



# 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

**Take home message**

- Lipids are essential for the structure and function of cell membranes
- Lipids are also used for energy storage
- Lipids are used for signaling
- Lipids are used for insulation
- Lipids are used for protection

# IPI

## Functions of lipids

- Lipids are essential for the structure and function of cell membranes
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## What are lipids?

- A hydrophobic or amphipathic molecule that is soluble only in organic solvents
- They diffuse across membranes and are found in cell membranes, tissues and proteins

## Functions of cholesterol

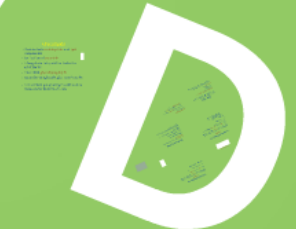
- Components of cell membrane
- Precursor for:
  - Bile acids / bile salts
  - Vitamin D
  - Steroid hormones
  - Adosterone, cortisol, testosterone, etc.
- High levels of plasma cholesterol is strongly associated with coronary artery disease and atherosclerosis

## Cholesterol

- What are lipids?
- Classification of lipids
- Functions of lipids
- Structure of lipids
- Synthesis of lipids
- Breakdown of lipids
- Transport of lipids
- Storage of lipids
- Regulation of lipids

## Steroids

- Steroids are a class of lipids
- They are synthesized from cholesterol
- They are used for signaling
- They are used for insulation
- They are used for protection



## 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 triphosphate
- 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



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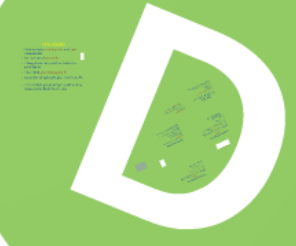
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*Simple lipids*

```
graph TD; A((Simple lipids)) --> B((Fatty acids)); A --> C((Triacylglycerols)); A --> D((Steroids (eg. cholesterol)))
```

Fatty acids

Triacylglycerols

Steroids  
(eg. cholesterol)



# *Simple lipids*



# Fatty acids



# Triacylglycerols



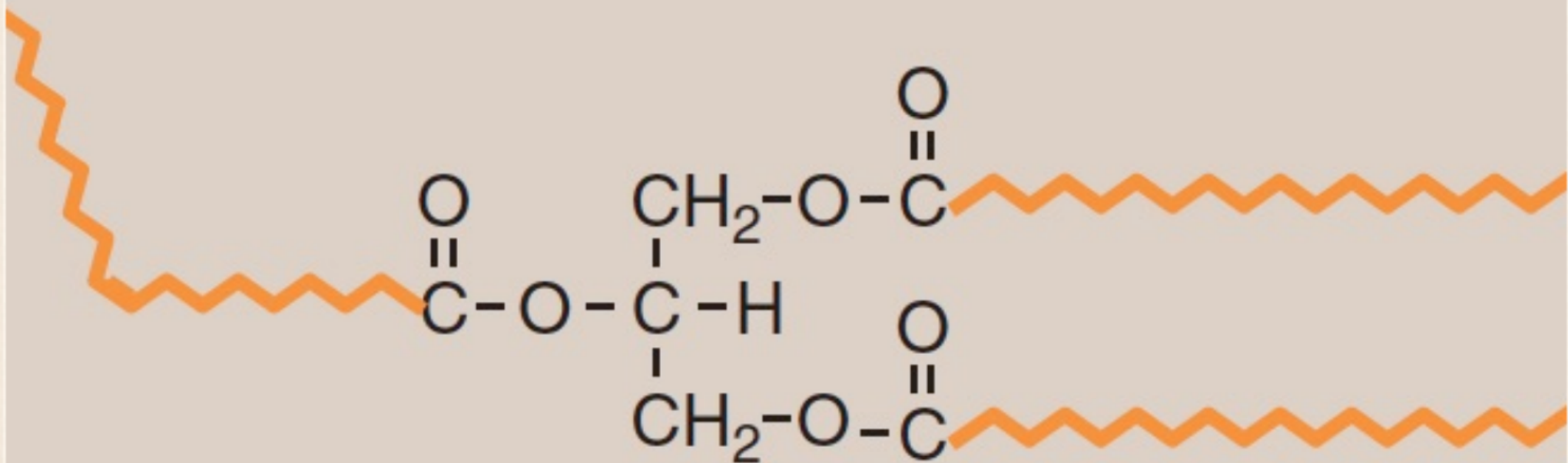


Steroids  
(eg. cholesterol)

