# Lipids of Physiological Significance

Dr. Usman Ghani

# Objectives

- By the end of this lecture the first year students will be able to:
- Define and classify lipids
- Understand the physiological importance of lipids
- List the examples of simple and complex lipids
- Correlate implications of lipids in clinical conditions

# Overview

- What are lipids?
- Classification of lipids
- Functions of lipids
- Simple lipids: Fatty acids, triacylglycerols, steroids
- Complex lipids: Phospholipids, sphingolipids, glycolipids
- Plasma lipid transport: types and functions of lipoproteins

# What are lipids?

- A heterogeneous group of hydrophobic (water-insoluble) organic molecules that are soluble only in organic solvents
- Body lipids are compartmentalized (packed) in cell membranes, tissue and plasma

# Functions of Lipids

- Lipids are essential components of biological membranes
- Lipids with hydrocarbon chains serve as major energy stores
- Cell signaling involves lipid molecules
  - e.g. Inositol tri-phosphate
- Fat-soluble vitamins, steroid hormones and prostaglandins are formed of lipids

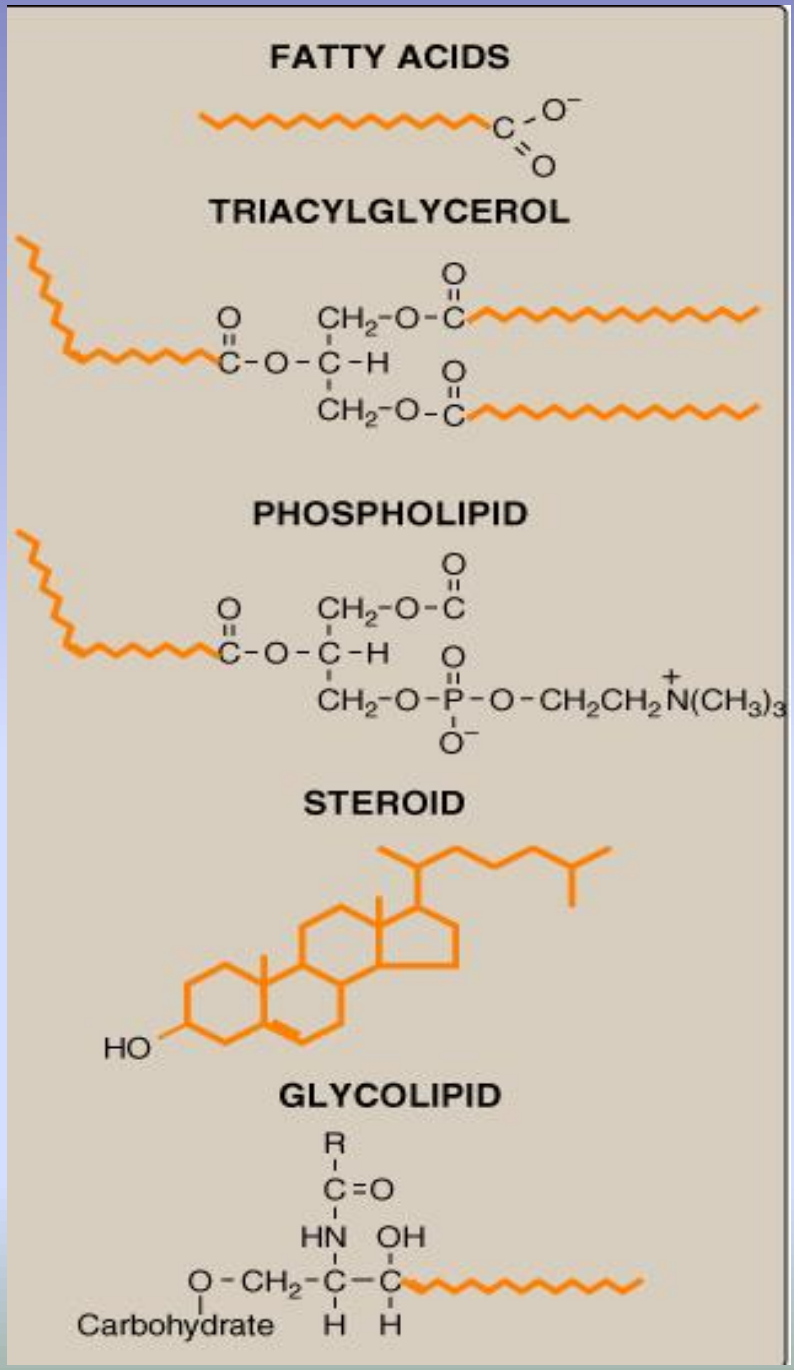
# Lipids and disease

Diseases that are strongly associated with abnormality in lipid metabolism:

