

# Lipids of Physiological Significance

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# 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

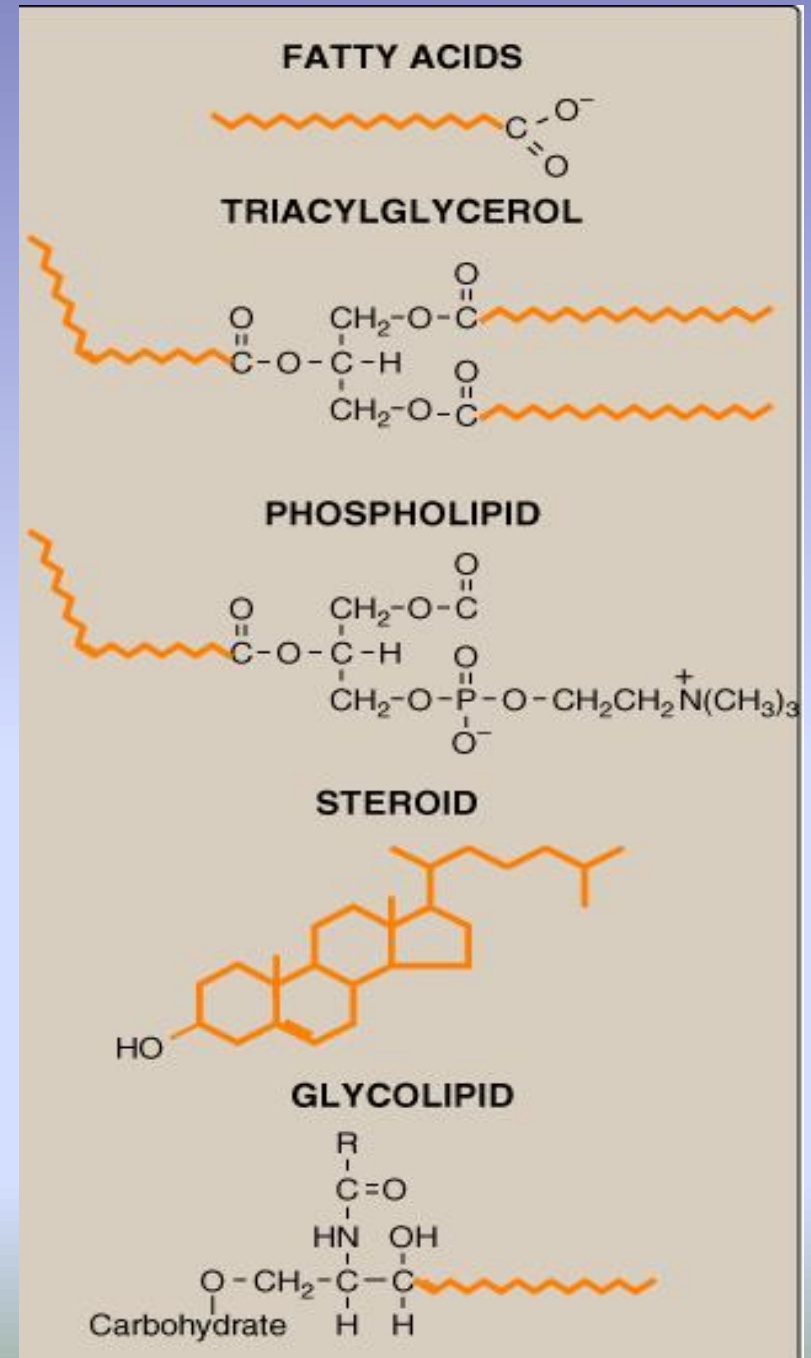
# Lipids and disease

Diseases that are strongly associated with abnormality in lipid metabolism:

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

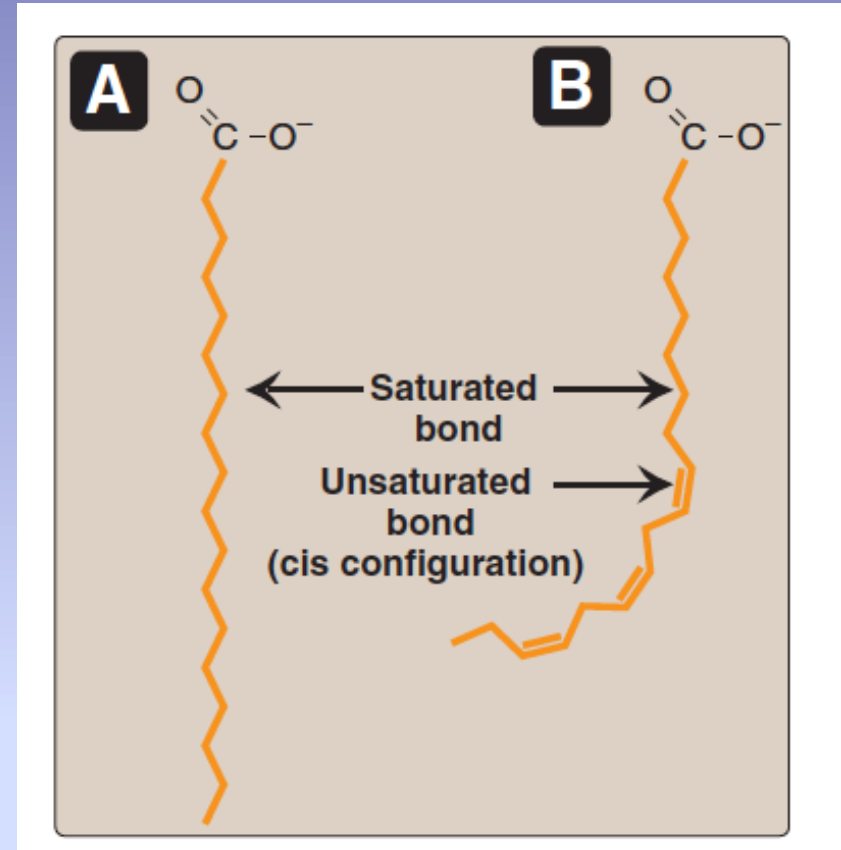
# Classification of Lipids

- **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**



<b>CH<sub>3</sub>(CH<sub>2</sub>)<sub>n</sub></b>	<b>COO<sup>-</sup></b>
Hydrophobic hydrocarbon chain	Hydrophilic carboxyl group (ionized at pH 7)



# 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

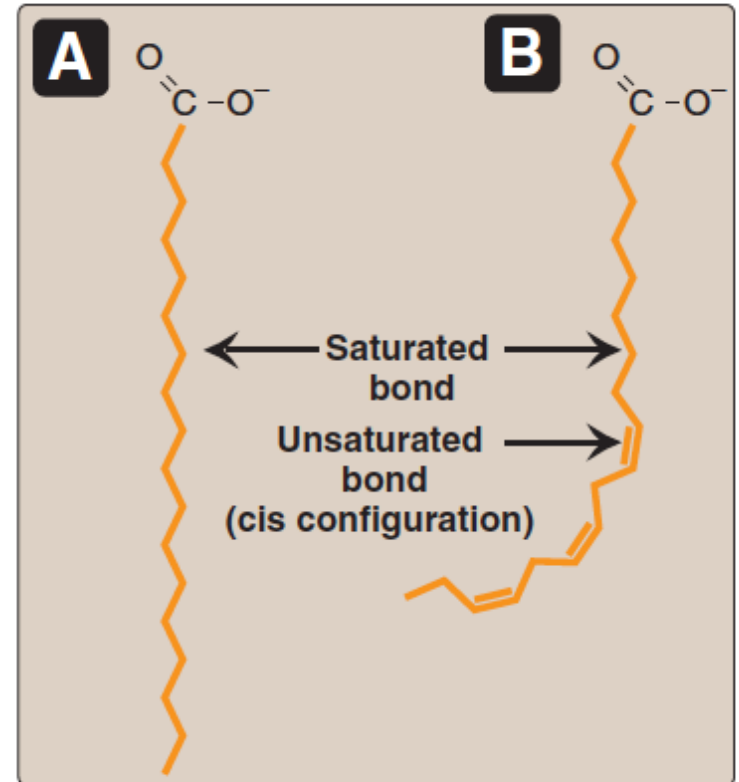
## Chain length

- 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."]

<b>Saturated FAs</b>	<b>Unsaturated FAs</b>
12:0 Lauric acid	18:1 Oleic acid
16:0 Palmitic acid	18:2 Linoleic acid
18:0 Stearic acid	20:4 Arachidonic acid

**16:0**

No. of carbon atoms      Zero double bonds

The diagram shows the notation '16:0' at the top. Two orange arrows point downwards from the '16' to the text 'No. of carbon atoms' and from the '0' to the text 'Zero double bonds'.