# FATTY ACIDS



# TRIACYLGLYCEROL







*Complex lipids*





# Phospholipids

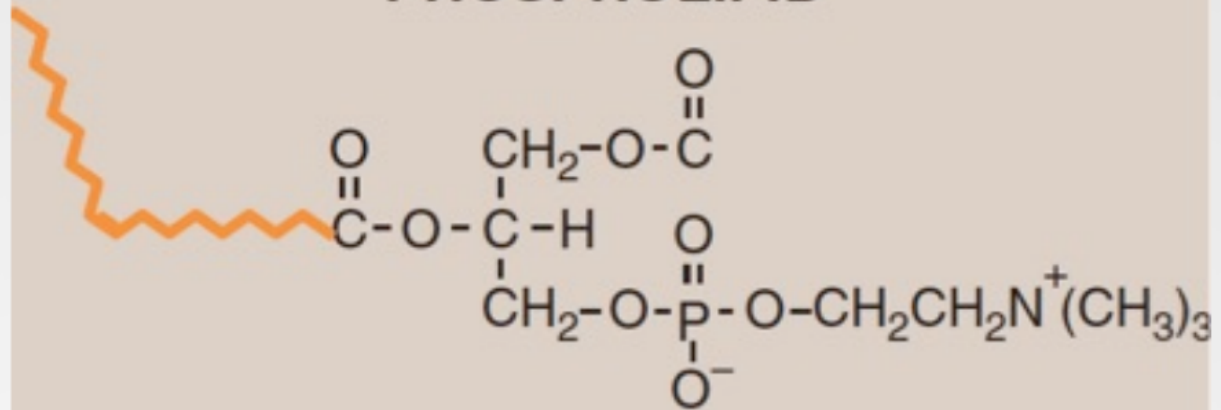
# Sphingolipids

A large blue circle is centered on the page. Inside the circle, the word "Sphingolipids" is written in orange. To the right of the text is a yellow dot, below it is a blue dot, and at the bottom right is a pink dot. The background is light gray.

# Glycolipids

The image features a large, thin blue circle centered on a light gray background. Inside this circle, the word "Glycolipids" is written in a bold, orange, sans-serif font. To the right of the text is a solid orange circle. Below the text is a solid blue circle. In the bottom right corner, outside the blue circle, is a solid pink circle. In the top left corner, there is a gray triangular shape pointing towards the center.

