# Lipids

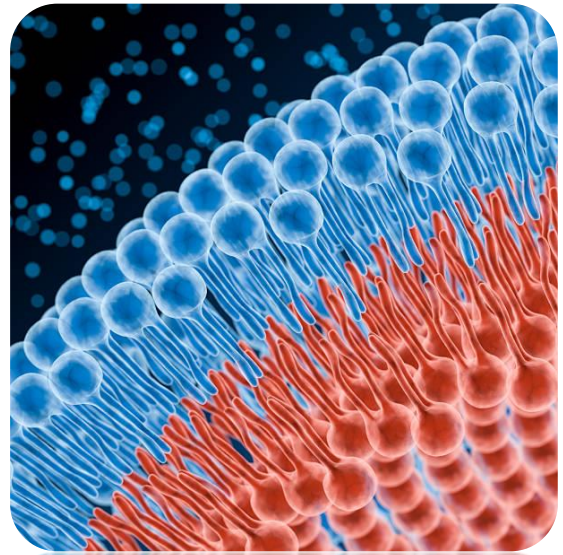
Lesson 3

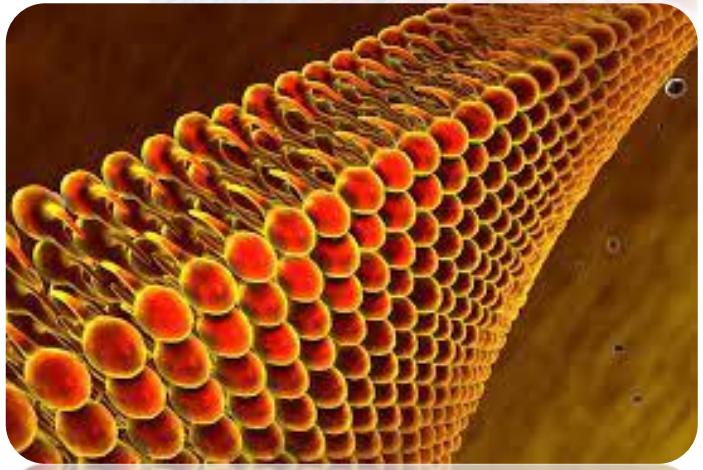
# Lipids

# Lipids

## Lipid

- Is an organic molecule present in living things that is that is ***insoluble*** (*or only sparingly soluble*) in ***water*** but ***soluble in non-polar organic solvents***.
- Unlike other biomolecules, lipids do not share a common structural property with other biomolecules that may be used to categorize them.





**Classification**: (based on two methods)

- Solubility in water
- Biochemical function

# Lipids

## Lipid Classification Based on Function

- **Energy storage**
  - Energy-storage lipids in the form of triacylglycerols (TAGs).
- **Membrane lipids**
  - amphipathic molecules that form the structural foundation of biological membranes (*phospholipids*, *sphingoglycolipids*, *cholesterol*)
- **Emulsification lipids**
  - Bile acids

# Lipids

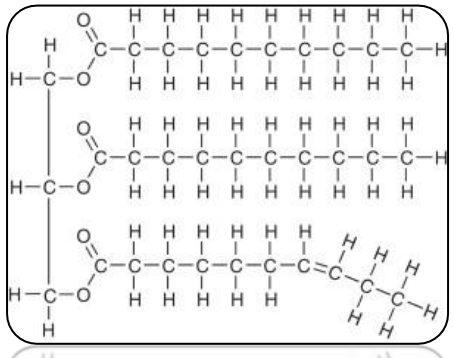
## Lipid Classification Based on Function

- **Chemical messenger lipids**
  - Steroid hormone lipids and eicosanoids.

- **Protective-coating lipids**
  - Biological waxes

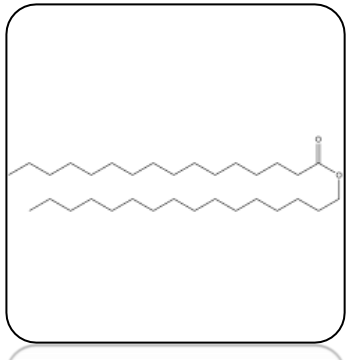
# Lipids

Energy-storage lipids

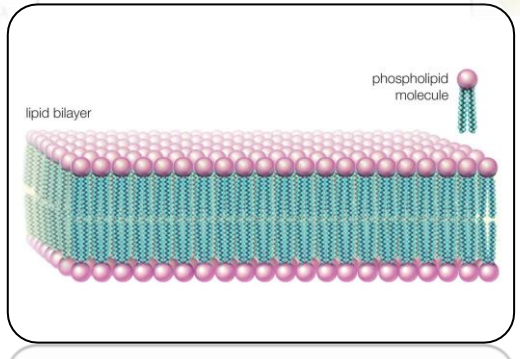


Emulsification lipids

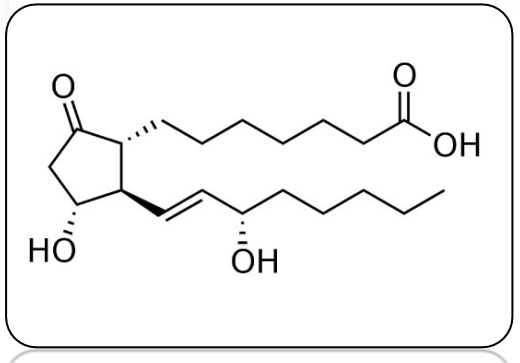
Wax lipids



Membrane lipids



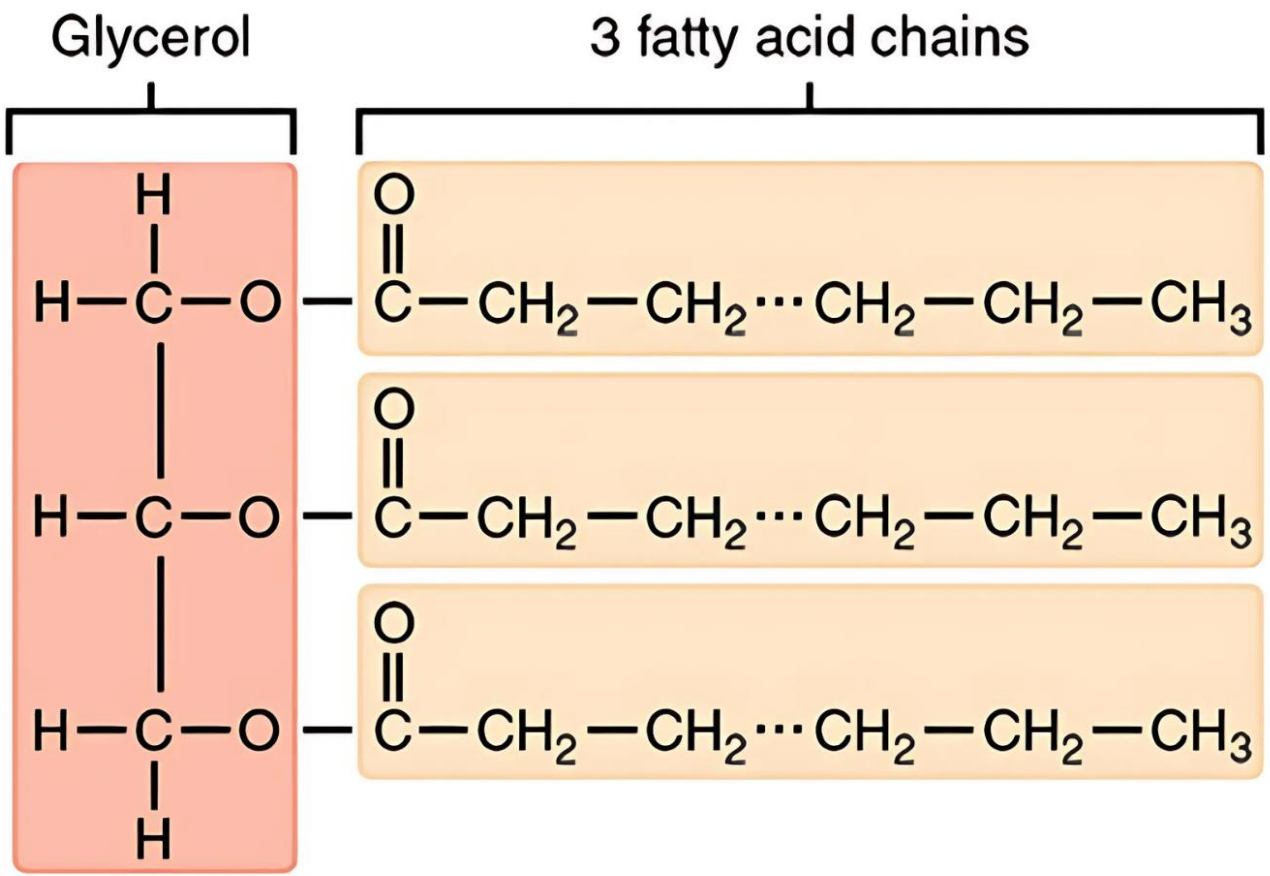

Messenger lipids



# Energy-Storage Lipids (TAGs)

# Energy-Storage Lipids

**Triacylglycerol (TAG)**

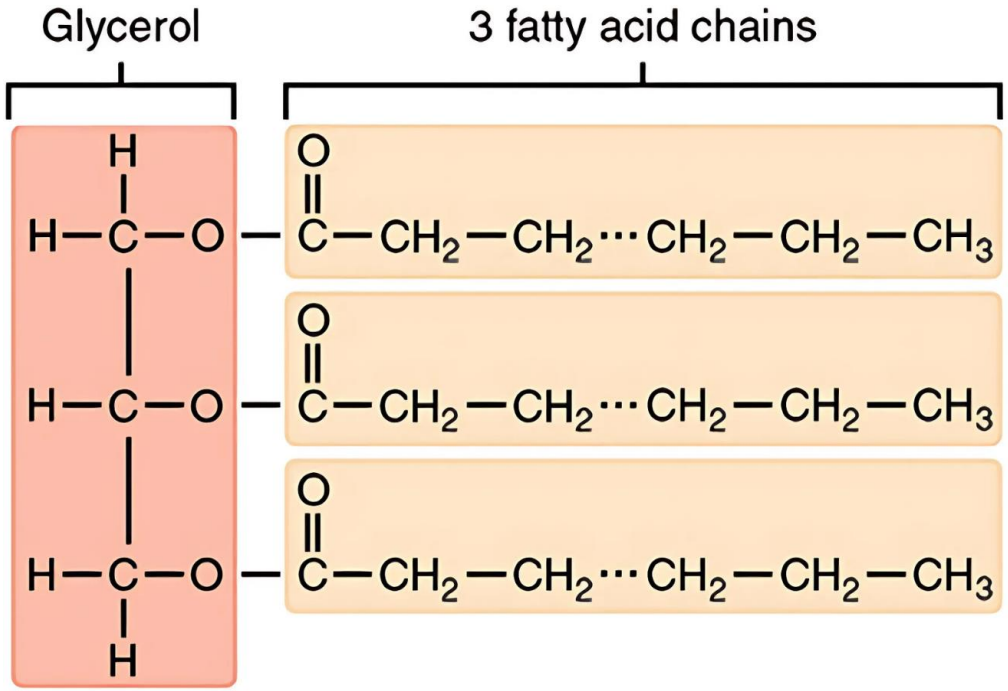


# Energy-Storage Lipids

## Two Types of TAGs

- **Simple Triacylglycerols**
  - Composed of three identical fatty acids esterified to glycerol.
  - (Rare)

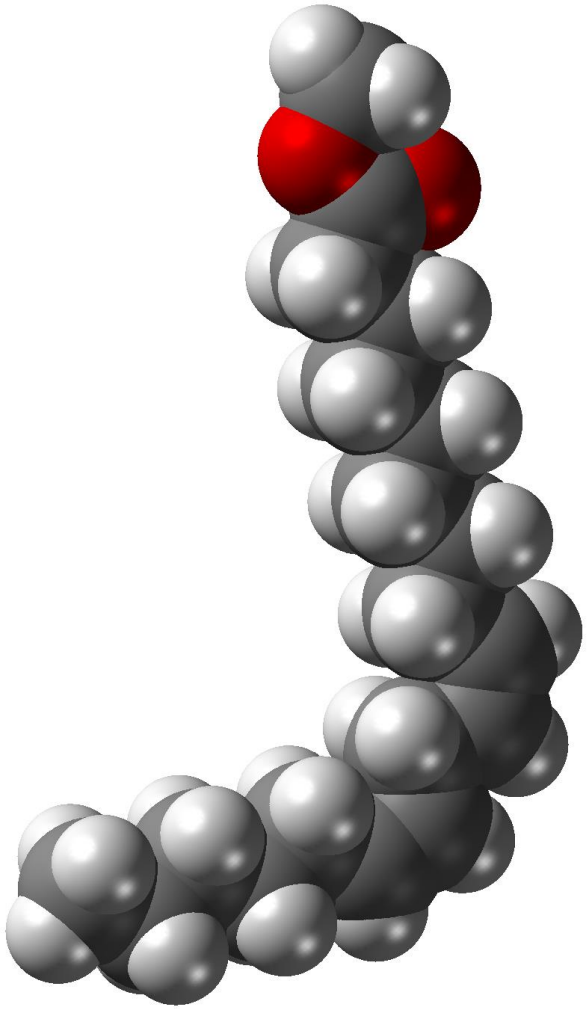
- **Mixed Triacylglycerols**
  - More than one type of fatty acid.
  - (Most predominant form)



# Energy-Storage Lipids

## Fatty Acids

- Fatty acids are **carboxylic acids** with a ***linear*** (unbranched) ***carbon-carbon chain***.
- (Can be represented in its condensed form or line-angle structural formula.)