- Atherosclerosis
- Coronary artery disease
- Obesity
- Metabolic syndrome
- Hypertension

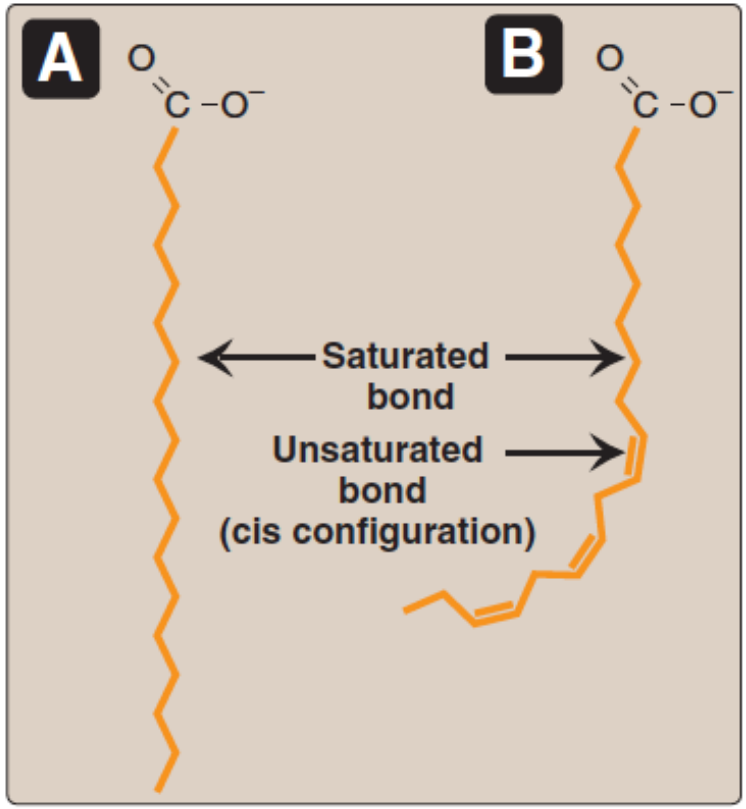
# Classification of Lipids

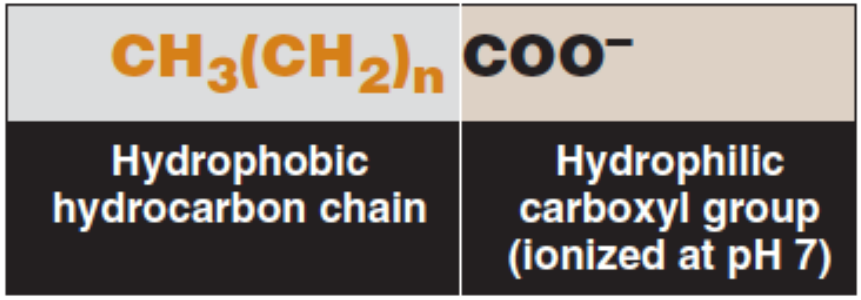
- Simple lipids:
  - Fatty acids
  - Triacylglycerols
  - Steroids (cholesterol)
- Complex lipids
  - Phospholipids
  - Sphingolipids
  - Glycolipids



# Fatty Acids (FAs)

- FAs are carboxylic acids with long-chain hydrocarbon side groups
- They are amphipathic in nature (both hydrophilic and hydrophobic)
  - The carboxylic group (COOH) is hydrophilic
  - The hydrocarbon chain is hydrophobic



# Fatty Acids (FAs)

- FAs are highly insoluble in water
- Must be transported in plasma with proteins
- Majority of plasma FAs are esters of:
  - Triacylglycerol
  - Cholesterol
  - Phospholipids

## Chain length

- In mammals it varies from $C_{16}$–$C_{18}$
- Examples: palmitic, oleic, linoleic, stearic acids

# Fatty Acids (FA)

## Degree of saturation

- FAs may contain:
  - No double bonds (Saturated / *trans* form)
  - One or more double bonds (Mono or Polyunsaturated / *cis* form)

