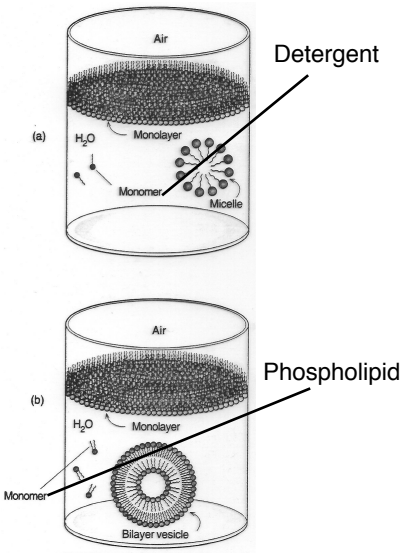
Shape

Solubility

Stability

Lipids: Membranes

Solubility

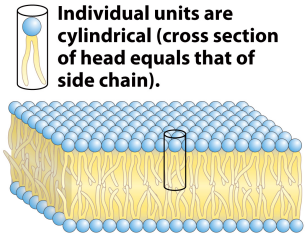


- The first molecules, at low concentration, go to the air/liquid interface and form a monolayer.
- Once that is crowded, they "dissolve" in the water
- Once the concentration is sufficient to form aggregates, micelles or vesicles form.
- Depending on the lipid, this concentration is called the "Critical Micellular Concentration" (CMC).

Lipids: Membranes

Solubility: Membrane Bilayer

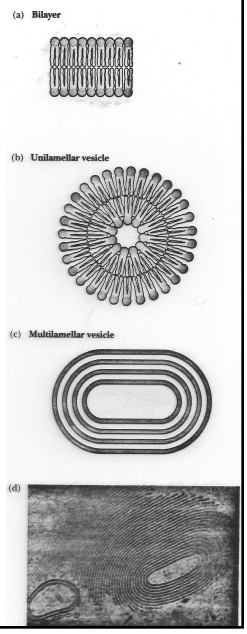
- Consists of two leaflets (e.g., layers) of lipid monolayers



Bilayer

– Forms when lipids with polar head groups and more than one lipid tail are in aqueous solution
  - phospholipids
  - sphingoglycolipids
– Hydrophilic head groups interact with water on both sides of the bilayer.
– Hydrophobic fatty acid tails are packed inside.

Vesicle (Liposome)
Originally called Bangosomes
after Sir Alex Bangham



Lipids: Membranes

The 4 S's

Size

Shape

Solubility

Stability

Lipids: Membranes

Stability

- Synthetic vesicle membranes can be made *in vitro* and can contain artificially inserted proteins.
- The central aqueous cavity can enclose dissolved molecules.
- They are useful artificial carriers of molecules (e.g., drugs).
- Vesicles fuse readily with cell membranes or with each other.
- Permeable to hydrophobic molecules (lipids, e.g., steroids) and water, but not permeable to large polar solutes and ions
- Dynamic and flexible structures