# Fatty Acids

## Classification Based on Length of Chain:

- Long chain fatty acids **(C12-C26)**
- Medium chain fatty acids **(C6-C11)**
- Short chain fatty acids **(<C5)**

# Fatty Acids

## Classification Based on C-C Bonds:

### Saturated

- All C-C bonds are single bonds.
- Numbering starts from the end –COOH group.
- *Lauric acid* has 12 C atoms and no double bonds, so it is (12:0).

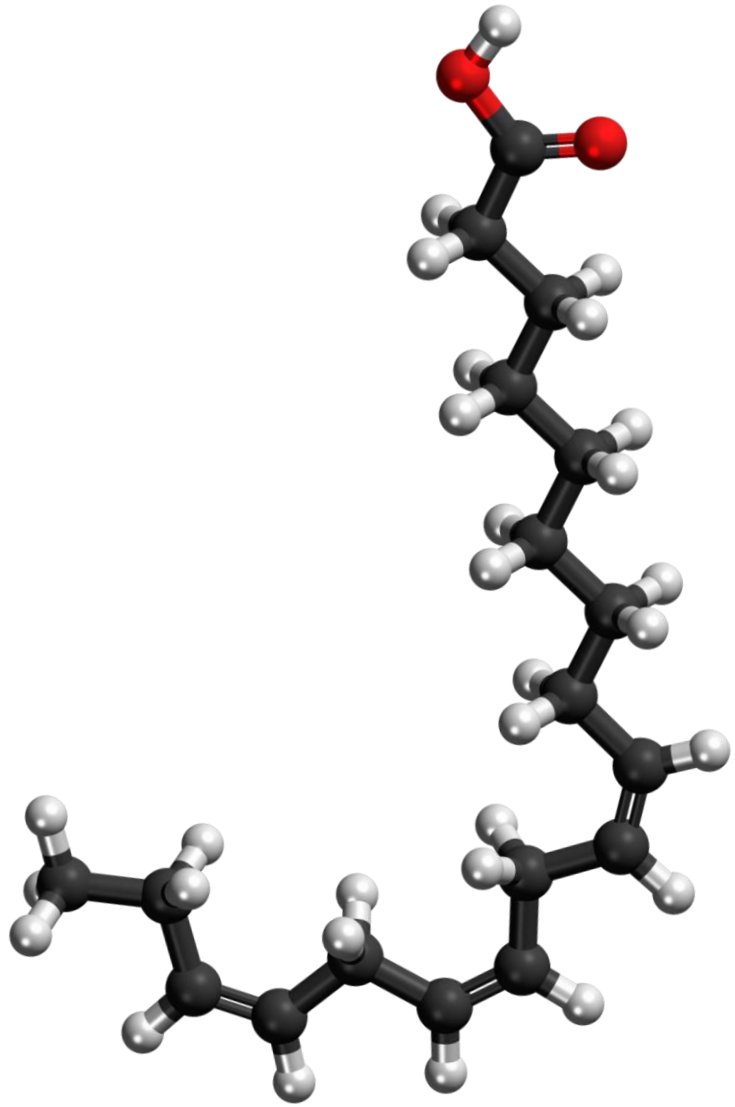
### Unsaturated

- There is at least one C=C double bond present.
- *Monounsaturated*: one C=C
- *Polyunsaturated*: 2 or more C=C

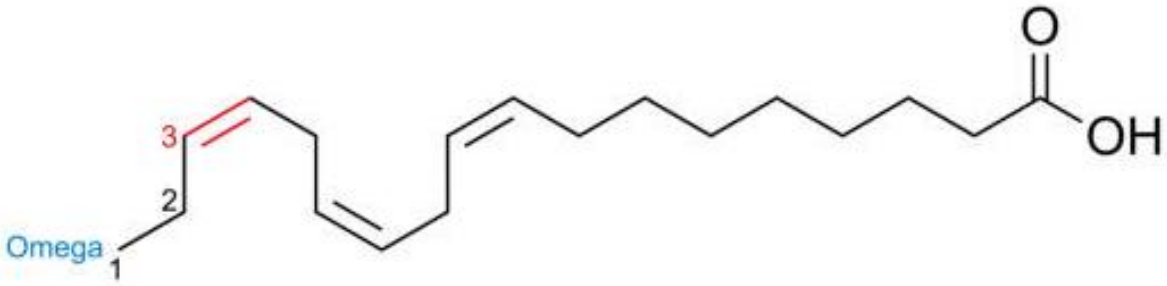
# Fatty Acids

## Omega Fatty Acids

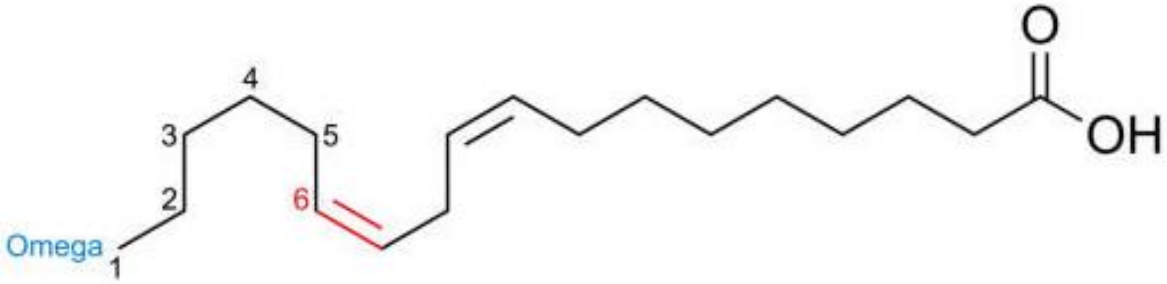
- *Omega-3* and *omega-6* FAs are **essential fatty acids** that play crucial roles in human health.
- The first C=C bond encountered starting from the *methyl end* of the FA determines the *omega* notation.



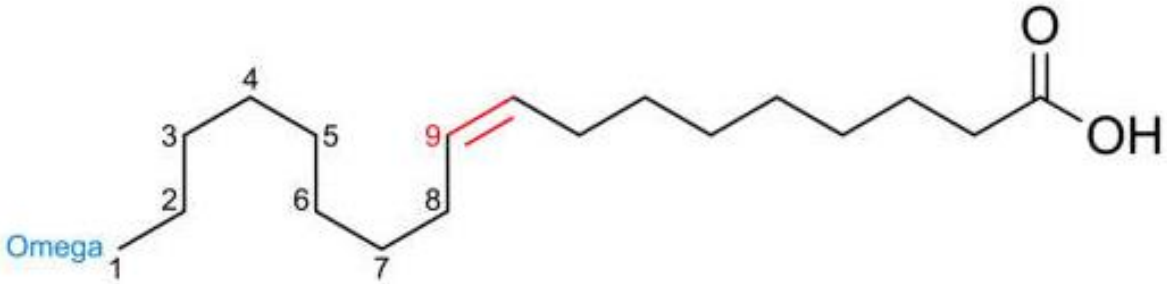
Both *linolenic* and *linoleic acid* are required for **proper membrane structure**!




Omega-3 (Linolenic acid)




Omega-6 (Linoleic acid)




Omega-9 (Oleic acid)

# Fatty Acids

## Linoleic Acid Deficiency

Also known as essential FA deficiency, is caused by the *inadequate dietary intake of lipids*.

Can cause

- Skin redness, drying, and irritation
- Infections and dehydration
- Liver abnormalities
- Impaired wound healing

*Scaly/flaky skin (symptomatic)*

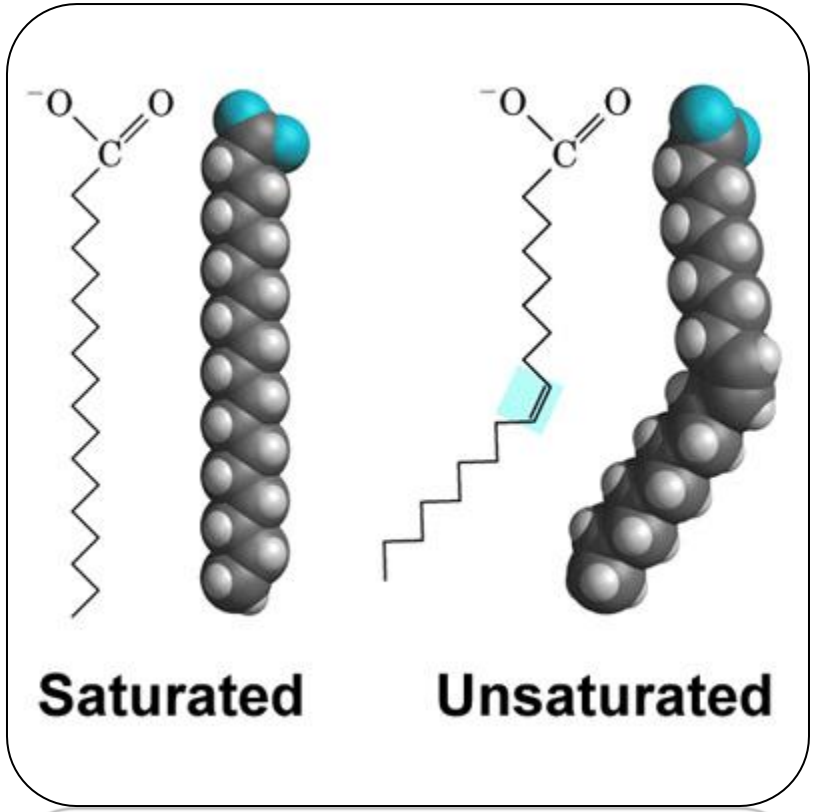
*Keratosis Pilaris* (Chicken Skin)

# Fatty Acids

## Physical Properties of Fatty Acids

- Melting point depends on:
  - Length of C-C chain
  - Number of double bonds in a molecule

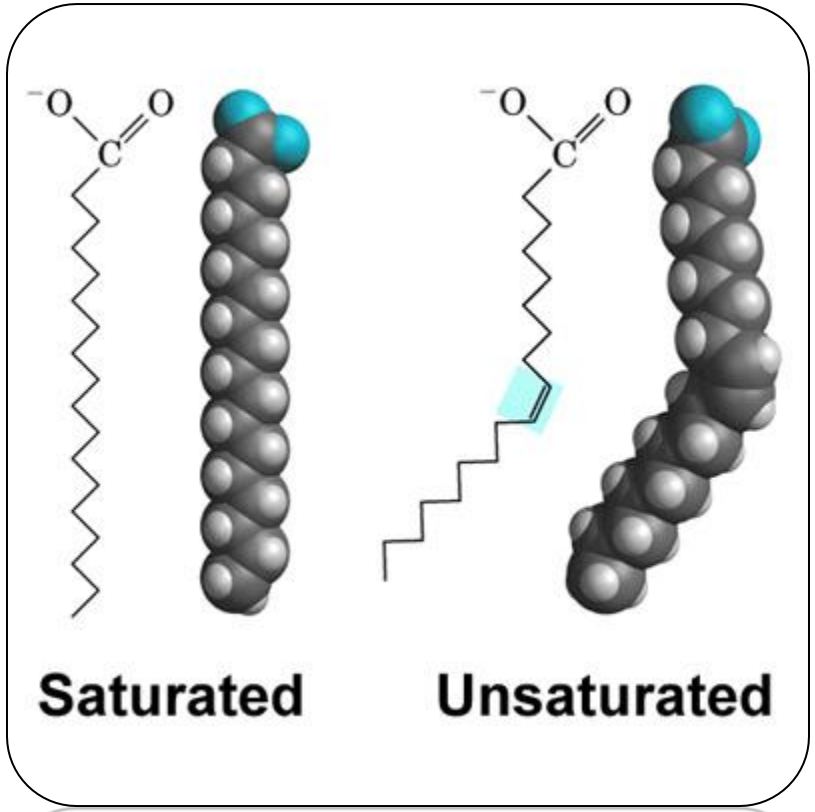
- The number of bends in a fatty acid chain increase as the number of double bonds increase.