**20:4**

No. of carbon atoms      Four double bonds

The diagram shows the notation '20:4' at the top. Two orange arrows point downwards from the '20' to the text 'No. of carbon atoms' and from the '4' to the text 'Four double bonds'.

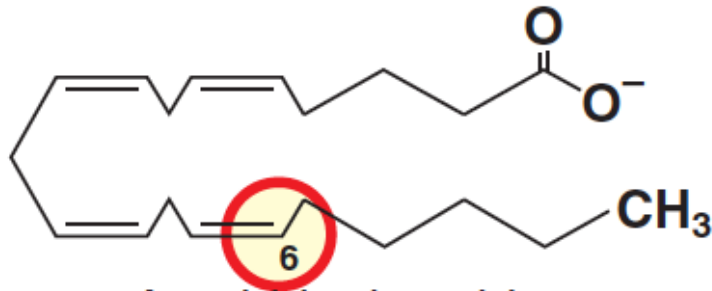
# Essential Fatty Acids (FA)

- Linoleic acid (precursor of arachidonic acid)
- $\alpha$ -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

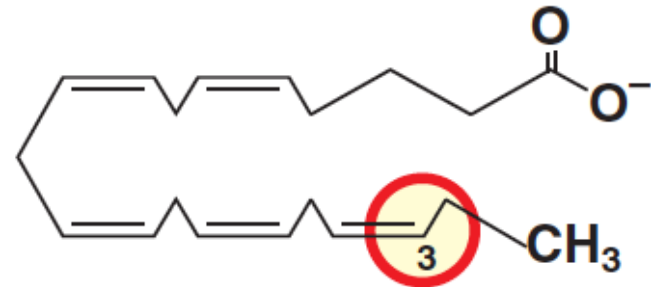
# $\omega$ -3 and $\omega$ -6 fatty acids

$\omega$  = Omega

- Long-chain polyunsaturated FAs with first double bond starting with 3<sup>rd</sup> carbon from the methyl end
- They reduce serum triglycerides, blood pressure and risk for heart disease
- Major source: Fish
- Examples:  $\alpha$ -linolenic acid, EPA (eicosapentaenoic acid), DHA (Docosahexaenoic acid)



Arachidonic acid  
(20:4,  $\omega$ -6)  
found in seed oils



Eicosapentaenoic acid (EPA)  
(20:5,  $\omega$ -3)  
found in fish oils

$\omega$ -3 and  $\omega$ -6 fatty acids

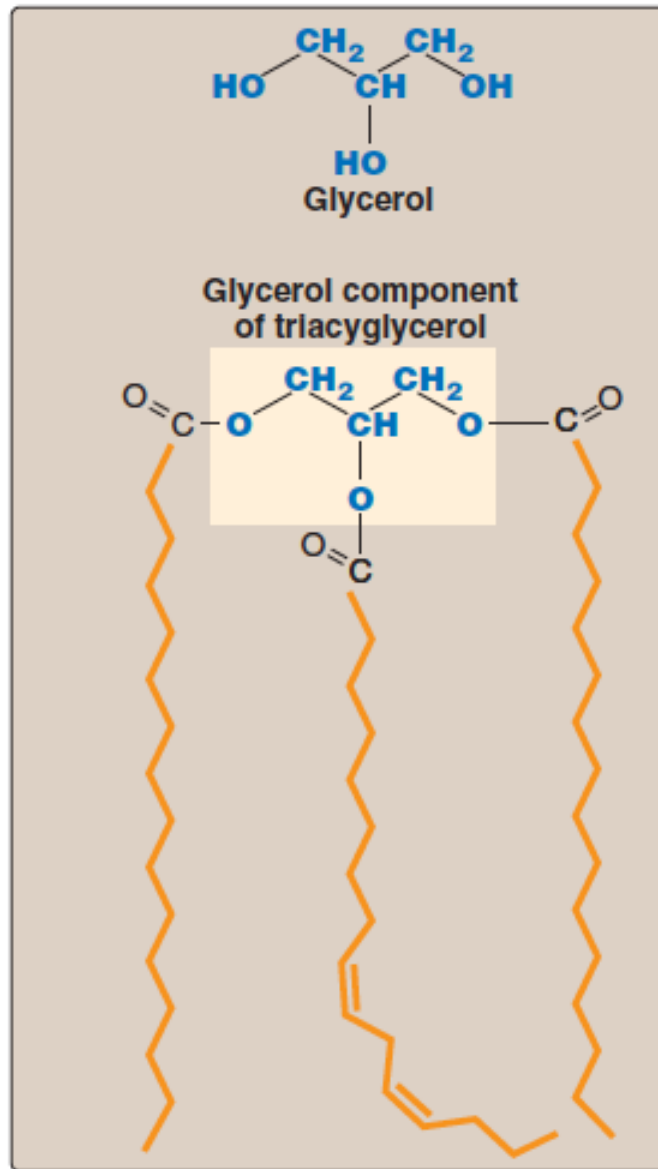
# $\omega$ -3 and $\omega$ -6 fatty acids