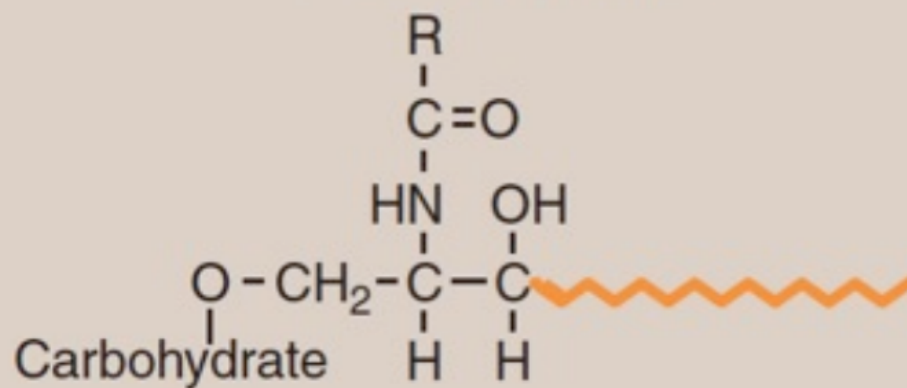
## PHOSPHOLIPID

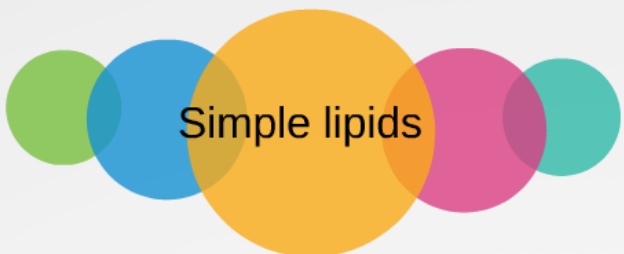


## STEROID



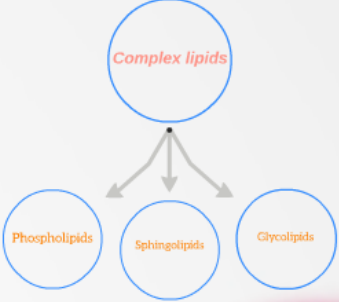
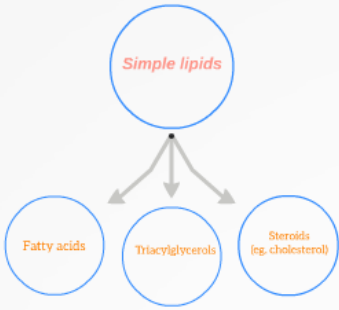
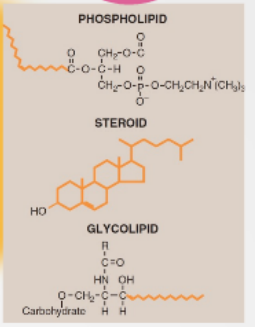
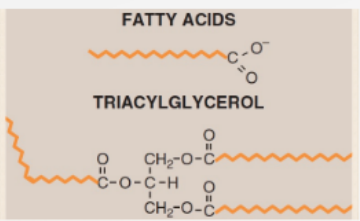
## GLYCOLIPID





# Classification of

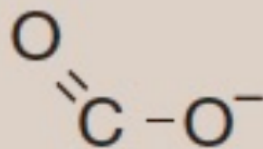
# LIPIDS



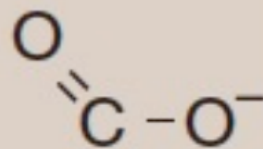
# Fatty Acids

- 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**

**A**



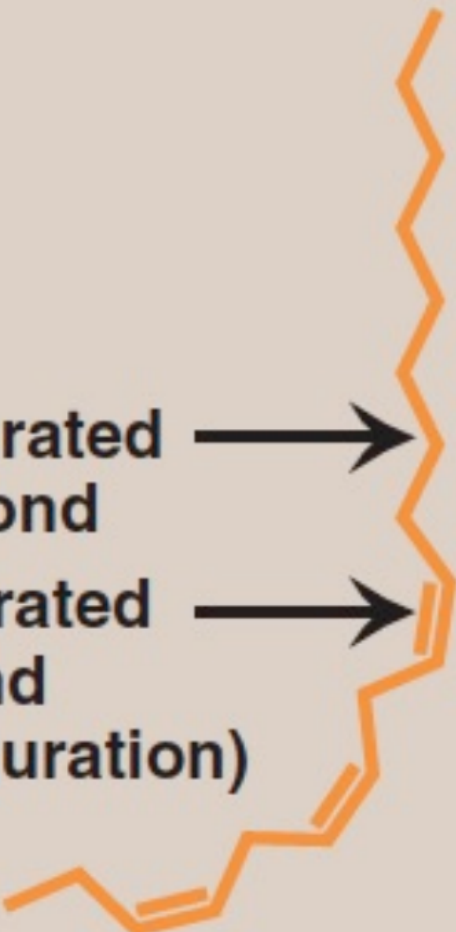
**B**



← Saturated bond →

← Unsaturated bond →

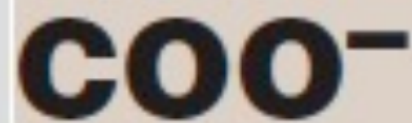
(cis configuration)







**Hydrophobic  
hydrocarbon chain**



**Hydrophilic  
carboxyl group  
(ionized at pH 7)**

# Fatty Acids

- FAs are highly insoluble in water
- Must be transported in plasma with proteins

Majority of plasma FAs are esters of:

- Triacylglycerol
- Cholesterol
- Phospholipids

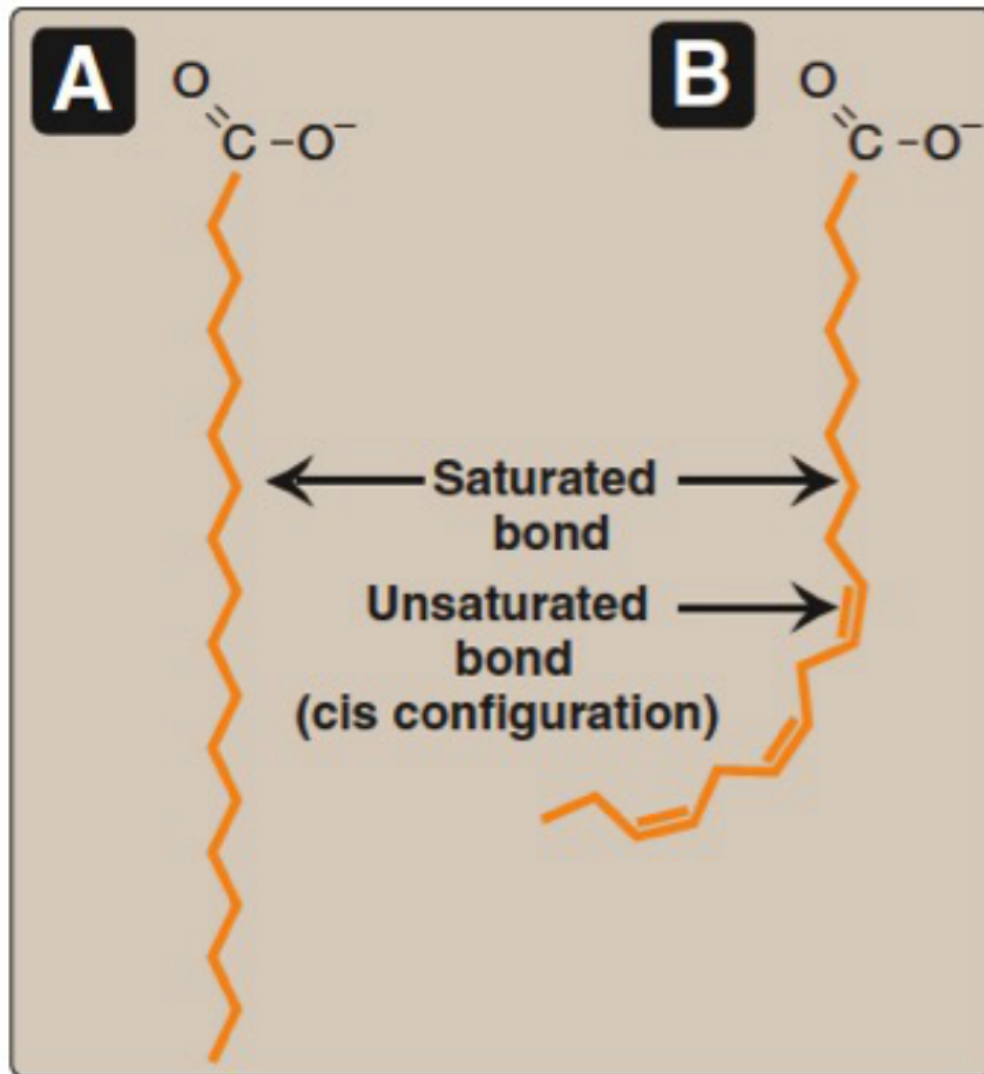
Chain length

- In mammals it varies from C16–C18
- Examples: palmitic, oleic, linoleic, stearic acids

## 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 number '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 number '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

- **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

# w-3 and w-6 Fatty acids

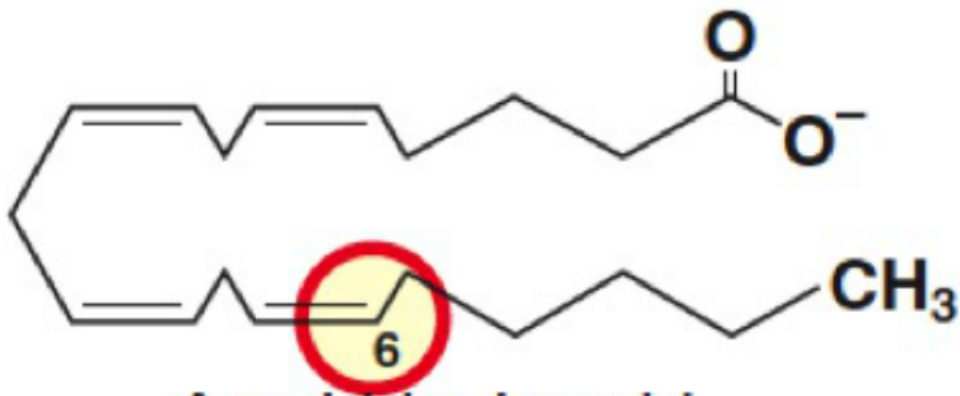
w = Omega

- 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

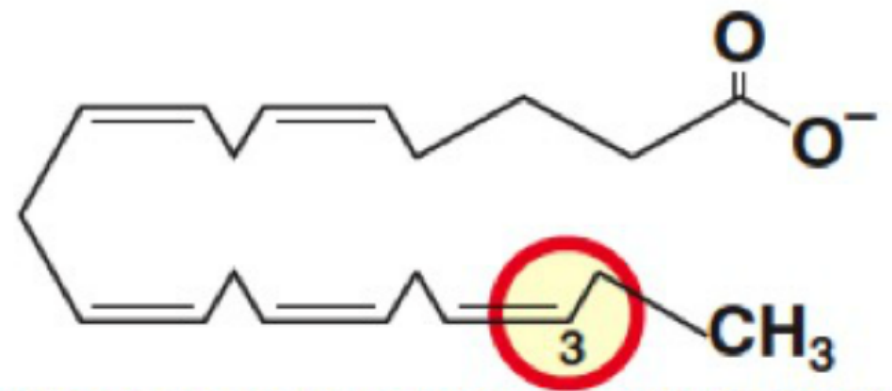
Examples:

- alpha-linolenic acid
- EPA (eicosapentaenoic acid)
- DHA (Docosahexaenoic acid)

## Omega-3 and Omega-6 fatty acids



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



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

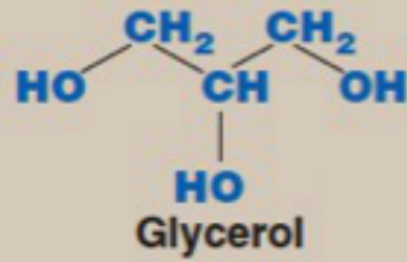


# w-3 and w-6 Fatty acids

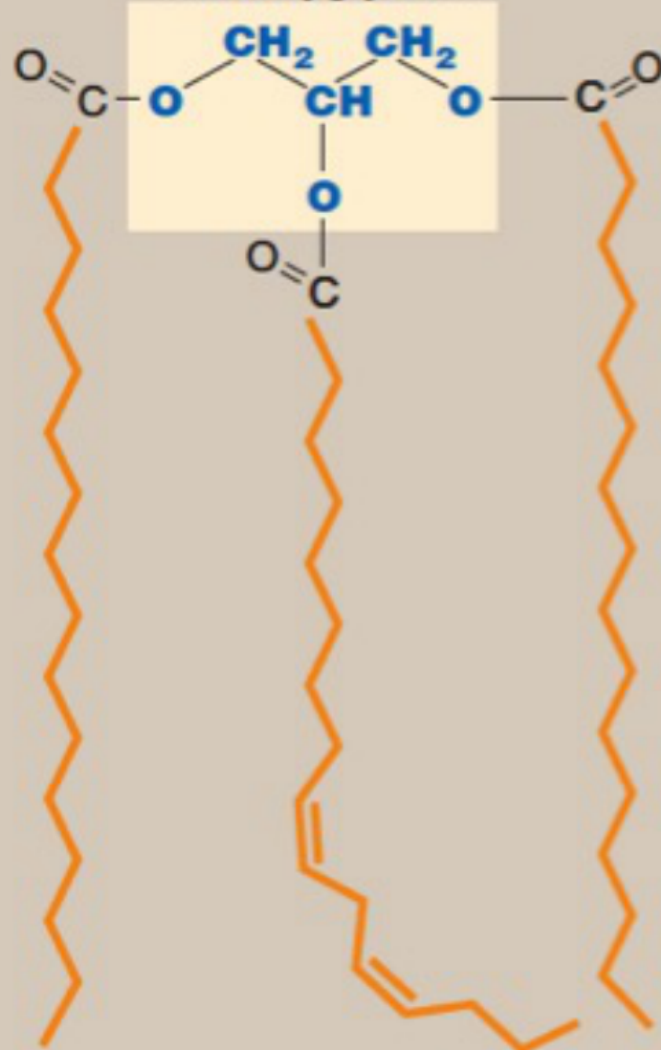
w = Omega

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

- 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



Glycerol component  
of triacylglycerol



**Take home message**

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## What are lipids?

- A hydrophobic or amphipathic molecule that is soluble only in organic solvents
- They diffuse into the cell membrane and form part of the cell membrane, tissue and proteins

## Functions of cholesterol

- Components of cell membrane
- Precursor for:
  - Bile acids / bile salts
  - Vitamin D
  - Steroid hormones
  - Adosterone, cortisol, testosterone, etc.
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## Cholesterol

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## Steroids

- Steroids are a class of lipids
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## Cholesterol

- Cholesterol is a major lipid in animal cell membranes
- It is used for signaling
- It is used for energy storage
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# 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



# IPI

**Functions of cholesterol**

- Support of cell membranes
- Production of steroid hormones
- Production of bile acids
- Absorption of fat-soluble vitamins, etc.

The level of cholesterol in a person's blood is affected by a variety of factors, including diet, exercise, and genetics.