# Fatty Acids

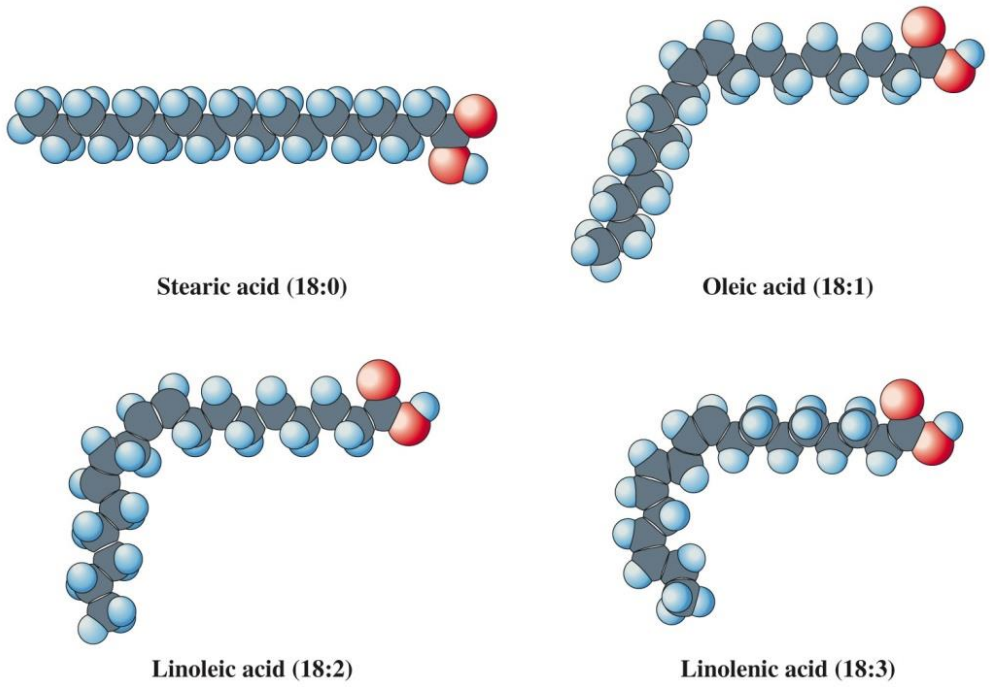
## Physical Properties of Fatty Acids

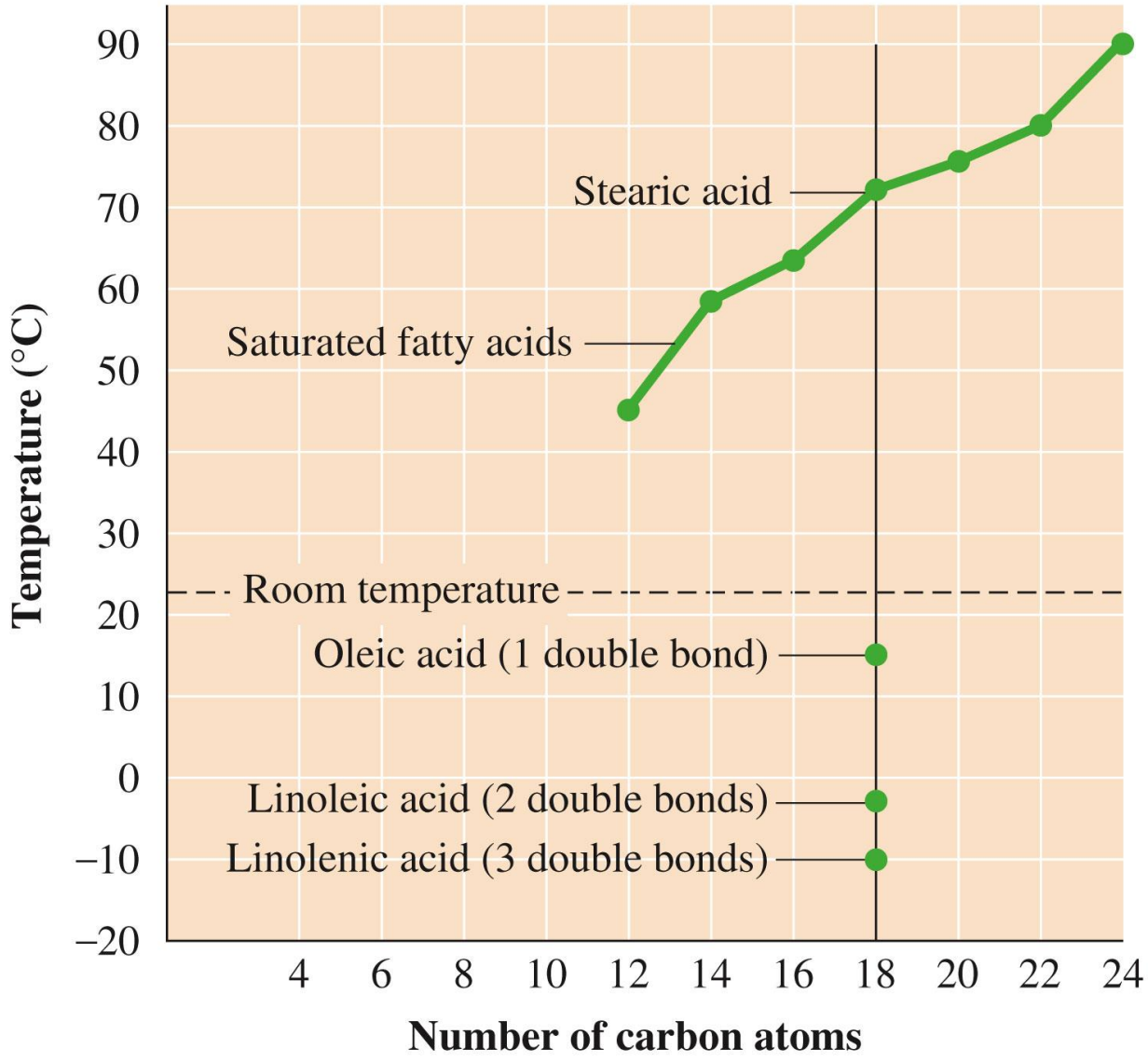
- Less packing occurs.
- Melting point is lower.
- Tend to be liquids at room temp.



# Fatty Acids

## Physical Properties of Fatty Acids

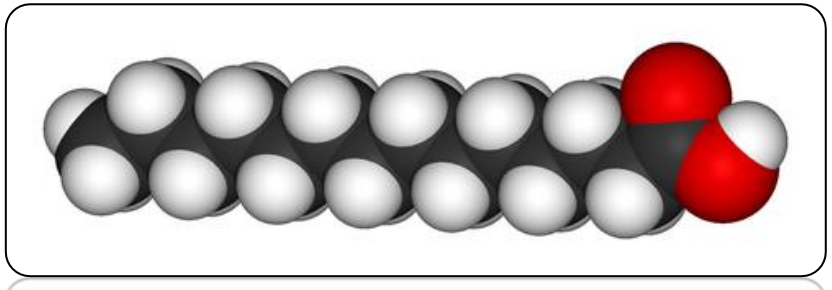


# Fatty Acids

## Difference of Fats and Oils

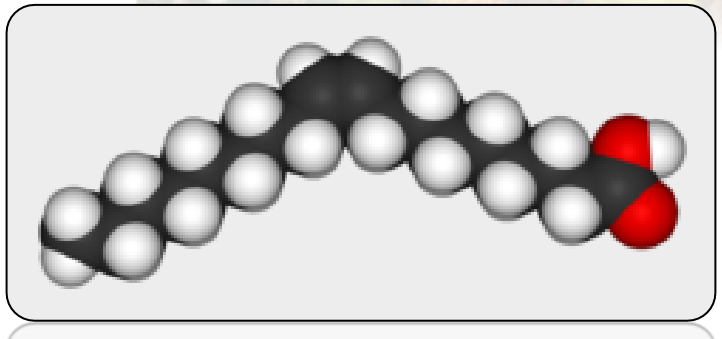
- **Fats**
  - TAGs that are predominantly composed of *saturated* fatty acids.
  - Solids or semisolids at room temperature.
  - Source: Animal sources



# Fatty Acids

## Difference of Fats and Oils

- **Oils**
  - TAGs that are predominantly composed of *unsaturated* fatty acids.
  - Liquids at room temperature.
  - Source: Plants and fish oil



# Membrane Lipids

# Membrane Lipids

## Types of Membrane Lipids

- **Phospholipids**
  - Glycerophospholipids
  - Sphingophospholipids
- **Sphingoglycolipids**
  - Gangliosides
- **Cholesterol**

# Membrane Lipids

## Phospholipids

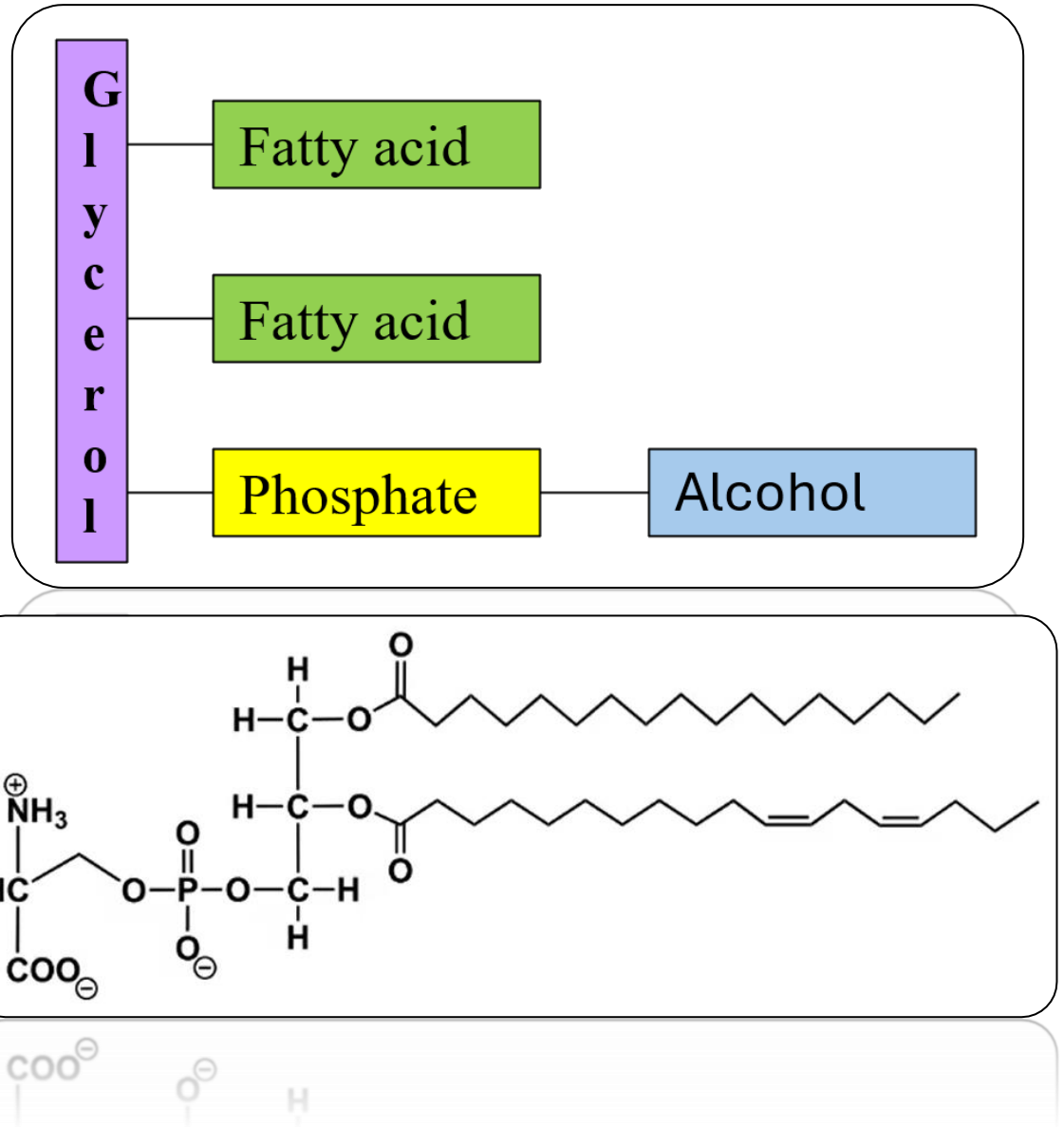
- All cells are surrounded by a membrane that confines its contents.
- Up to 80% of the mass of a cell membrane can be lipid materials -- dominated by phospholipids.

- Phospholipids are a type of lipid made up of **two fatty acid tails**, a **glycerol** backbone, and a **phosphate** group.

