INDUCTION

Enumerate Food Nutrients

Ghee

Butter

Cheese

Curds

Butter Milk

Milk

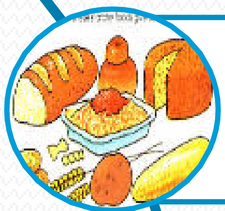
Chicken

Fish

Cheese

Food Nutrients

Body Constituents



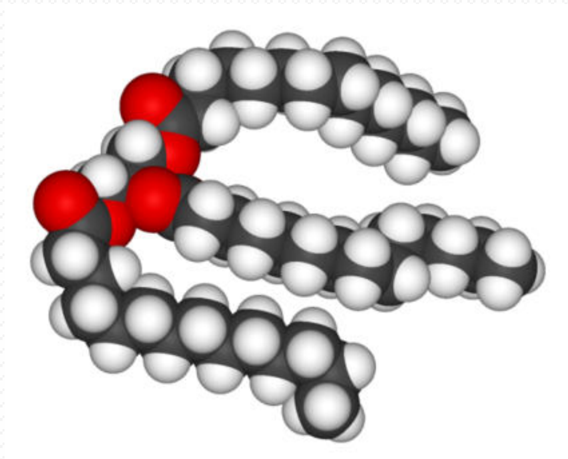
Carbohydrates

Proteins

Lipids

LIPIDS

CHEMISTRY AND FUNCTIONS



SYNOPSIS/CONTENTS

- WHAT ARE LIPIDS?
- DEFINITION OF LIPIDS
- CLASSIFICATION OF LIPIDS
- BIOMEDICALLY IMPORTANT LIPIDS
- STRUCTURE,FUNCTIONS,PROPERTIES AND RELATED DISORDERS OF LIPIDS.

INTRODUCTION

WHAT ARE LIPIDS?

- Lipids are :
- Organic Biomolecules
- Occurs in Plants and Animals
- Hydrophobic
- Heterogeneous
- Esters
- Food Nutrient
- Secondary Source of Energy
- Structural Components

Heterogeneous Nature Of Lipids

Features Of Lipids

L
I
P
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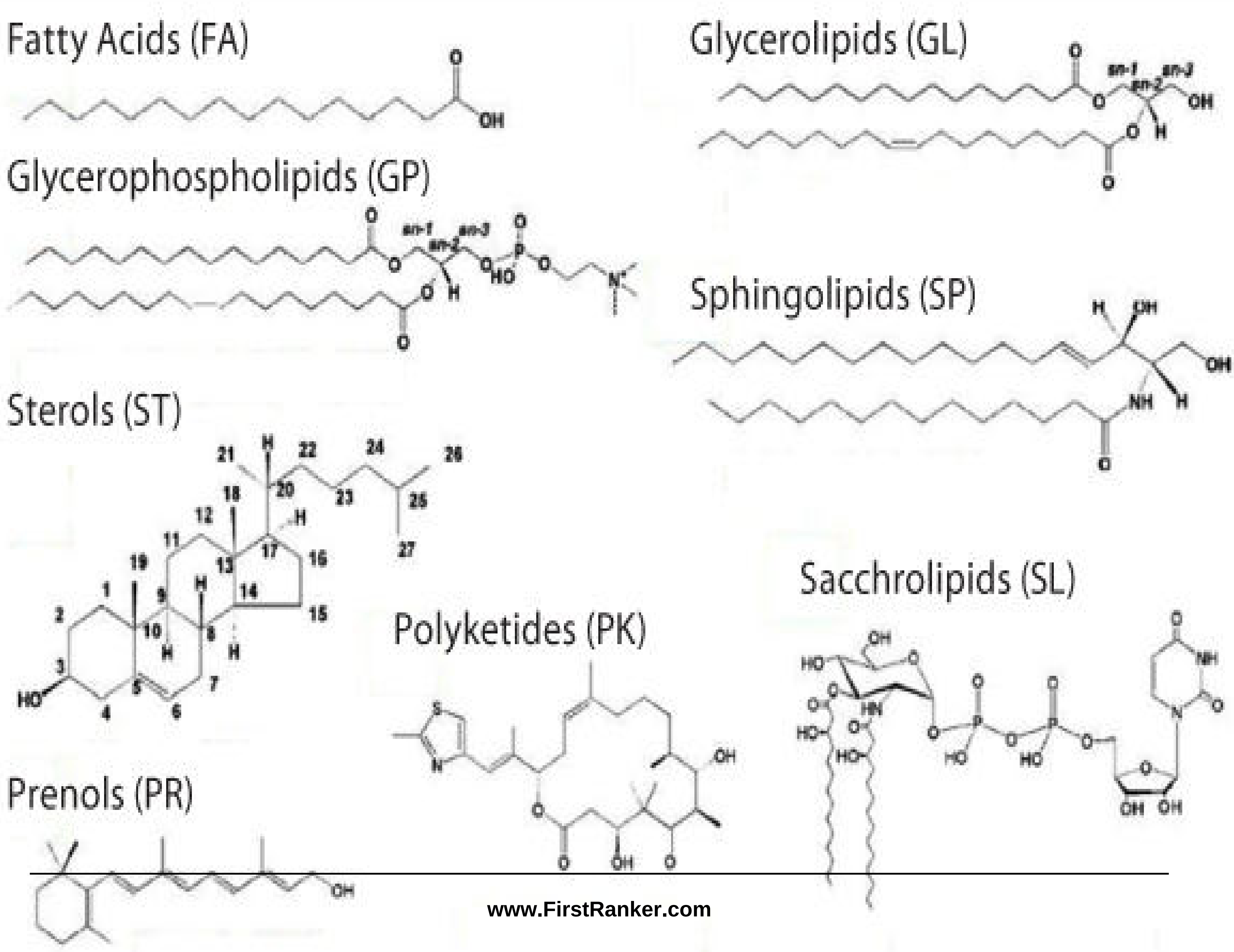
D
S

Heterogeneous

Structure

Functions



- Lipids are biomolecules relatively :
  - Smaller in size
  - Less dense

- Unlike Carbohydrates and Proteins Lipid structures are not Bio-Polymers.

(Lipid structure contains no repeatedly linked Monomeric units)

Solubility Of Lipids

Solubility Of Lipids

Lipids are relatively Insoluble in Water/Polar Solvent Water/polar solvents

Since they are **Non polar and Hydrophobic**

Solubility of Lipids

- Lipids are readily soluble in non polar Organic solvents /Fat Solvents
  - Acetone
  - Alcohol (Hot)
  - Benzene
  - Chloroform
  - Ether

Chemical Nature Of Lipids

- **Chemically Lipids are Esters :**

- **Lipids are Esters of Fatty acids with Alcohol and attached with other groups.**

- **Lipids are relatively or potentially associated with Fatty acids.**

DEFINITION OF LIPIDS

Lipids Bloor's Definition

- Lipids are **Organic, Heterogeneous Hydrophobic Biomolecules**
- **Relatively insoluble in water** and **soluble in organic solvents**.
- Chemically **Esters of Fatty acids with Alcohol.**
- **Utilized by body to produce ATP**

Classification Of Lipids With Examples of Biomedically Important Lipids

Lipids are Classified Into Three Main Classes

- Three Main Classes of Lipids are:

i. Simple Lipids
ii. Compound /Complex Lipids
iii. Derived Lipids

1. Simple Lipids/Neutral Lipids

- Chemically Simple Lipids are:
- **Esters of Fatty acids with an Alcohol**

Sub Classes Of Simple Lipids

- **Depending upon the type of Alcohol :**

- **Simple Lipids are of two sub types:**
  - **Fats/Oils**

  (Alcohol is Glycerol)
  - **Waxes**

  (Alcohol- Cholesterol/ Retinol)

Fats/Oils/TAG

Chemical name of Fat /Oil
Triacylglycerol

- **Fats/Oils/TAG**:
- Chemically **Esters of Fatty acids** with **Glycerol**(**Trihydric Alcohol**)
- **Three Fatty acids linked to a Glycerol molecule.**

• Waxes :

- Waxes are Simple Lipids
- Waxes are chemically Esters of Fatty acids with **higher complex, monohydric ,Alcohols,** other than Glycerol.

Examples Of Human Body Waxes :

- **Cholesterol Ester (Cholesterol Palmitate)**
- **Retinol Ester (Retinol Palmitate)**

Compound/Complex Lipids

- Compound Lipids is a class of Lipids
- Chemically composed of **Fatty acids Alcohol** and an **Additional group.**

Depending upon the Type of Additional group

Types of Compound Lipids are:

Four Names Of Compound Lipids

1. Phospholipids
2. Glycolipids
3. Lipoproteins
4. Sulfolipids

Phospholipids

- Glycerophospholipds
- Sphingophospholipids

Glycosphingolipids

- Cerebrosides
- Gangliosides
- Globosides
- Sulfatides

Lipoproteins

- Chylomicrons
- VLDL
- LDL
- HDL

Derived Lipids

- Derived Lipids are **Hydrolytic products** of **Simple or Compound** Lipids and **their derivatives**.

Examples of Derived Lipids:

- **Fatty Acids**
- **Alcohols:**
  - **Glycerol**
  - **Sphingol**
  - **Cholesterol**

Other Examples Of Derived Lipids

- **Lipid like compounds Derived from Fatty acids and Sterols:**
  - **Steroidal Hormones:** Derived from Cholesterol
  - **Fat Soluble Vitamins** (A,D,E and K)
  - **Eicosanoids** (Prostaglandins , Leukotrienes ,Thromboxanes)
  - **Ketone Bodies** (Partial Oxidized Products of Fatty acids)

Bloor's Classification Of Lipids

- Four Classes of Lipids By Bloor

A. Simple Lipids
B. Complex/Compound Lipids
C. Derived Lipids
D. Miscellaneous Lipids

A. Simple Lipid

Simple Lipids are Ester of fatty acids with various alcohols

- Fats and Oils
  - Triglycerides
- Waxes
  - Cetyl alcohol esters of fatty acids(Bees wax)
  - Cholesterol Esters
  - Vitamin A Esters
  - Vitamin D Esters

B. Compound lipid

B. Compound Lipids are **Esters of fatty acids with alcohol with an additional groups**

- **Phospholipids : contains phosphoric acid and often a nitrogenous base**
- **Glycolipids: contains aminoalcohol Spingosine, carbohydrate, N-base;**
- **Lipoproteins : Lipids attached to plasma/other proteins**
- **Sulfolipids : contains sulfate group**
- **Lipopolysaccharides: lipids attached to polysaccharides**

C. Derived Lipids –

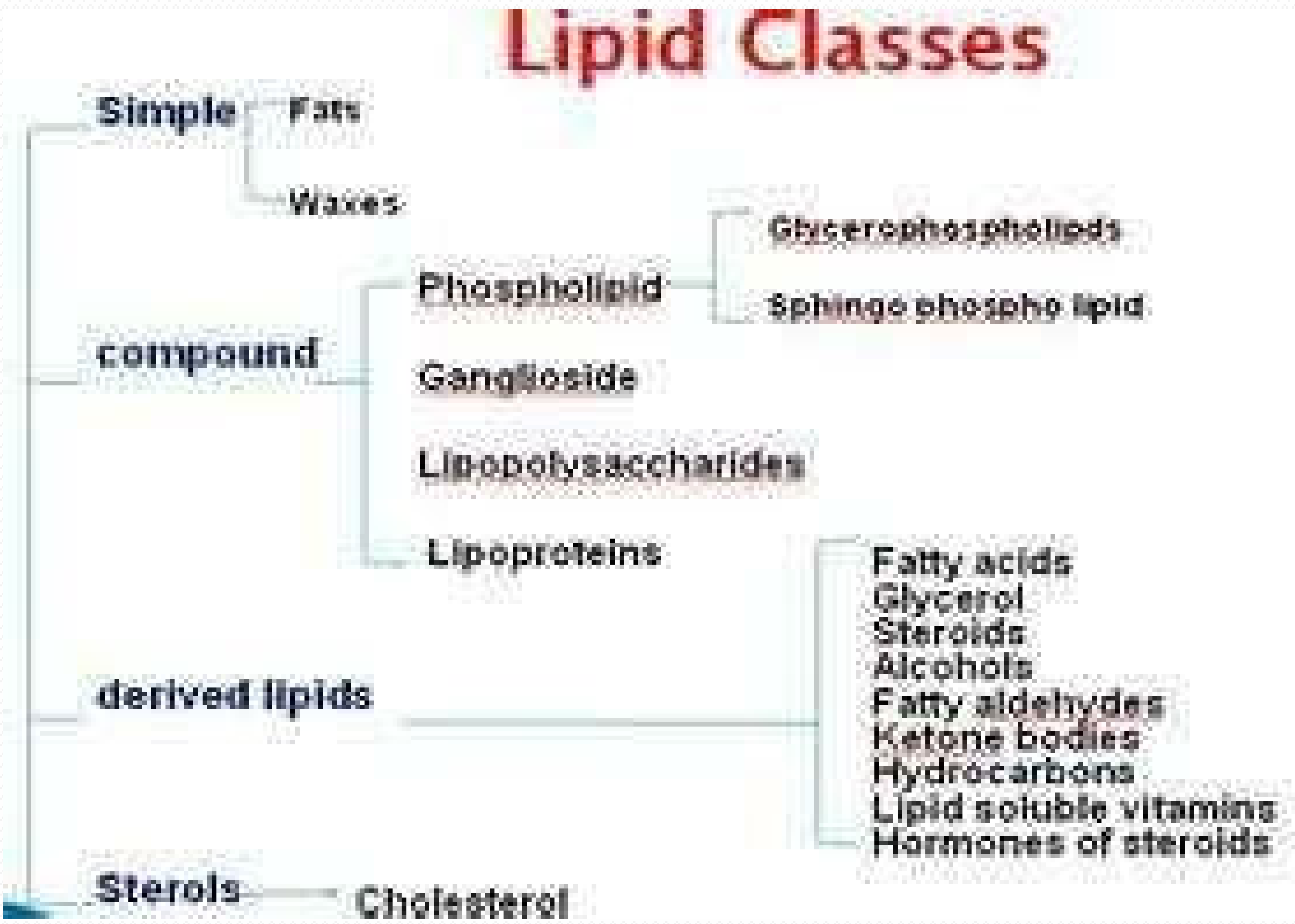
Hydrolytic products of Simple & Compound Lipid

- **Diacylglycerol**
- **Monoacylglycerol**
- **Fatty acids**
- **Alcohols : Cholesterol**

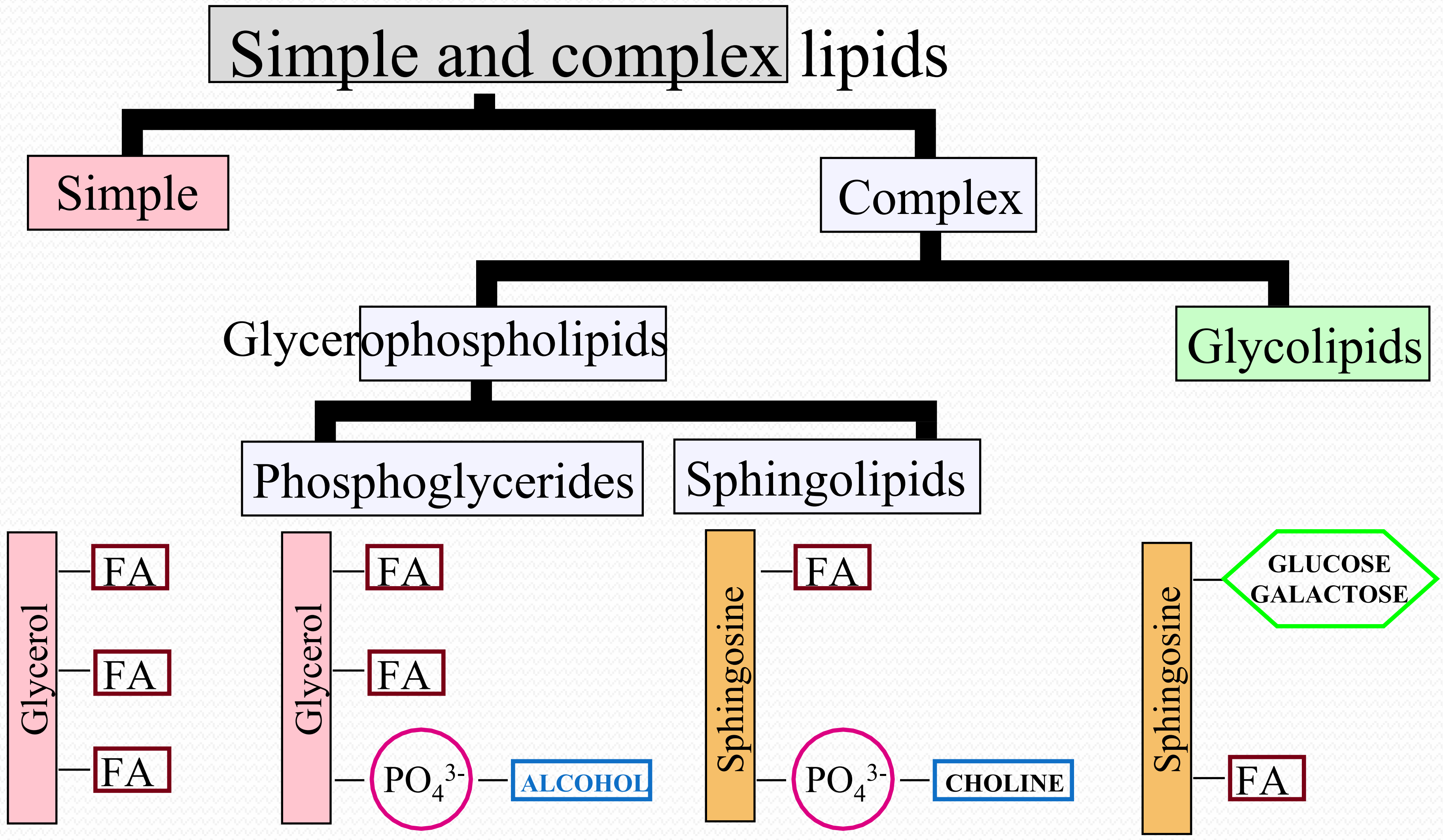
D.Miscellaneous Lipids

Substances with Lipid characters

- Carotenoids: β-Carotenoid
- Squalene :
- Vitamin E and K
- Eicosanoids



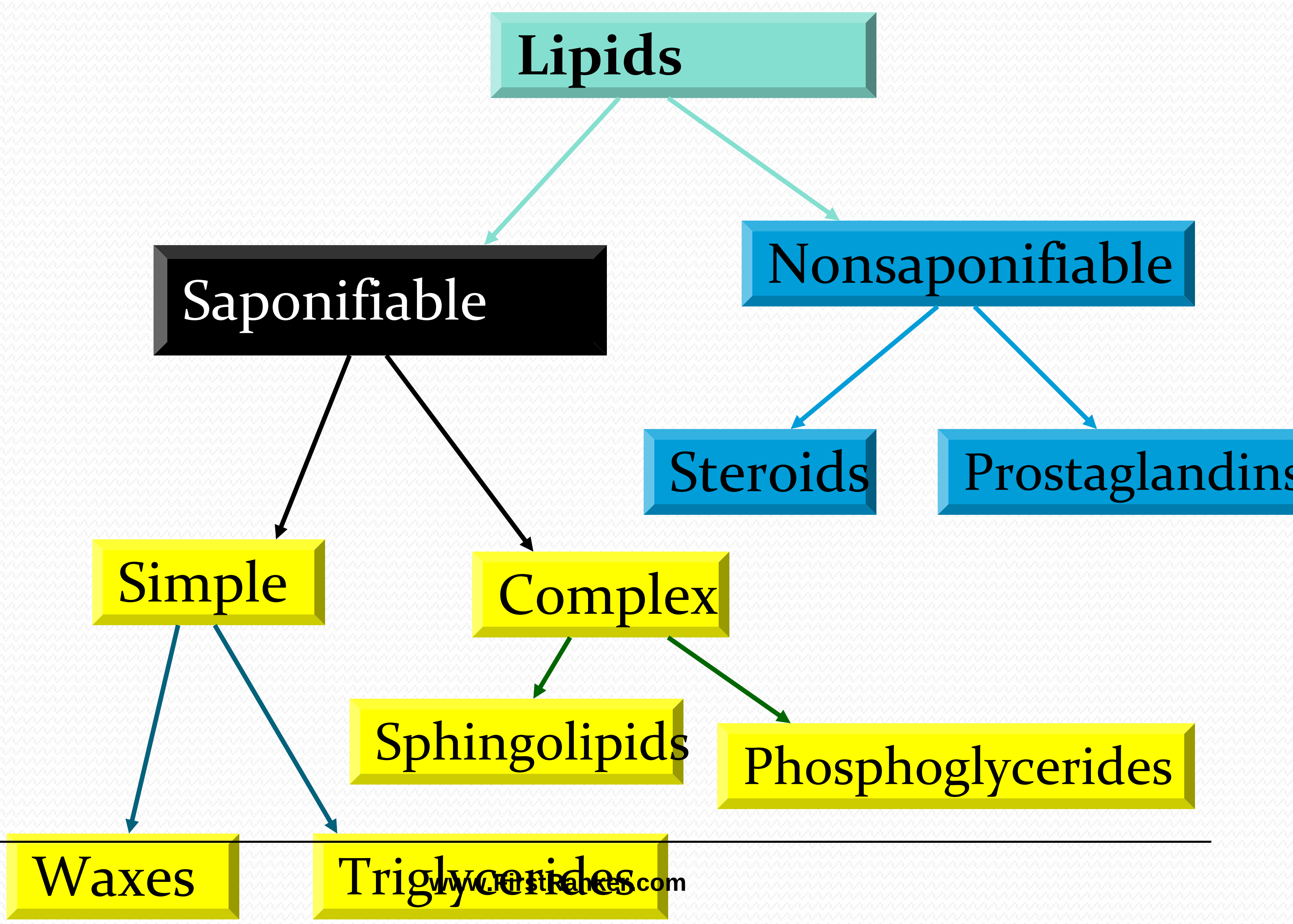
Classification of Lipids



Human body Lipids

Types of Lipids Depending On Saponification Property

Lipid Classification

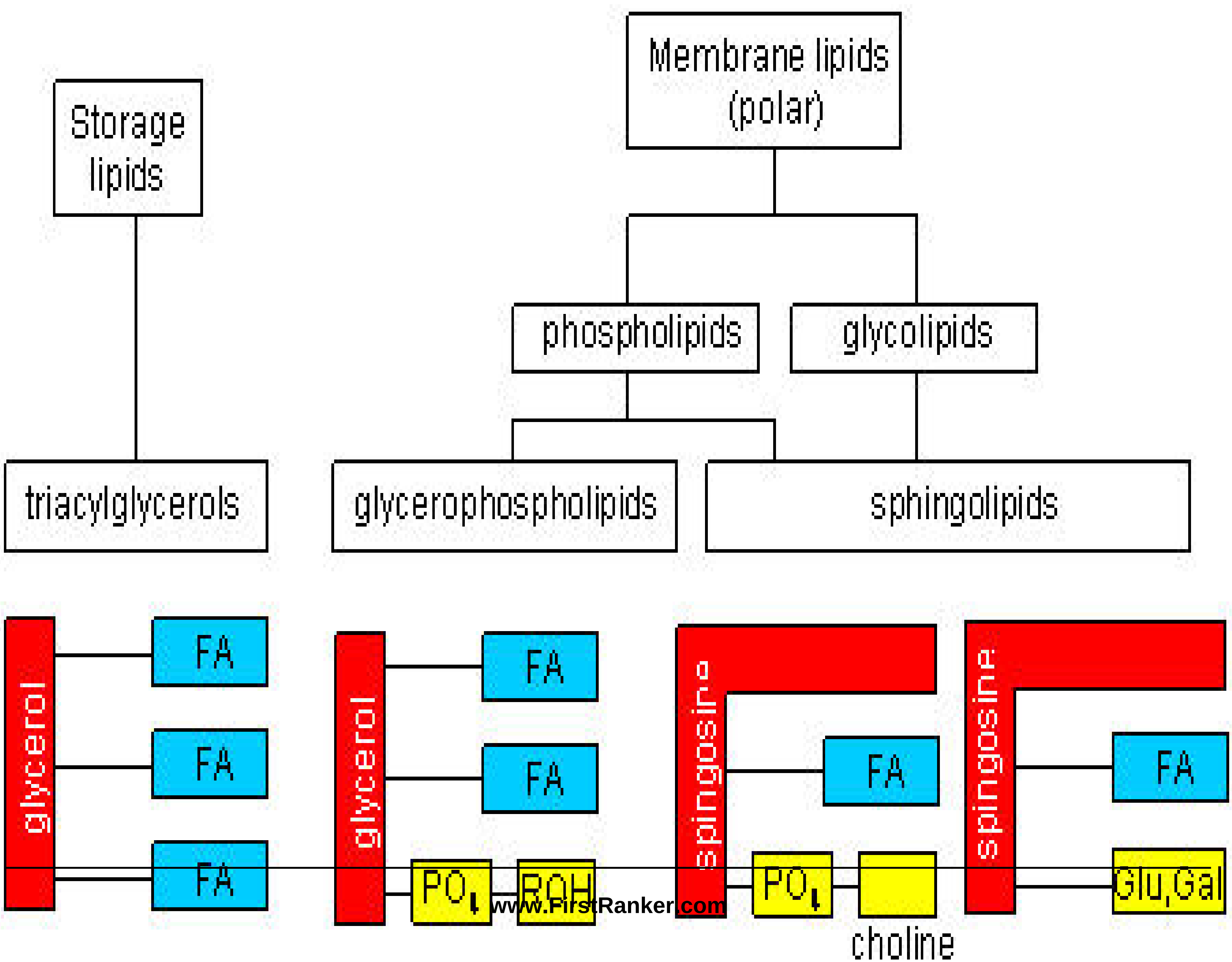


Types of Lipids Depending Upon Polarity

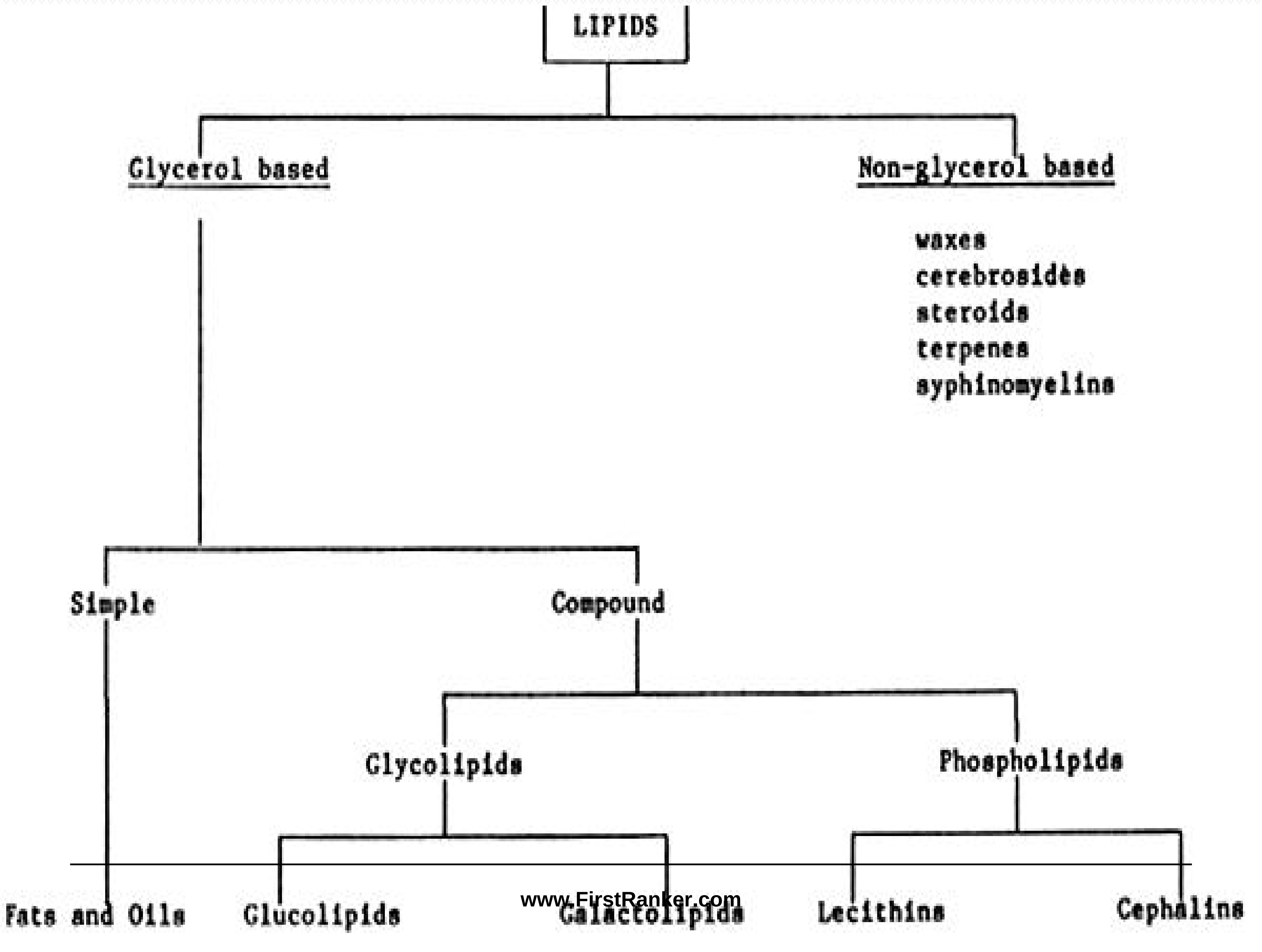
- **Neutral Lipids: (Non Polar Lipids)**
  - Triacylglycerol
  - Cholesterol Ester (Cholesterol Palmitate)