- Long-chain polyunsaturated FAs with first double bond starting with 6<sup>th</sup> 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

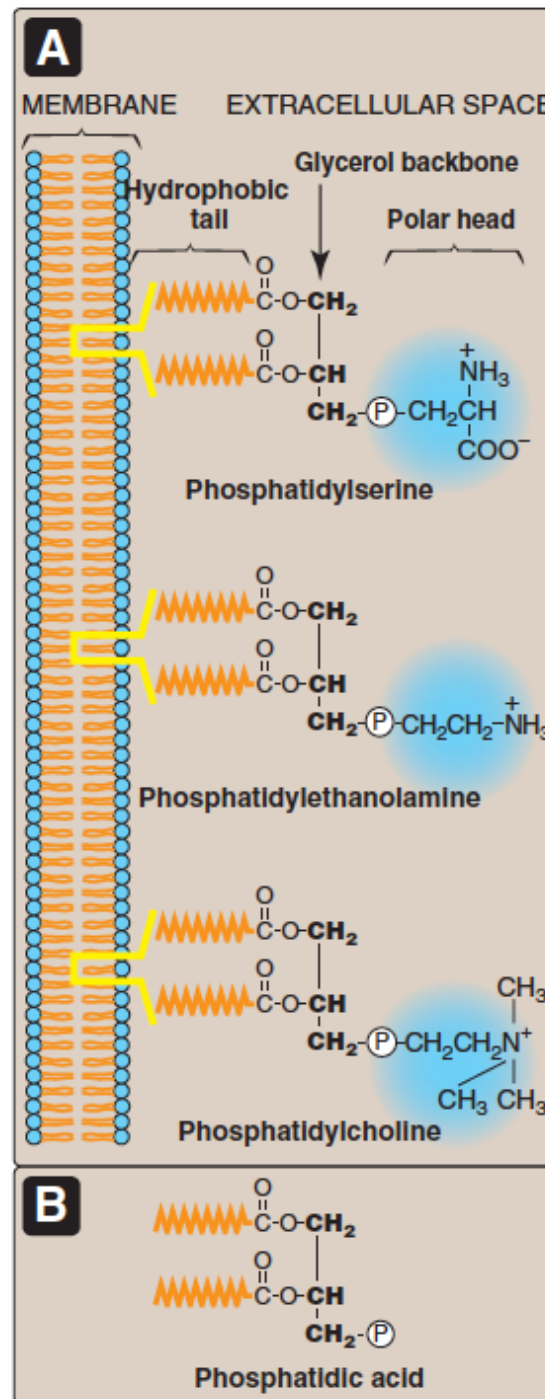
# Phospholipids

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

## Glycerophospholipids

- Glycerol-3-PO<sub>4</sub> is bonded to two fatty acid chains
- The PO<sub>4</sub> group is linked to a hydrophilic group
- Amphiphilic in nature
  - Hydrophobic tail
  - Hydrophilic phosphoryl heads