# Membrane Lipids

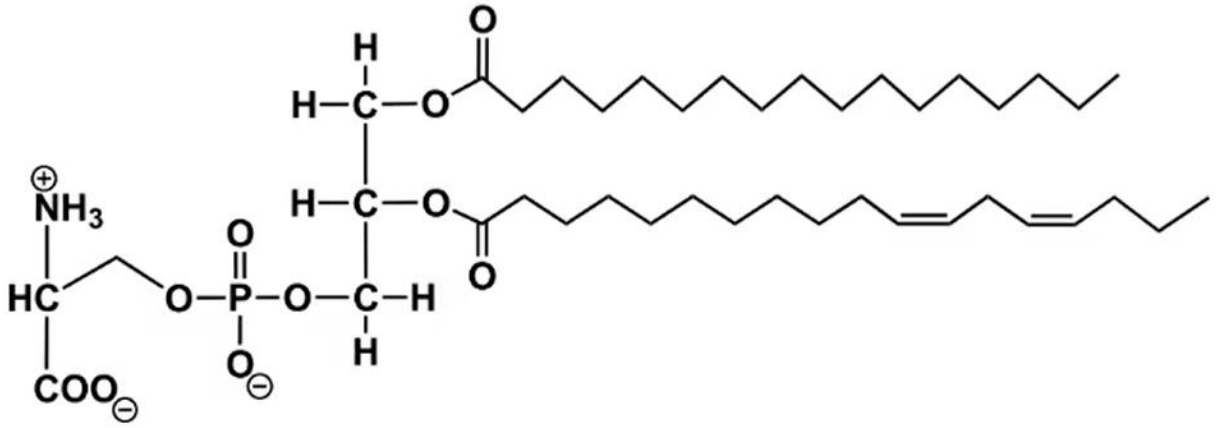
## Glycerophospholipids

- A glycerophospholipid is a lipid that contains:
  - Two FAs
  - Phosphate group
  - Glycerol backbone
  - Alcohol esterified to the phosphate group



# Membrane Lipids

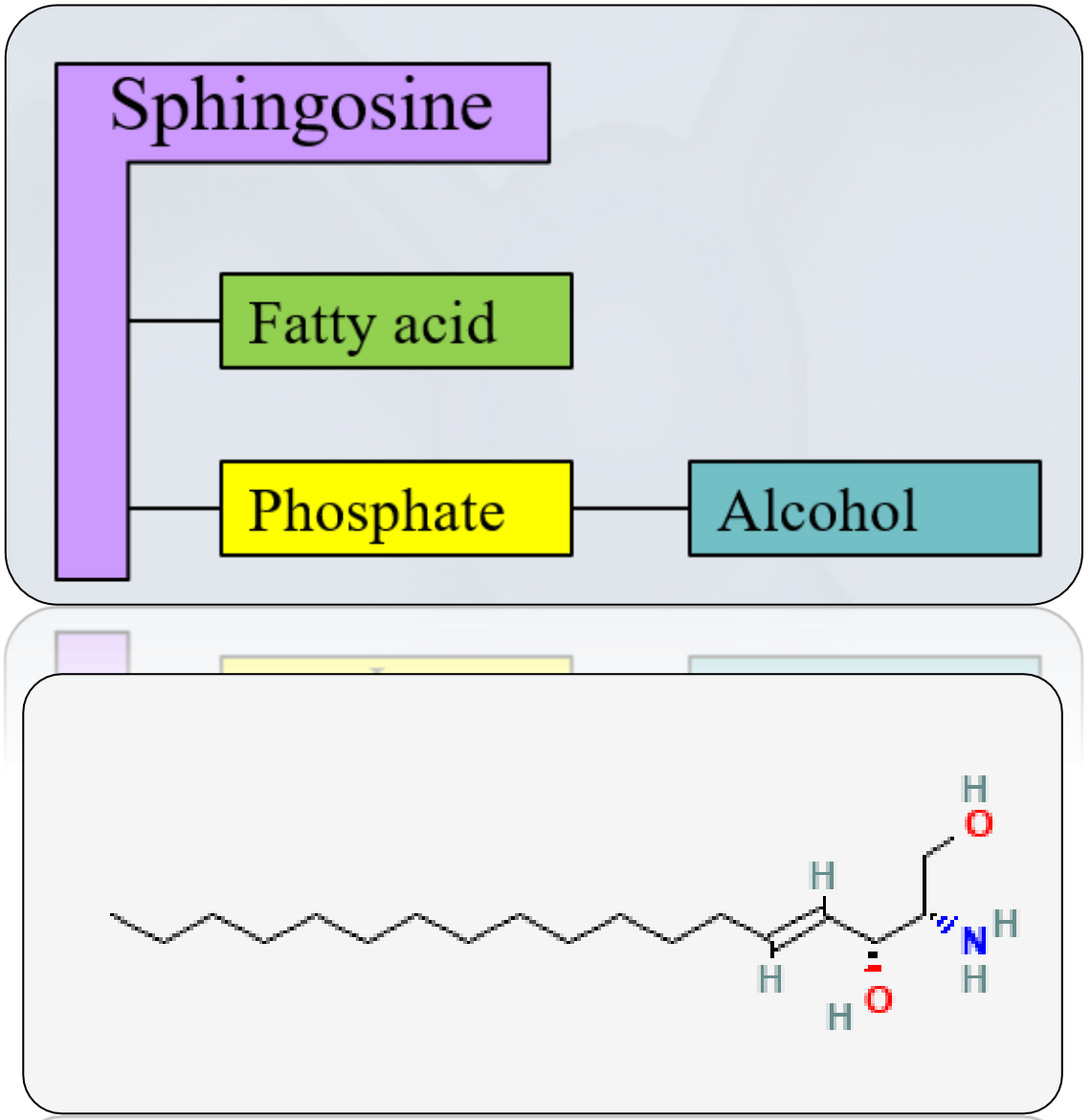
- Structurally, glycerophospholipids are although similar to triacylglycerols, however, they have different biochemical functions.
  - Triacylglycerols serve as energy storage molecules
  - Glycerophospholipids function as components of cell membranes



# Membrane Lipids

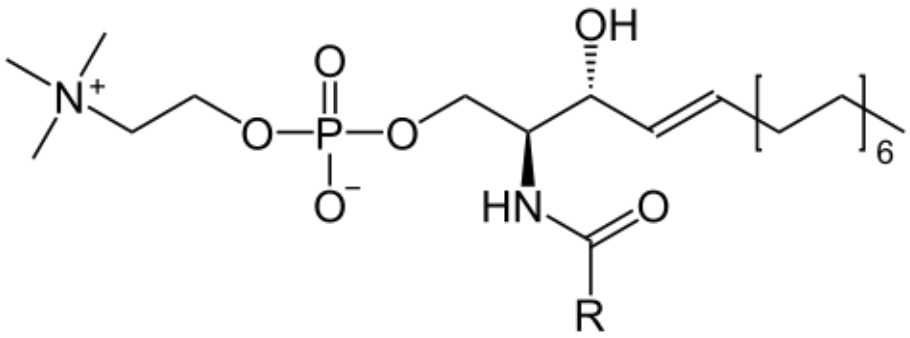
## Sphingophospholipids

- A sphingophospholipid is a lipid whose structure is based on *sphingosine*.
- Contains one fatty acid and one phosphate group attached to a sphingosine molecule.

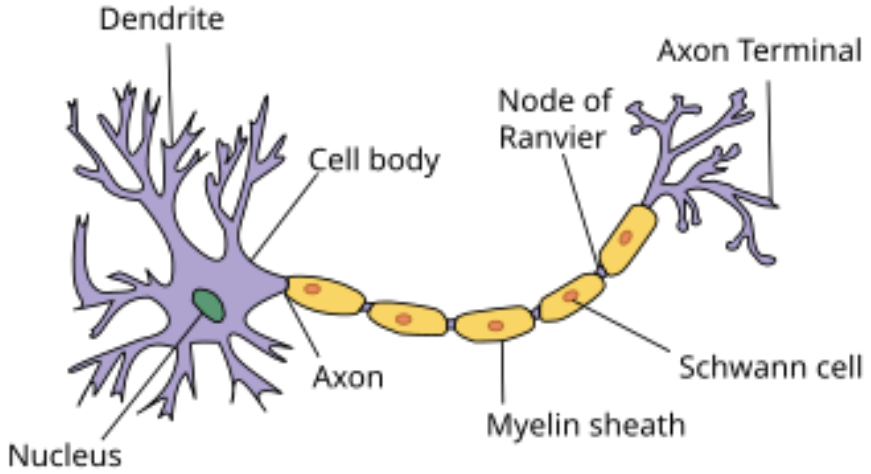


# Membrane Lipids

- Sphingophospholipids are found in all cell membranes and are highly concentrated in nervous tissue.
- An example is ***sphingomyelin***, the most well-known sphingophospholipid, it's a major component of cell membranes and myelin.



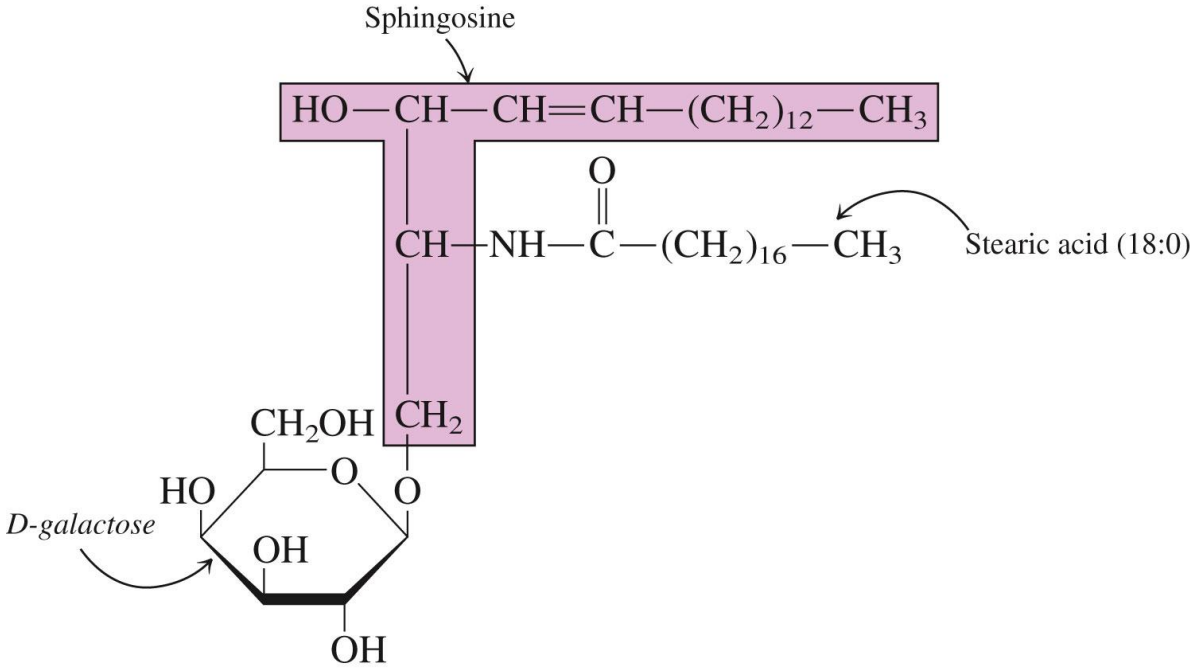

***Sphingomyelin***



# Membrane Lipids

## Sphingoglycolipids

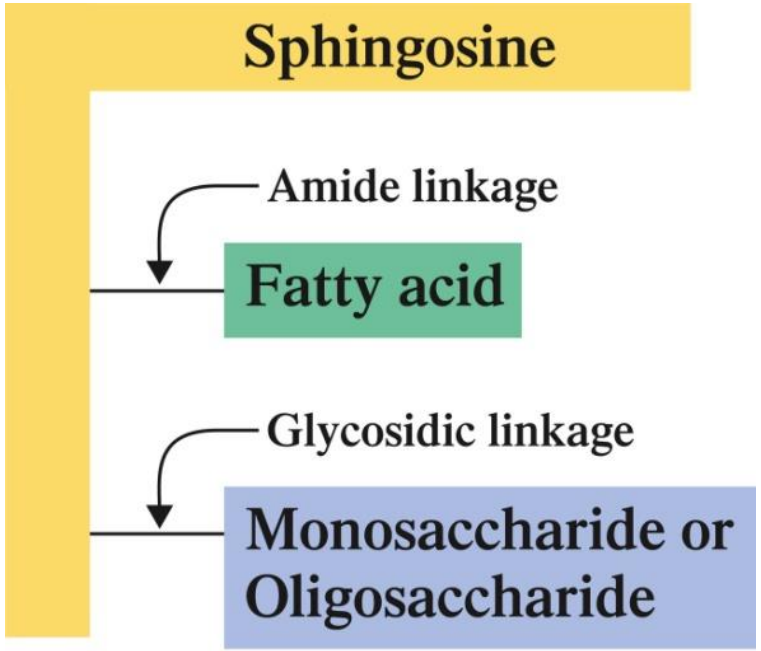
- Contains both a fatty acid and carbohydrate.
- Simple sphingoglycolipids are called **cerebrosides**.
- Cerebrosides contain a single monosaccharide unit – either glucose or galactose
- They occur primarily in the brain (7% of dry mass).