- **Amphipathic/Amphiphillic Lipids**:
  (Contain Polar and Non polar Groups)
  - Phospholipids
  - Cholesterol

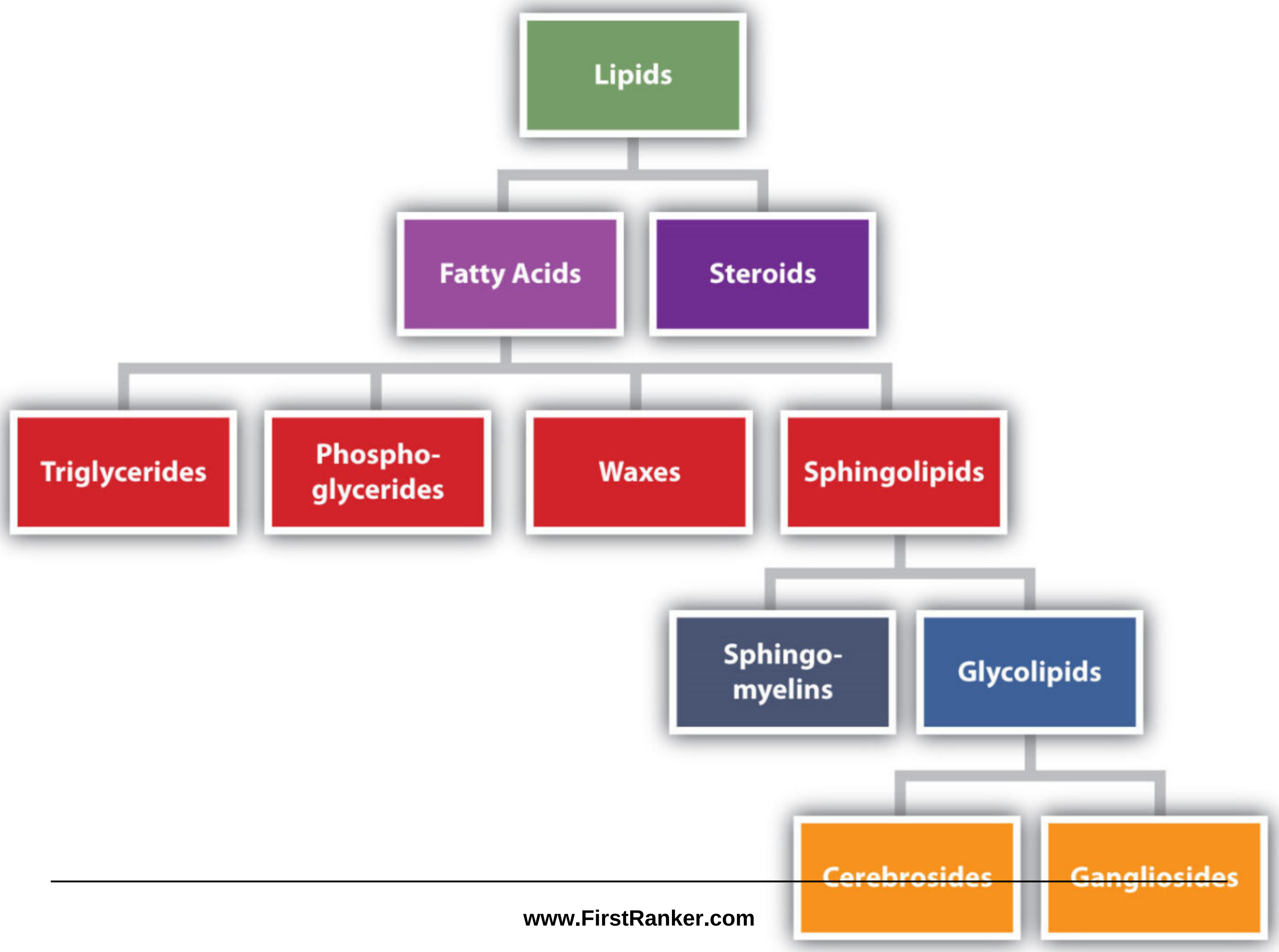
Types of Lipids
Depending Upon Functions

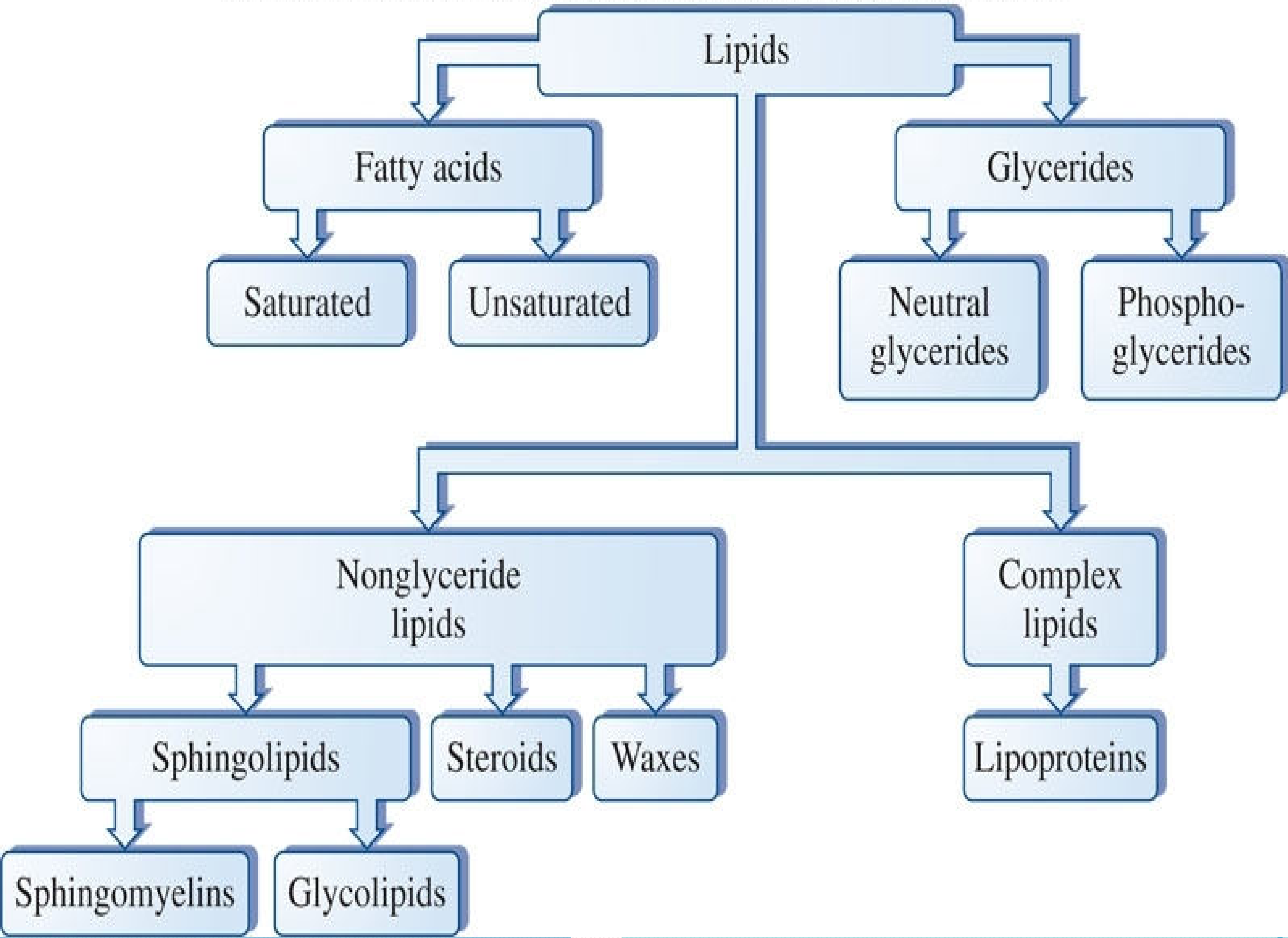


Types Of Lipids Based On Alcohol



Types Of Lipids Based Upon the Main Components





Names Of Important Body Lipids

Biomedically Important Lipids

1. Fatty Acids (FAs)
2. Triacylglycerol (TAG)
3. Phospholipids (PL)
4. Lipoproteins (LP)
5. Glycolipids
6. Cholesterol (Free)
7. Cholesterol-Ester (Esterified)

Biological Functions Of Lipids

- Lipids have **dietary and Calorific value**

- Lipids are **chief constituents of human food**.
- Dietary Lipids **Ingested** (eaten) are **digested**, **absorbed** and **assimilated** in human body.

- Lipids are **highly reduced substances with CH_2 bonds**.
- **Oxidation of the CH_2 bonds** of **Fatty acids, generate chemical form of energy ATP.**

- Thus **Lipids serve** as a **secondary source of energy (ATPs) to human body.**

Lipids are Reservoir of Energy

In a Well Fed Condition

- Lipid Triacyl Glycerol (TAG) **subcutaneously** is **stored in Adiposecytes**
- **In unlimited amount and in anhydrous concentrated form.**
- It provide **high potential source of energy** for cellular use.

Lipids
Superior Than
Carbohydrates

Lipids are Superior Than Carbohydrates

- **Lipids have Higher Calorific value** (9Kcal/gm)
- **High storage content** , can be stored in unlimited amount.
- They **provide energy source for longer duration**.

(During Marathon Races)

- Thus Lipids serve as **major reservoir of energy** for **long term use** in human beings.

Other Importance Aspect Of Dietary Lipids

- **Fatty Foods are associated with Fat soluble Vitamins**

  (Vit A,D,E and K)

- Dietary Lipids (**TAG and PL**) are **sources of essential Fatty acids** to human body.

Structural Role Of Lipids

- Lipids are fundamental **structural components of biomembranes**

Biomembranes Lipids

1. **Phospholipid bilayer**
2. **Glycosphingolipids**
3. **Cholesterol**

Study Of Various Classes Of Lipids

Study Of Derived Lipids

Study Of Fatty Acids

FATTY ACIDS(FAs) Derived Lipids

BASIC COMPONENT OF LIPIDS

Fatty Acids (FA)

- **Fatty Acids (FA) are relatively or potentially related to various Lipid structures.**

Fatty Acids (FA)

- Fatty acids are **responsible to form different forms of Lipids:**
  - **Simple Lipids**
  - **Compound Lipids**
  - **Miscellaneous Lipids**

Fatty Acids Are Derived Lipids

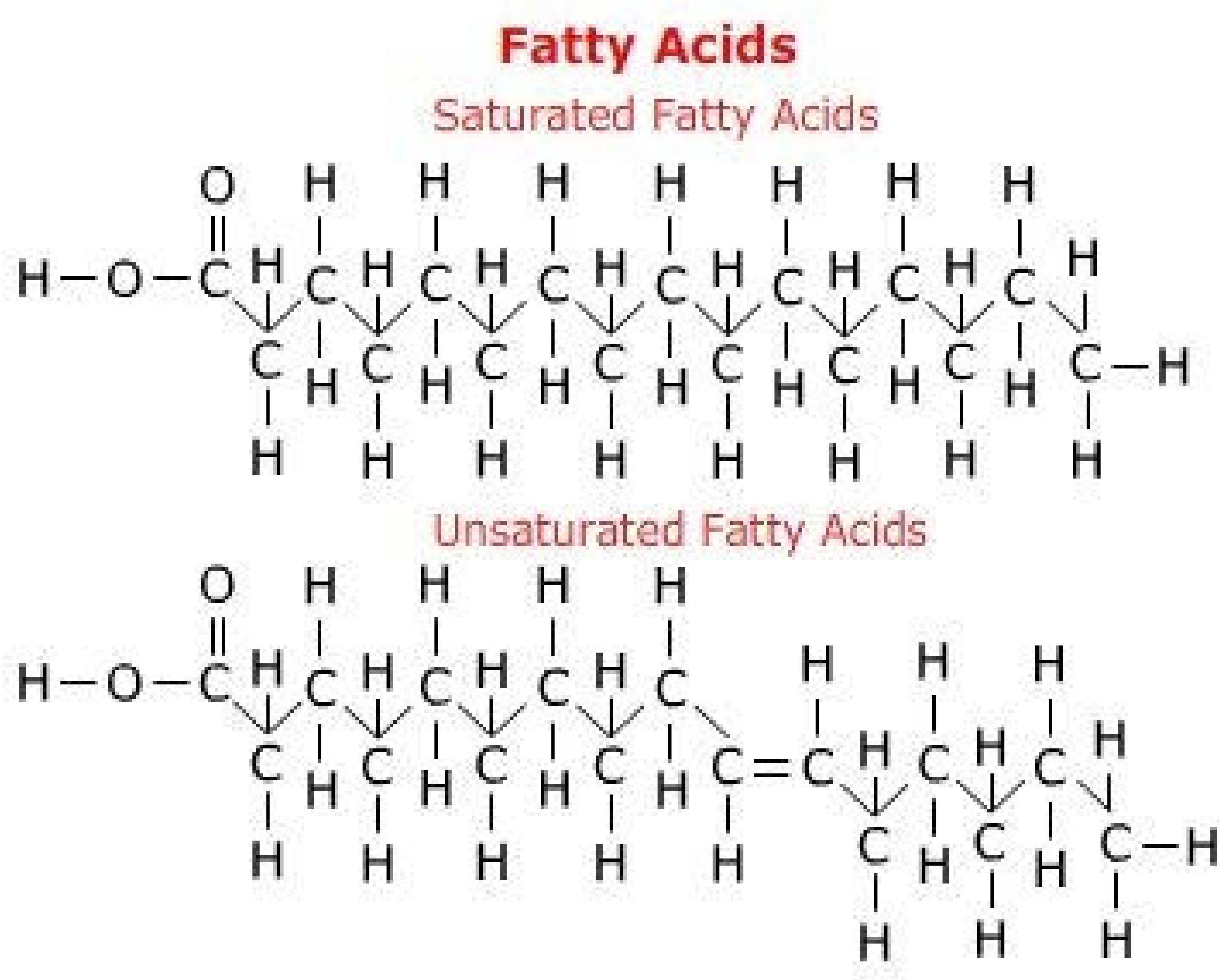
- Fatty acids are classified under Derived Lipids:
  - Since Fatty acids are Hydrolytic products of Simple and Compound Lipids.

Definition of Fatty acids

- **Fatty acids are chemically Organic acids**

- With **Aliphatic Hydrocarbon chain** **(of varying length C_2 to C_{24})** with **Mono terminal Carboxylic acids.**

Structure Of Fatty Acids



Different Forms Of Fatty acids In Body

Free Fatty acid /Unesterified Fatty acid

- Fatty acid **has free Carboxylic group**
- Fatty acid not linked to an Alcohol by an Ester bond.

Esterified Fatty acid/Bound form of Fatty Acid

- Fatty **has no free Carboxylic group**
- **Fatty acid is linked to an Alcohol** with an **Ester bond.**

- In living beings **Fatty acids are not generally present in free form.**

- Fatty acids are **naturally** and **mostly present in bound form in the plant and animals.**

- **Fatty acids** are **linked to Hydroxyl group** of an **Organic Alcohol** by an **Ester linkage.**

- **Thus Fatty acids are** mostly present as **Esterified form in natural living beings.**

(Plant, Animal and Human Bodies)

Classification of Fatty acids With Different Modes:

- **Classification of FAs Based on:**

1. **Total number of Carbon atoms** in a Fatty acid structure.
2. **Hydrocarbon chain length** of Fatty acid
3. **Bonds present** in Fatty acid
4. **Nutritional requirement** of Fatty acid
5. **Chemical nature and structure** of Fatty acids
6. **Geometric Isomerism of UFAs**

Fatty acids Based on Total Number of Carbon atoms

- **Even numbered Carbon** Atom **Fatty acids**

- **Odd numbered Carbon** Atom **Fatty acids**

- Most **naturally occurring** Fatty acids are **even carbon numbered FAs.**

- Since **biosynthesis of Fatty acids uses 2 Carbon units** **Acetyl-CoA(C_2)**.

- **Examples of Even Carbon Numbered Fatty acids:**
  - **Butyric Acid (C_4)**
  - **Palmitic Acid (C_{16})** **(Most Common)**
  - **Stearic Acid (C_{18})**
  - **Arachidic acid (C_{20})**

- **Odd Carbon numbered Fatty acids** are **less related to human body**
- Examples of Odd carbon Fatty acid
  - **Propionic Acid (3C)**
  - **Valeric acid (5C)**

Types Of Fatty acids Based on Hydrocarbon chain length

- Short Chain Fatty acids (2-6 Carbon length)
- Examples:
- Acetic acid (C_2)
- Propionic acid (C_3)
- Butyric acid (C_4)
- Valeric acid (C_5)
- Caproic acid (C_6)

- Medium Chain Fatty acids (8-14 Carbon length)
- Examples:
- Caprylic acid (C_8)
- Capric acid (C_{10})
- Lauric acid (C_{12})
- Myristic acid (C_{14})

- Long Chain Fatty acids (16-20 Carbon length)
- Examples:
  - Palmitic acid (C16)
  - Palmitoleic acid (C16)
  - Stearic acid (C18)
  - Arichidic acid (C20)
  - Arachidonic acid /ETA(C20)
  - Timnodonic acid/EPA (C20)

- Very Long Chain Fatty Acids (C22 onwards)
- Examples:
  - Behenic acid/Docosanoic (C22)
  - Cervonic acid/DocosaHexaEnoic (C22)
  - Clupanodonic (C22)
  - Erucic acid/Docosa 13 Enoic (C22)
  - Lignoceric acid (C24)
  - Nervonic /Tetracosaenoic (C24)
  - Cerotic acid/Hexacosanoic (C26)

Fatty acids Based on the number of Bonds present

- **Saturated Fatty acids(SFAs)**
- Fatty acids having **single bonds** in hydrocarbon chain structure.
- **Examples**:
  - **Acetic acid (C_2)**
  - **Butyric acid (C_4)**
  - **Palmitic acid (C_{16})**
  - **Stearic acid (C_{18})**
  - **Arachidic acid(C_{20})**

- **Unsaturated Fatty acids(UFAs)**
- Fatty acids having **double bonds** in its structure.

- **Types of UFAs:**
- **Monounsaturated Fatty acids (MUFAs)**
- **Polyunsaturated Fatty acids (PUFAs)**

- **Monounsaturated Fatty Acids(MUFAs):**
- **MUFAs h**ave **one double bond** in a fatty acid structure
- **Examples:**
  - **Palmitoleic acid (C16:1;9) (ω7)**
  - **Oleic acid (C18:1;9)(ω9)**

- **Poly Unsaturated Fatty Acids (PUFAs):**
- UFAs with **two or more double bonds in** the structure are termed as **PUFAs.**
- **Examples:**
- **Linoleic(18:2;9,12) (ω6)**
- **Linolenic(18:3;9,12,15) (ω3)**
- **Arachidonic(20:4;5,8,11,14) (ω6)**
- **Timnodonic (20:5;5,8,11,14,17) (ω3)**
- **Cervonic/Docosa Hexaenoic acid(DHA) (22:6;4,7,10,13,16,19) (ω3)**

- **Remember**
- **Double bonds are weaker /unstable bonds.**
- They get **easily cleavable/metabolized**

- **More the degree of Unsaturation** in Fatty acids.

- **More is the unstability** of Fatty acids.

Fatty acids Based on the Nutritional Requirement

Nutritionally Essential Fatty acids

- **Nutritionally Essential Fatty acids:**

- The Fatty acids which are **not biosynthesized in the body and** are **taken through** nutrition/diet essentially.

- **PUFAS are nutritionally essential Fatty acids**.

Examples of Essential Fatty Acids/PUFAs:

- **Linoleic**
- **Linolenic**
- **Arachidonic acids**
- **Timnodonic and**
- **Cervonic**

- Human body have **no Enzyme system to introduce double bond beyond Carbon atom 10** in the hydrocarbon chain.

- Hence **PUFAs not biosynthesized** in human beings.

Nutritionally Non essential Fatty acids

- **Nutritionally Non essential Fatty acids:**
- Fatty acids which are **biosynthesized in the body** and are nutritionally non essential Fatty acids.
  - **Saturated Fatty acids and MUFAs are non essential Fatty acids.**

Examples Of Non Essential Fatty Acids

- Palmitic
- Stearic
- Oleic acid

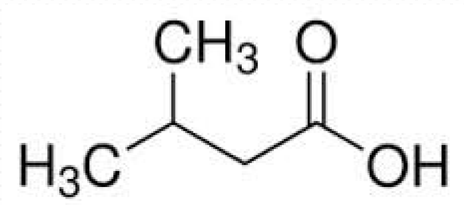
Fatty acids Based on Chemical nature and Structure

- **Aliphatic Fatty acids:**

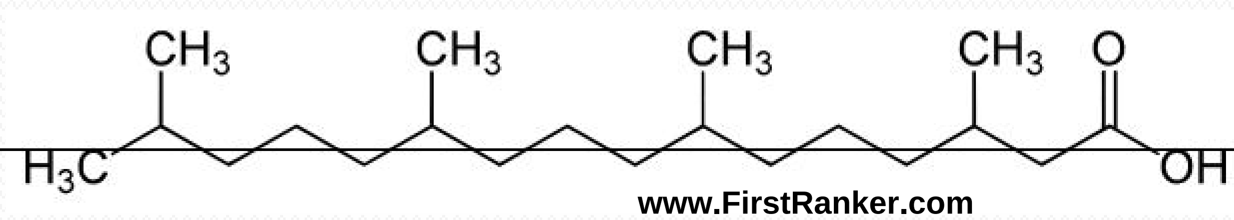
Straight Hydrocarbon chain

- Examples:
  - **Palmitic acid (C16)**
  - **Stearic acid (C18)**

- **Branched Chain Fatty acids:**
  - Possess Branched chains
- **Examples:**
  - **Isovaleric (C5)**



- **Phytanic acid (Butter , dairy products)**



- **Cyclic Fatty acids :**
  - Contains Ring structure
- **Examples:**
  - **Chaulmoogric acid**

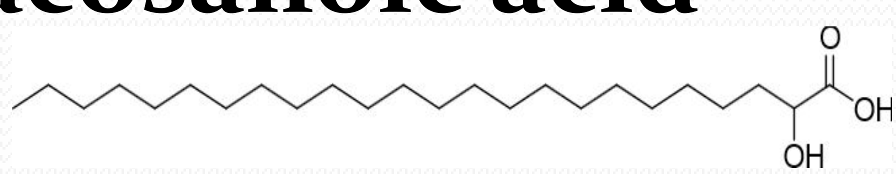
(Used for Leprosy treatment in olden days)

  - **Hydnocarpic acid**

Hydnocarpic acid (n=10)
Chaulmoogric acid (n=12)

- **Hydroxy Fatty acids:**
  - Contain Hydroxyl Groups
- **Examples:**
  - **Cerebronic acid (C24)/**

2-HydroxyTetracosanoic acid



- **Ricinoleic acid(C18) (Castor oil)**

RICINOLEIC ACID

Based on Geometric Isomerism of Unsaturated Fatty acids

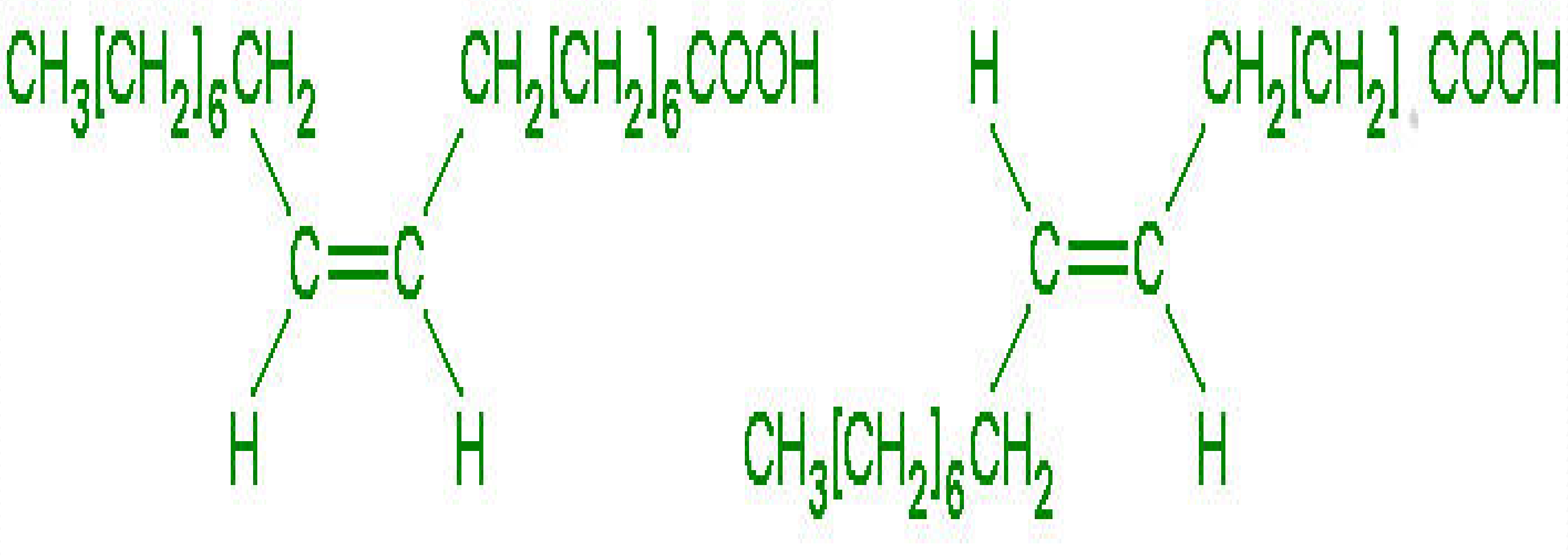
- **Cis Fatty Acids:**

The **Groups around double bond** of Unsaturated FAs are on **same side.**

- **Examples:**
  - **Cis Oleic acid (rich in Olive oil)**
  - **Palmitoleic acid**

Trans Fatty Acids :

- The groups around double bond of UFAs are on **opposite side**
- **Example :**
  - **Elaidic acid /Trans Oleic acid (Hydrogenated Fats)**

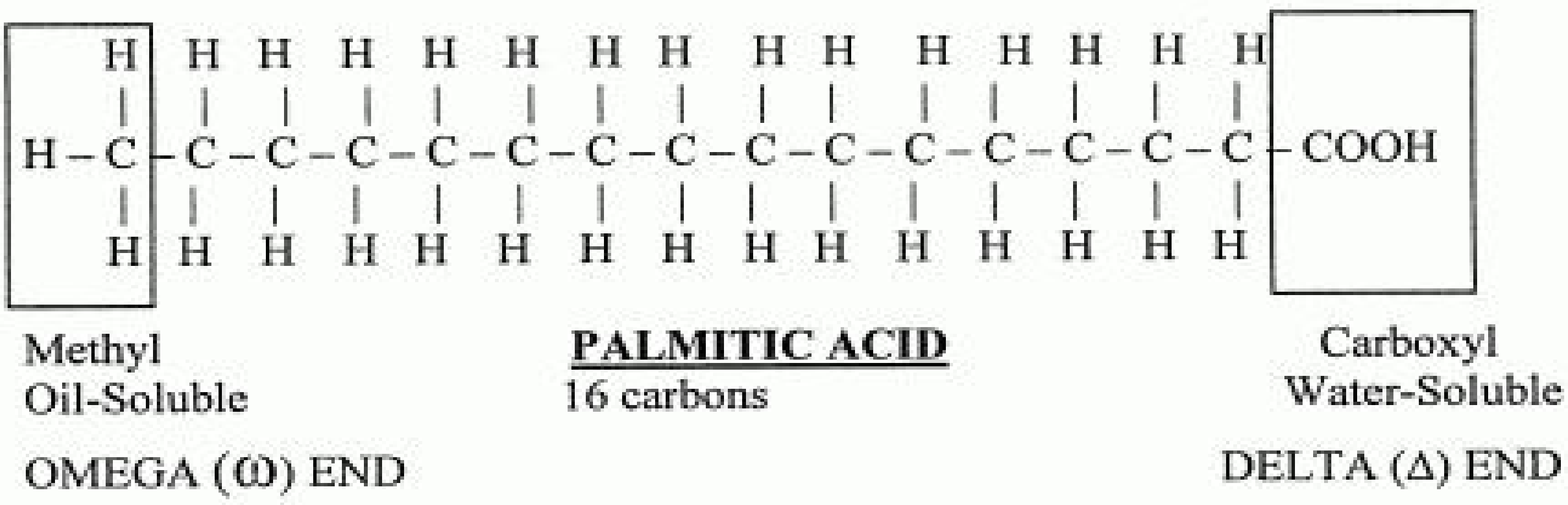


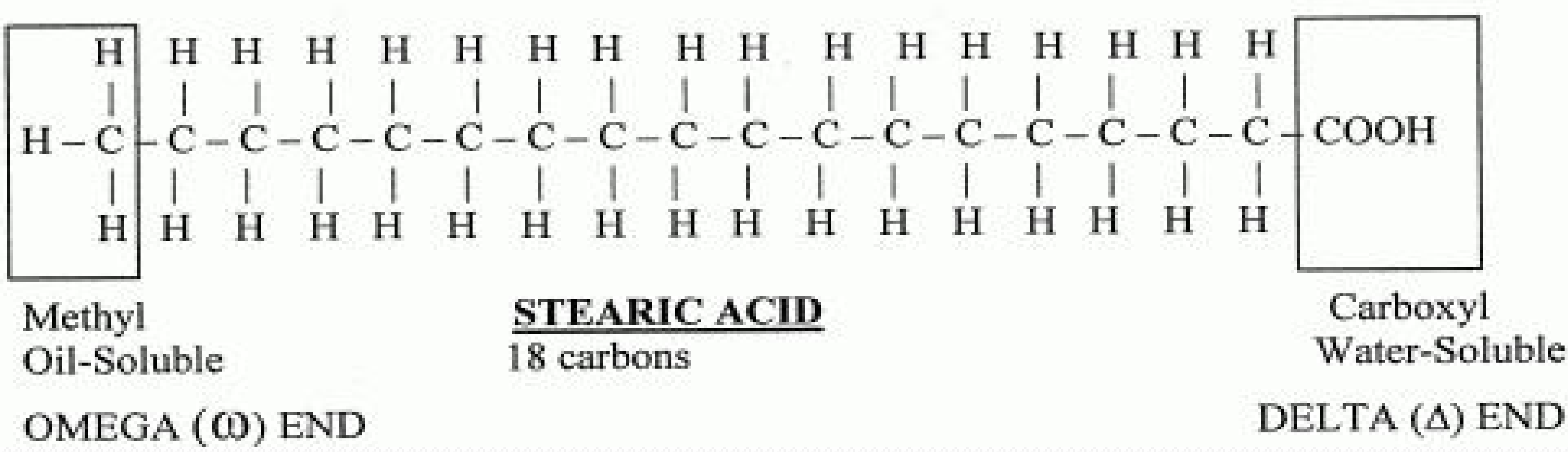
Oleic acid Elaidic acid

Structures Of Fatty Acids

- The **Hydrocarbon chain** of each Fatty acid is of **varying chain length (C_2 - C_{24}).**