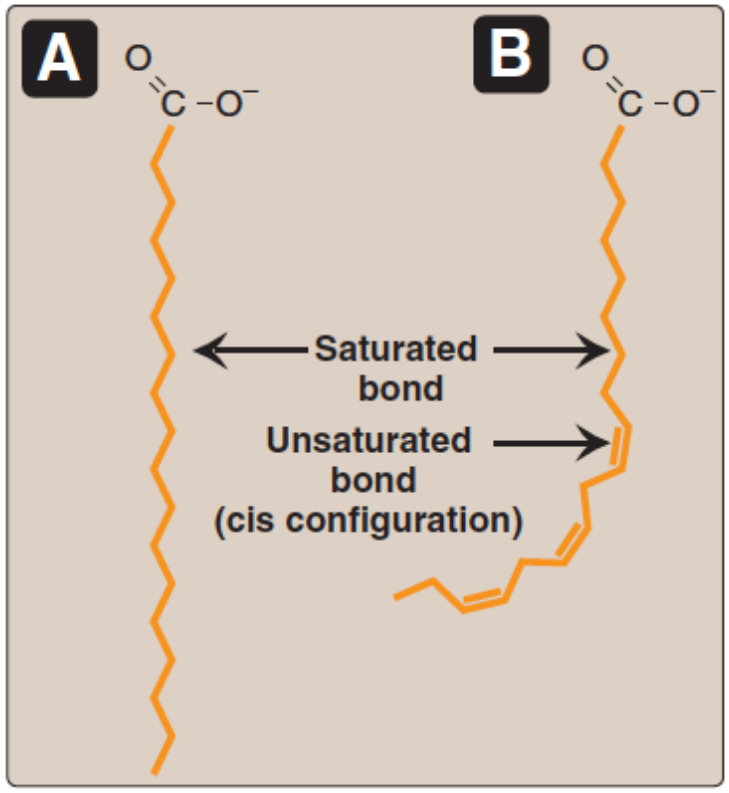
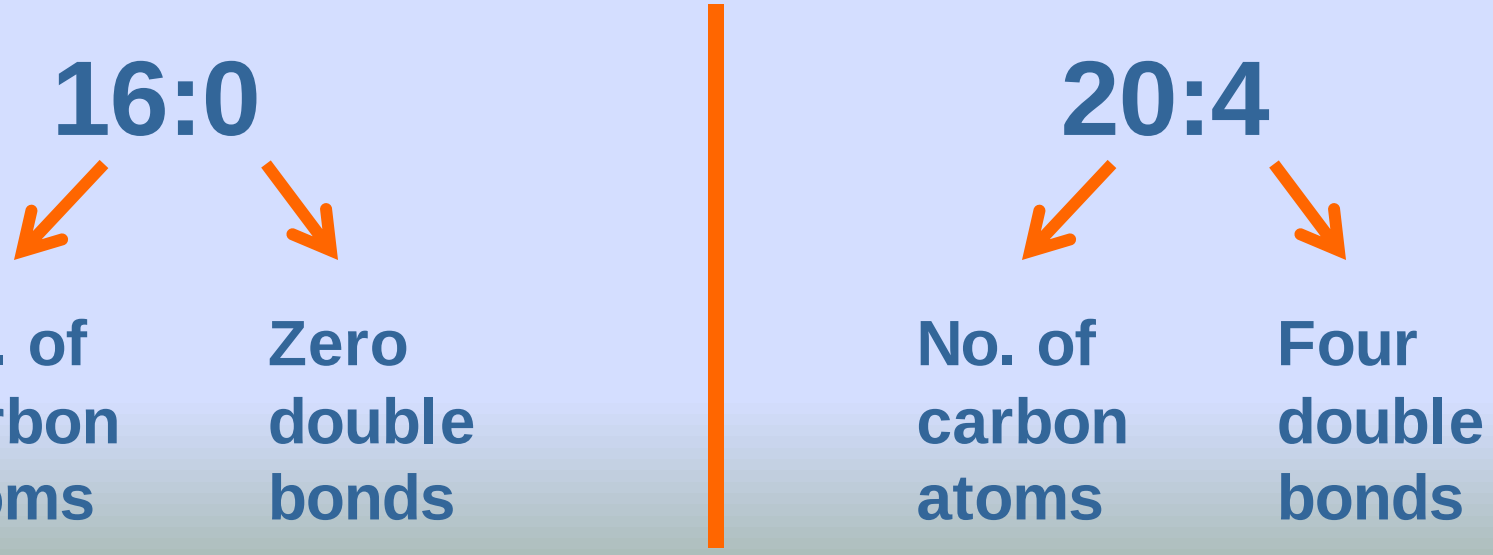