# Membrane Lipids

## Sphingoglycolipids

- Complex sphingoglycolipids are called ***gangliosides***.
- Gangliosides contain a branched chain of up to seven monosaccharide residues.
- Occur in the gray matter of the brain as well as in the myelin sheath.

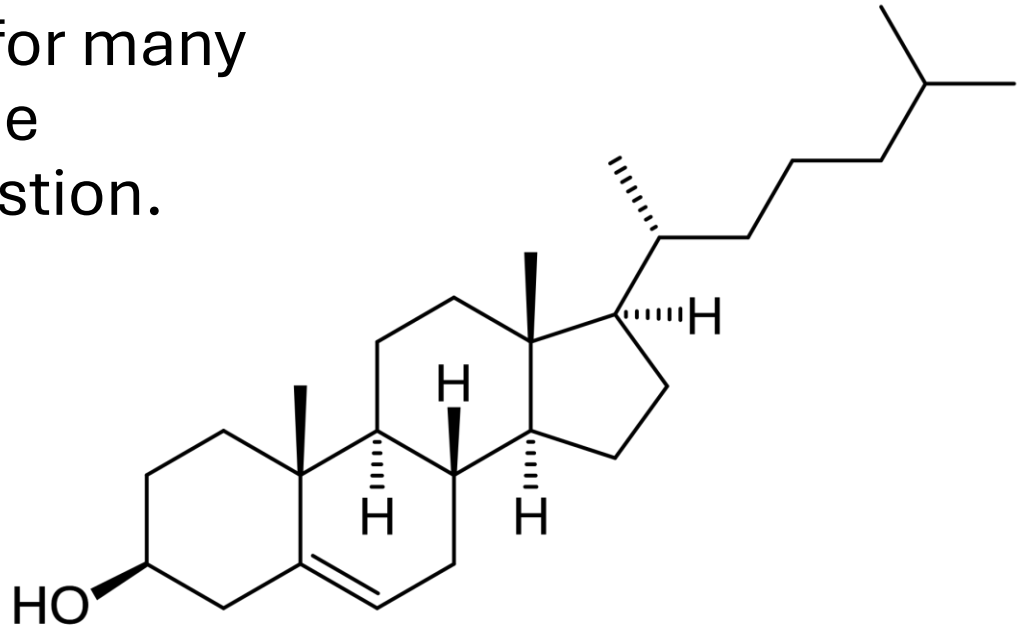



Sphingoglycolipid
(one amide linkage and one or more glycosidic linkages)

# Membrane Lipids

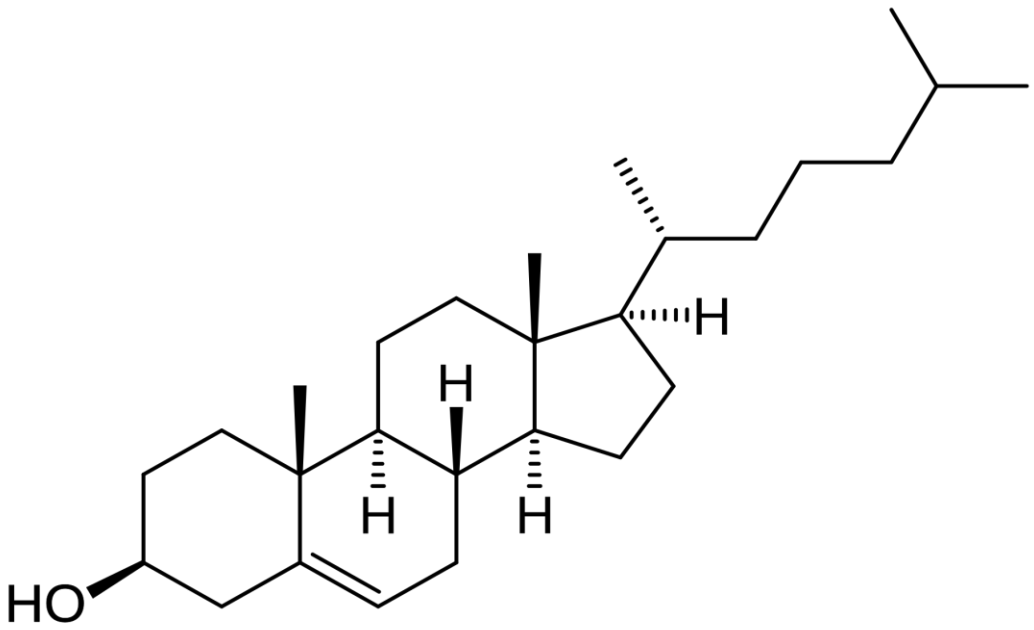
## Cholesterol

- is a type of lipid, specifically a **sterol** (steroid), found in the body's cells and blood.
- It's a waxy, fat-like substance that's vital for many bodily functions, including cell membrane structure, hormone production, and digestion.




**Cholesterol**

# Membrane Lipids




**Cholesterol**

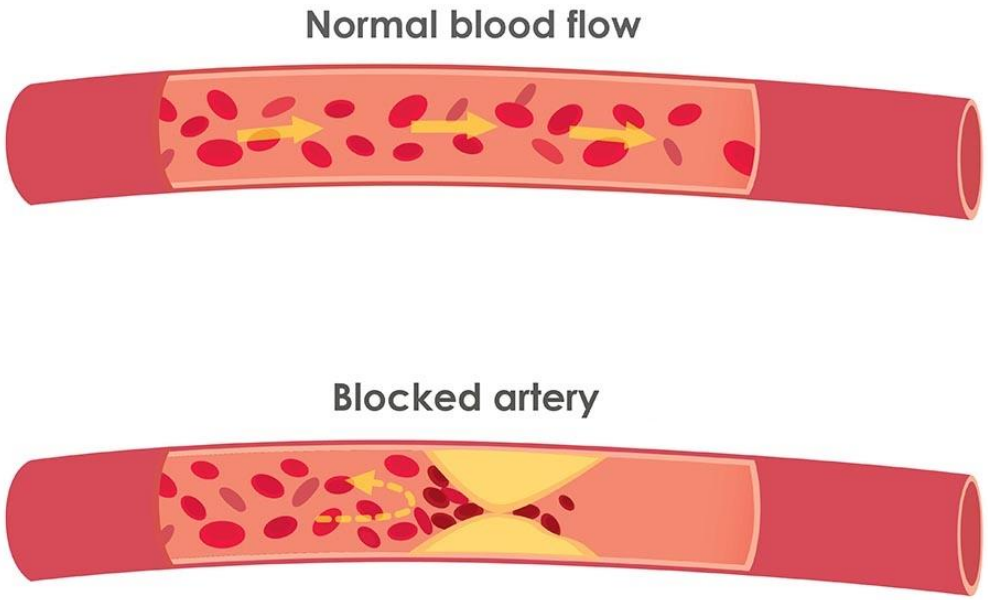
## Cholesterol

- Is a lipid whose structure is based on a fused ring system of three 6-carbon rings and one 5-carbon ring.
- The liver synthesizes cholesterol:
  - ~1g / day
- Animal food = lot of cholesterol
- Plant food = no cholesterol

# Membrane Lipids

## Cholesterol

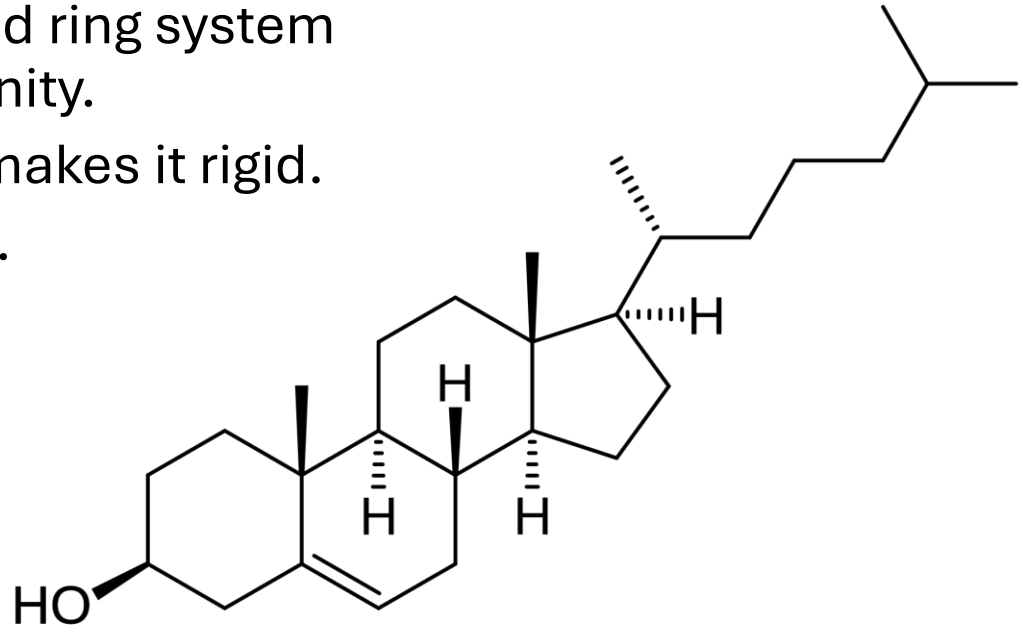
- Too much cholesterol in the blood can be detrimental.
- High levels of LDL cholesterol (often called "bad" cholesterol) can cause fatty deposits to accumulate on artery walls.



# Membrane Lipids

## Cholesterol

- Cholesterol molecules are also components of plasma membranes:
  - Helps regulate membrane fluidity – the fused ring system does not allow rotation of FA tails in the vicinity.
  - Fits between FA chains of the lipid bilayer: makes it rigid.
  - Cholesterol acts as a membrane plasticizer.