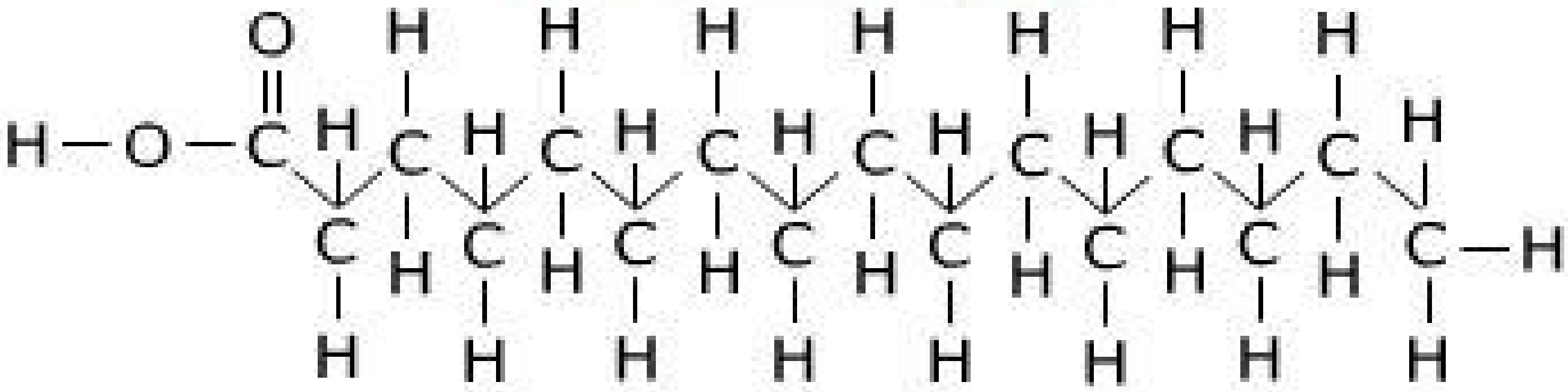
- **Fatty acid** structure have **two ends**:
  - **Carboxylic group**(-COOH) at one end (**Delta end denoted as Δ**)
  - **Methyl group** (-CH_3) at another end (**Omega end denoted as ω**)



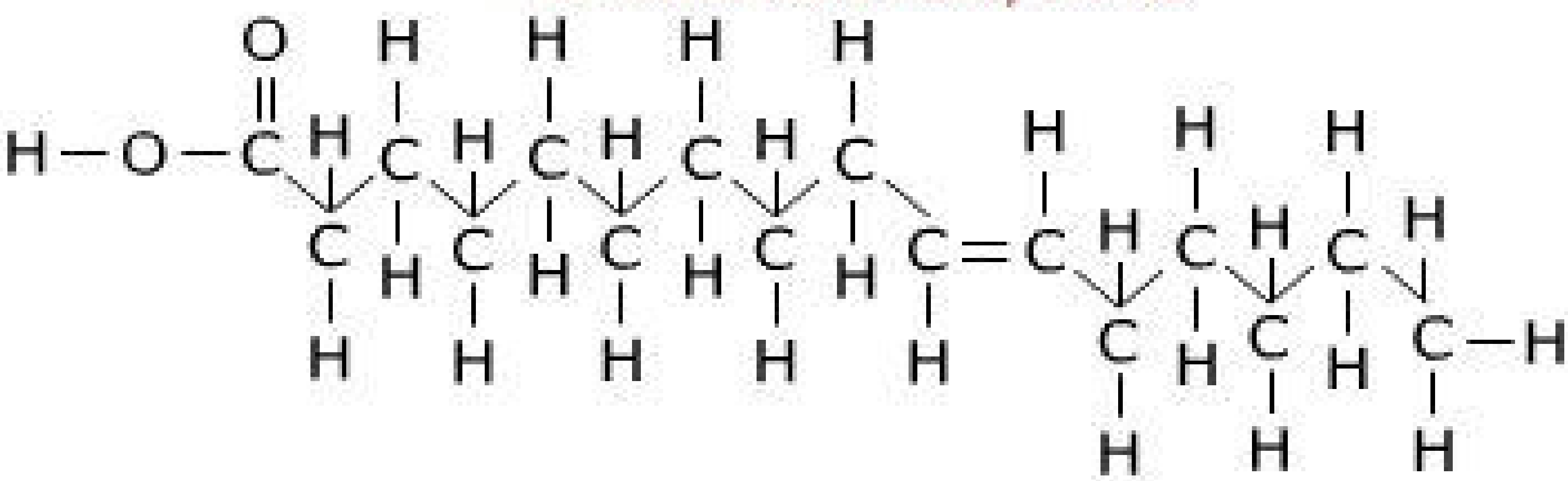


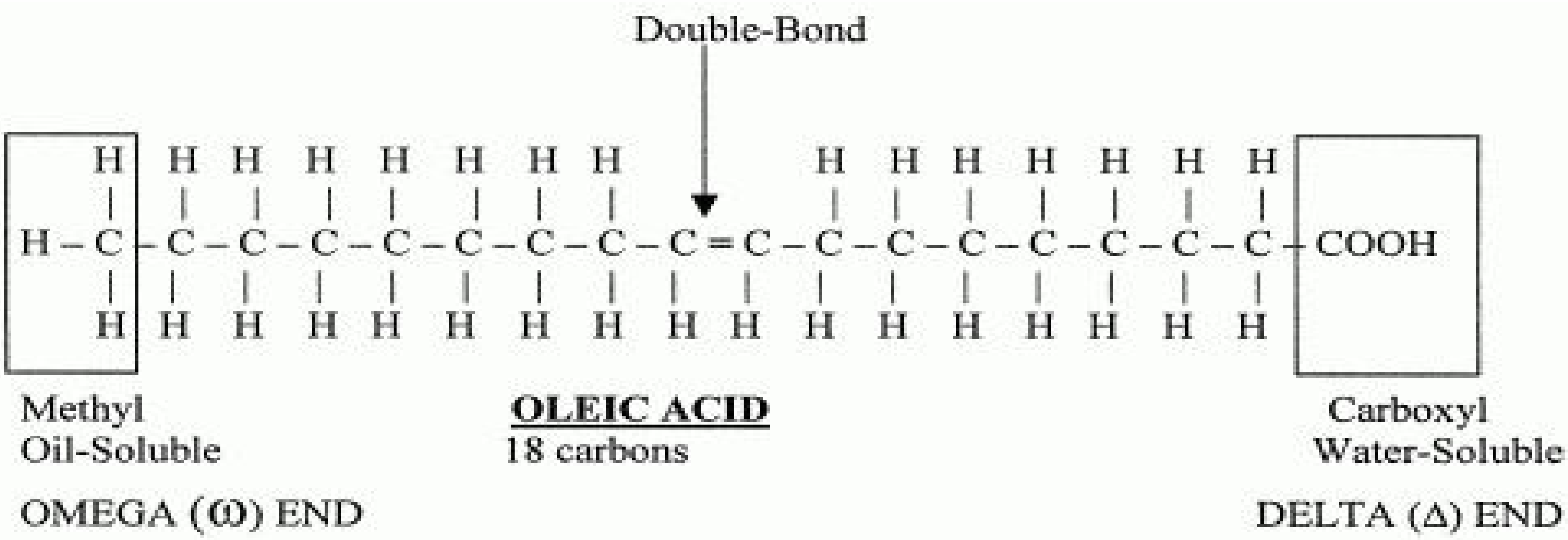
Fatty Acids

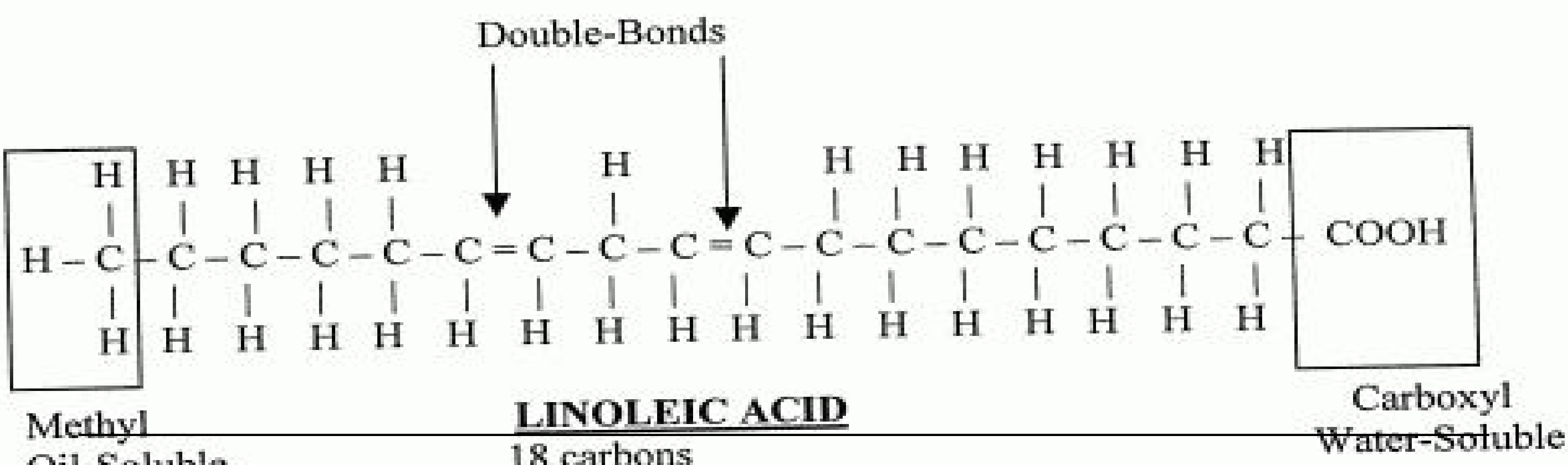
Saturated Fatty Acids



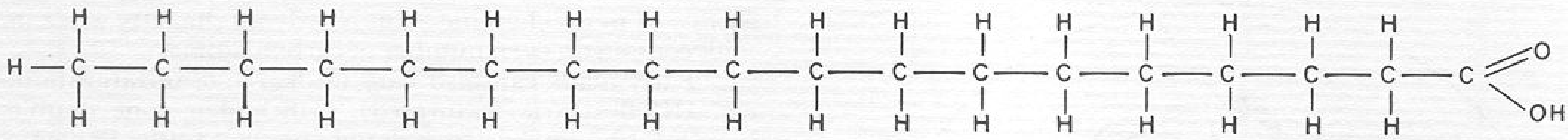
Unsaturated Fatty Acids



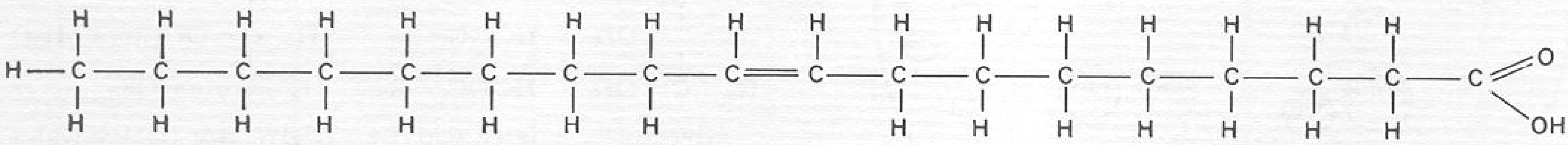




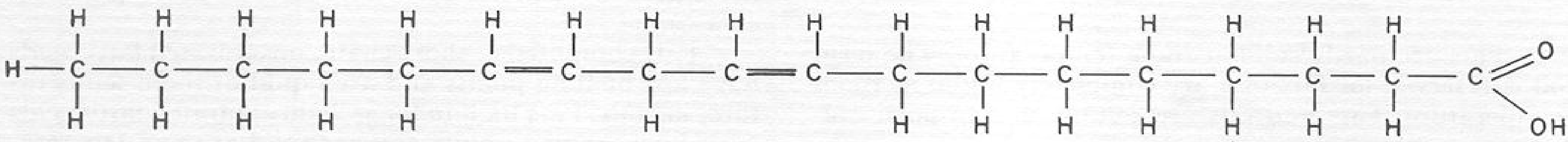
Stearic acid Cl8:0



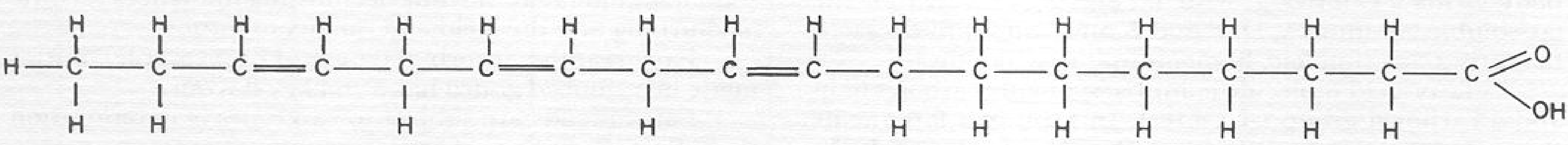
Oleic acid Cl8:1



Linoleic acid Cl8:2

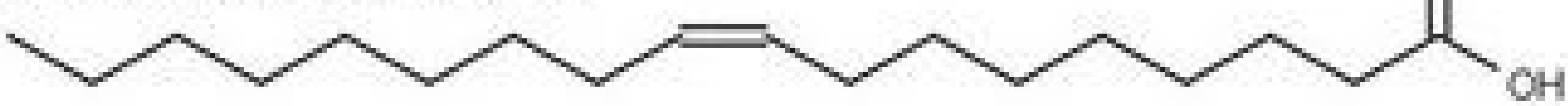


Linolenic acid Cl8:3



A

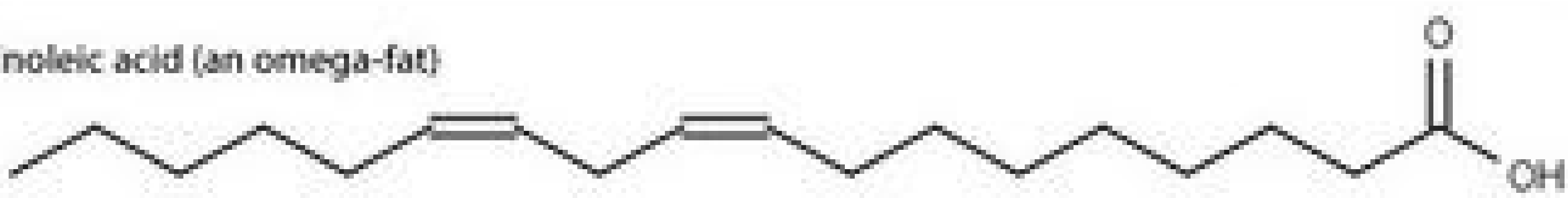
The mono-unsaturated fat oleic acid



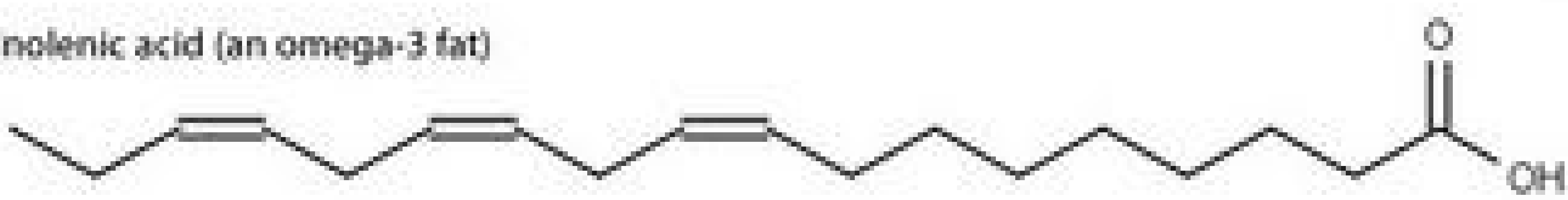
An 18 carbon saturated fatty acid-stearic acid

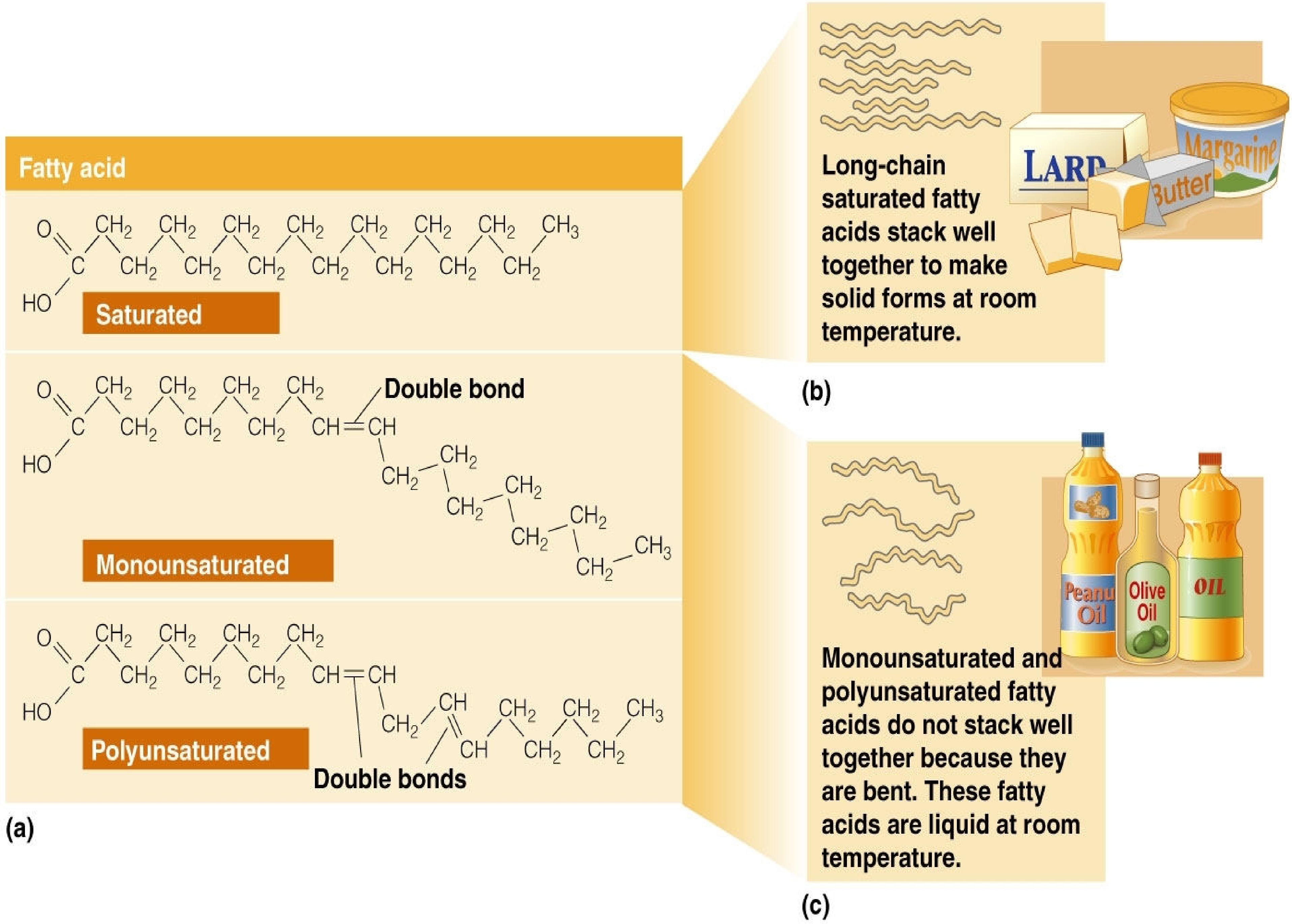
B

Linoleic acid (an omega-fat)



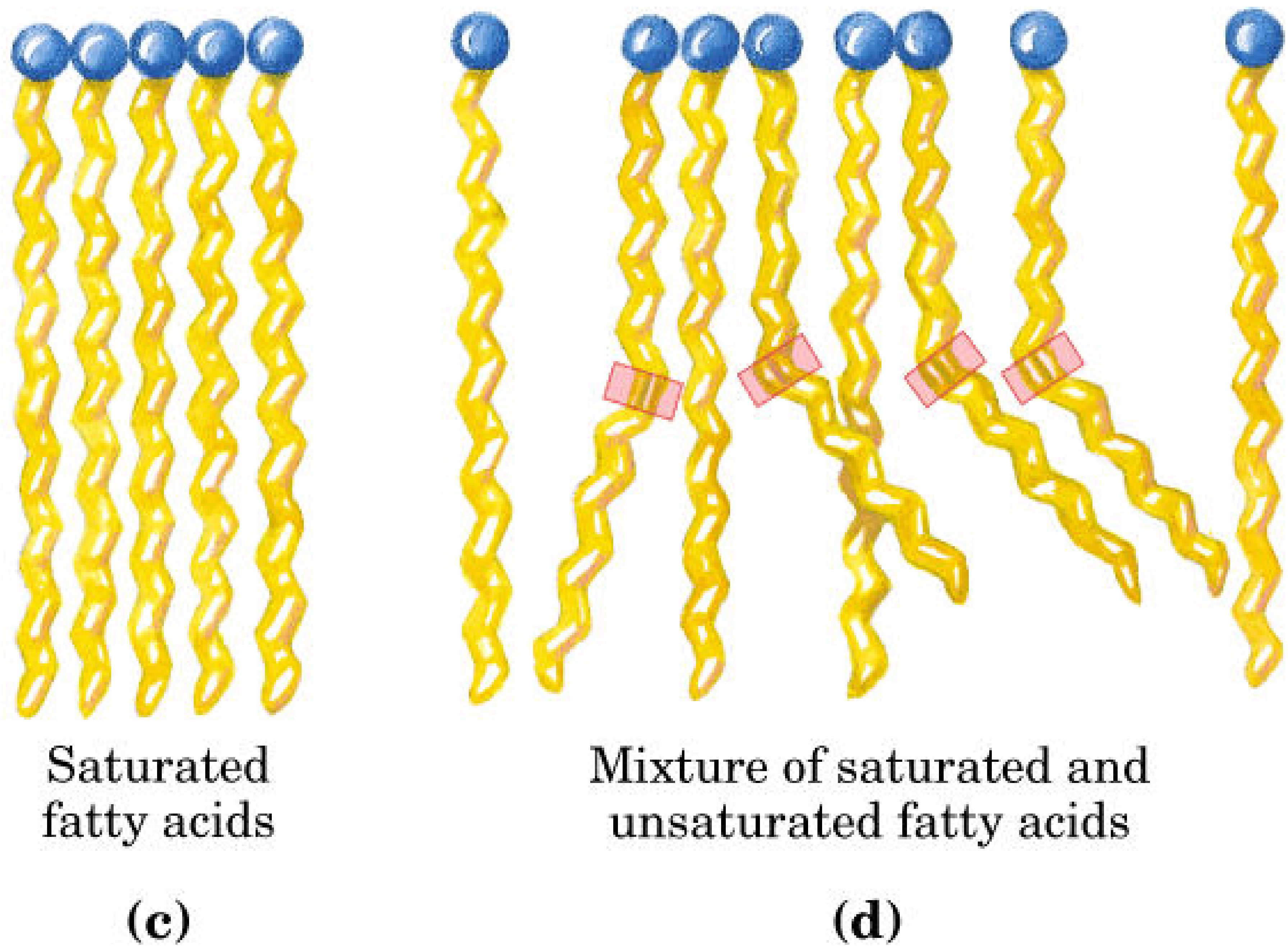
Linolenic acid (an omega-3 fat)



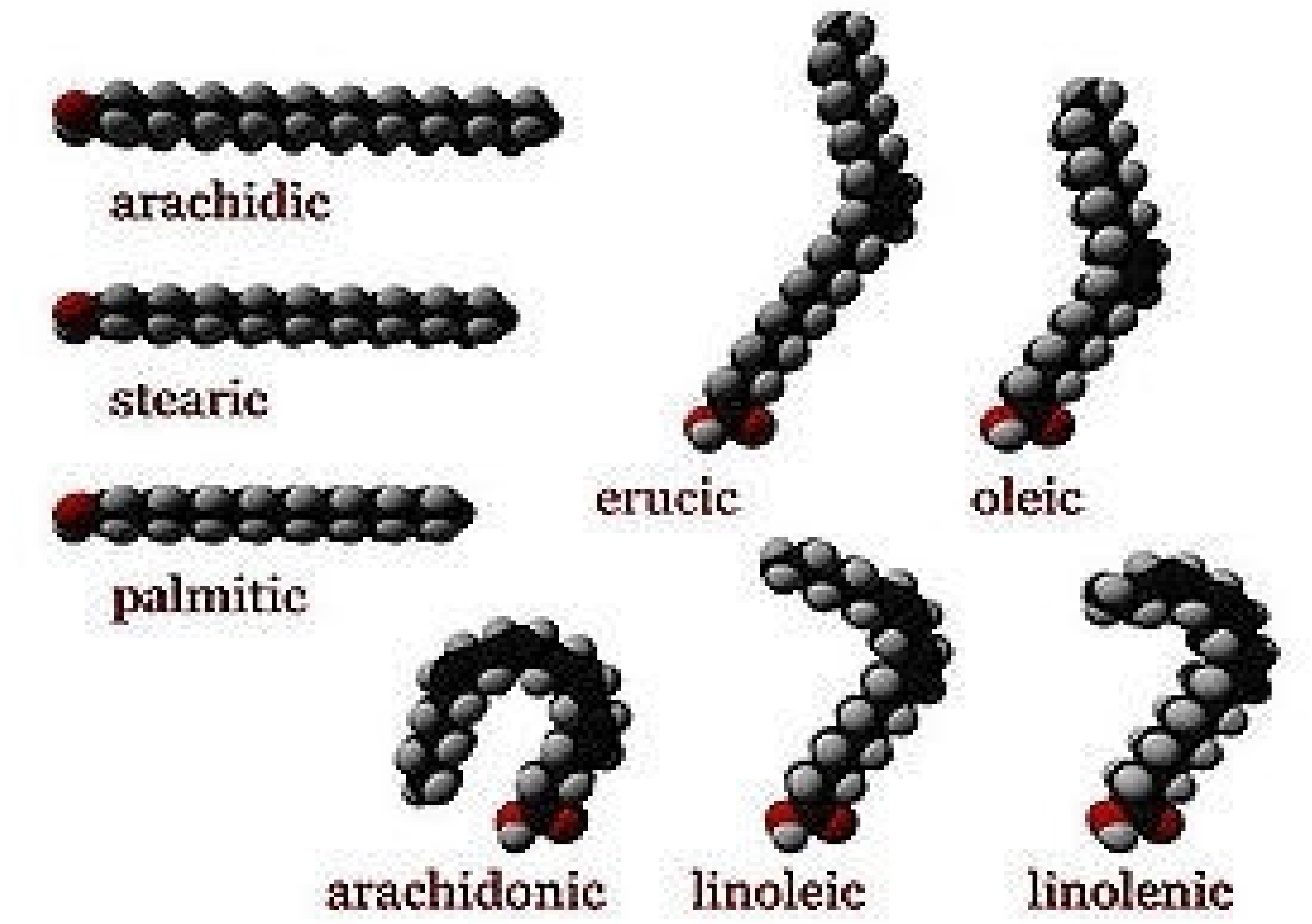


- **Saturated Fatty acids** structures are **Straight.**

- **Unsaturated Fatty acids** structures are **bent**(Kink).



- **More the degree of unsaturation in FA/More double bonds in FA structure**
- **More is the bent** of Fatty acid structure.



- **Saturated** FAs: with **straight structures** are **tightly packed together**.