**Figure 16.3**
A saturated (A) and an unsaturated (B) fatty acid. Orange denotes hydrophobic portions of the molecules. [Note: Cis double bonds cause a fatty acid to "kink."]

| Saturated FAs | Unsaturated FAs |
|---|---|
| 12:0 Lauric acid | 18:1 Oleic acid |
| 16:0 Palmitic acid | 18:2 Linoleic acid |
| 18:0 Stearic acid | 20:4 Arachidonic acid |



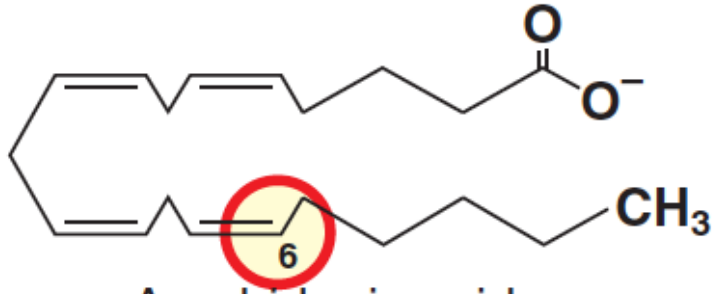
# Essential Fatty Acids (FA)

- Linoleic acid (precursor of arachidonic acid)
- α-Linolenic acid
- Body cannot synthesize
- Must be supplied in the diet
- Deficiency can cause dermatitis, membrane function loss
- Arachidonic acid is essential when linoleic acid is deficient in the diet

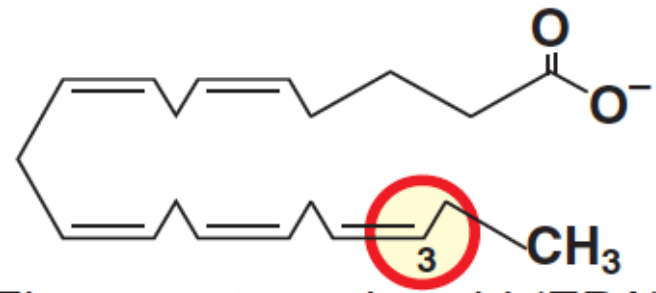
# ω-3 and ω-6 fatty acids

ω = Omega

- ω-3 Fatty acids: Long-chain polyunsaturated FAs with first double bond starting with 3rd carbon from the methyl end
- They reduce serum triglycerides, blood pressure and risk for heart disease
- Major source: Fish
- Examples: α-linolenic acid, EPA (eicosapentaenoic acid), DHA (Docosahexaenoic acid)