**Cholesterol**

# Membrane Lipids

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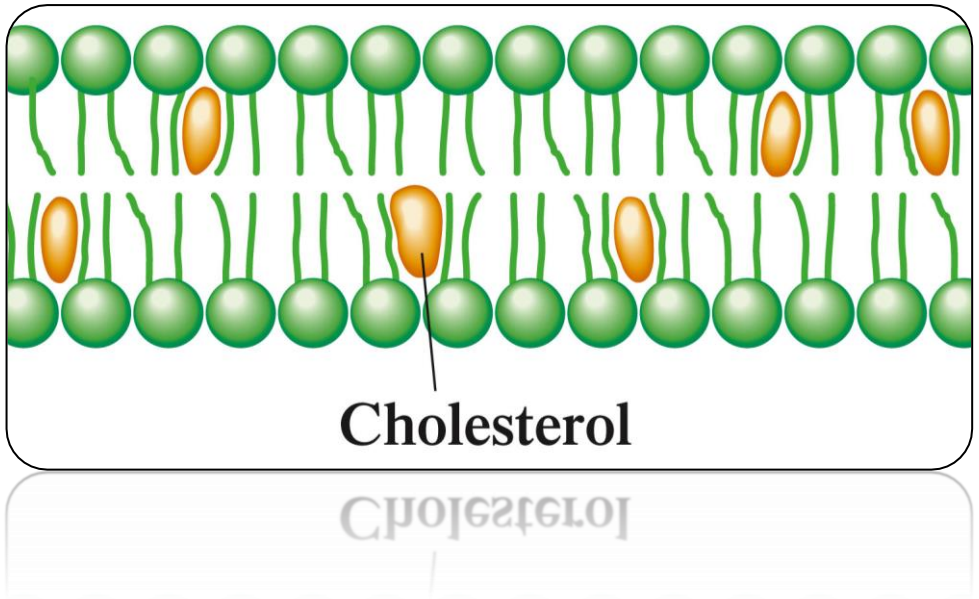
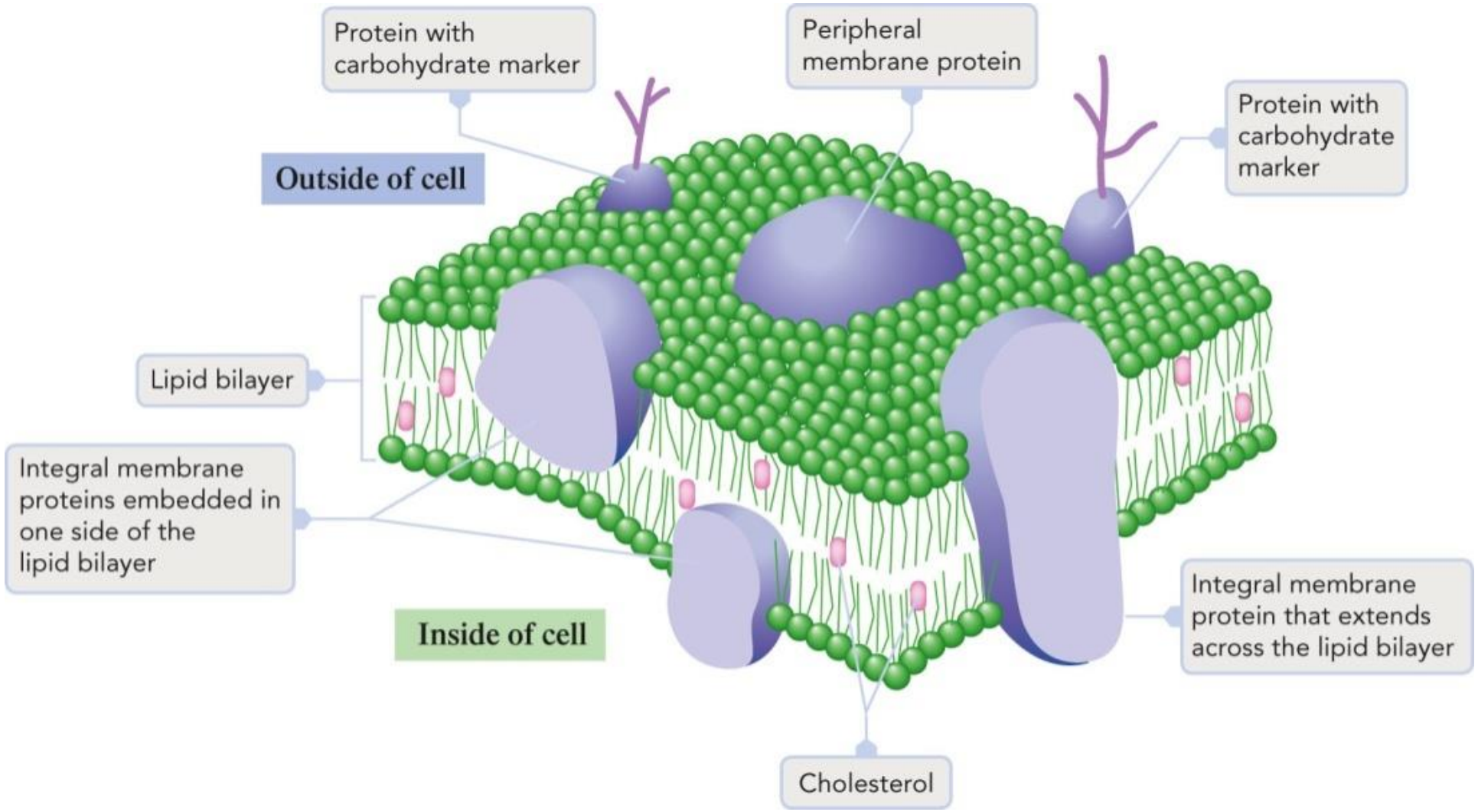
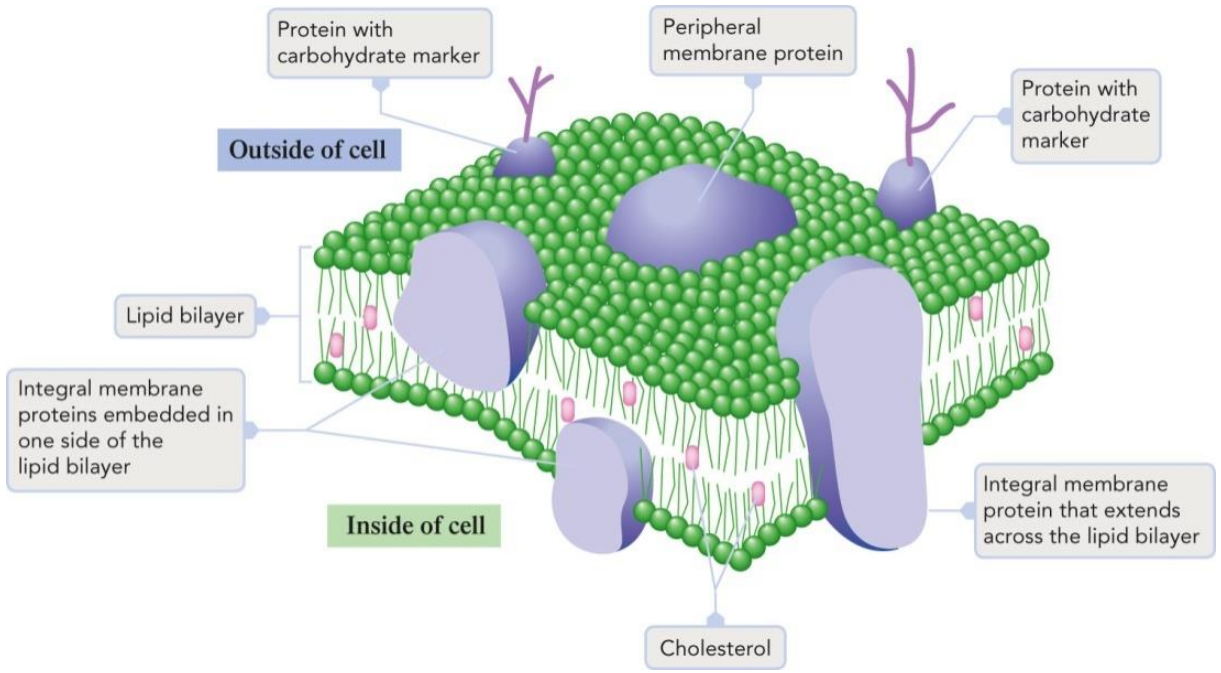


# Cell Membrane

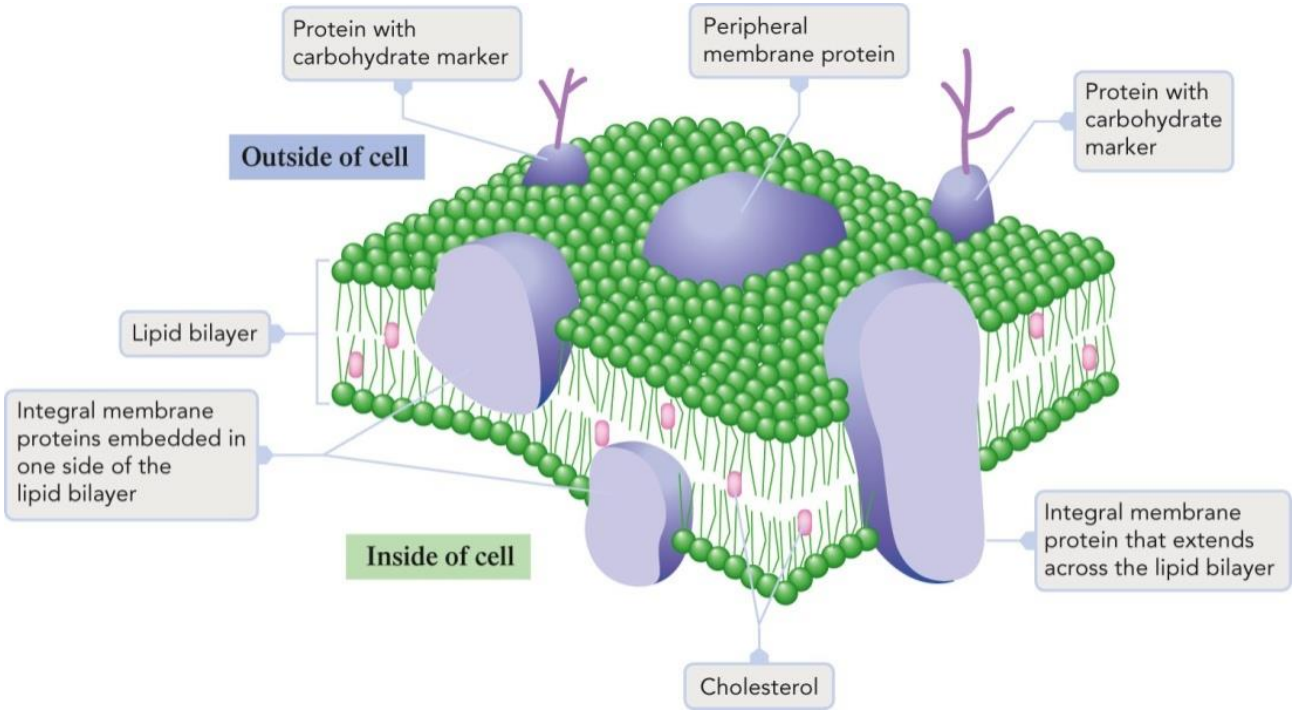


# Cell Membrane

- Cells are surrounded by plasma membranes.
  - ***Separates*** aqueous interior of a cell from the aqueous environment surrounding the cell.
  - **80%** of plasma membrane is lipid material.
  - The membranes are lipid bilayers made up of phospholipids.



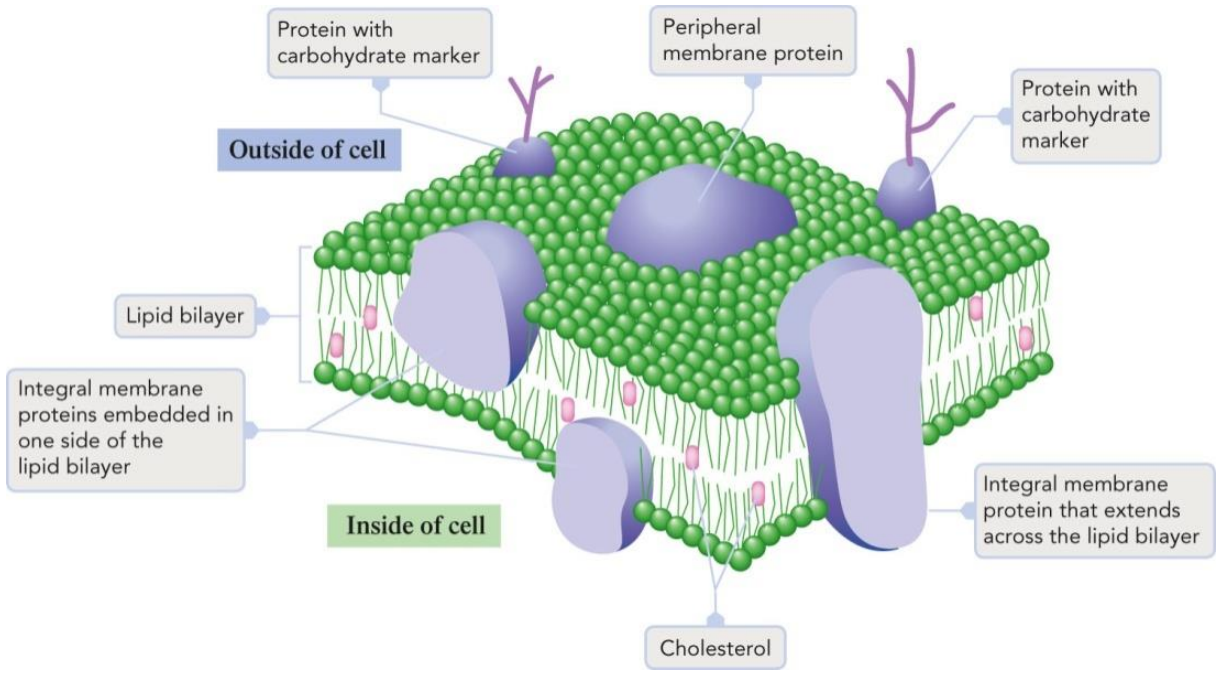
# Cell Membrane




- The membranes also contain proteins:
  - Responsible for **moving substances** such as nutrients and electrolytes across the membrane
  - **Receptors** for hormones and neurotransmitters

# Cell Membrane

- Membrane proteins and some lipids react with carbohydrate molecules
- These molecules act as markers, which provides the ability for different cells to recognize each other.



# Transport Across Cell Membranes

- To maintain cellular processes, various molecules are transported across the cell membranes.
- Three types of transport:
  - Passive transport
  - Facilitated transport
  - Active transport

# Transport Across Cell Membranes

## Passive Transport

It is when a substance moves across a cell membrane by diffusion from a region of higher concentration to a region of lower concentration.

- Only a few type of molecules, including $O_2$, $N_2$, $H_2O$, urea, and ethanol, can cross membranes by passive transport.

# Transport Across Cell Membranes

## Facilitated Transport

It is when a substance moves across a cell membrane with the ***aid of a membrane protein*** from a region of higher concentration to a region of lower concentration.