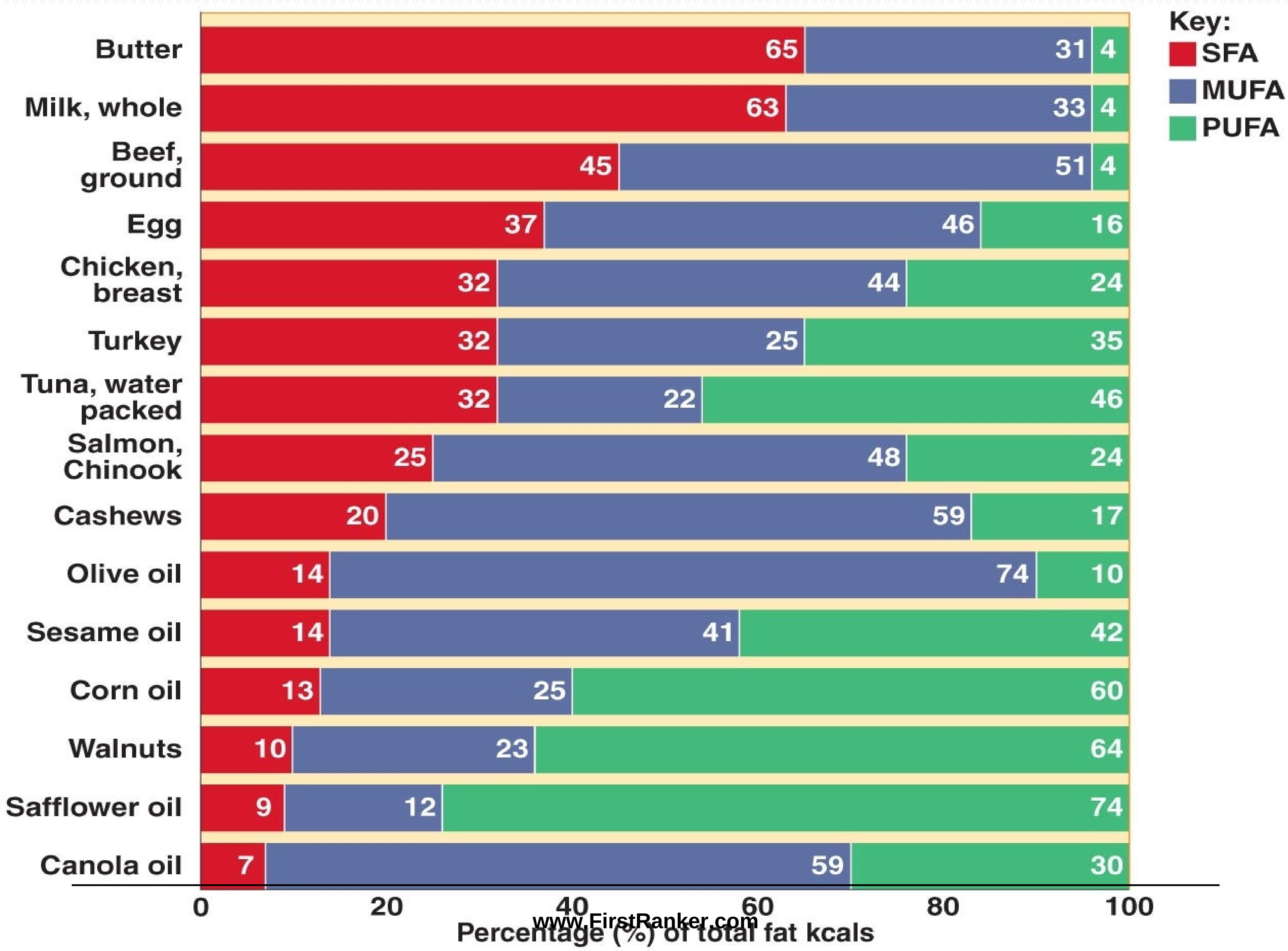
- **Unsaturated FAs:** with **bent structures** are **not compact** and has **no tight packing.**

Fatty acid Composition of Human Body

Fatty acid	Percentage
Oleic acid	**50% (MUFA)**
Palmitic acid	35% (SFA)
Lionleic acid	10% (PUFA)
Stearic acid	5% (SFA)

- Thus the most **abundant Fatty acids** present in **human Lipids** are:
  - **Oleic acid (50%)**
  - **Palmitic acid(35%)**

- Most abundant Fatty acid in a healthy human body is **Oleic acid (Rich in MUFA).**
- Oleic acid is **richly associated** with **Olive oil.**
- Hence **eating Olive oil is advisable** for proper body **development and good health.**



Nomenclature Of Fatty acids

Naming And Numbering Of Fatty Acids

- Every Fatty acids has a:
  - **Common Name**
  - **Systematic Name**
- Most of the Fatty acids are known by their **common names**.(since easy to use)

- **Systematic names** of Fatty acids are **limited in use**.

  (Since not easy to use)

- **Long chain Fatty acids** are termed as **Acyl chains.**

- The systematic names of **Saturated Fatty acids** are named by adding **suffix 'anoic'.**

- Example : Hexadec**anoic** acid(Palmitic acid- C16)

- The systematic names of **Unsaturated Fatty acids** are named by **suffix 'enoic'.**

- **Example:** Octadeca**enoic** acid(Oleic acid- C18)

S.N	Common Name	Systematic Name
1	Palmitic Acid	Hexadec**anoic** Acid
2	Stearic Acid	Octadec**anoic** Acid
3	Oleic acid	Octadeca**enoic** acid
4	Linoleic Acid	Octadeca**dienoic** acid
5	Linolenic Acid	Octadeca**trienoic** acid
6	Arachidonic acid	Eicosa**tetraenoic** acid

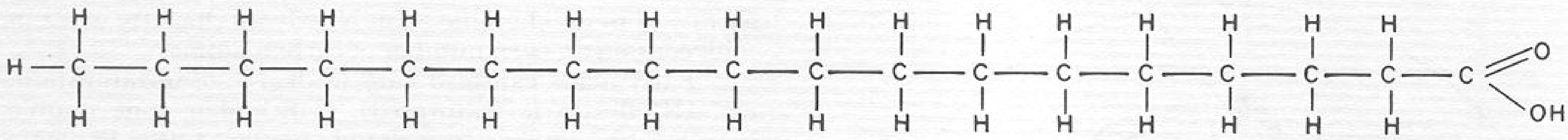
Numbering Of Fatty Acids

- **Numbering of Fatty acids is done from :**
  - **Both the ends of Fatty acids Δ and ω**
  - From **Carboxyl Group end(Δ)** : the Carboxylic acid group of Fatty acid is C_1, C_2 is next adjacent ,C_3 and so onn.

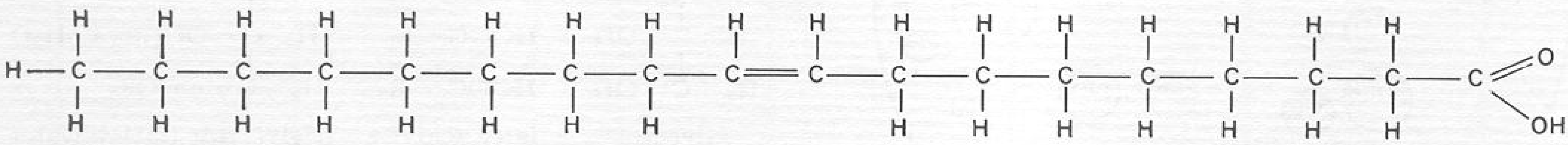
- The name of Carbon atom next to the functional group –COOH of a Fatty acid is **α , next Carbon is β, γ,δ ,ε and so onn.**

- Carbon atoms from Methyl(–CH_3) group at non polar end(ω) of a fatty acid are numbered as **ω1,ω2,ω3 and so onn.**

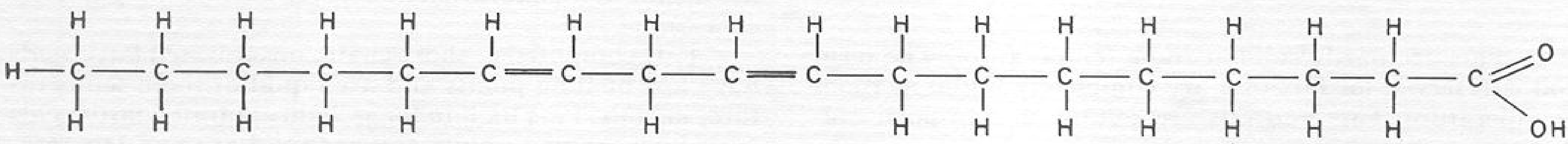
Stearic acid C18:0



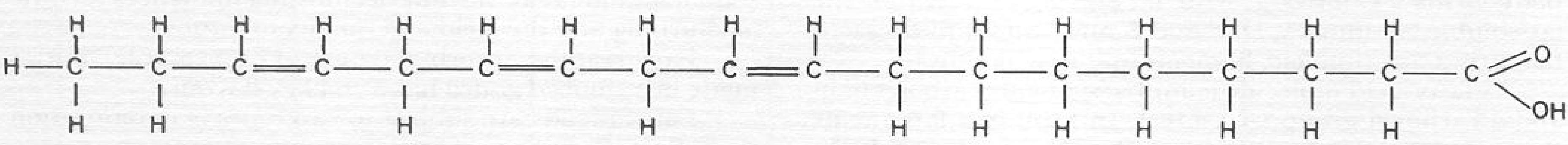
Oleic acid C18:1



Linoleic acid C18:2



Linolenic acid C18:3



Fatty Acid Nomenclature

FA Nomenclature is Based On

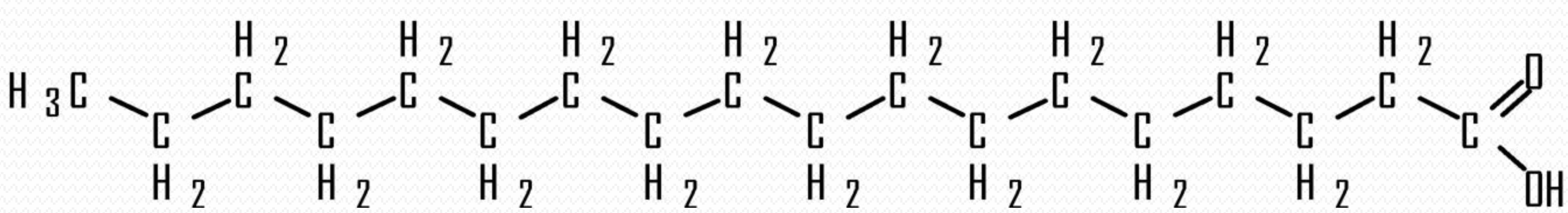
- **Chain length**
  - Number of Carbon atoms in FA
- **Number and Position of Double bonds**
  - Position of double bond from Methyl/Omega or Carboxyl/Delta end

Short Hand Representations of Fatty acids

- **Short Hand Representations of Fatty acids:**
  - **Palmitic Acid (16:0)**
  - **Palmitoleic acid (16:1;9)**
- **First digit stands** for total number of carbon atoms in the fatty acid.
- **Second digit designates** number of double bonds.
- **Third digit onwards** indicates the position of double bonds.

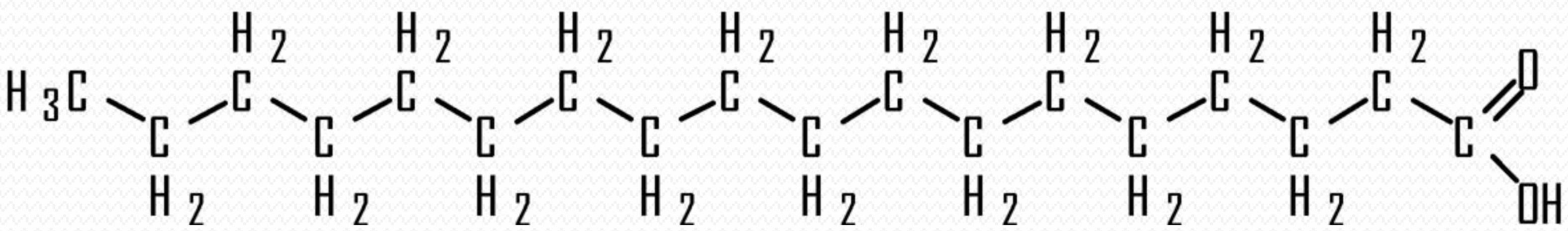
Fatty-acid Nomenclature

- **Named according to chain length**
  - **C18**



Fatty-acid Nomenclature

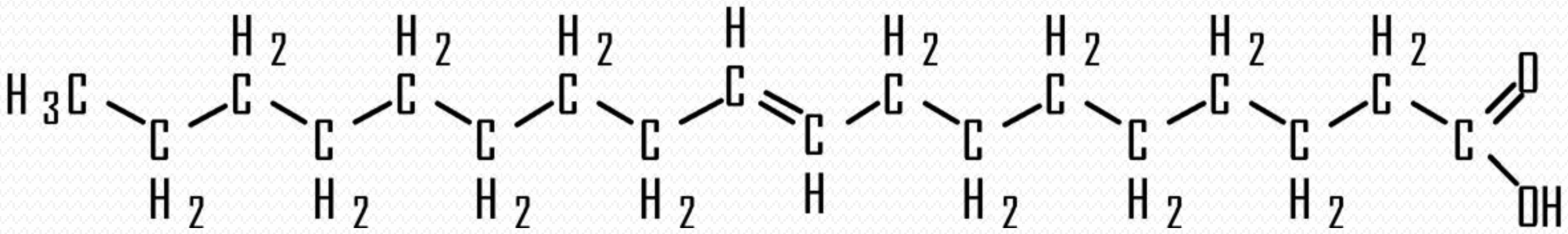
- **Named according to the number of double bonds**
  - **C18:0**



Common name:
Stearic acid

Fatty-acid Nomenclature

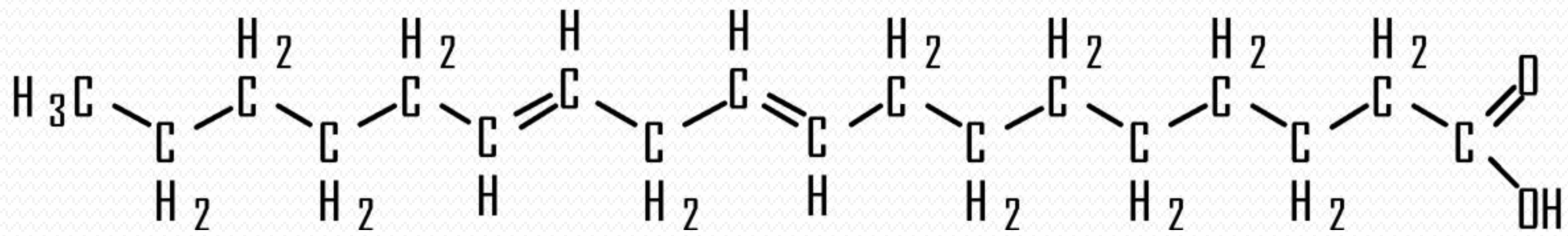
- **Named according to the number of double bonds**
  - **C18:1**



Common name:
Oleic acid

Fatty-acid Nomenclature

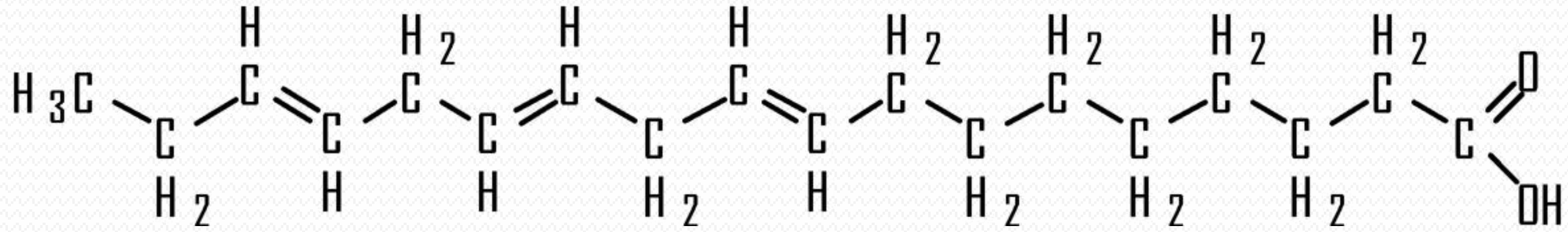
- **Named according to the number of double bonds**
  - **C18:2**



Common name:
Linoleic acid

Fatty-acid Nomenclature

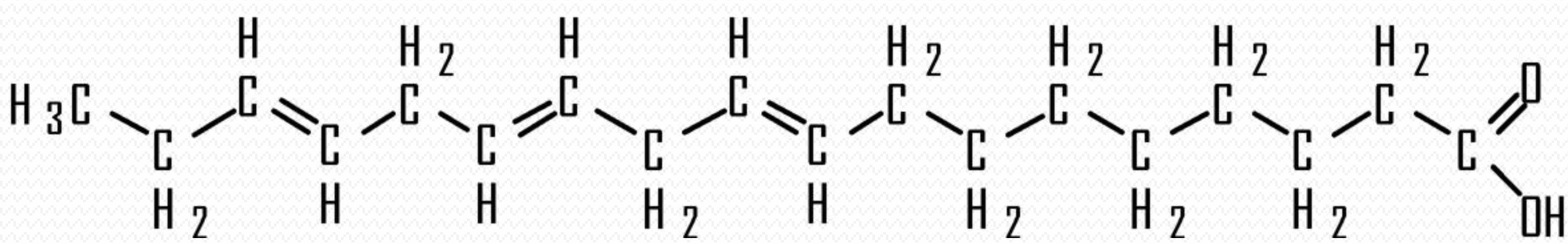
- Named according to the number of double bonds
  - **C18:3**



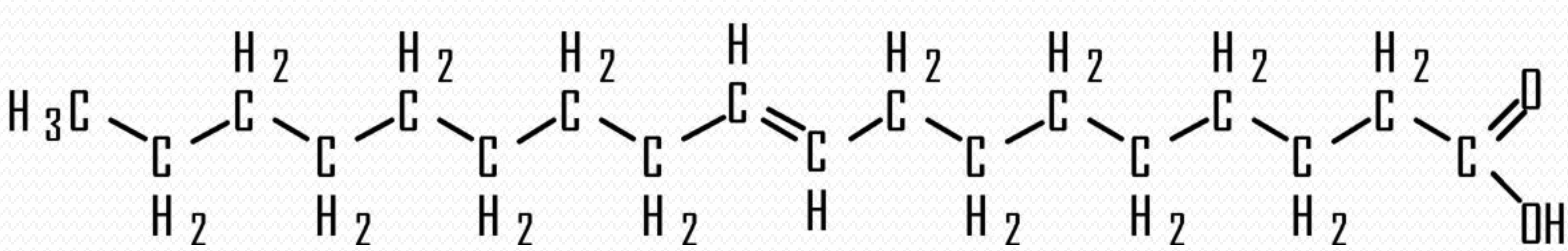
Common name:
Linolenic acid

Omega System Nomenclature

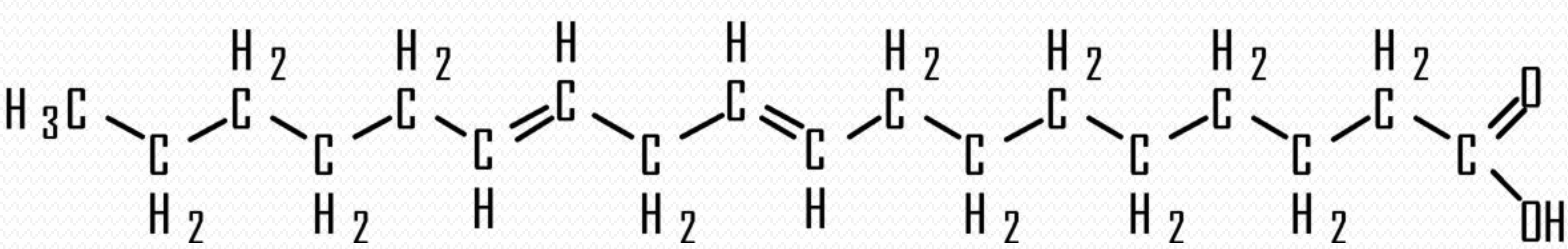
- Named according to the location of the ***first* double** bond from the non-carboxyl **Methyl end** (count from the Methyl end /**Omega end ω**)



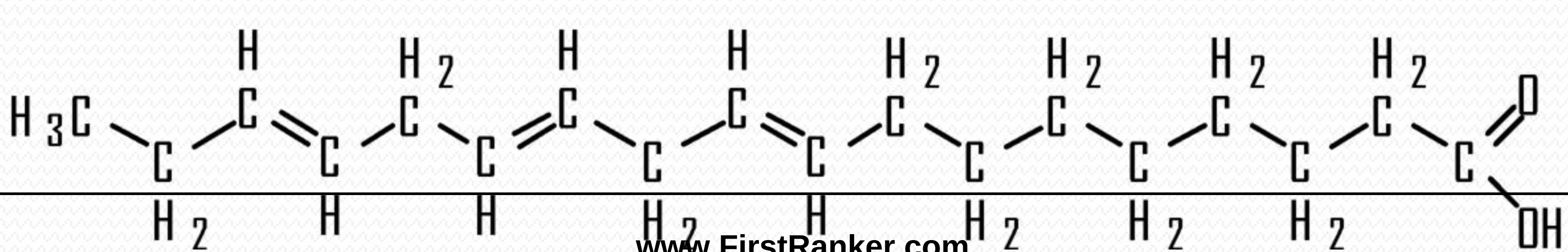
Omega Fatty-acid Nomenclature



Omega 9 or n–9 fatty acid



Omega 6 or n–6 fatty acid



Omega 3 or n–3 fatty acid

- **Stearic acid (18:0)**
- **Oleic acid (18:1;9)**
- **Linoleic acid (18:2;9,12)**
- **Linolenic acid (18:3;9,12,15)**
- **Arachidonic acid (20:4;5,8,11,14)**

- **A Fatty acid may also be designated as :**
- Linoleic acid (18C;$\Delta^{9,12}$)
- Linolenic acid (18C;$\Delta^{9,12,15}$)
- Δ indicates from COOH end.
- 9,12,15 are double bond positions from delta end.

Short Hand Presentation of FA

14:0 **Myristic acid**

16:0 **Palmitic acid**

18:0 **Stearic acid**

18:1 cis Δ^{9} **Oleic acid** **(ω9)**

18:2 cis$\Delta^{9,12}$ **Linoleic acid(ω6)**

18:3 cis$\Delta^{9,12,15}$ **α-Linolenic acid (ω3)**

20:4 cis$\Delta^{5,8,11,14}$ **Arachidonic acid(ω6)**

20:5 cis$\Delta^{5,8,11,14,17}$ **Eicosapentaenoic acid(ω3)**

Omega Series Fatty Acids

Omega Fatty Acids

- **Omega Fatty acids are Unsaturated Fatty acids (UFAs)**
- In whom the **position of double bond is counted from Omega end/Methyl end as**(ω) carbon atom
- **Terminal Methyl group is ω1**

Classification/Types Of Omega Fatty Acids

Types Of Omega Fatty acids

- **ω3 Fatty acids**
- **ω6 Fatty acids**
- **ω7 Fatty acids**
- **ω9 Fatty acids**

- **Omega Classification** of Fatty acids is used frequently in
  - **Nutrition and Clinical practice.**

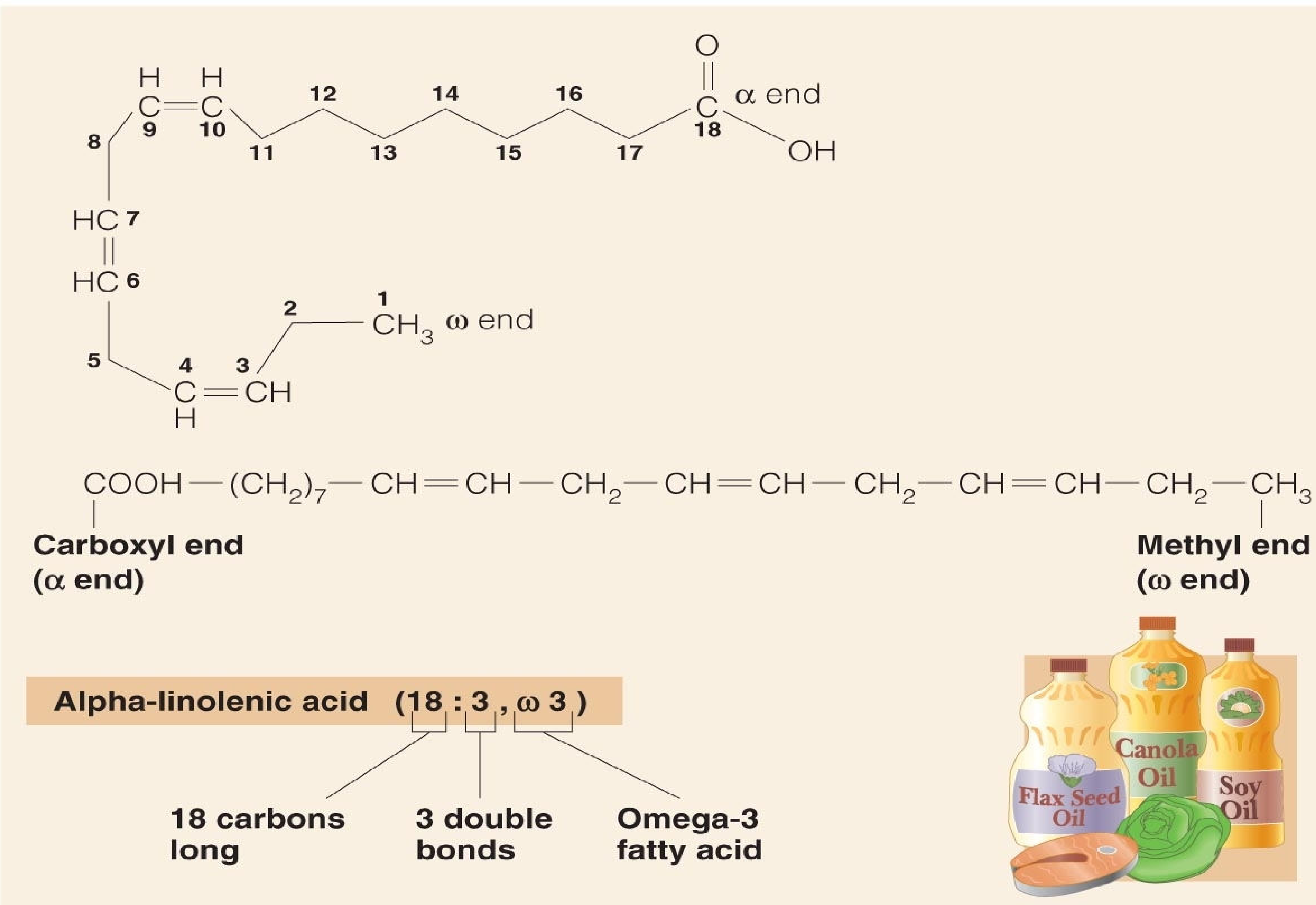
Omega 3 Fatty Acids

Omega 3 Fatty Acids

- Fatty acids having their **first double bond at ω3 carbon atom** are **Omega 3 Fatty acids**.

Examples of ω3 Fatty acids

- **Linolenic** (18:3;9,12,15) (ω3)
- **Timnodonic**/EPA (20:5;5,8,11,14,17)(ω3)
- **Clupanodonic acid**/(Docosa Pentaenoic Acid): (DPA) (C22:5;7,10,13,16,19)(ω3)
- **Cervonic**/Docosa Hexaenoic Acid (DHA)(22:6;4,7,10,13,16,19)(ω3)



(b)

- **Omega 3 Fatty acids** are **PUFAs**
- **Not biosynthesized** in human body.
- **Nutritionally essential Fatty acids.**
- They have to be taken **essentially through diet .**

Dietary Sources Of Omega 3 Fatty Acids

- **Omega 3 Fatty acids** are richly present in:
  - **Green leaves**
  - **Algae**
  - **Fishes**
  - **Animal Meat**
  - **Natural Plant Oils**

- **Dietary rich sources of Omega-3 Fatty acids Are Fish and Fish oils:**
- **Docosahexaenoic acid (DHA)/Cervonic acid**
- **Eicosapentaenoic acid (EPA)/Timnodonic acid**

Functions Of Omega 3 FAs

- Omega 3 Fatty acids are component of **cell biomembranes**.
- Omega 3 Fatty acids are more **associated to Human brain**.
- Helpful in **growth ,development and functioning of brain.**

- Thus **Omega 3 fatty acids** plays **good role in**
- **Developing mental well being of infants and adults.**

Since Omega 3 Fatty Acids are PUFAS
They are easily metabolizable in human body

- **Omega 3 Fatty acids Reduces risk of heart disease:**
  - By stimulating Prostaglandins and Prostacyclin's that **reduces Platelet aggregation.**
  - **Which reduces** blood clotting and **Thrombus formation.**

- Omega 3 Fatty acids have pleiotropic effects(more than on effect):
  - Cardio protective effect
    - Lowers Blood pressure
    - Anti-Inflammatory
    - Anti-Atherogenic
    - Anti-Thrombotic

  - Thus Fish Eaters has good
- Brain development with an efficient nervous function.
- Protected from Heart attacks.