# Glycero-phospholipids

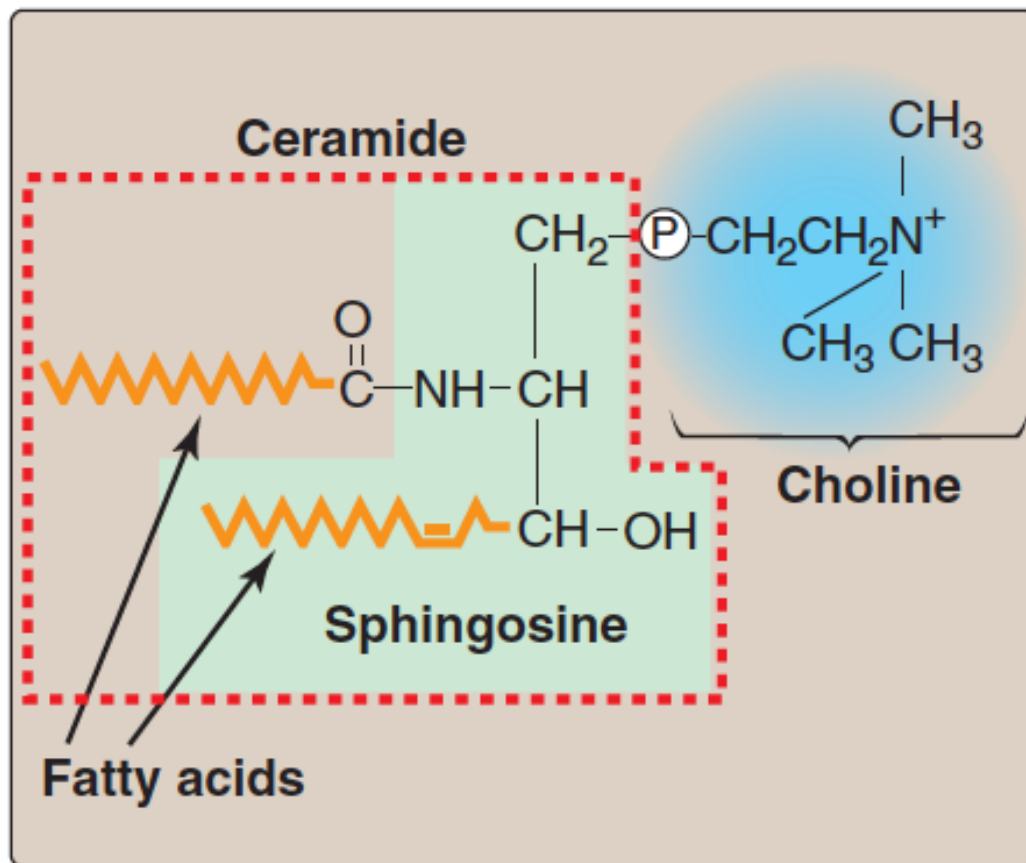


# Phospholipids

- 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

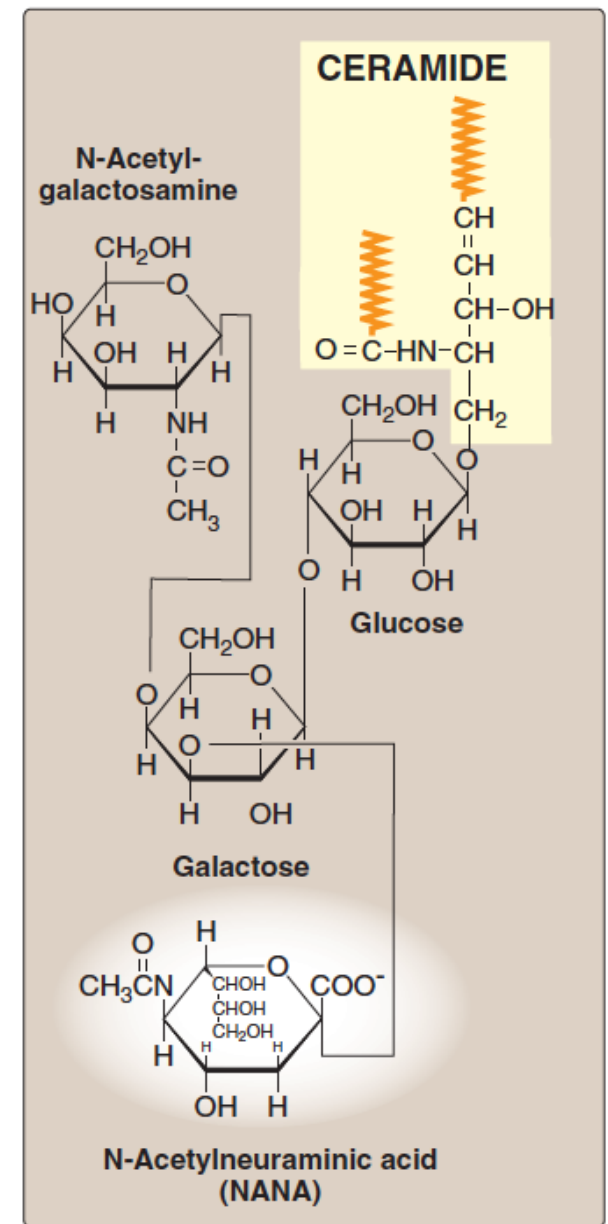


### Figure 17.4

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 **glycosphingolipids**
- Examples: Ganglioside, galactocerebroside
- Act as: Blood group antigens, cell surface receptors for bacteria/viruses