Arachidonic acid
(20:4, ω-6)
found in seed oils




Eicosapentaenoic acid (EPA)
(20:5, ω-3)
found in fish oils

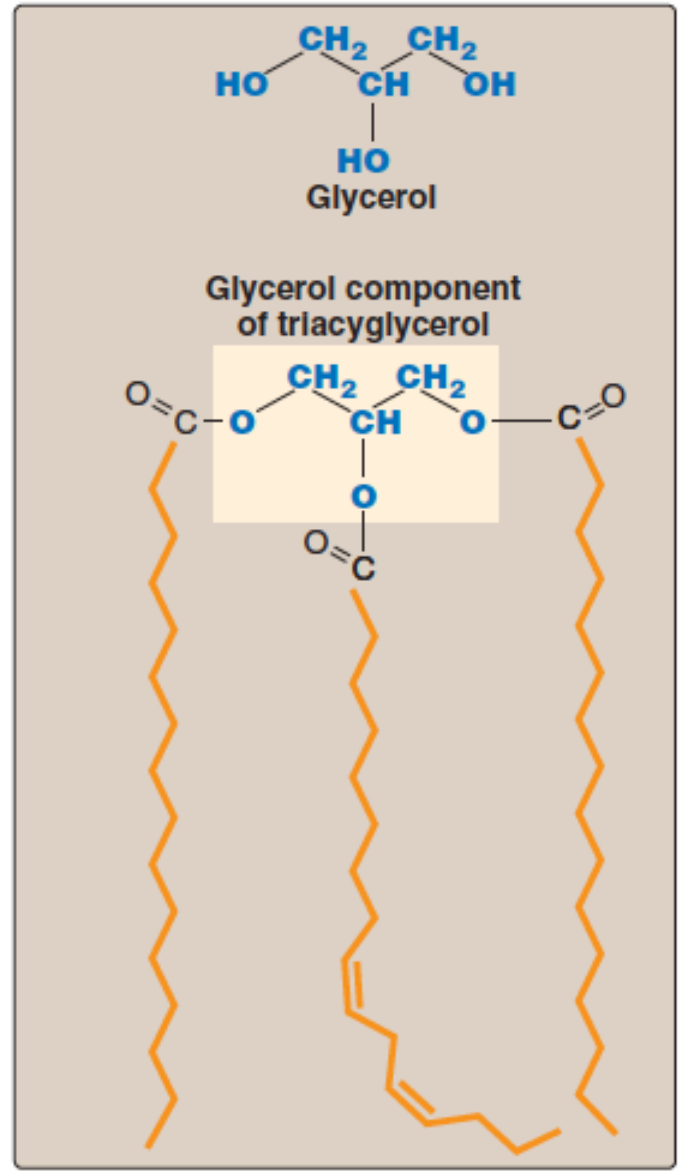
# ω-3 and ω-6 fatty acids

# ω-3 and ω-6 fatty acids

- ω-6 Fatty acids: Long-chain polyunsaturated FAs with first double bond starting with 6th carbon from the methyl end
- They reduce serum cholesterol
- Major source: Vegetable oils, nuts
- Examples:
  - Linoleic acid 18:2

# Triacylglycerols (TGs)

- TGs are tri-esters of fatty acids also called fats
- Three fatty acids are bonded to a glycerol molecule
- Constitutes majority of dietary lipids
- Stored in adipocytes (fat cells) as energy reservoir
- Not a component of cell membranes
- Subcutaneous layer of fats provides thermal insulation




# Structure of a triacylglycerol

# Steroids

- Derivatives of cyclopentanoperhydrophenanthrene ring
- Consists of four fused rings called steroid nucleus with an 8-carbon chain
- Steroids with a hydroxyl group are called sterols
- Cholesterol is a major sterol in humans and animals
- Cholesterol in plasma is bound to fatty acids called cholesteryl esters

# Functions of cholesterol

- Component of cell membranes
- Precursor for:
  - Bile acids / Bile salts
  - Vitamin D
  - Steroid hormones (Aldosterone, cortisol, testosterone, estrogen, progesterone)
- High levels of plasma cholesterol is strongly associated with coronary artery disease and atherosclerosis

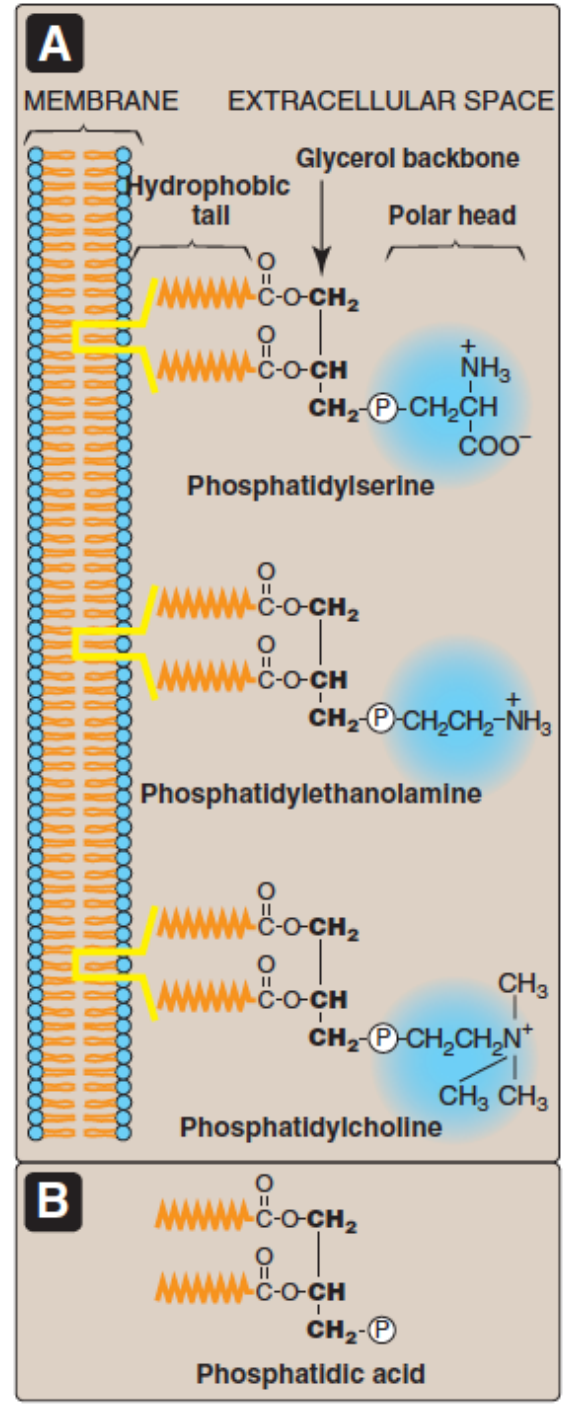
# Phospholipids

- Two classes of phospholipids:
  - Glycerophospholipids (contain glycerol backbone)
  - Sphingophospholipids (contain sphingosine)