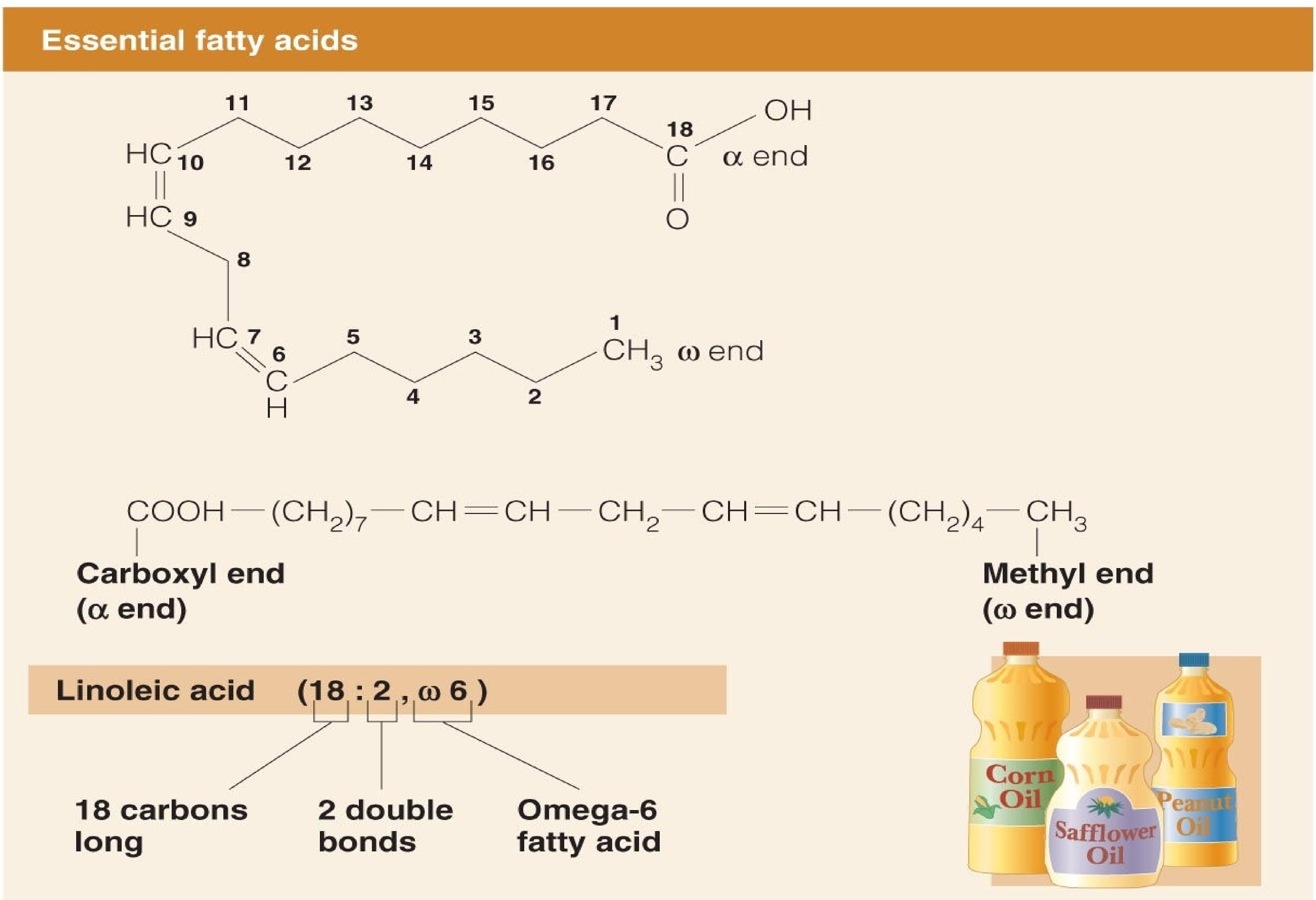
Deficiency Of Omega 3 Fatty acids

- Deficit of omega 3 fatty acids **affect the normal growth ,development and functioning of brain.**
- Persons may suffer from **mental illness** like:
  - **Depression**
  - **Attention deficit**
  - **Dementia**

- Deficiency of **Omega 3 Fatty acids** :
  - **Alters the cell membrane structure**.
  - Increases the **risk of heart attack.**

Omega 6 Fatty Acids

- **Omega 6 Fatty Acids:** These fatty acids has their **first double bond at ω6 carbon atom.**
- **Examples of ω6 Fatty acids:**
- **Linoleic acid(18:2;9,12) (ω6)**
- **Arachidonic acid(20:4;5,8,11,14) (ω6)**



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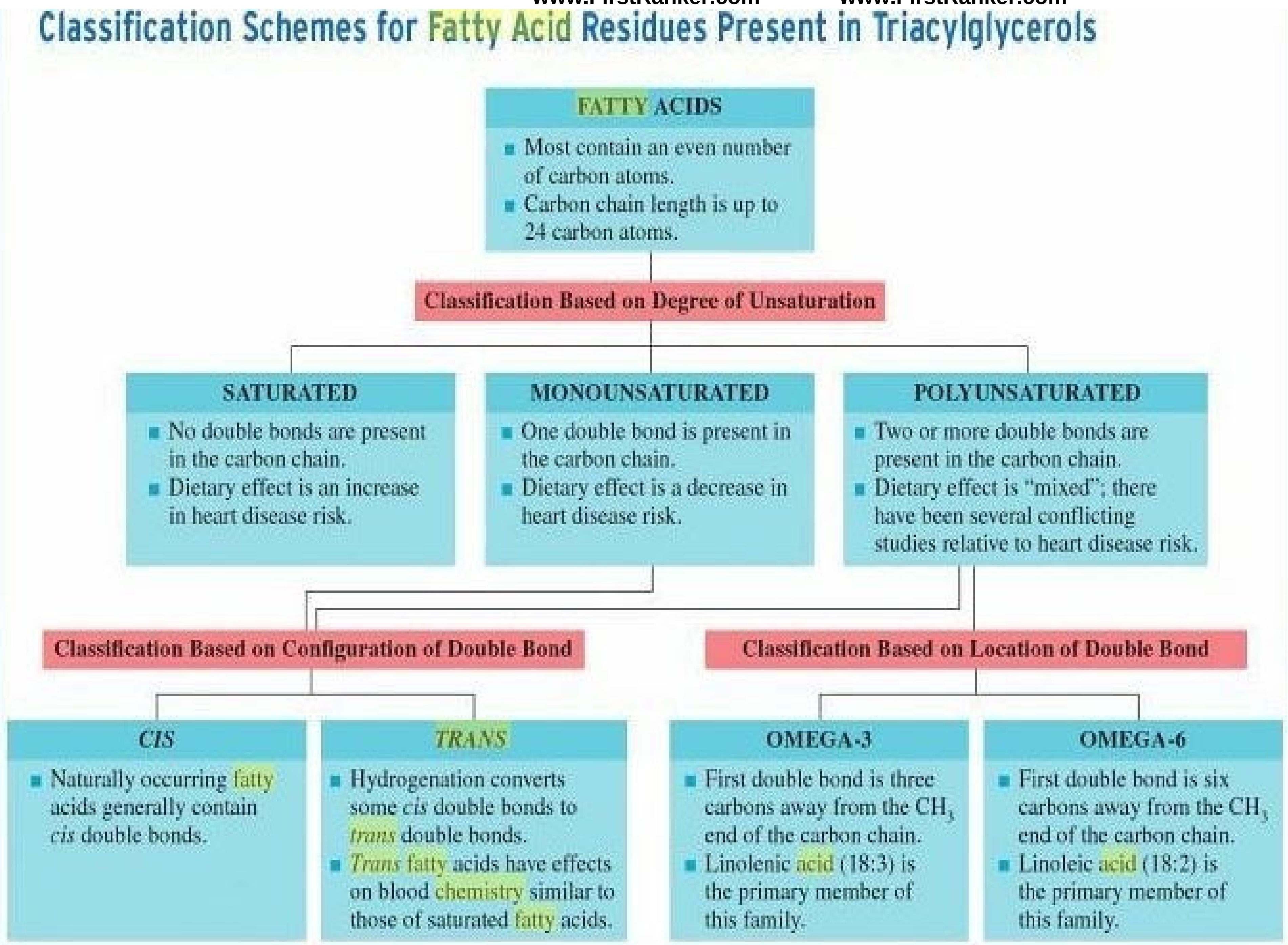
Omega 7 Fatty Acids

- **Omega 7 Fatty Acids** fatty acids has their first double bond at ω7 carbon atom.
- **Palmitoleic acid (C16:1;9) (ω7)**

Omega 9 Fatty Acids

- Omega 9 Fatty Acids: These fatty acids has their first double bond at ω9 carbon atom.
- Examples of ω9 fatty acids:
  - **Oleic acid (C18:1;9)(ω9)**
  - **Nervonic acid (C24:1;9)(ω9)**



Poly Unsaturated Fatty Acids (PUFAs)

Dietary Rich Sources Of PUFAs

- **PUFAs are nutritionally essential** since they are **not biosynthesized by human beings**
- Hence Human beings **should take dietary Lipids** to get **essential Fatty acids.**

- **Rich sources of dietary essential PUFAs are:**
  - **Vegetable Oils**
  - **Fish and Fish oils**
  - **Green Leaves, Algae**

- **Arachidonic acid(PUFA)** can be **synthesized from Linoleic acid(PUFA)** in human body.

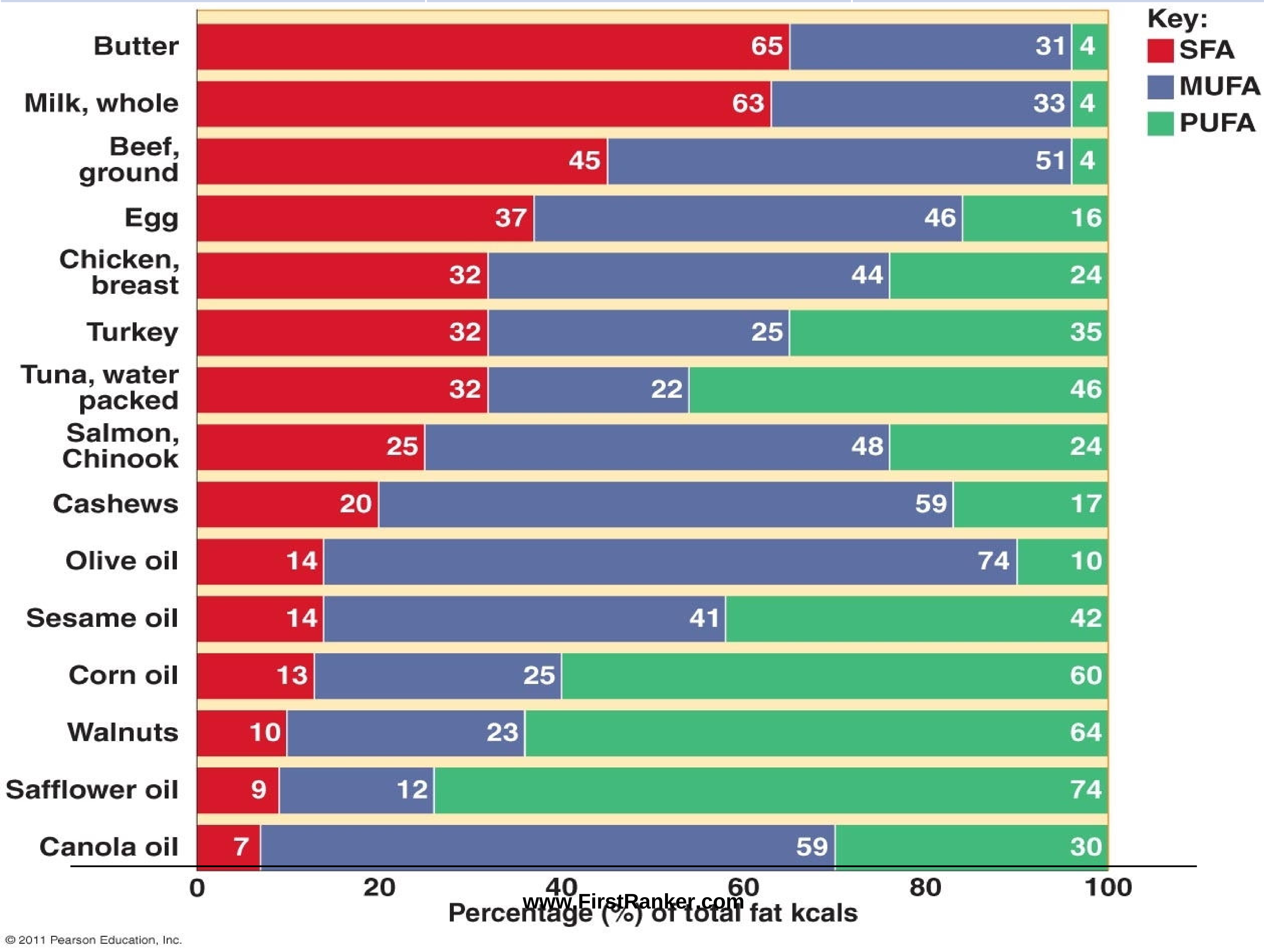
Proper Requirement Of Fatty Acids To Human Body

- It is ideal to **consume ratio** of:
- **1 : 1 : 1**
- **SFA MUFA PUFAs**

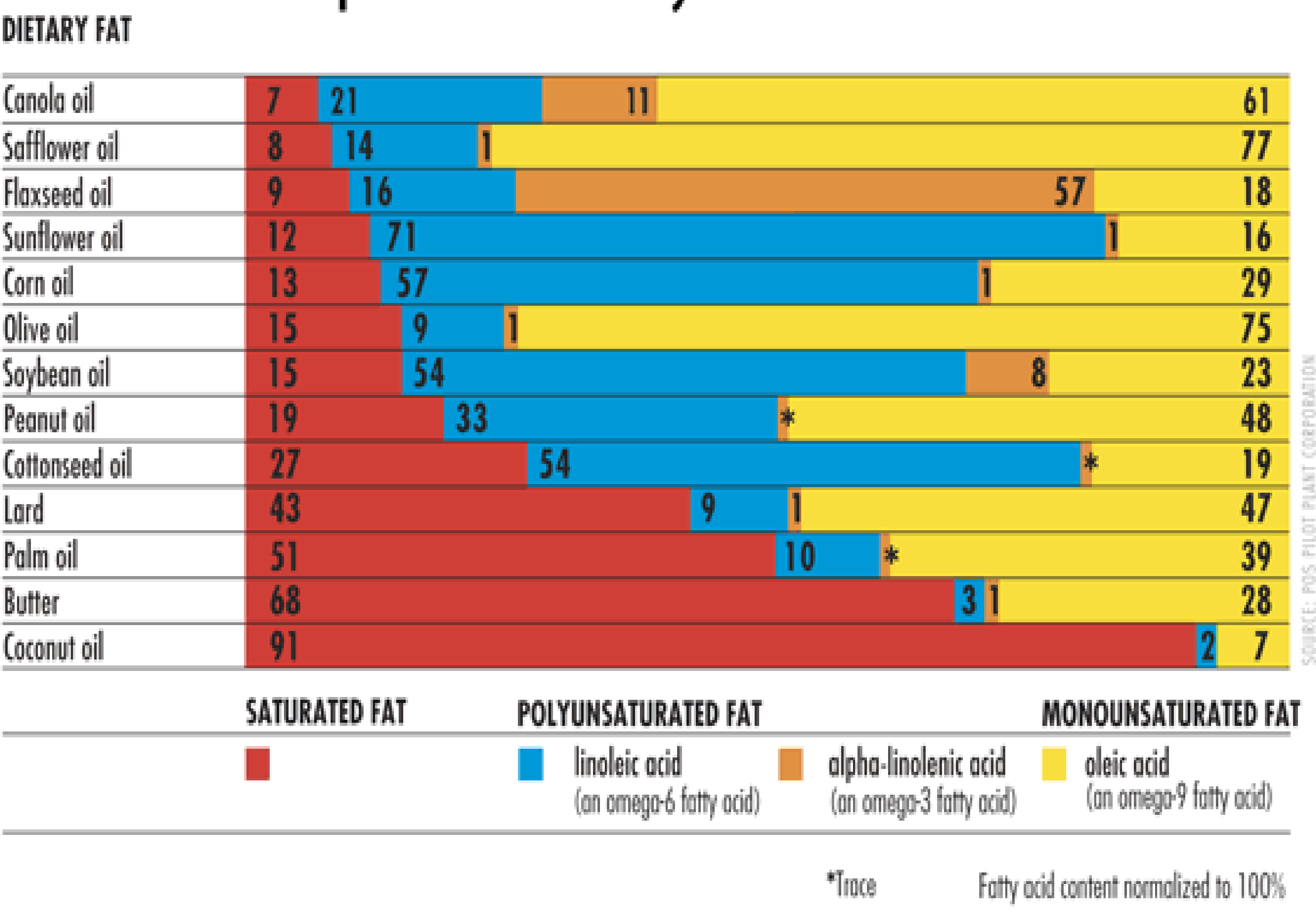
- respectively **from the diet to maintain good health**.

- Naturally there is **no single oil which** has all **3 types of fatty acids in ideal proportion.**
- Hence it is always **advisable to mix a combination of oils and consume**.

Oils Rich In SFAs	Oils rich in MUFAs	Oils rich in PUFAs
Coconut Oil	Olive Oil (75%)	Flax seeds/ Linseed Oil
Palm Oil	Sunflower Oil (85%)	Soya /Safflower Oil
Butter	Ground nut / Pea nut Oil	Almond Oil
Animal Fat	Almond Oil	Rice Bran
	Sesame Oil	Walnuts Oil
	Beef Fat (Tallow Fat) 50%	Corn Oil
	Lard (Pork Fat) 40%	Marine Fish



Comparison of Dietary Fats



Fatty Acids	Carbons	Double bonds	Abbreviation	Source
Acetic	2	0	2:0	bacterial metabolism
Propionic	3	0	3:0	bacterial metabolism
Butyric	4	0	4:0	**butterfat**
Caproic	6	0	6:0	**butterfat**
Caprylic	8	0	8:0	**coconut oil**
Capric	10	0	10:0	**coconut oil**
Lauric	12	0	12:0	**coconut oil**
Myristic	14	0	14:0	palm kernel oil
Palmitic	16	0	16:0	**palm oil**
Palmitoleic	16	1	16:1	**animal fats**
Stearic	18	0	18:0	**animal fats**
Oleic	18	1	18:1	olive oil
Linoleic	18	2	18:2	grape seed oil
Linolenic	18	3	18:3	flaxseed (linseed) oil
Arachidonic	20	4	20:4	peanut oil, fish oil

Functions/Role/Significance Of Fatty Acids/PUFAS

1.Secondary Source Of Energy

- Fatty acids/PUFAs are **essential components** of different forms of **simple** and **compound lipids**.
- Fatty acids are **highly reduced compounds.**
- **Oxidation of FAs** in the body provide **secondary source of energy** (ATP).

2.Components Of Biomembranes

- PUFAs are **component of Phospholipids.**
- Since the second Fatty acid in Phospholipid is mostly **PUFA.**
- **PUFAs** are important **constituents of biomembranes** of **every body cell and cell organelles.**

- PUFAs of membrane play role in:(Less compact)
  - **Membrane fluidity**
  - **Selective permeability**

3.PUFAs Lower Blood Cholesterol Levels

- **Essential Fatty acids lower** the serum levels of **Cholesterol.**
- By **esterifying Cholesterol**.
- **Cholesterol ester** is later degraded and **excreted out through feces via bile**.

4.PUFA Precursor for Eicosanoid Biosynthesis

- **Arachidonic acid** (20 Carbon PUFA) is a **precursor for biosynthesis** of various **Eicosanoids.**

5.Structural Component Of Organs

- PUFAs has role in **Brain development and its functions.**
- Maintains the **viability of islet cells of Pancreas.**

- Essential fatty acids are **structural components of gonads.**
- Lionlenic acid **increases vision**.

- Essential fatty acids **prevents Fatty Liver.**
- By helping in formation of **Lipoproteins** and mobilizing out the Lipids from Liver.

- PUFAs **prevents early ageing.**
- EFAs **Prolongs Clotting time.**

6.PUFAs Protect Heart

- **Dietary PUFAs are easily metabolized in the body.**

- Since the **double bonds** are unstable and **easily cleavable**.
- PUFAs do **not get accumulated** in the blood arteries and capillaries.
- Thus PUFAs have **low risk of Atherosclerosis** and **Cardio vascular disorders.**

Deficiency Of PUFAs

- **Deficiency Of PUFAs is Rare.**
- **May be Suffered by:**
- **Infants :Not fed with natural milk and natural food items.**
- But fed with **formula diets** which have low fat content.
- **Adults** : Eating **poor diet** not containing PUFAs for long periods.

Phrynoderma /Toad Skin is due to PUFA deficiency.

- Phrynoderma /Toad Skin Symptoms
- The skin becomes dry with lesions (Scaly Dermatitis).
- Presence of horny erruptions on the posterior and lateral parts of limbs, back and Buttock.
- Loss of hair
- Poor wound healing

- Deficiency of Essential Fatty acids :
  - Affects every cell ,organ and system
- Growth retardation
- Problems with reproduction
- Skin lesions
- Kidney and Liver disorders
- Brain disorders/Behavioral disorders

Transportation Of Fatty Acids Through Blood Circulation

Fatty acids Transportation In body

- **More than 90%** of the fatty acids found in plasma are in the form of **Fatty acid esters.**
  - **Fatty acids are in bound form as:**
  - Triacylglycerol
  - Cholesteryl esters
  - Phospholipids

- Bound form of Fatty acids are **Transported through various** **Lipoproteins.**

- **Unesterified/Free Fatty acids** are very less amount in body.
- **FFA are transported i**n the blood circulation in **association with Albumin.**

Properties Of Fatty Acids

• Solubility Of Fatty acids:

- **Solubility** of Fatty acids depends upon
  - The **hydrocarbon chain length**
- Fatty acids with **small chain length are more soluble.**

- **Solubility of Fatty acids decreases**

- With **increase in Fatty acid hydrocarbon chain length.**

- **Acetic acid** most simplest fatty acid is **soluble in water.**

- Palmitic acid ,Stearic acid are **insoluble in water.**

- **Melting Point Of Fatty acids:**
- Melting point of a Fatty acid depends upon:
  - **Chain length** of FA
  - **Nature of bonds** in hydro carbon chain of FA.

- **Short and unsaturated** Fatty acids has **low melting point.**
- **Long and Saturated** Fatty acids are has **high melting point.**

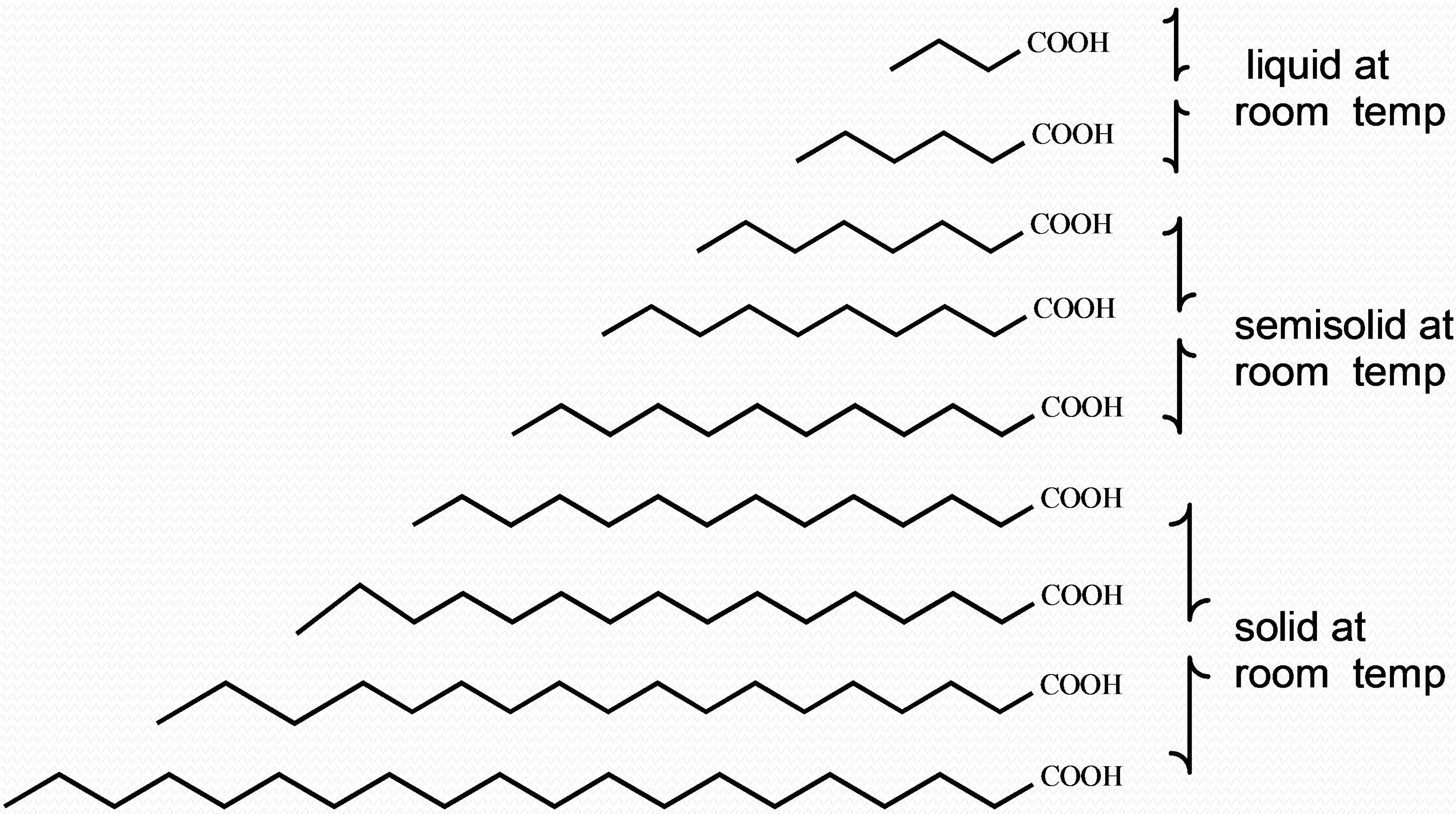
- Thus melting point of Fatty acids(FAs):
- Increases with increase in chain length of FAs.
- Decreases with decrease in chain length of FAs.

Melting Points

- Affected by chain length
- Longer chain = higher melting temp

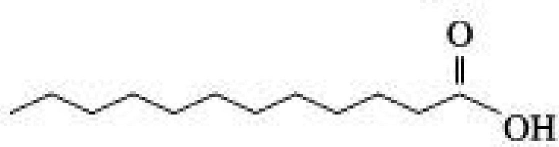
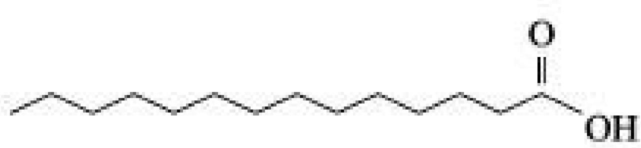
Fatty acid:	*C12:0*	*C14:0*	*C16:0*	*C18:0*	*C20:0*
Melting point:	*44°C*	*58°C*	*63°C*	*72°C*	*77°C*

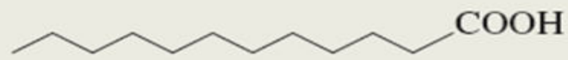
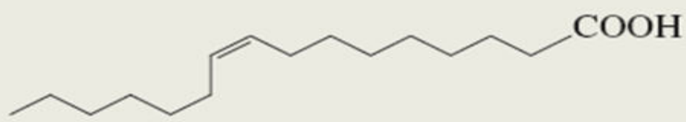
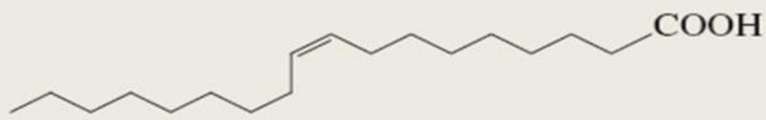
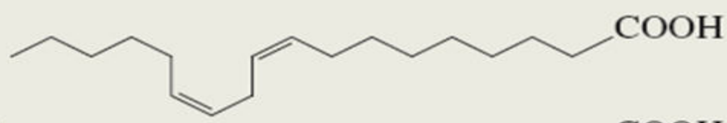
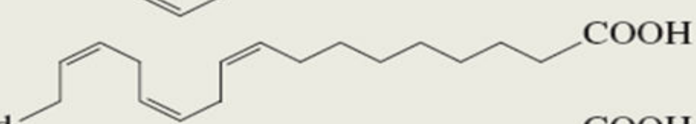
Fatty Acids



Structures and Melting Points of Saturated Fatty Acids

Table 18.1 Structures and Melting Points of Common Fatty Acids

Name	Carbon Atoms	Structure	Melting Point (°C)	Source
Saturated Fatty Acids				
Capric acid	10		32	Saw palmetto
Lauric acid	12		43	Coconut
Myristic acid	14		54	Nutmeg
Palmitic acid	16		62	Palm
Stearic acid	18		69	Animal fat
Arachidic acid	20		76	Peanut oil, vegetable and fish oils

Number of carbons	Common name	Systematic name	Structure	Melting point °C
Saturated				
12	lauric acid	dodecanoic acid		44
14	myristic acid	tetradecanoic acid		58
16	palmitic acid	hexadecanoic acid		63
18	stearic acid	octadecanoic acid		69
20	arachidic acid	eicosanoic acid		77
Unsaturated				
16	palmitoleic acid	(9Z)-hexadecenoic acid		0
18	oleic acid	(9Z)-octadecenoic acid		13
18	linoleic acid	(9Z,12Z)-octadecadienoic acid		−5
18	linolenic acid	(9Z,12Z,15Z)-octadecatrienoic acid		−11
20	arachidonic acid	(5Z,8Z,11Z,14Z)-eicosatetraenoic acid		−50
20	EPA	(5Z,8Z,11Z,14Z,17Z)-eicosapentaenoic acid		−50

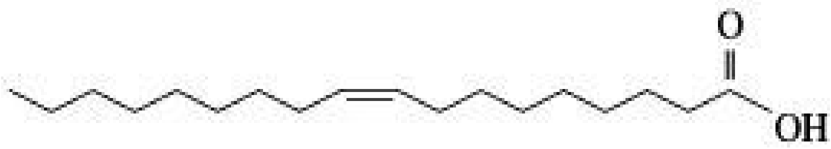
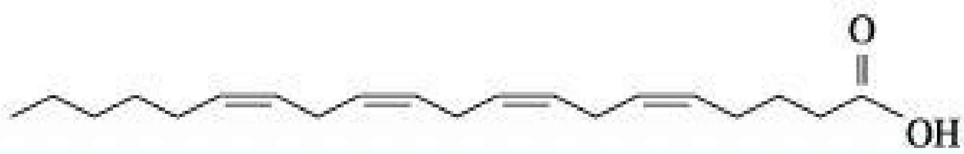
Melting Points

- Affected by number of double bonds
  - More saturated = higher melting temp

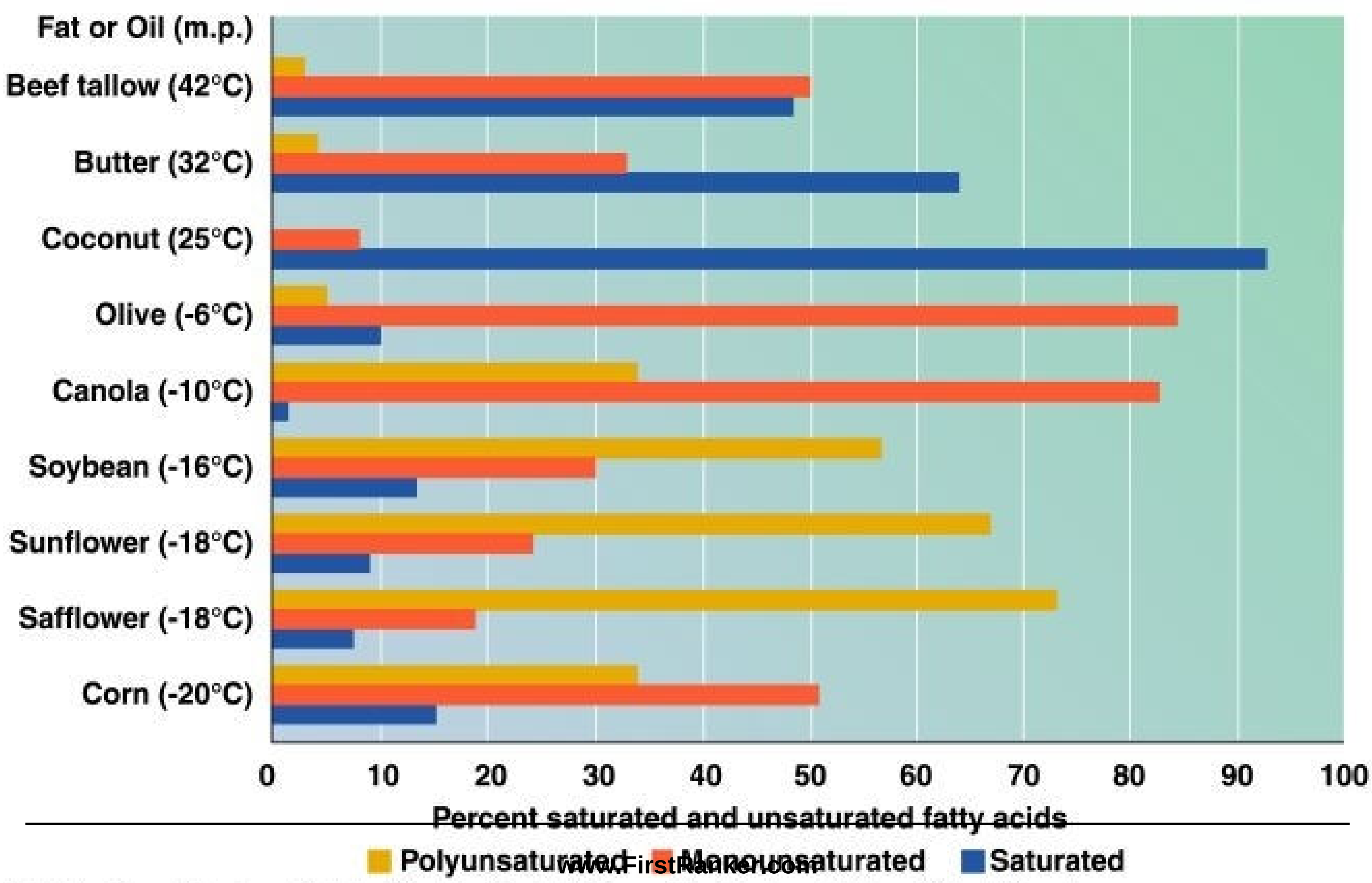
Fatty acid:	***C18:0***	***C18:1***	***C18:2***	***C18:3***
Melting point:	***72°C***	***16°C***	***–5°C***	***–11°C***

Structures and Melting Points of Unsaturated Fatty Acids

Table 18.1 Structures and Melting Points of Common Fatty Acids *(Continued)*

Name	Carbon Atoms	Structure	Melting Point (°C)	Source
Monounsaturated Fatty Acids				
Palmitoleic acid	16		0	Butter
Oleic acid	18		13	Olives, corn
Polyunsaturated Fatty Acids				
Linoleic acid	18		−9	Soybean, safflower, sunflower
Linolenic acid	18		−17	Corn
Arachidonic acid	20		−50	Prostaglandins

Melting Point and Fatty Acid Composition of Some Fats and Oils



Timberlake, *General, Organic, and Biological Chemistry*. Copyright © Pearson Education Inc., publishing as Benjamin Cummings

- **Saturated Fatty acids** has straight and extended conformation which can be **packed into compact structure.**
- **More heat energy** is required to **remove the compact** structures of Saturated Fats.