**What are lipids?**

Lipids are a group of organic molecules that are insoluble in water. They are found in all living organisms and are essential for the structure and function of cell membranes. Lipids are also used for energy storage and as signaling molecules.

**Take home message**

Cholesterol is a waxy substance found in all cells. It is essential for the production of hormones, bile acids, and vitamin D. However, high levels of cholesterol in the blood can lead to the formation of plaque in the arteries, which can increase the risk of heart disease and stroke.



protects and insulates nerve fibers

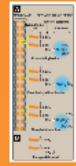
# Functions of cholesterol

- Component of cell membranes

## Precursor for:

- Bile acids / Bile salts
  - Vitamin D
  - Steroid hormones
  - Aldosterone, cortisol, testosterone, etc.
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# Phospholipids



Glycerophospholipids

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

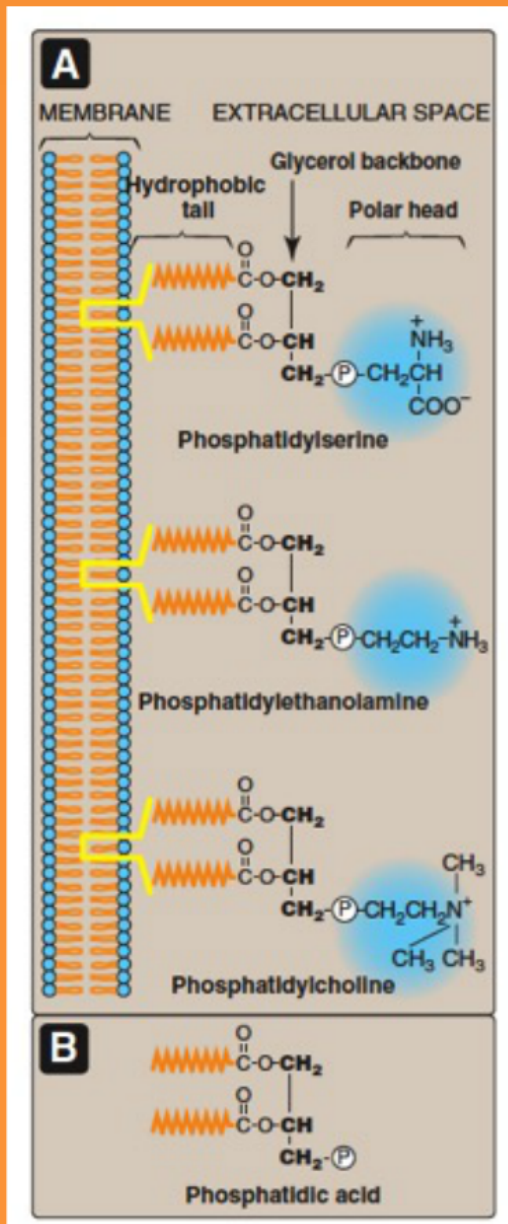
## Glycerophospholipids

- 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

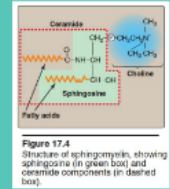
- Hydrophobic tail
- Hydrophilic phosphoryl heads