## Glycerophospholipids

- Glycerol-3-$PO_4$ is bonded to two fatty acid chains
- The $PO_4$ group is linked to a hydrophilic group
- Amphiphilic in nature
  - Hydrophobic tail
  - Hydrophilic phosphoryl heads

# Glycero-phospholipids



# Phospholipids

- Major components of biological membranes
- Examples: phosphatidic acid, phosphatidyl – choline and serine

Sphingophospholipids

- Long-chain fatty acids attached to sphingosine
- Example: Sphingomyelin
- An important component of myelin that protects and insulates nerve fibers

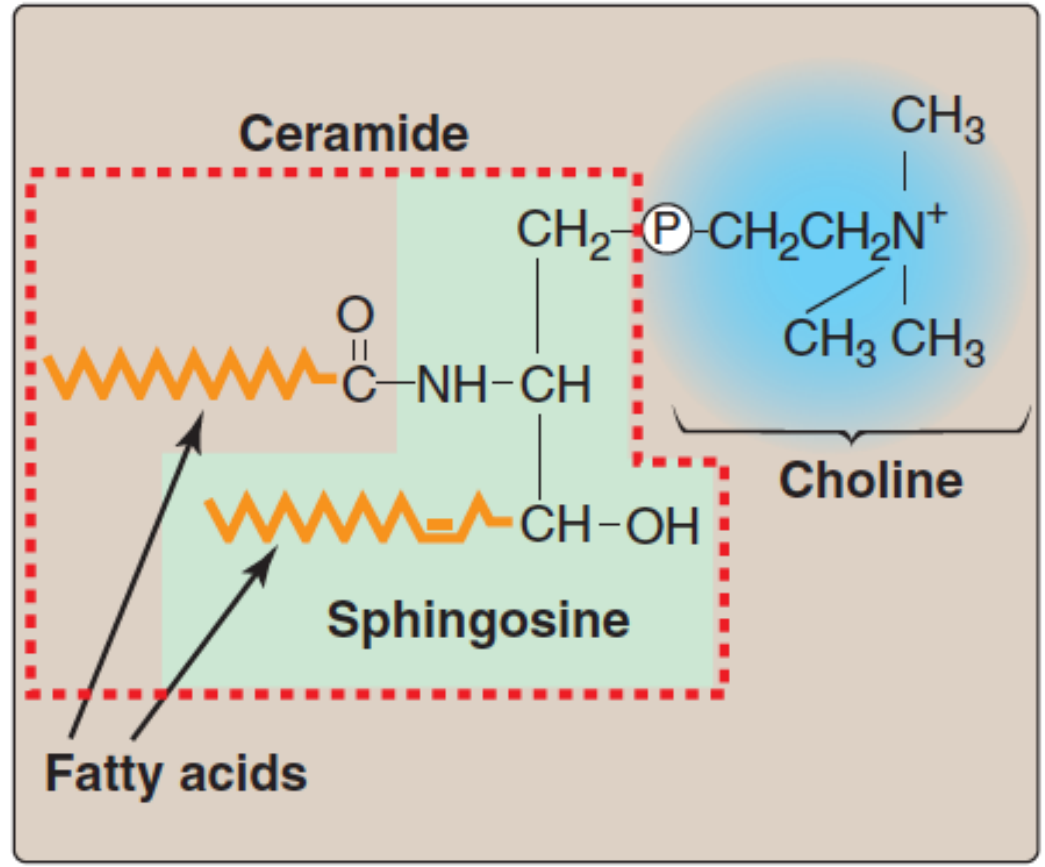



**Figure 17.4**
Structure of sphingomyelin, showing sphingosine (in green box) and ceramide components (in dashed box).

# Glycolipids

- Contain both carbohydrate and lipid components
- Derivatives of ceramide
- A long chain fatty acid is attached to sphingosine
- Also called glycoshpingolipids
- Examples: Ganglioside, glactocerebroside
- Act as: Blood group antigens, cell surface receptors for bacteria/viruses