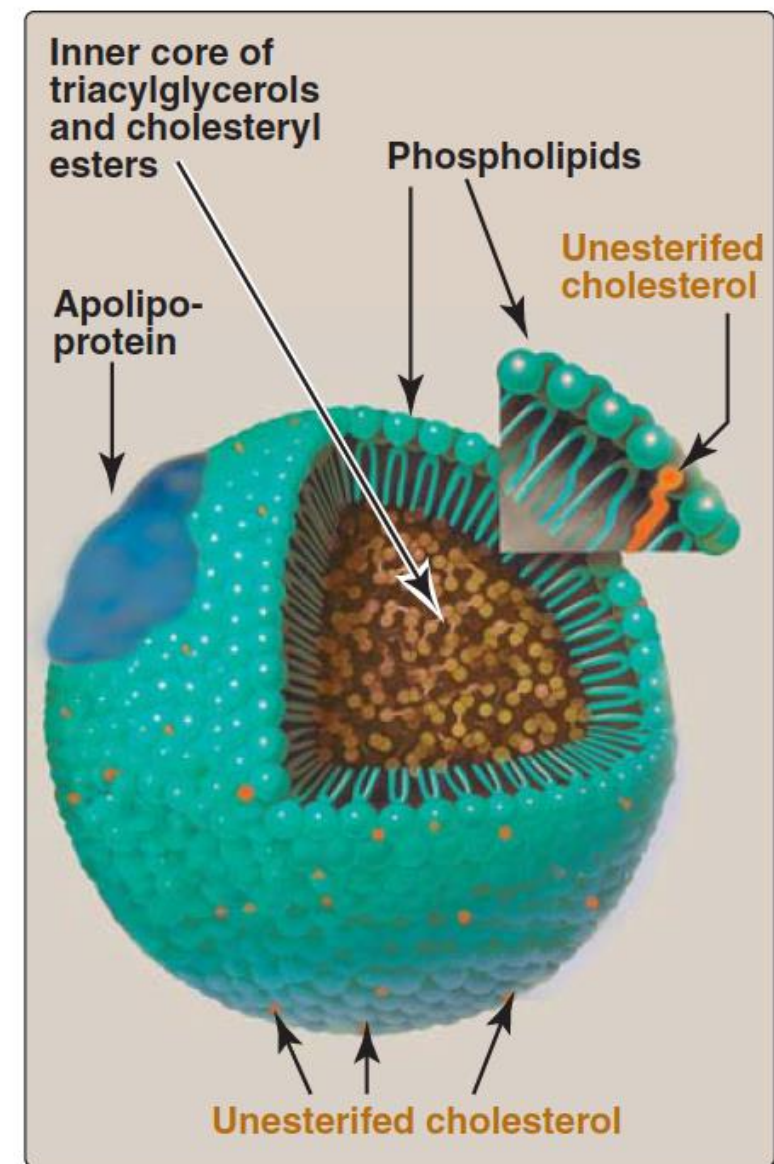


**Figure 17.15**  
Structure of the ganglioside GM<sub>2</sub>.



# 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

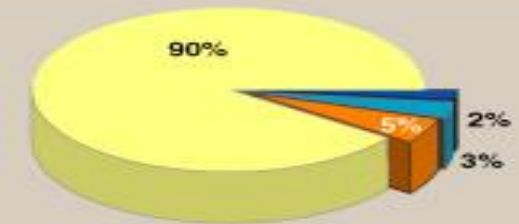


**Figure 18.14**

Structure of a typical lipoprotein particle.

# Types and functions of lipoproteins

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



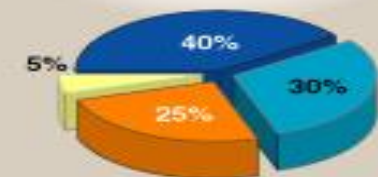
Chylomicron



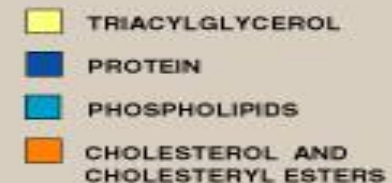
Very-Low-Density Lipoprotein (VLDL)



Low-Density Lipoprotein (LDL)



High-Density Lipoprotein (HDL)



# 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