- **Unsaturated fatty acids** has **rigid bends** in its structure hence **not packed compactly.**

- **Less heat** energy is required to separate these **less compact** Unsaturated fatty acids.

- **Membrane Lipids** are fluid by consistency as they are more composed of **unsaturated fatty acids.**
- **Storage Lipids** which are anhydrous has **Long saturated Fatty acids.**

Significance Of -COOH group Of Fatty Acids

Saponification /Salt Formation

- The Carboxyl groups of Fatty acids **reacts with strong Alkalies KOH/NaOH**
- To form their Salts which are **Soaps**.
- This property is used for **commercial manufacture of Soaps.**

Ester Formation

- The Carboxyl group of Fatty acids **reacts with Hydroxyl groups of Alcohols** Glycerol/Sphingosine)
- To form Esters bonds, of Simple and Compound Lipids.

- Fatty acids get esterified with Alcohols to form various simple and compound Lipids:
  - **Triacylglycerol**
  - **Waxes: Cholesterol ester**
  - **Phospholipids**
  - **Glycolipids**
  - **Lipoproteins**

Hydrogenation Of Fatty Acids

- Hydrogenation of Fatty acids is a **conversion of**
- **Double bonds of a unsaturated fatty acid to single saturated bonds**.

- Thus process of Hydrogenation transforms **Unsaturated Fatty acids** to **Saturated Fatty acids.**

- The process of **Hydrogenation** also **transforms** naturally occurring **Cis Fatty acids to Trans Fatty acids.**

Halogenation Of Fatty acids

- Adding Halogens like Cl, Br or I at double bonds of UFAs and making saturated.

- The number of Halogen atom taken up are dependent on the **number of double bonds in the structure of Fatty Acid.**

Significance Of Halogenation

- Halogenation of fatty acids is an **index of assessing the degree of unsaturation**

- **Iodine Number** is a process of **Halogenation** which checks the **content of SFA and PUFAs** of Fats and Oils.
- **SFA** has **zero Iodine number.**
- PUFAs has **high Iodine number.**

Geometric Isomerism Of Unsaturated Fatty acids

- Depending on orientation of atoms or groups around the axis of double bonds.
  - **Cis form of Fatty acids**
  - **Trans form of Fatty acids**

Cis Form Fatty acids

- Most **naturally occurring UFAs** are of **cis form.**
- The **groups around double bond are on same side.**

- **All Cis** FA has an **angle of 120 degree at the double bond**.
- Cis forms are **L shaped** structures

(due to bend /kink in structure).

- Phospholipids of biological **membranes contain Cis form of fatty acids** which has kinks/bents .
- **This prevent compact packing** of fatty acid chains and are responsible for the **fluidity of membranes.**

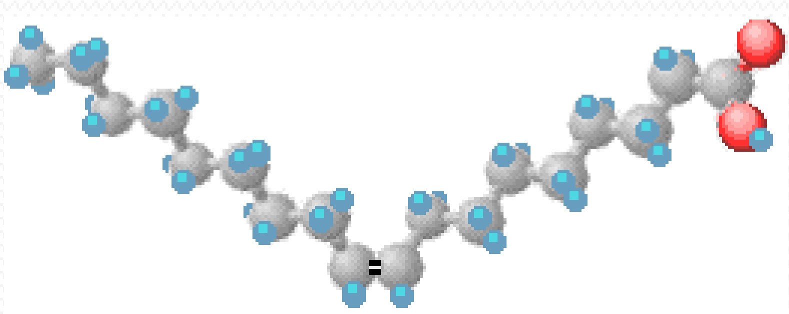
All-Cis Fatty acids Good for Health

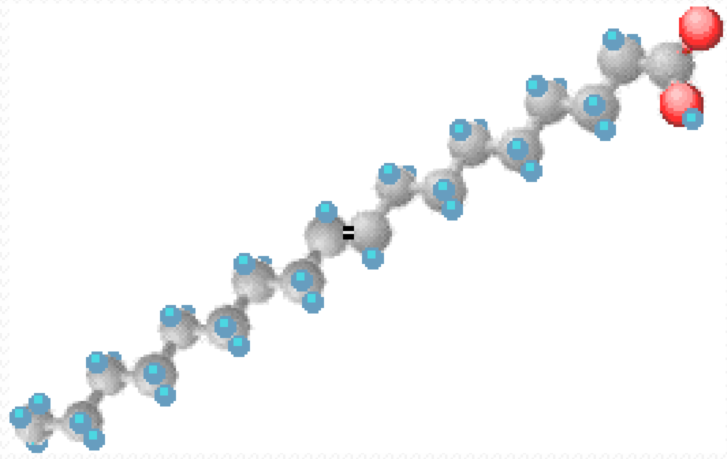
- Human body **contain Enzyme system** to **metabolize Cis form** of Fatty acids.
- Cis forms when ingested through food are easily metabolized and does not retain in the body.
- Hence good for health and **no risk of Atherosclerosis and CVD.**
- **All Cis form of fatty acids are unstable and easily metabolizable.**

Trans Form Of Fatty acids

- Trans fatty acid **structures are straight** and **has no bend.**
- The **groups around the double bonds** are on **opposite sides**.
- **Trans form of fatty acids are stable and less metabolizable.**

- Named According to Location of H's
  - *Cis* or *trans* fatty acids

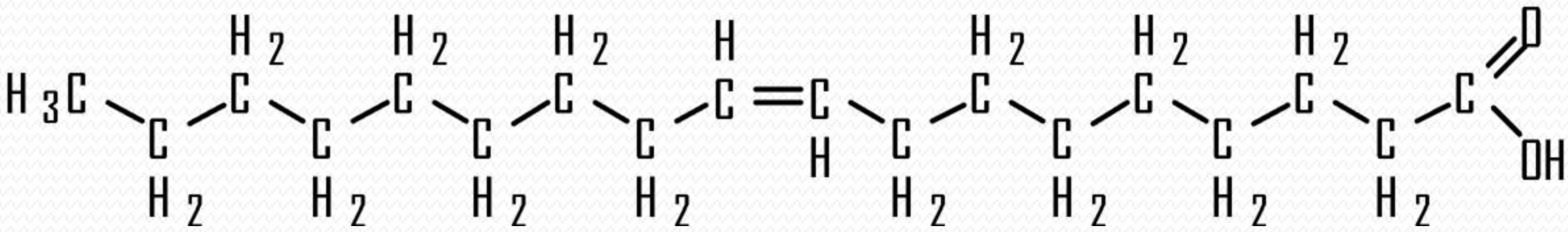


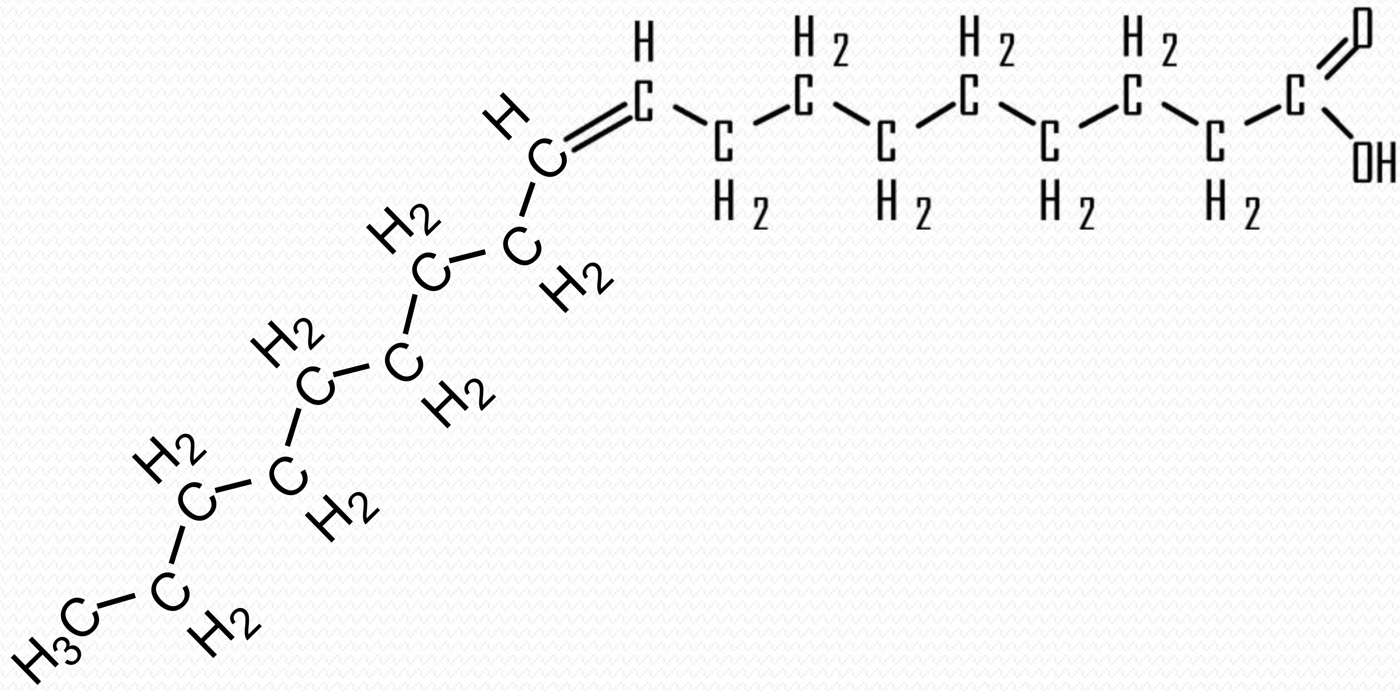


***Cis*-9-octadecenoic acid (Oleic acid)**

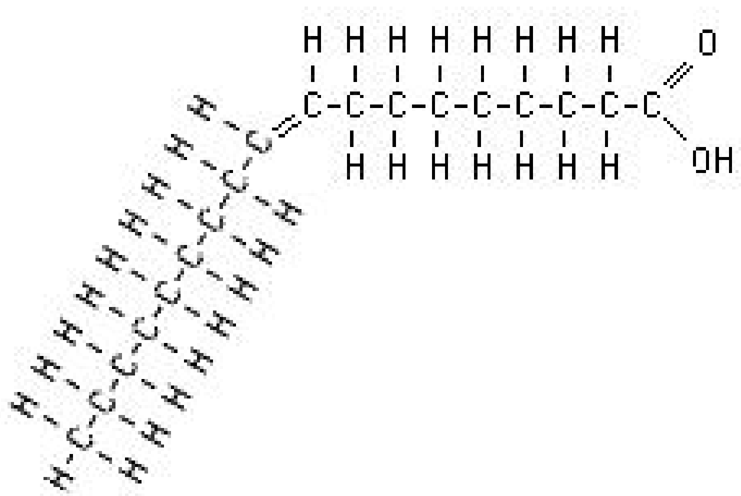
***Trans*-9-octadecenoic acid (Elaidic acid)**

Cis and Trans Fatty Acids

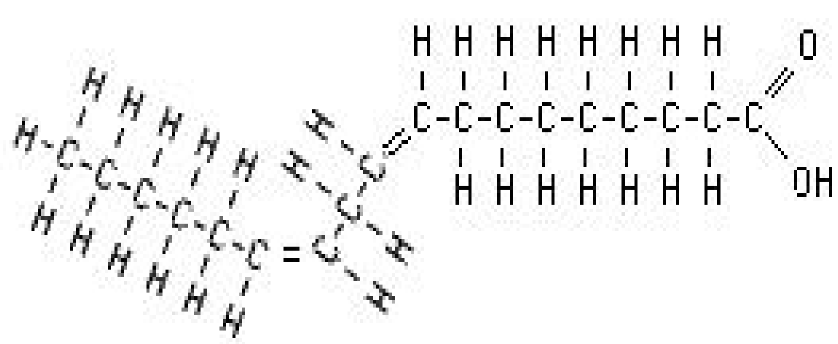




Cis Fatty Acids



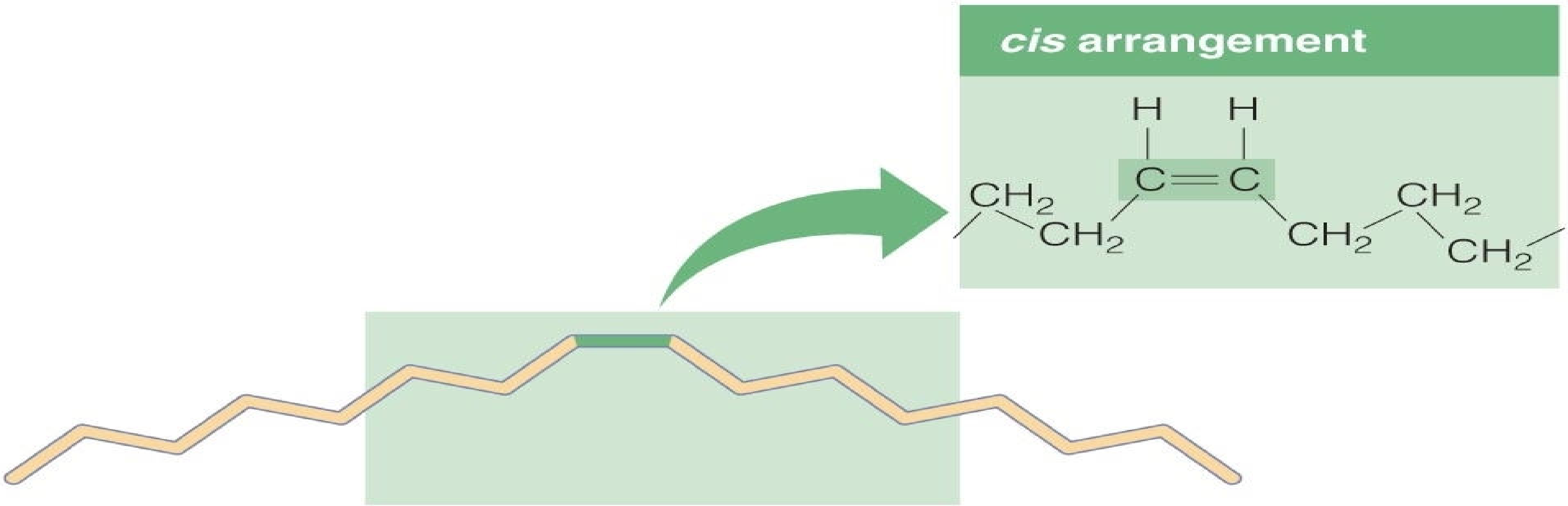
Oleic acid, a monounsaturated fatty acid. Note that the double bond is *cis*; this is the common natural configuration.



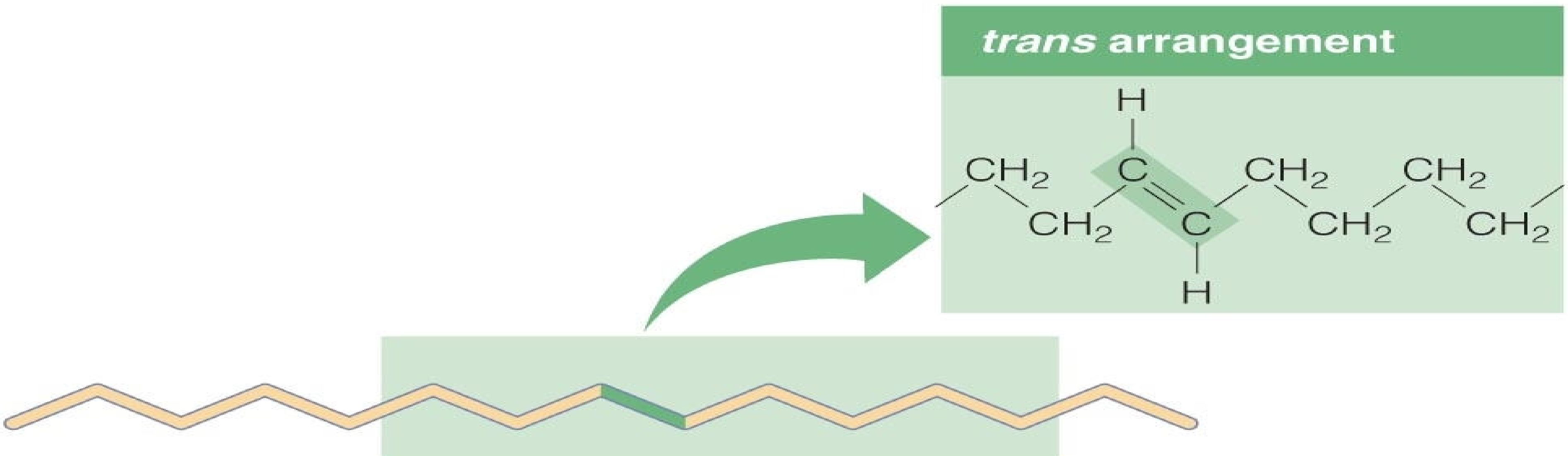
Linoleic acid, a polyunsaturated fatty acid. Both double bonds are *cis*.

- **Trans form of Fatty acids**
  - **Less occur in natural foods**.
  - **Obtained as byproducts of Hydrogenation of oils.**

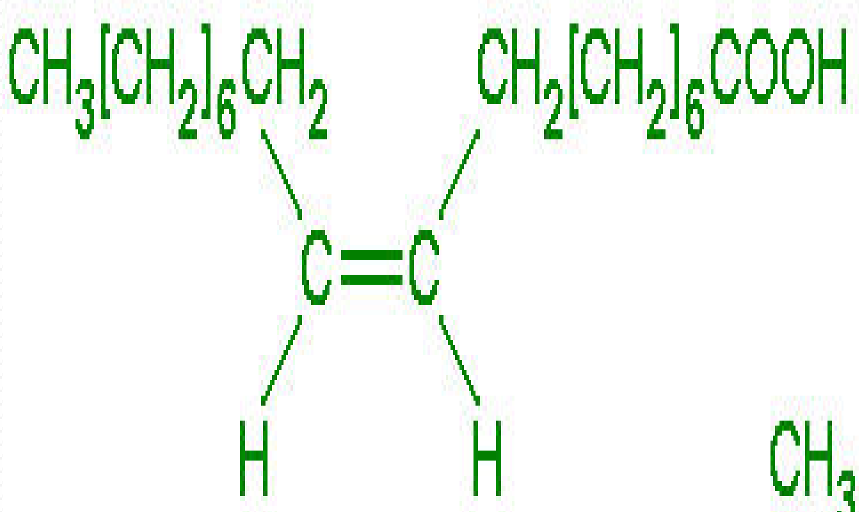
- More content of **Trans Fatty acids** are found in **processed foods** viz:
  - **Hydrogenated Oils (Vanaspati Dalda)**
  - **Ghee**
  - **Margarine**
  - **Bakery products /Fast foods**
  - **Deeply Fried recipes in Oils which are prepared in repeatedly heated oils.**



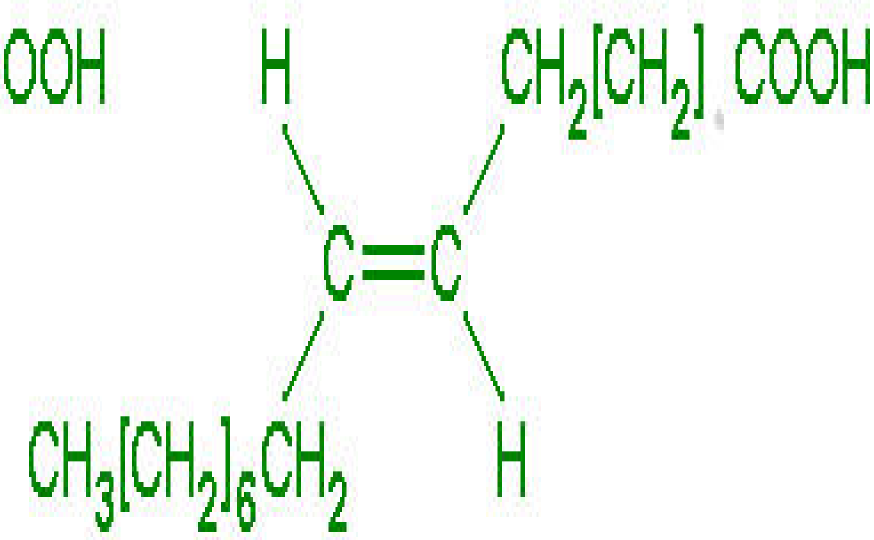
(a) *cis* polyunsaturated fatty acid



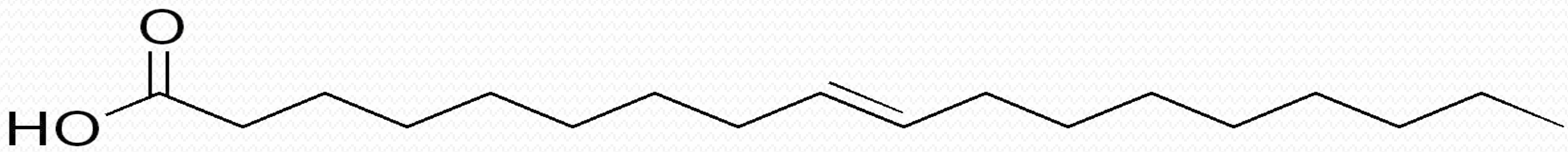
(b) *trans* polyunsaturated fatty acid



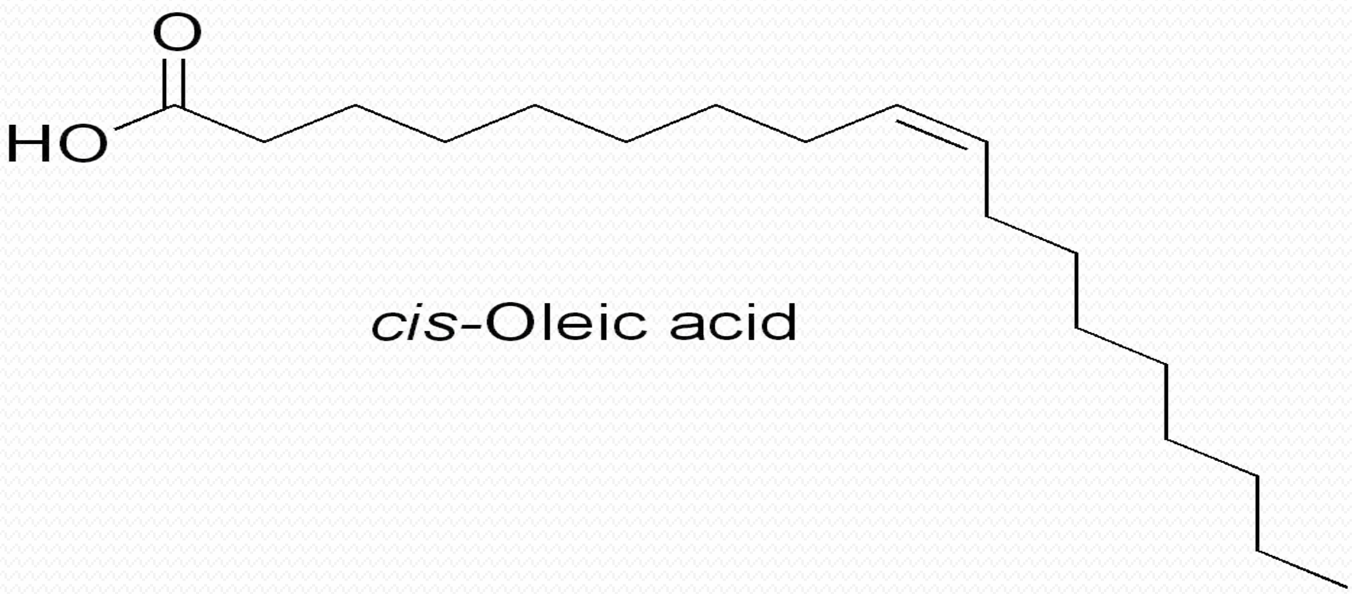
Oleic acid



Elaidic acid



trans-Oleic acid



cis-Oleic acid

Trans Fatty Acids Detrimental to Health

Trans Fatty Acids Not Metabolized Easily

- Human body has **no Enzyme system to metabolize the Trans Fatty acids**.
- Foods ingested with rich concentration of **Trans fatty acids** do **not get metabolized**.
- Trans fatty acids **get retained in body tissues**, blood vessels(harden the blood vessels).
- They **increases risk of Atherosclerosis**.
- **Block or reduce the blood supply to tissues**.