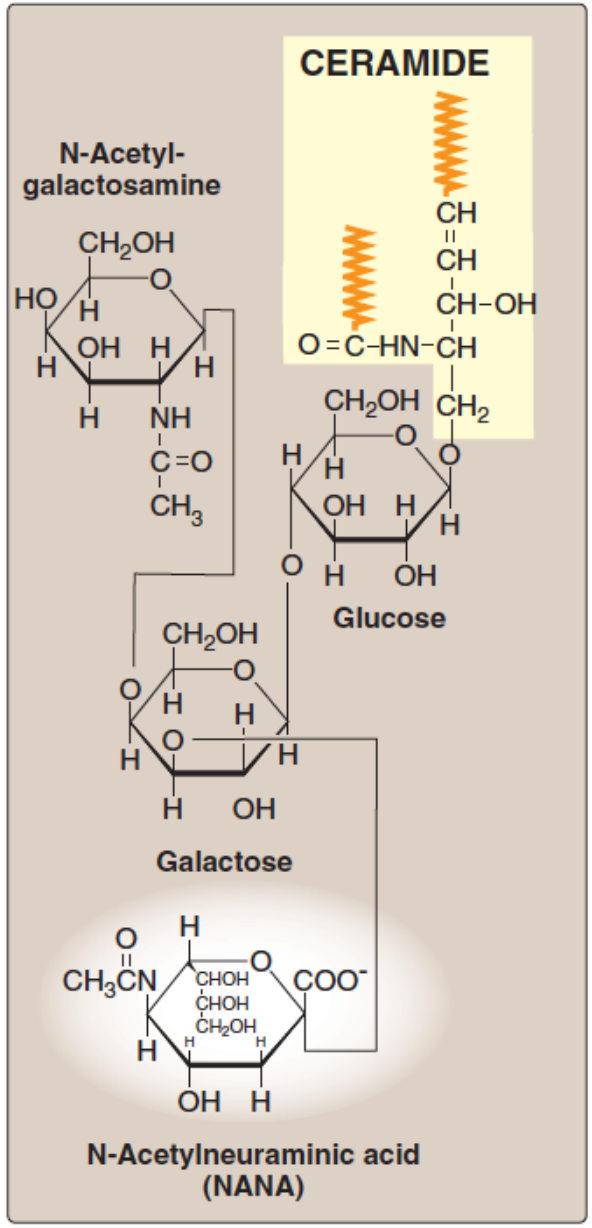



**Figure 17.15**
Structure of the ganglioside $G_{M2}$.

# Transport of plasma lipids

- Plasma lipids are transported as lipoprotein particles (lipids + protein)
- Protein part: Apoproteins or apolipoproteins
  - Examples: Apolipoproteins A, B, C
  - Functions: lipid transport, enzymatic functions, ligands for receptors
- Lipid part: Contains lipids of various types