# Glycerophospholipids

# Phospholipids



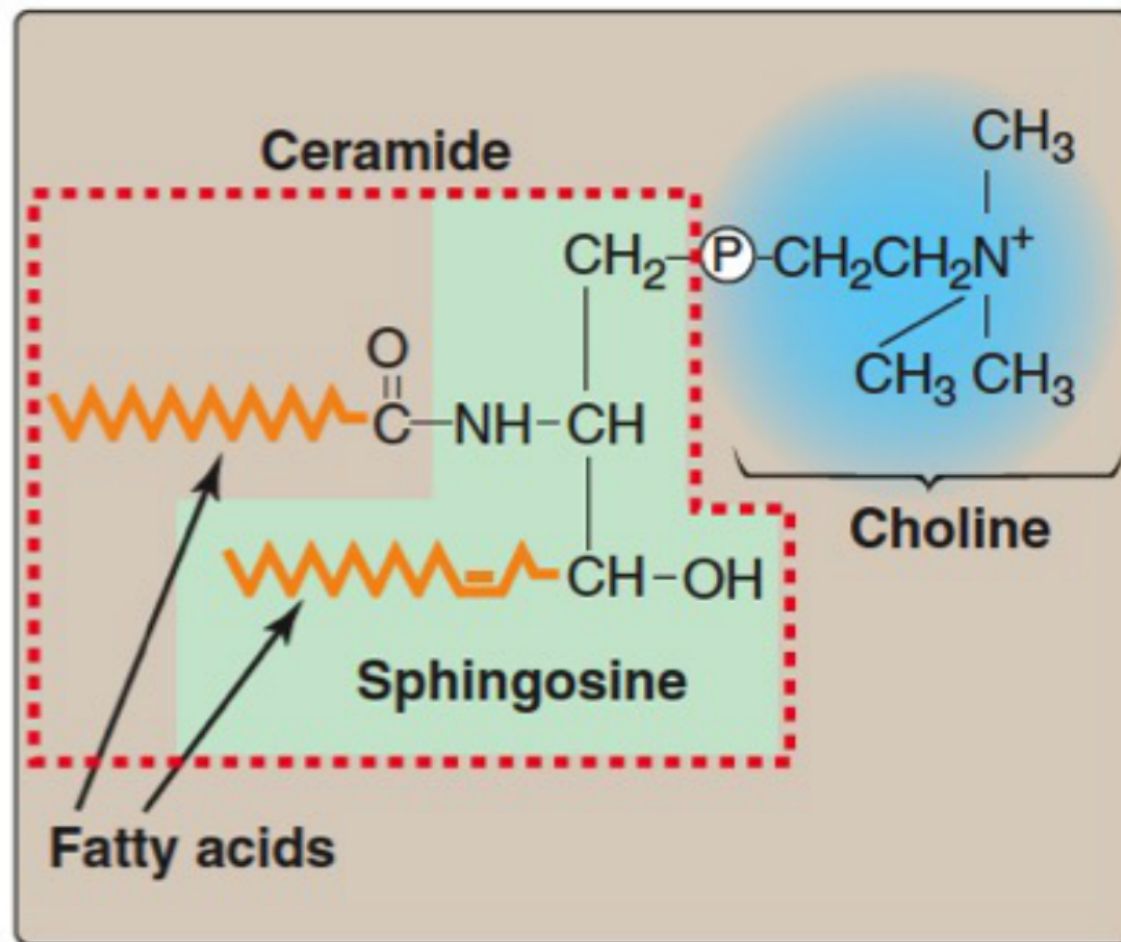
- Major components of biological membranes