- **Trans fatty acids increases risk of :**
  - **Atherosclerosis**
  - **Cardio Vascular disorders:**
    - **Ischemia**
    - **Myocardial Infarction**
  - **Stroke(Brain attack)**

Study Of Derived Lipids Alcohols

Alcohols Involved In Lipid Structures

3 Alcohols Involved In Lipids

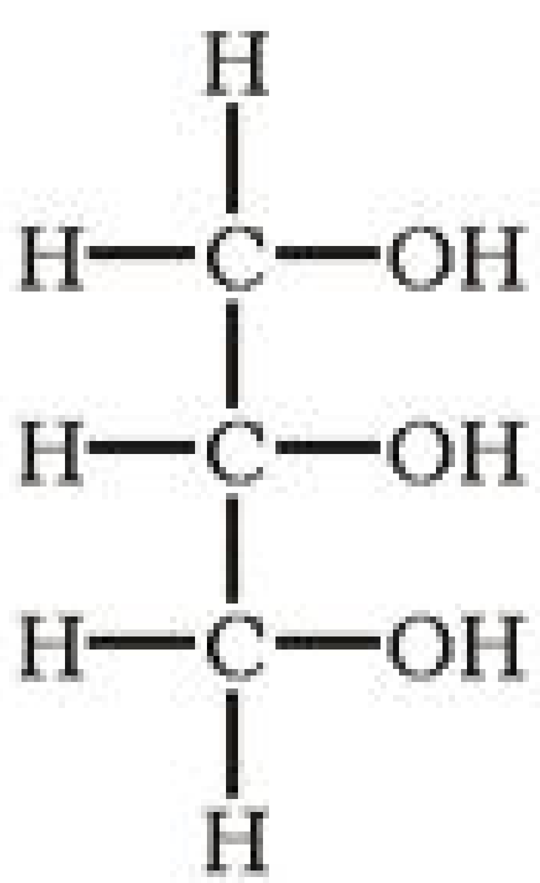
1. Glycerol
   (C_3-Trihydric Alcohol)
2. Sphingol/Sphingosine
   (C_{18}-Dihydric Alcohol)
3. Cholesterol
   (C_{27}-Monohydric Alcohol)

Alcohols Of Lipids Are Classified As Derived Lipids

Glycerol/ Glycerin

- Glycerol [C3]is a **POLYOL**
- Glycerol is chemically **Trihydric Alcohol** (3 –OH groups)
- In human body **Glyceraldehyde on reduction gives Glycerol.**

Figure 1. Structure of Glycerol



- Glycerol is a **backbone of Glycerol based Lipids** viz:
  - **Triacylglycerol**
  - **Glycerophospholipids**

Glycerol is a Derived Lipid

Obtained from Hydrolysis of Simple and Compound Lipids

SPHINGOSINE/SPHINGOL

- Sphingosine is a **C18, complex Dihydric, Amino alcohol**.

- **Serine** provides **NH2 group** of Sphingosine.

Sphingolipids

Sphingosine

$$CH_3(CH_2)_{12}CH{=}CH{-}CH{-}OH$$

$$\qquad\qquad\qquad\qquad\qquad\quad |$$

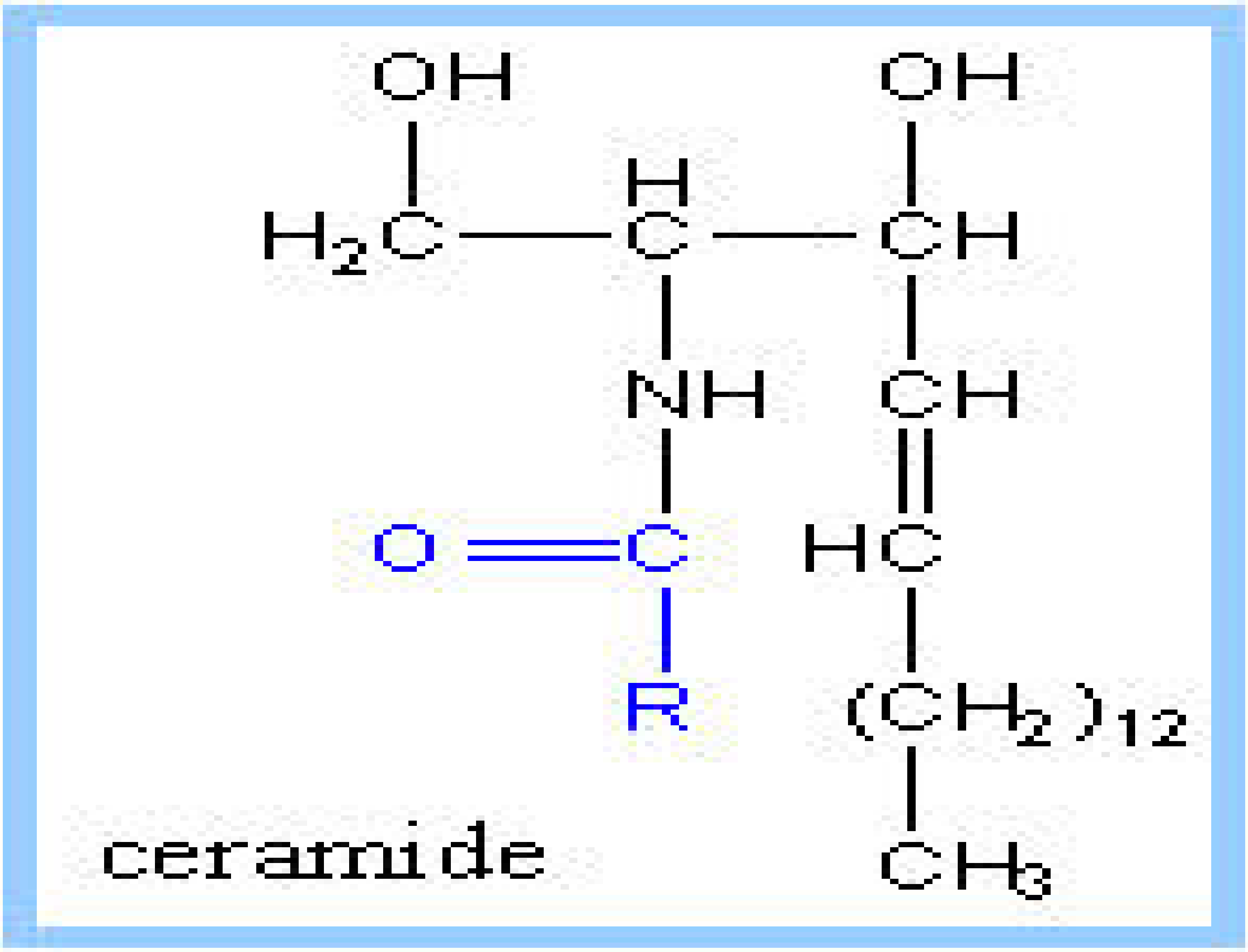
$$\qquad\qquad\qquad\qquad\qquad\quad CH{-}NH_2$$

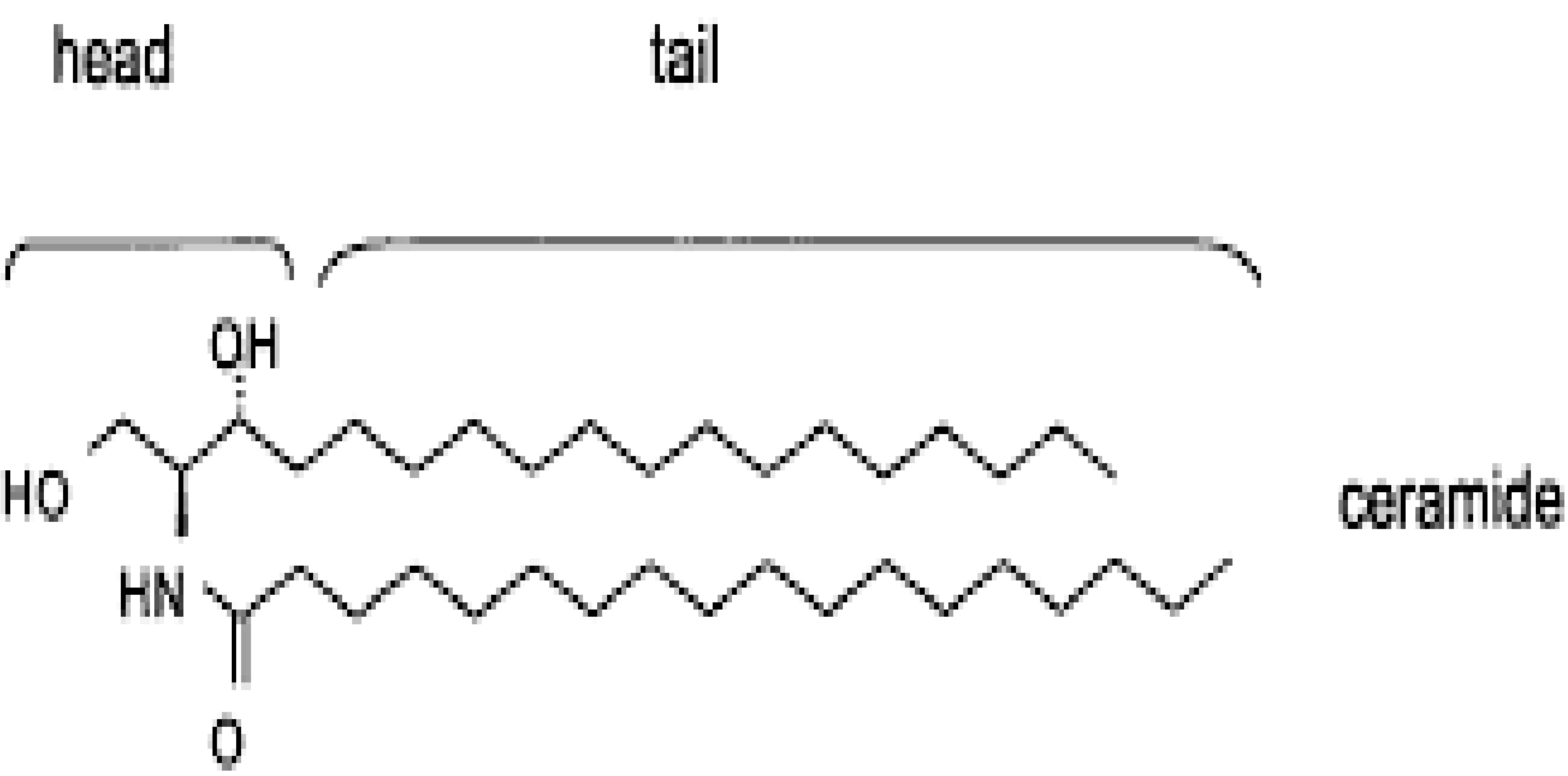
$$\qquad\qquad\qquad\qquad\qquad\quad |$$

$$\qquad\qquad\qquad\qquad\qquad\quad CH_2{-}OH$$

What Is a Ceramide?

- A Fatty acid linked to an **amino group** of Sphingosine
- With an **amide linkage** form a **Ceramide.**


OH
OH
H
H_2C
C
CH
NH
CH
O
C
HC
R
$(CH_2)_{12}$
ceramide
CH_3

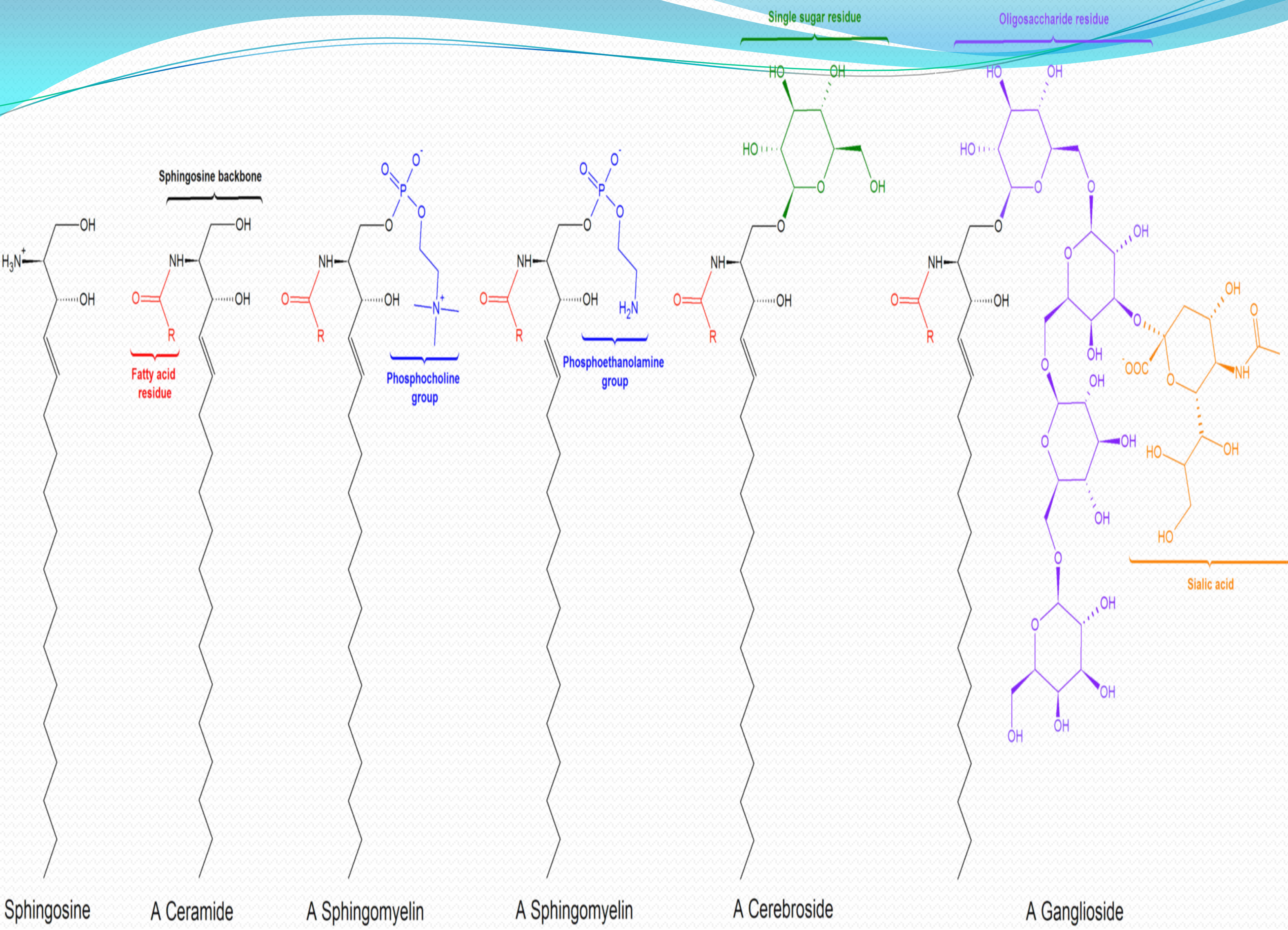

head
tail
OH
HO
HN
O
ceramide

- **Ceramide** if linked to **Phosphate and Nitrogenous** groups forms **Sphingophospholipids.**

- **Ceramide** linked to **Carbohydrate moieties** form **Glycolipids.**

- **Sphingosine forms Sphingolipids /Compound Lipids with Alcohol Sphingol**

- **Examples of Sphingolipids**:
  - **Sphingophospholipids**
  - **Glycolipids**



- **Sphingosine** is a **derived Lipid**.
- **Obtained from Hydrolysis of Sphingolipids**

Sterols

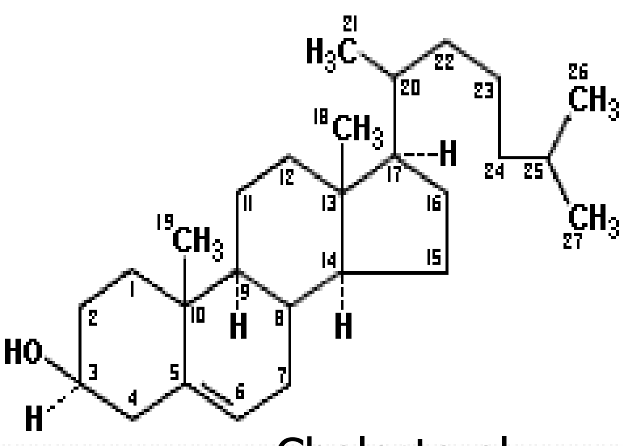
- **Sterols are chemically complex, cyclic ring structures.**
- Sterols are complex **organic monohydric Alcohols.**

Examples Of Sterols

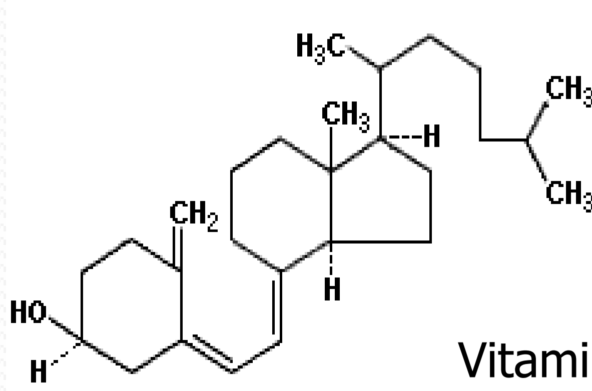
- **Cholesterol** (Animal Sterol)
- **7 Dehydrocholesterol**(Provitamin D)
- **Ergosterol** (Plant Sterol)
- **Sitosterol** (Plant Sterol)
- **Coprosterol** (Excretory form of Cholesterol)

- Sterols have **a parent ring**
- **Cyclo Pentano Perhydro Phenantherene** (CPPP) nucleus.

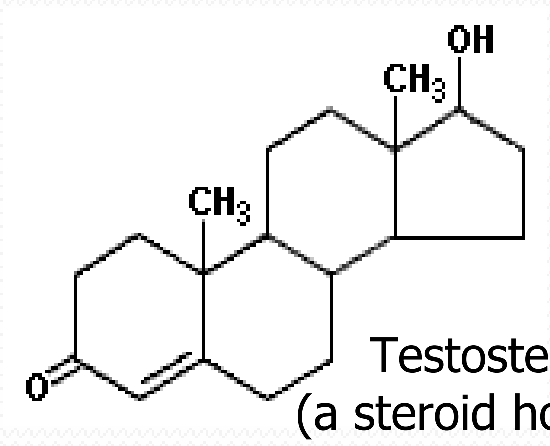
Common Sterol Compounds



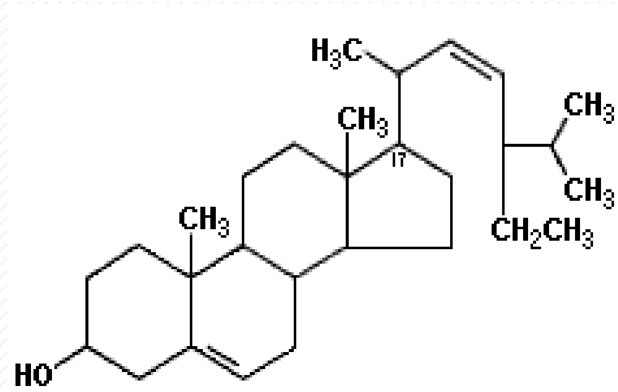
Cholesterol
(a sterol)



Vitamin D3
(cholecalciferol)



Testosterone
(a steroid hormone)



Stigmasterol
(a phytosterol)

Cholesterol A Derived Lipid

- Cholesterol is classified as **Derived Lipid.**

- It is **derived** from **Cholesterol Ester (Wax).**

Cholesterol

- Cholesterol is an **Animal Sterol .**

- Cholesterol means **Solid Alcohol** as it was first obtained from gall stones of bile.

- Cholesterol is **richly composed in Gall stones.**

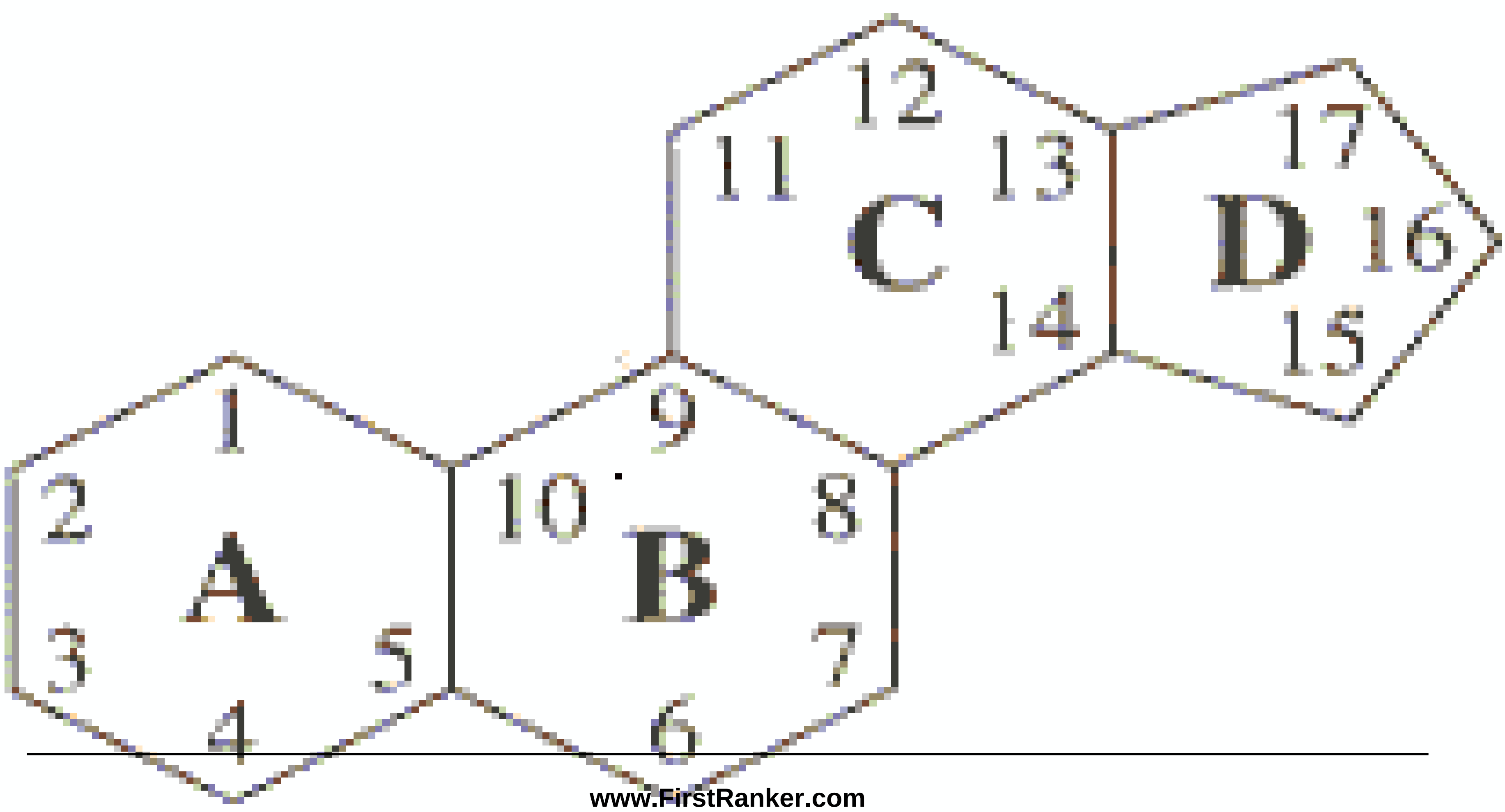
Structure Of Cholesterol

- Cholesterol is complex cyclic unsaturated, **monohydric Alcohol.**
- Its molecular formula is **$C_{27}H_{45}$ OH.**

- Cholesterol has parent nucleus as **Cyclo Pentano Per hydro Phenantherene ring** system(CPPP).
- The structure of CPPP has **four fused cyclic rings** (A,B,C and D)

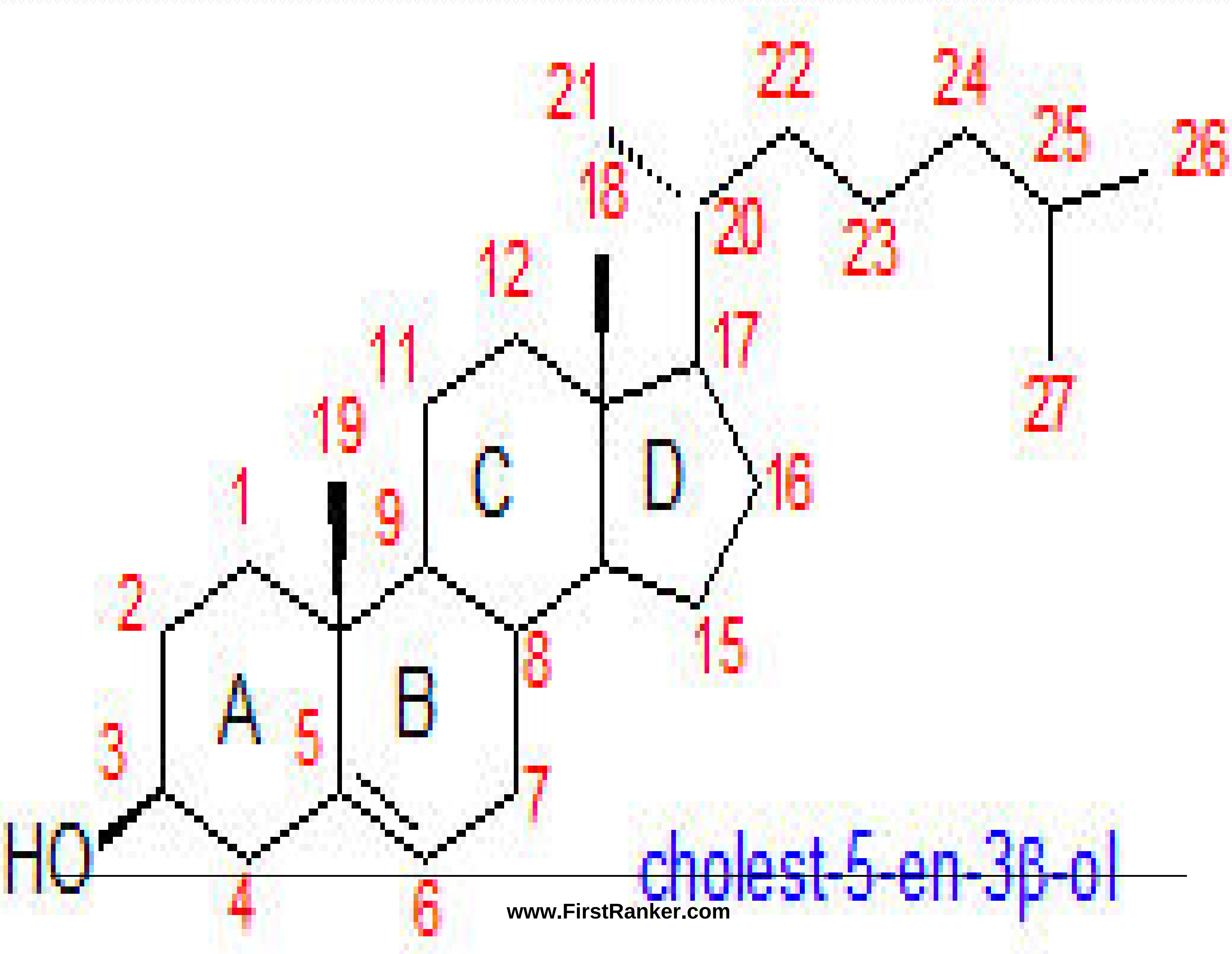
- Hexane ring **A,B,C** is a **Phenatrene** nucleus.
- **D** ring is **Cyclopentane** ring.

Pentahydrophenantrene (sterane)

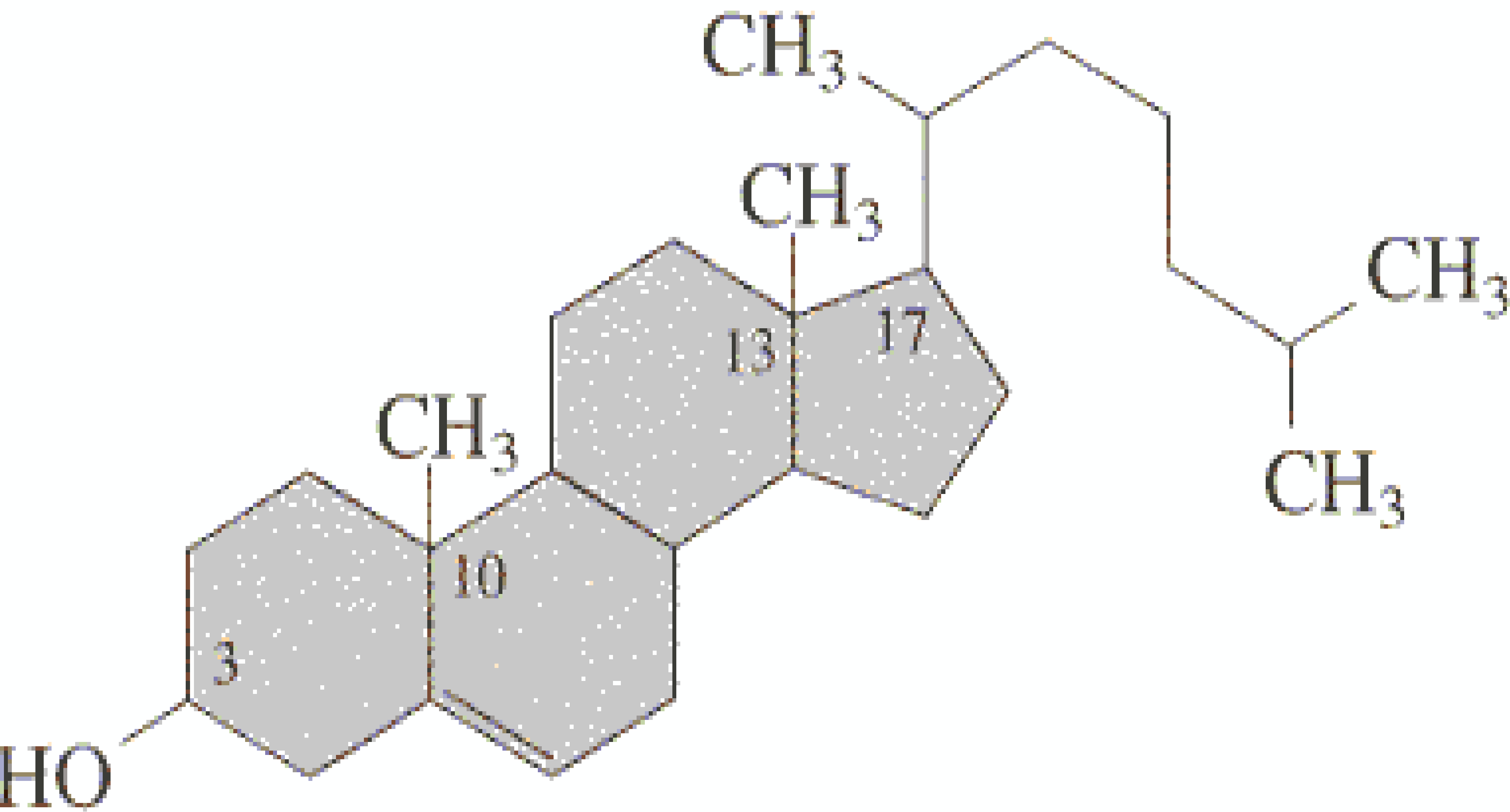


- **The Structure of Cholesterol Possess:**

1. **Hydroxyl group** (-OH) at C3.
2. **Double bond** between C5 and C6.
3. **5 Methyl** (-CH3) groups.
4. A **8 Carbon side chain** linked to C17 of the structure.