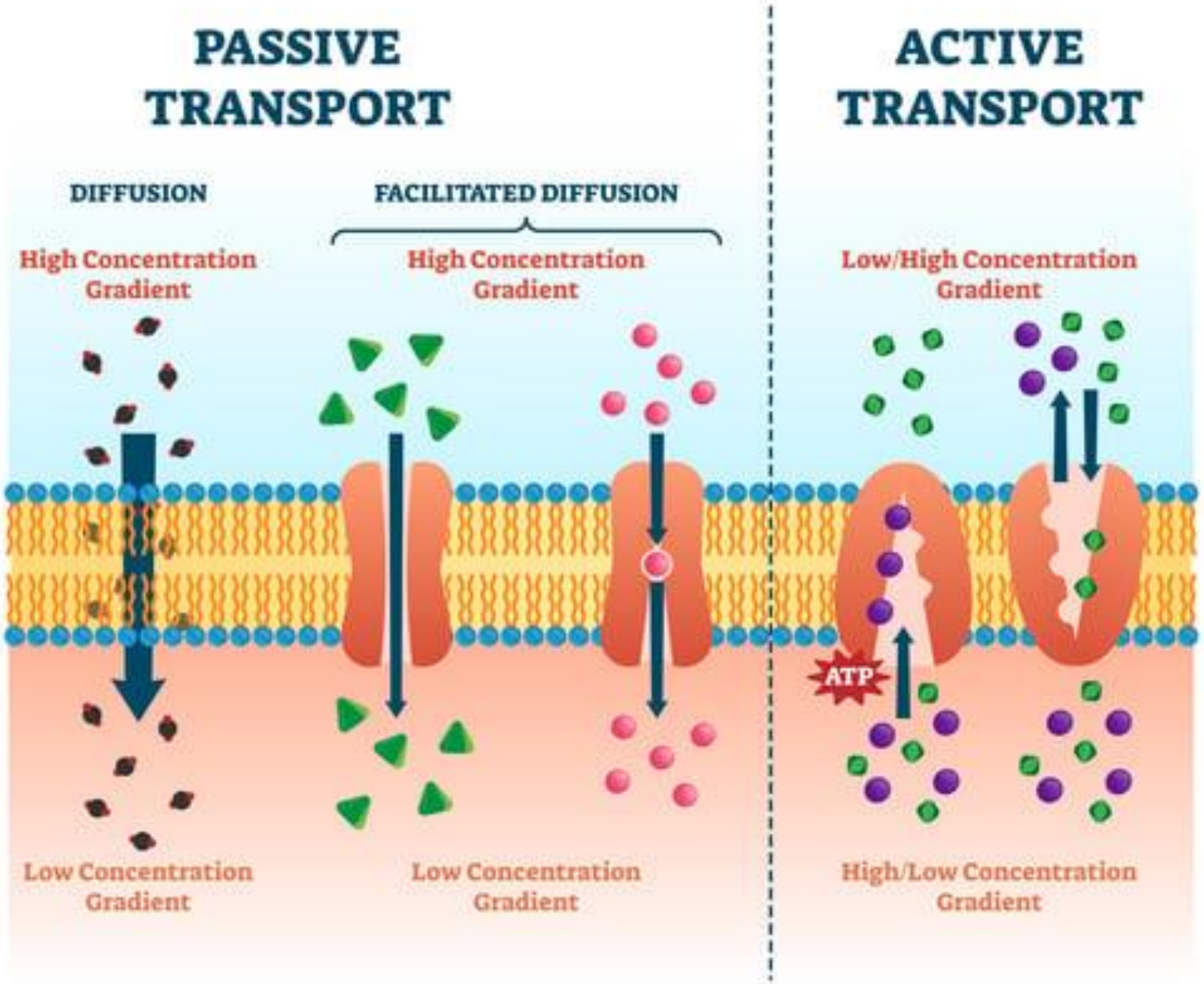
- The specific protein carriers or transporters are involved in the process.

# Transport Across Cell Membranes

## Active Transport

It is when a substance moves across a cell membrane, with ***the aid of membrane proteins***, against a concentration gradient with the ***expenditure of cellular energy***.

- Proteins involved in active transport are called “pumps.” The needed energy is supplied by molecules such as ATP.


PASSIVE TRANSPORT
ACTIVE TRANSPORT
DIFFUSION
FACILITATED DIFFUSION
High Concentration Gradient
High Concentration Gradient
Low/High Concentration Gradient
ATP
Low Concentration Gradient
Low Concentration Gradient
High/Low Concentration Gradient

# Emulsification Lipids (Bile Acids)

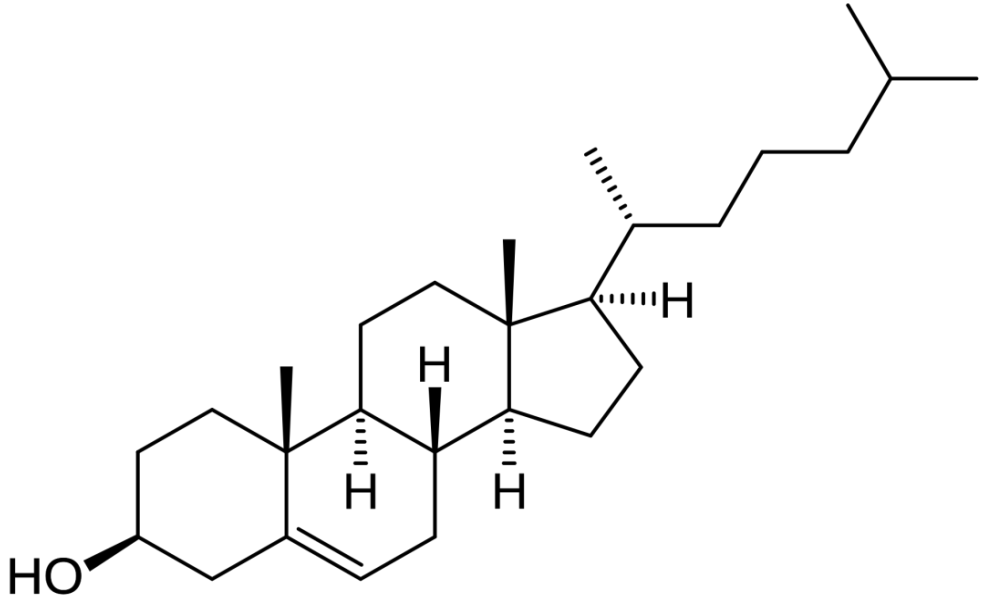
# Emulsification Lipids: Bile Acids

- An **emulsifier** is a substance that can disperse and stabilize water-insoluble substances as colloidal particles in an aqueous solution.
- **Bile Acids**: Cholesterol derivatives that functions as emulsifying agents that make dietary lipids soluble in aqueous environment of the digestive tract:
  - Approximately one third of cholesterol produced by liver is converted to bile acids.
  - Action similar to soap in washing

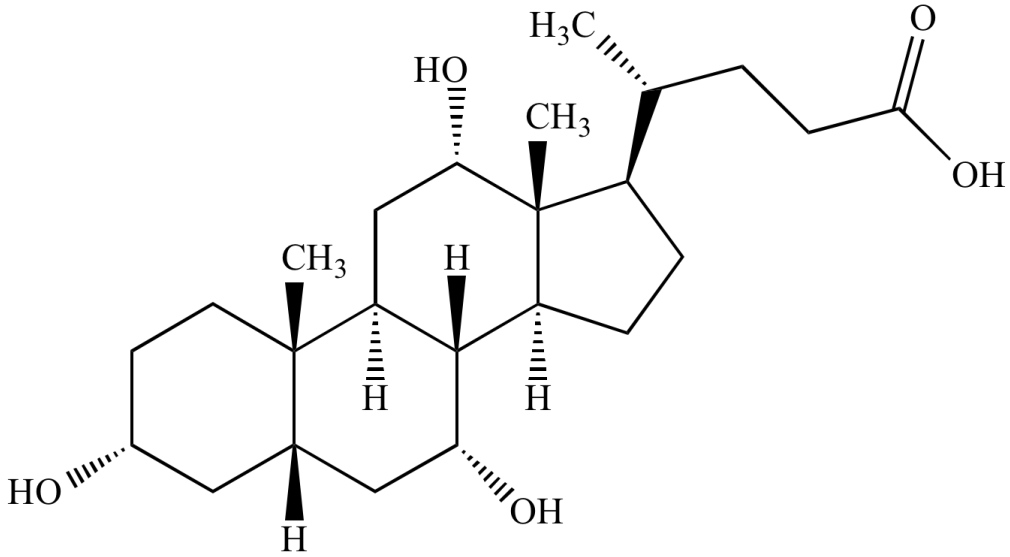
# Emulsification Lipids: Bile Acids

## Bile Acids

- Bile acids are tri- or dihydroxy cholesterol derivatives.




**Cholesterol**

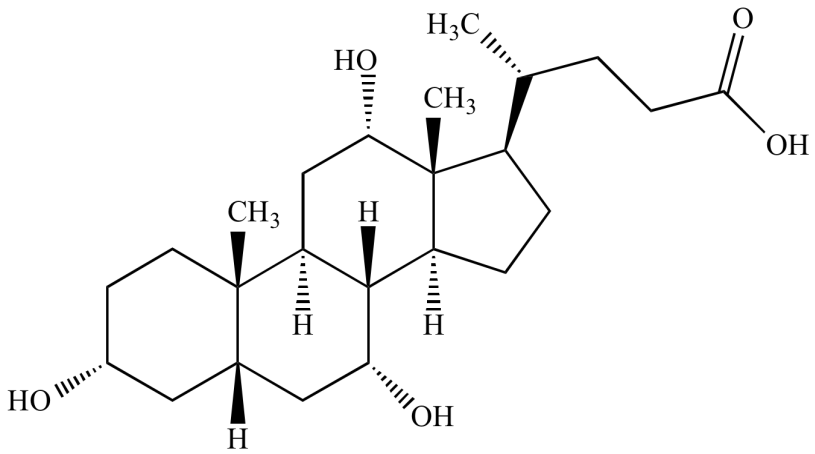



**Bile Acid**

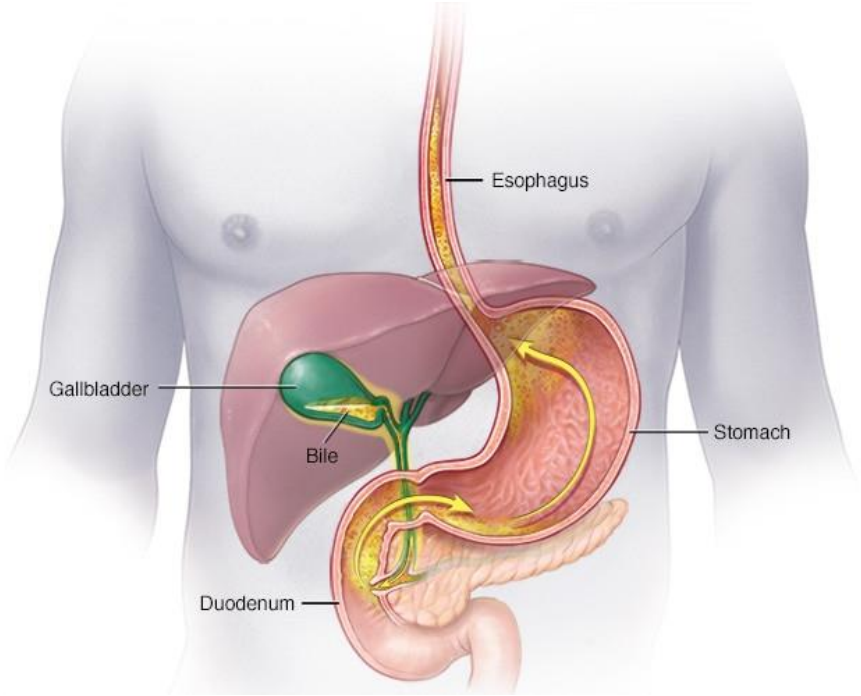
# Emulsification Lipids: Bile Acids

## Bile Acids

- **Bile:** A fluid containing emulsifying agents (Bile acids) secreted by the liver, stored in the gallbladder, and released into the small intestine during digestion.




**Bile Acid**



# Messenger Lipids

# Messenger Lipids

## Hormones

- A hormone is a biochemical substance produced by a ductless gland that has a messenger function.
- Hormones serve as a means of communication between various tissues (Only some hormones are lipids).
- The lipids that play the role of “chemical messengers” include:
  - **Steroid hormones –** derivatives of cholesterol
  - **Eicosanoids-** derivatives of arachidonic acid

# Messenger Lipids

## Steroid Hormones

There are two major classes of steroid hormones:

- **Sex hormones** - control reproduction and secondary sex characteristics
- **Adrenocorticoid hormones** – control numerous biochemical processes in the body

# Messenger Lipids

## Sex Hormones

Classified into three major groups:

- **Estrogens** - the female sex hormones
- **Androgens** - the male sex hormones
- **Progestins** - the pregnancy hormones

# Messenger Lipids

## Adrenocorticoid Hormones

- Produced by the adrenal glands - small organs located on top of each kidney
- Two types of adrenocorticoid hormones:
  - **Mineralocorticoids** - control the balance of Na and K ions in cells
  - **Glucocorticoids** - control glucose metabolism and counteract inflammation

# Messenger Lipids

## Eicosanoids

- Eicosanoids are **arachidonic acid (20:4) derivatives**:
  - Have profound physiological effects at extremely low concentrations.
  - Eicosanoids are hormone-like molecules
  - Exert their effects in the tissues where they are synthesized.
  - Eicosanoids usually have a very short “life.”