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



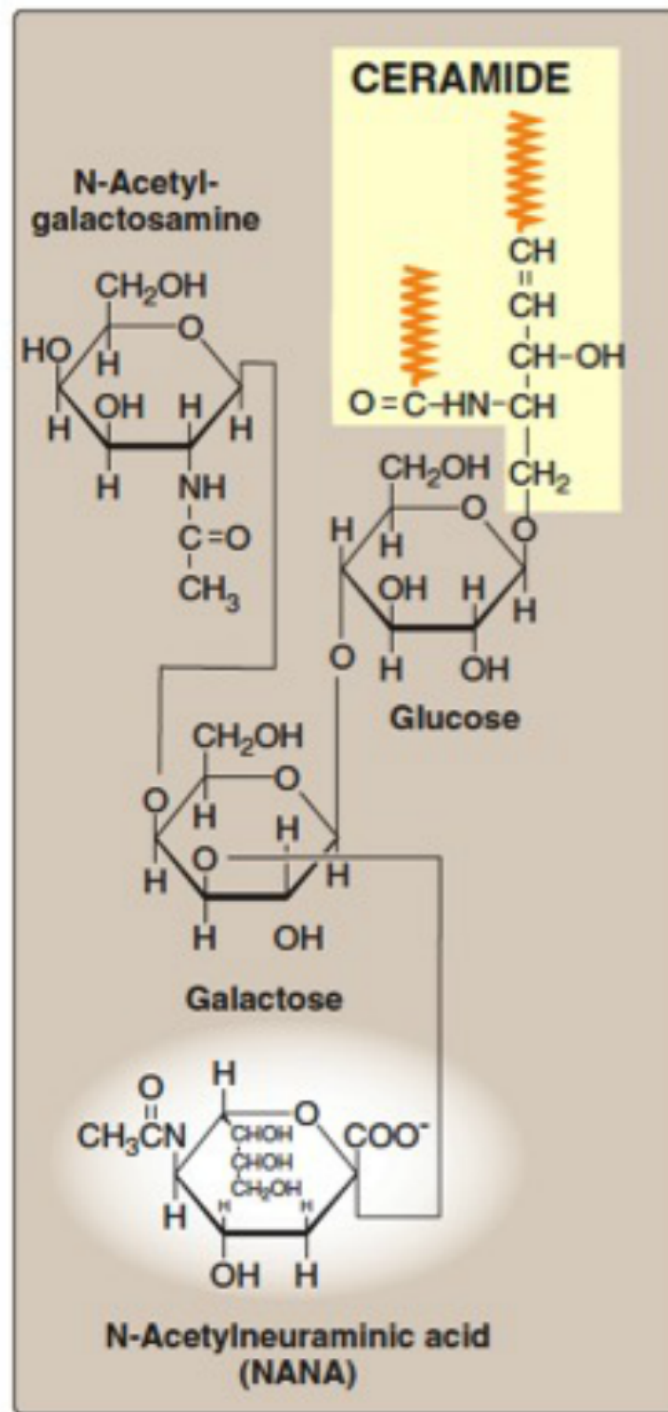
**Figure 17.4**

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



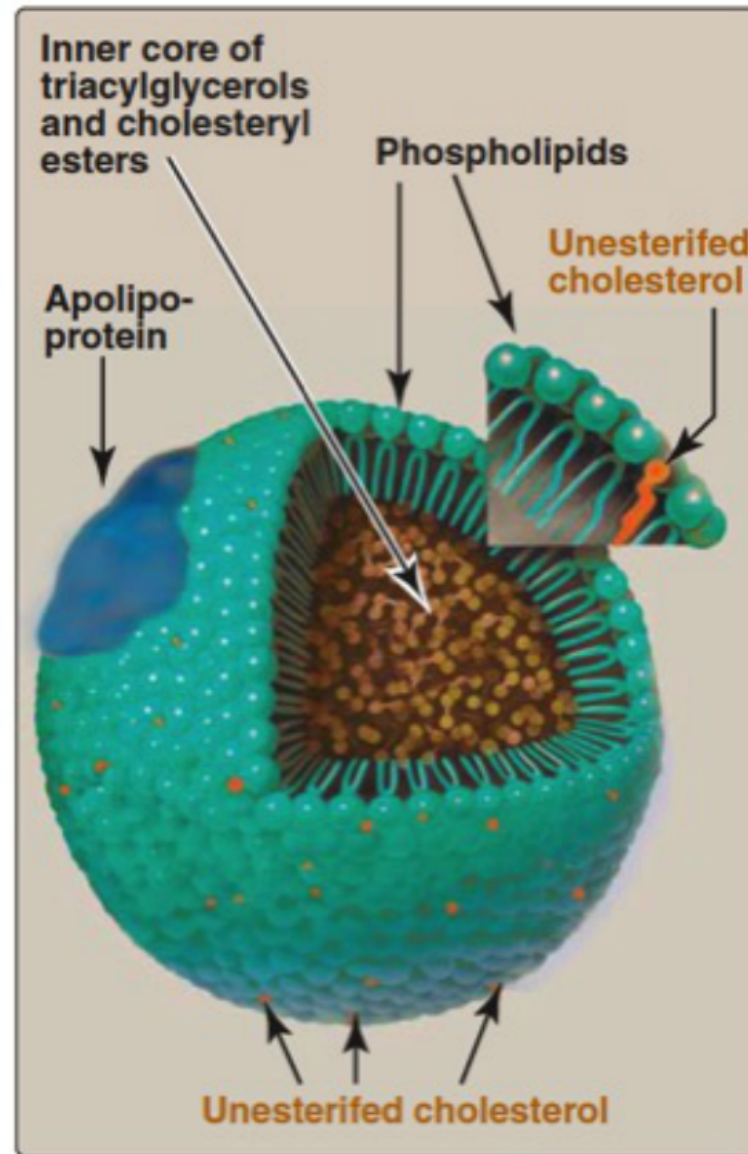


**Figure 17.15**  
Structure of the ganglioside  $G_{M2}$ .



# 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



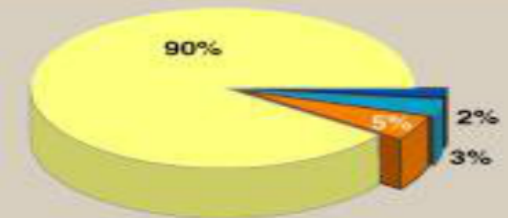
**Figure 18.14**  
Structure of a typical lipoprotein particle.





# Types and functions of lipoproteins

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



Chylomicron



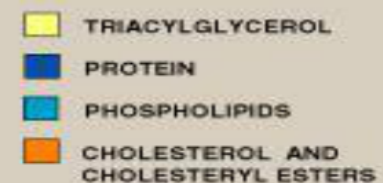
Very-Low-Density Lipoprotein (VLDL)



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



*Thank you very much*