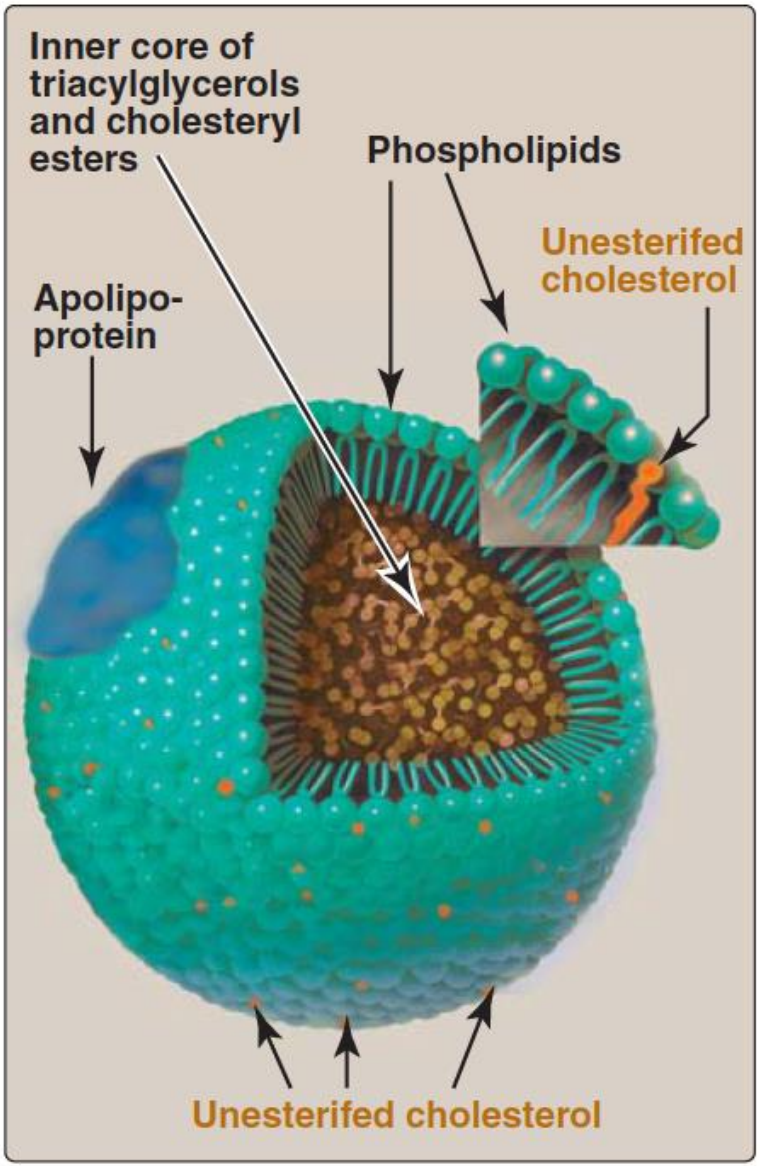
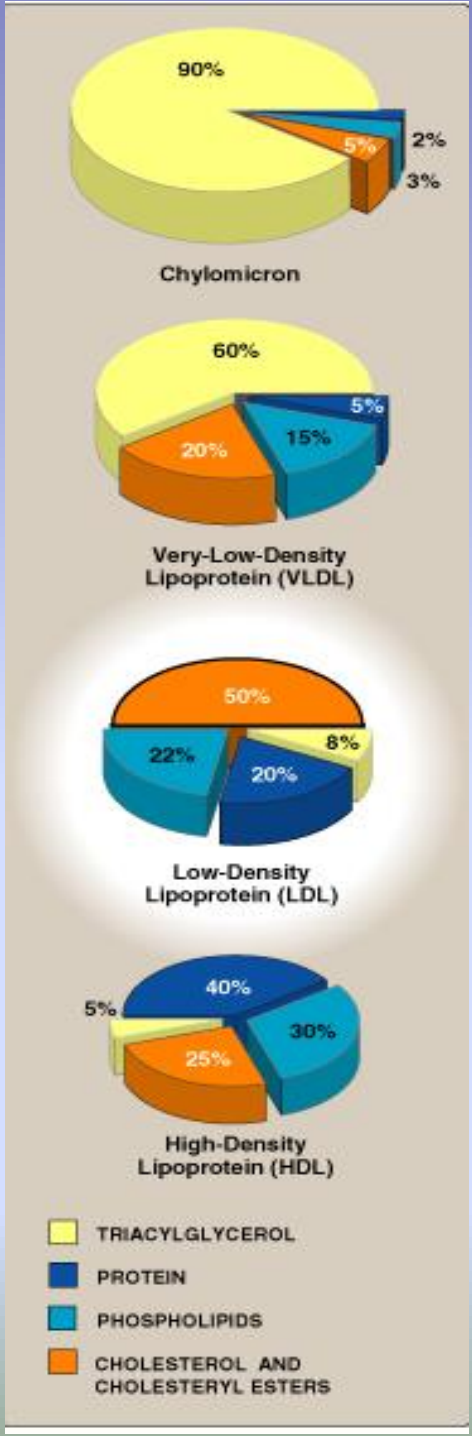



**Figure 18.14**
Structure of a typical lipoprotein particle.

# Types and functions of lipoproteins

| Lipoprotein | Mainly Transports |
|---|---|
| Chylomicrons | Dietary TGs |
| Very low density lipoprotein (VLDL) | Endogenous TGs |
| Low density lipoprotein (LDL) | Free cholesterol |
| High density lipoprotein (HDL) | Cholesteryl esters |



# Take home message

- Lipids are a group of hydrophobic molecules
- Perform essential physiological functions in the body
- Simple lipids include: fatty acids, TGs and steroids
- Complex lipids include: phospholipids, sphingolipids and glycolipids
- A number of diseases are associated with abnormal lipid metabolism

# References


- Lippincott's Illustrated Reviews, Biochemistry, 6th Edition, Denise R. Ferrier, Lippincott Williams & Wilkins, USA.
- Chapter 16: pages 181-182, 195-198
- Chapter 17, page 201-202, 205-206
- Chapter 18, page: 219-220, 226-232