# Messenger Lipids

## Eicosanoids

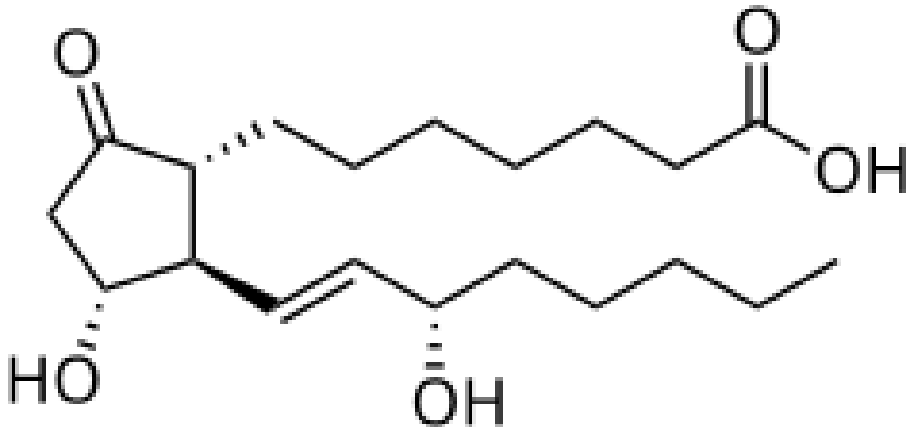
- Physiological effects of eicosanoids:
  - Inflammatory response
  - Production of pain and fever
  - Regulation of blood pressure
  - Induction of blood clotting
  - Control of reproductive functions, such as induction of labor
  - Regulation of the sleep/wake cycle

# Messenger Lipids

## Principle Types of Eicosanoids

### 1. Prostoglandins

$C_{20}$-fatty-acid derivative containing cyclopentane ring and oxygen-containing functional groups




Prostaglandin $E_1$ ($PGE_1$)

# Messenger Lipids

## Principle Types of Eicosanoids

**1. Prostoglandins**

- Involved in raising body temperature,
- Inhibiting the secretion of gastric juices,
- Increasing the secretion of a protective mucus layer into the stomach,
- Relaxing and contracting smooth muscle, directing water and electrolyte balance, intensifying pain, and enhancing inflammation responses.

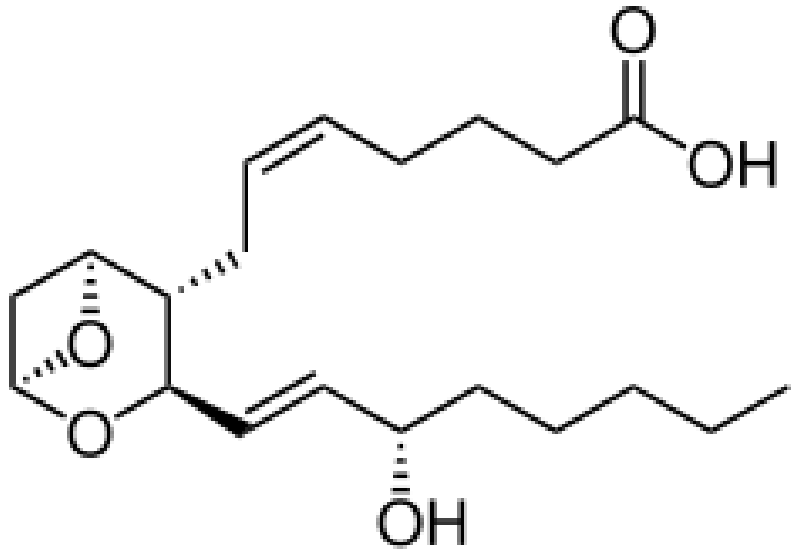
# Messenger Lipids

## Principle Types of Eicosanoids

### 2. Thromboxanes

$C_{20}$-fatty-acid derivative containing a cyclic ether ring and oxygen-containing functional groups

- Promote platelet aggregation.




Thromboxane E2

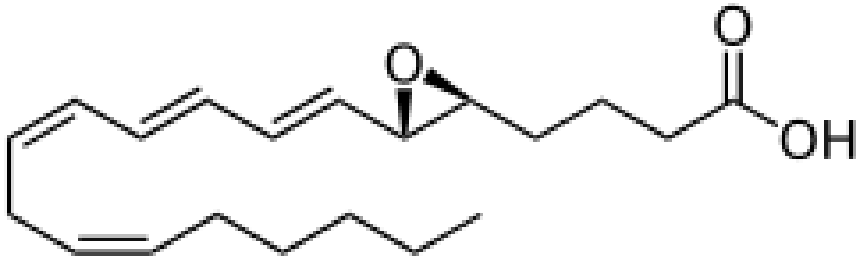
# Messenger Lipids

## Principle Types of Eicosanoids

### 3. Leukotrienes

$C_{20}$-fatty-acid derivative containing three conjugated double bonds and hydroxyl groups

- Promote inflammatory and hypersensitivity (allergy) responses

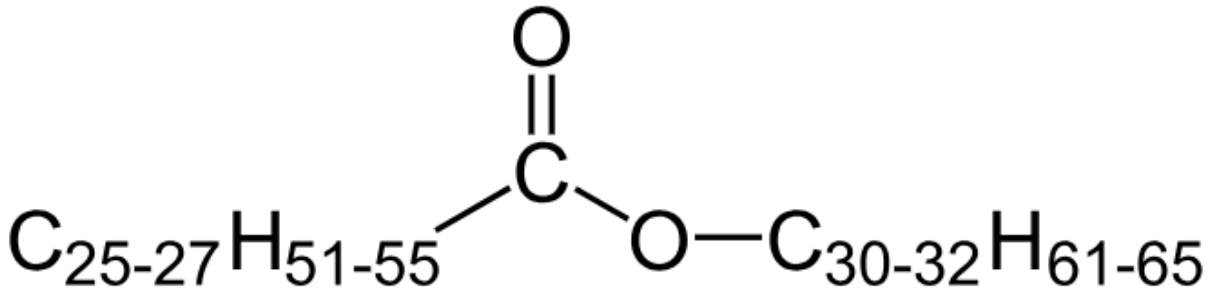



Leukotriene $A_4$

# Protective-Coating Lipids (Biological Waxes)

# Protective-Coating Lipids

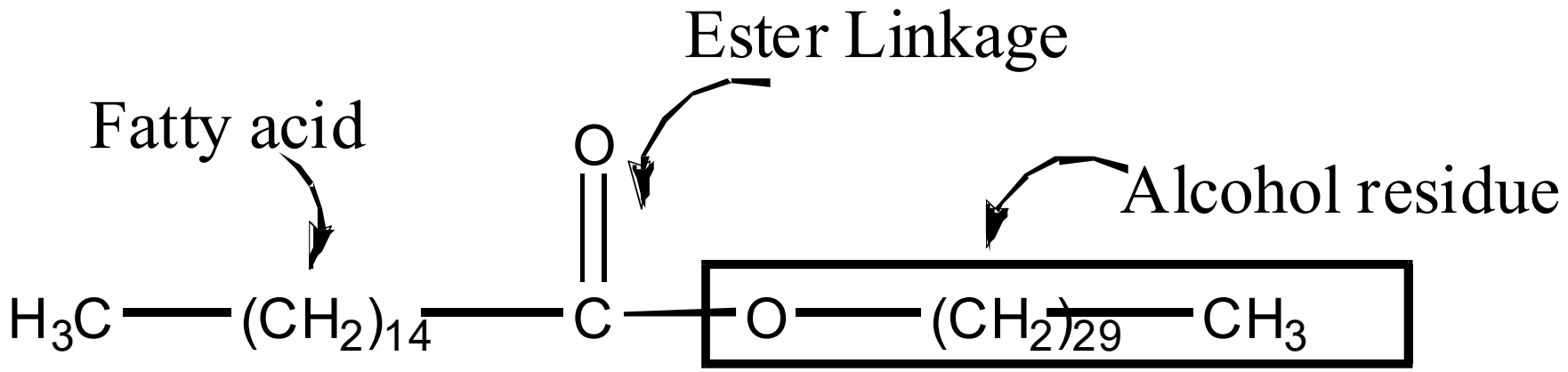
- **A biological wax**: a monoester of a long-chain fatty acid and a long-chain alcohol.

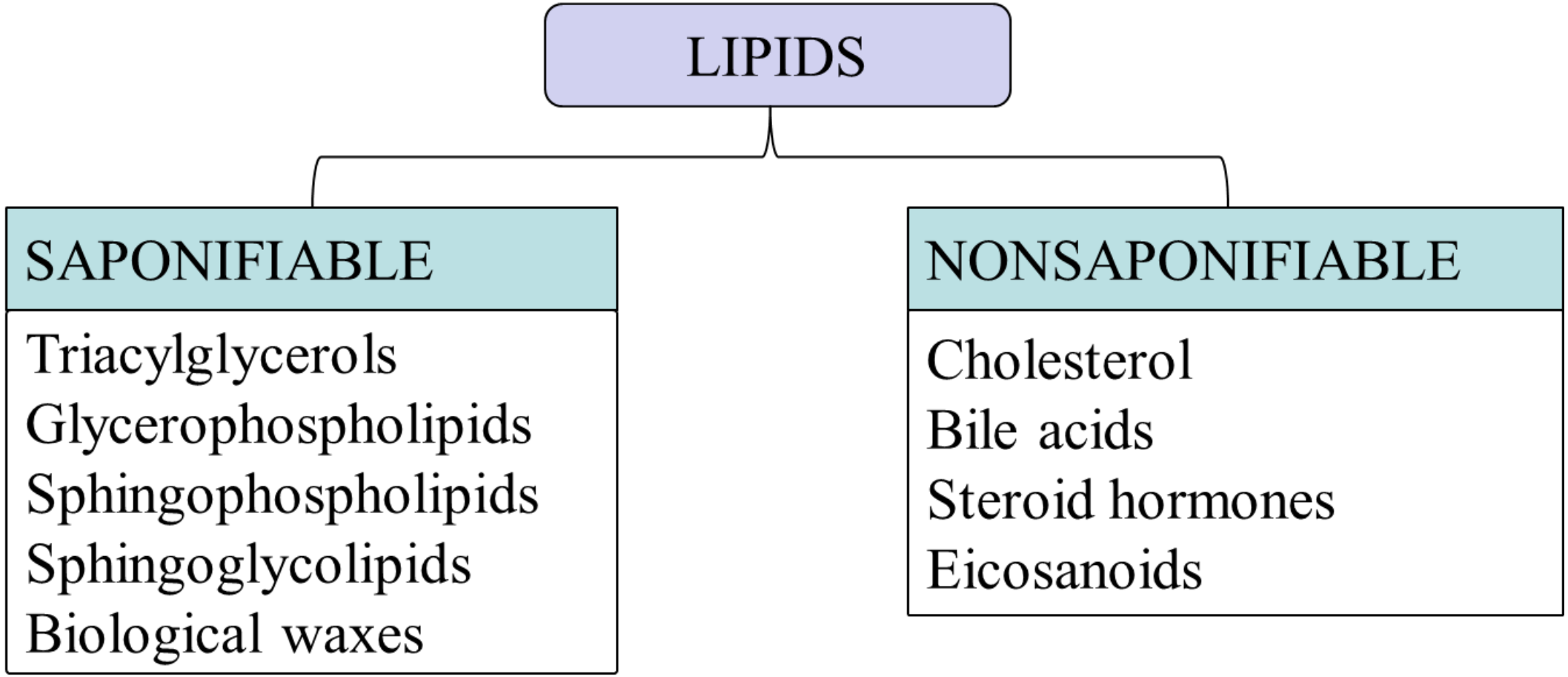



**Ester myricyl palmitate**: a major component of beeswax.

# Protective-Coating Lipids

- The **FAs** found in biological waxes are generally saturated FAs (14-36 carbon atoms).
- The **alcohols** found in biological waxes can be saturated or unsaturated (16-30 carbon atoms).




LIPIDS
SAPONIFIABLE
Triacylglycerols
Glycerophospholipids
Sphingophospholipids
Sphingoglycolipids
Biological waxes
NONSAPONIFIABLE
Cholesterol
Bile acids
Steroid hormones
Eicosanoids

# Saponifiable and Non-saponifiable Lipids

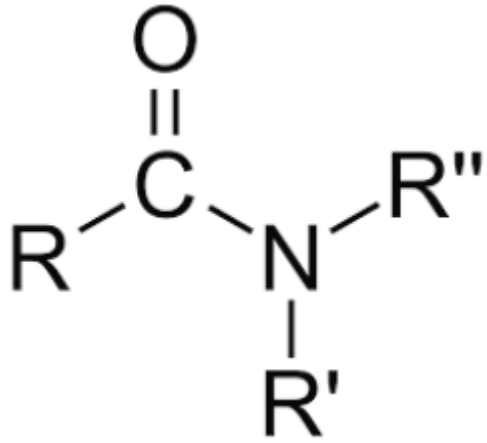
**“Saponifiable Lipid”**

A lipid that undergoes *hydrolysis* in a basic solution to yield 2 or more small molecules.

# Saponifiable and Non-saponifiable Lipids

**Saponification** is possible in molecules that contain the following linkages (bonds):

- Ester
- Amide
- Glycosidic




Amide