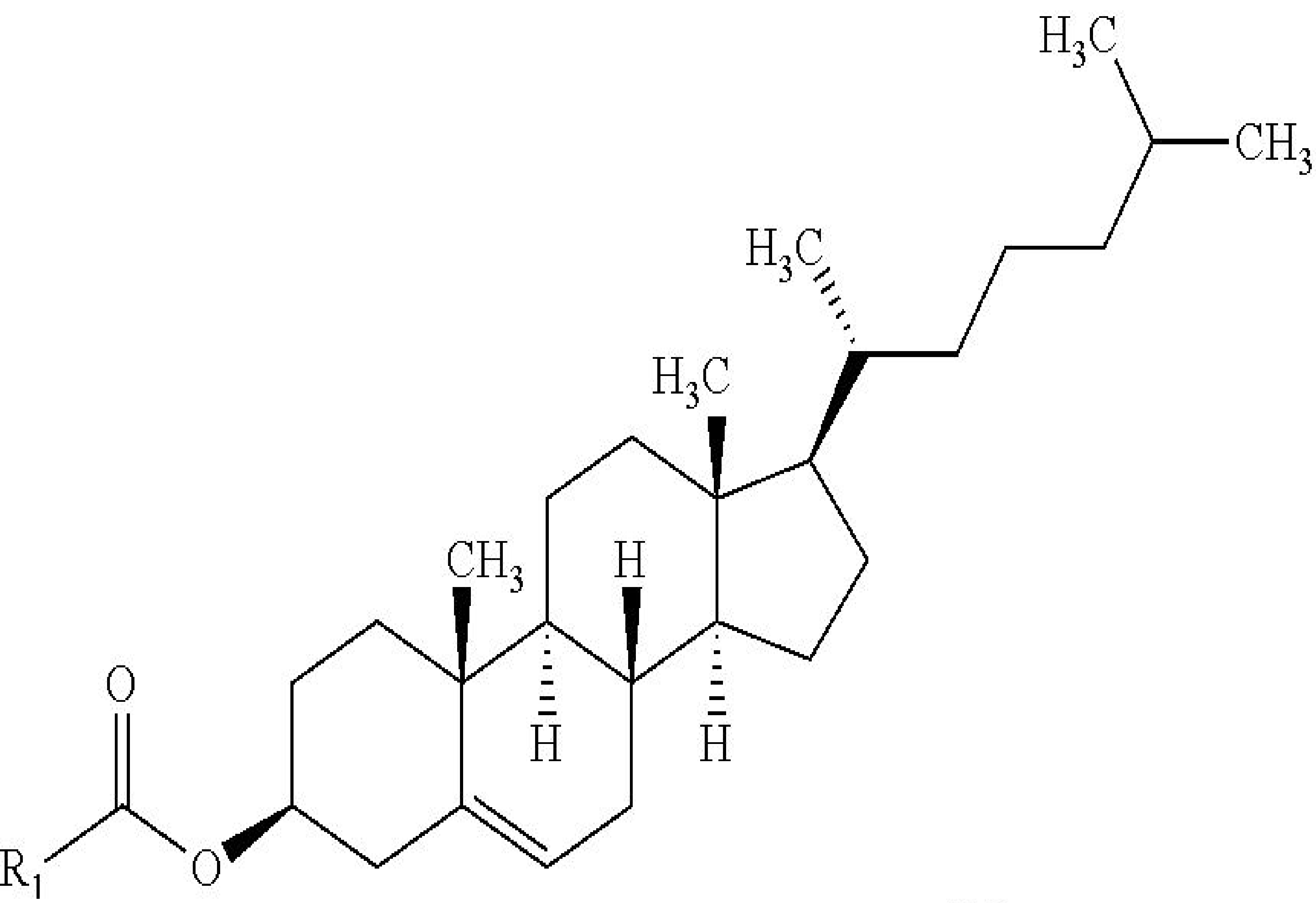
Cholesterol is the Most abundant Sterol of Human body

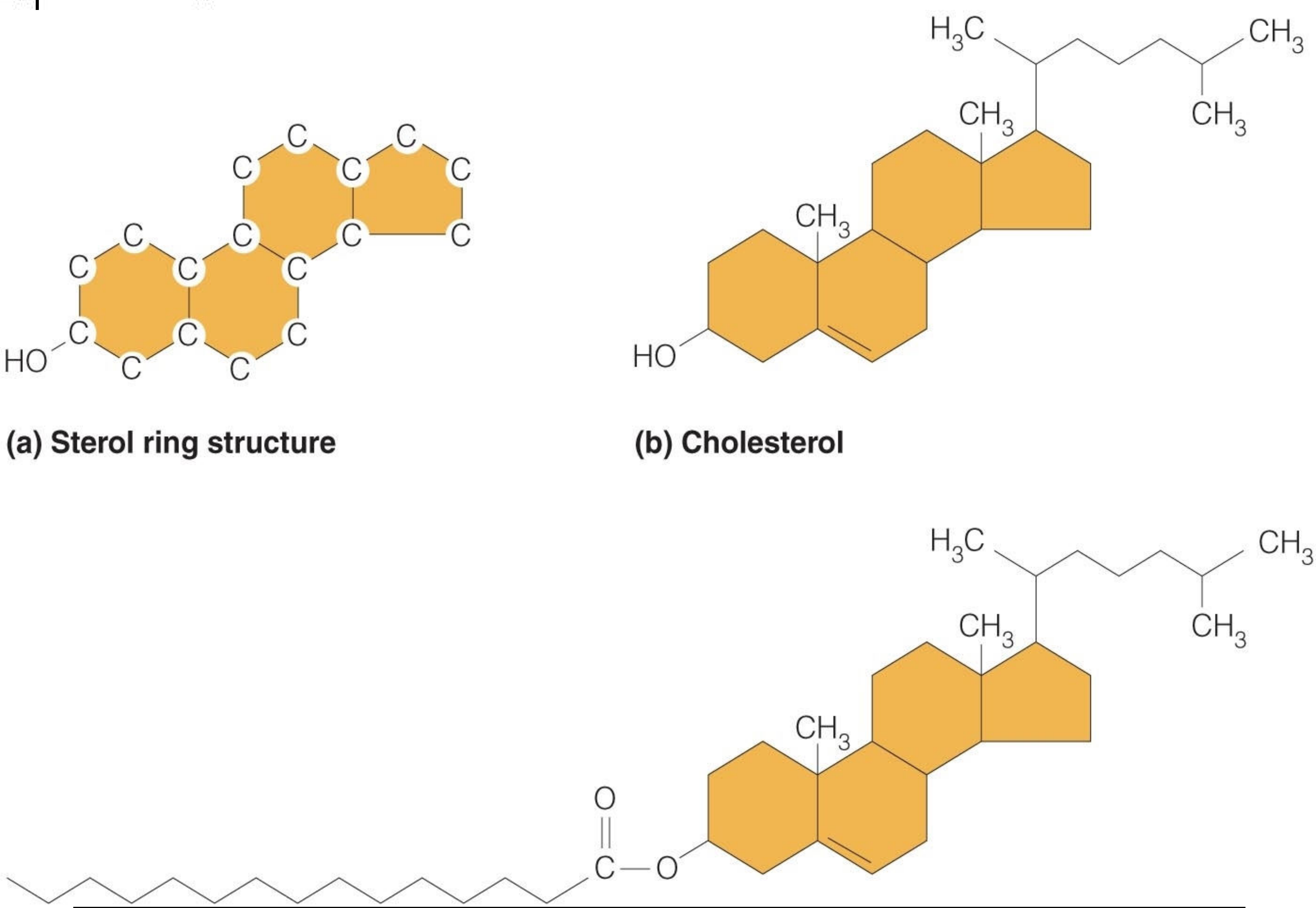


Forms Of Cholesterol

- Cholesterol exists in two forms:
  - **Free Cholesterol - 30%** (Amphipathic form)
  - **Cholesterol Ester - 70%** (Non polar form)

Formula I

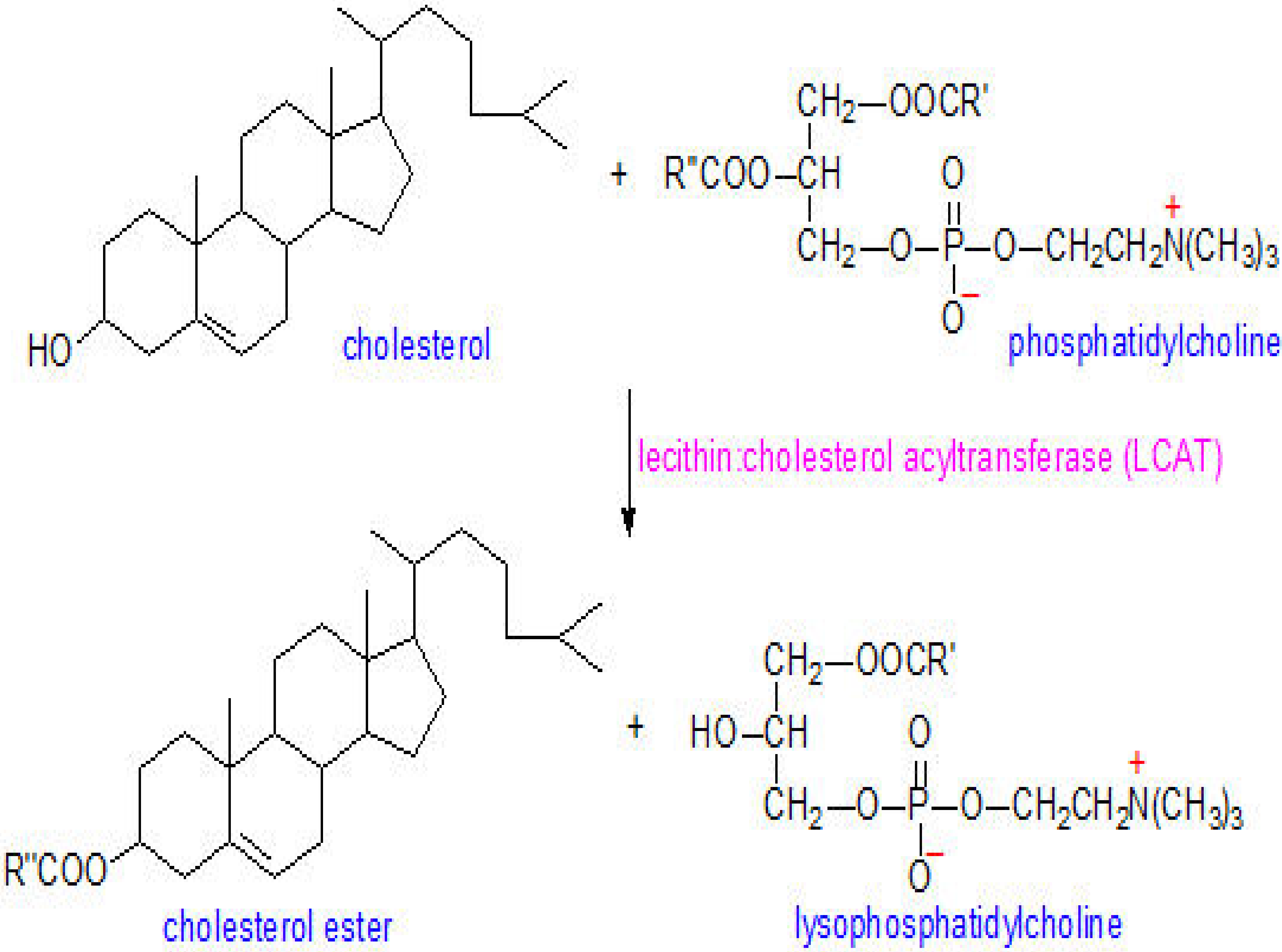


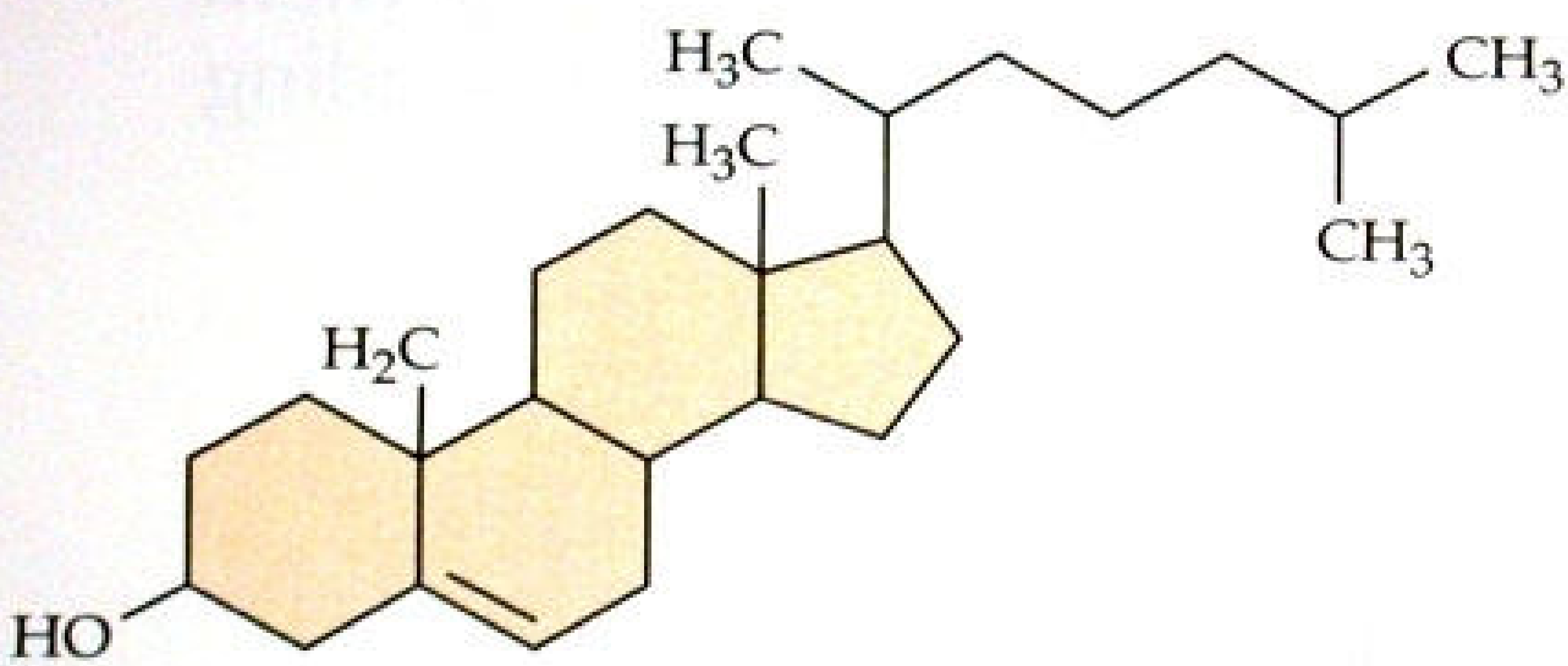


(a) Sterol ring structure

(b) Cholesterol

(c) Cholesterol ester

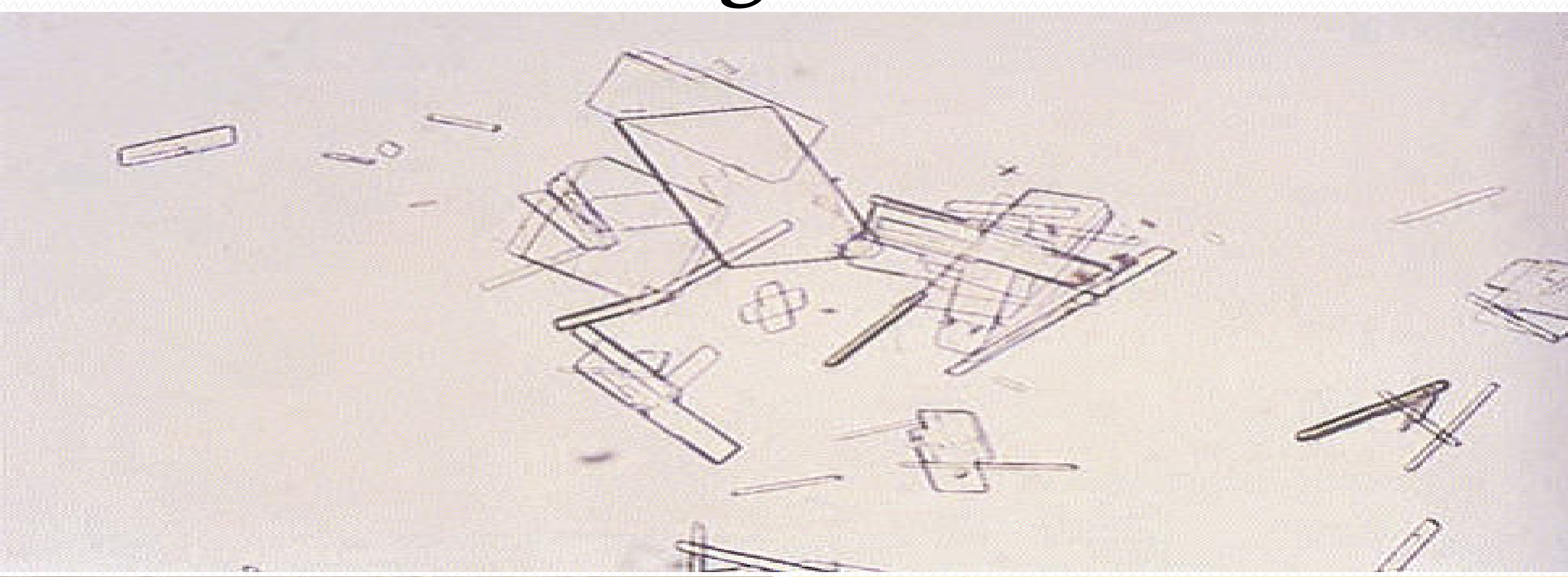


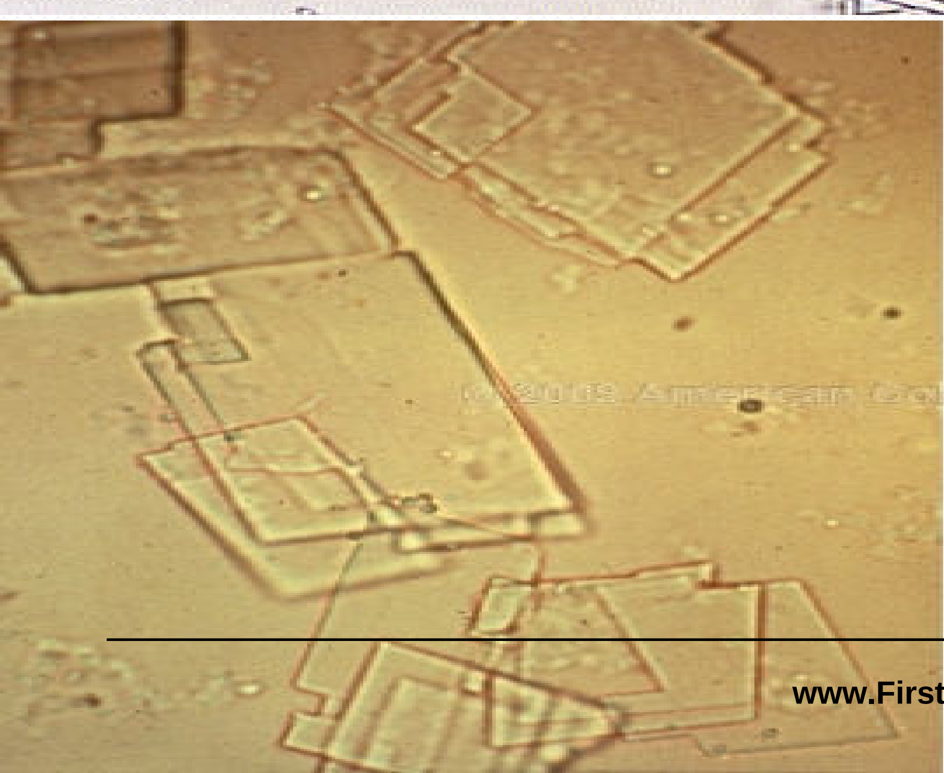


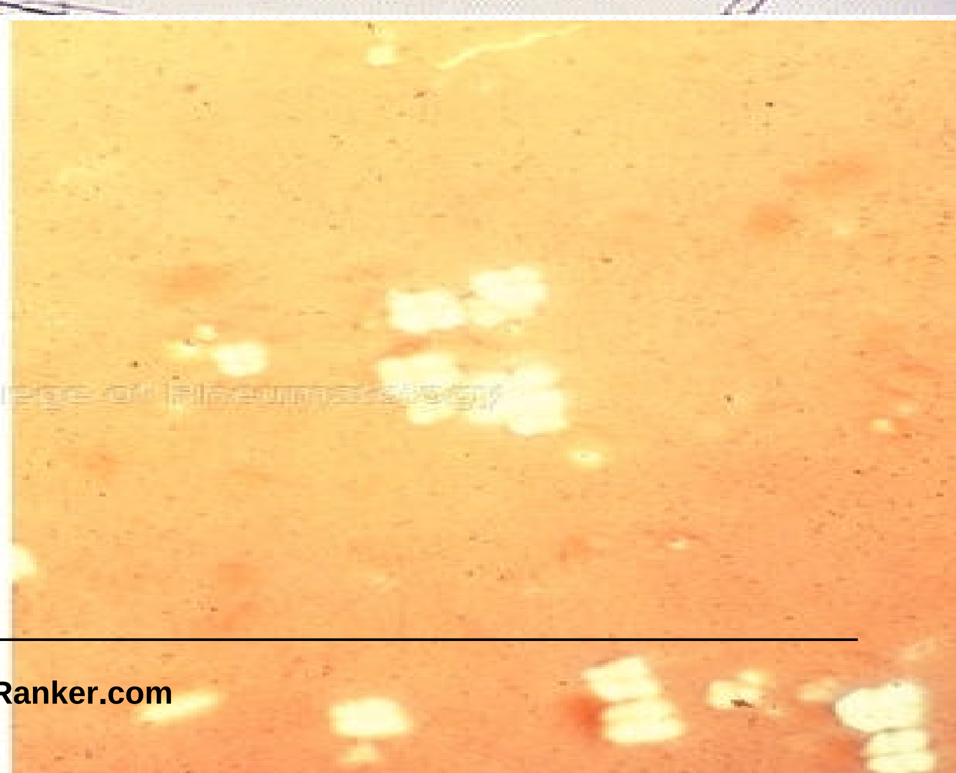
Cholesterol is a constituent of membranes and the source of steroid hormones.

Properties Of Cholesterol

- Cholesterol is **white or pale yellowish, crystalline ,odorless compound.**
- **Insoluble in water and soluble in organic solvents** like **Ether and Chloroform.**
- It forms crystal of **rhombic plates** with **notched edges**.







- **Qualitative Tests Of Cholesterol detection are:**
  - Liebermann Burchard Reaction
  - Salkowski Reaction
  - Zak's Reaction

Sources Of Cholesterol To Human Body

- **Exogenous Sources of Cholesterol:**
  - **Animal Origin Food Items**
- **Endogenous Source Of Cholesterol:**
  - Obtained In **well fed condition from Excess Glucose**

Dietary Sources Of Cholesterol

- Cholesterol is exclusively present in animal body hence it is an **animal sterol.**

- The dietary rich sources of Cholesterol are **animal origin foods** like:
  - **Egg Yolk**
  - **Meat**
  - **Milk**
  - **Butter**
  - **Cream**

- Remember **Cholesterol** is **absent in plant origin food items.**

Occurrence and Distribution Of Cholesterol in the Body

- Cholesterol is richly present in **Nervous tissue Brain.**
- Other organs containing Cholesterol are:
  - **Intestinal Mucosal cells**
  - **Skin**
  - **Liver**
  - **Adrenal Cortex**
  - **Gonads**

- 70 % of Cholesterol associated with cellular components
- 30 % of Cholesterol is in the plasma.

Transportation Of Cholesterol

- **Cholesterol in blood is transported by :**
- **HDL and LDL**

Functions Of Cholesterol

- Cholesterol is the **constituent of biomembranes of the cell and has structural importance.**

- Cholesterol richly **present in nervous tissue and covers Myelin sheaths.**

- Cholesterol helps in nerve impulse transmission since:
  - **It has high dielectric constant.**
  - **It is a poor conductor of heat and electricity.**

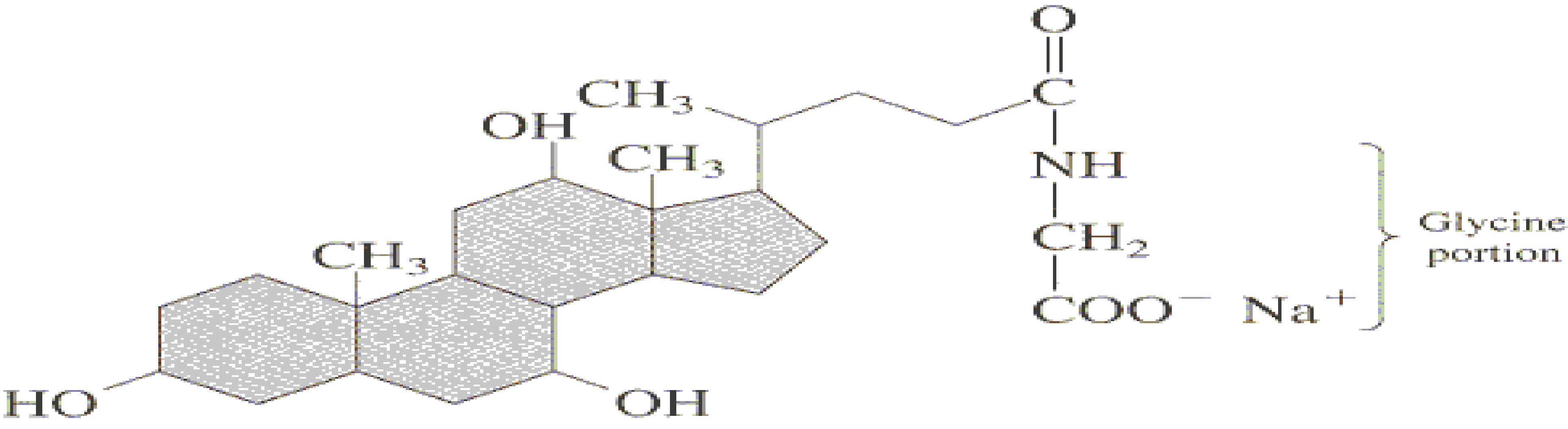
Cholesterol Serve Precursor for Biosynthesis Of Many Steroids

Steroids

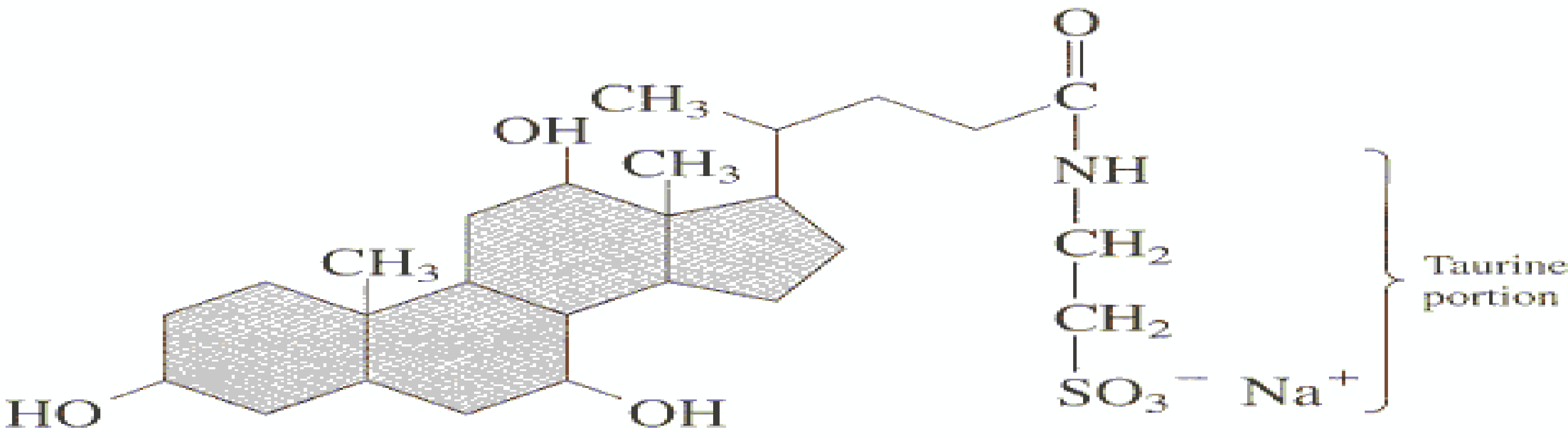
- Steroids are **derivatives of Sterols.**
- Chemical **Compounds obtained from Cholesterol** are termed as **Steroidal compounds.**

- **Examples of Steroidal Compounds**
- **Vitamin D** (Cholecalciferol)
- **Bile acids** (Cholic and Chenodeoxycholic acid)
- **Bile Salts** are obtained from Bile acids.
- **Steroidal Hormones**
  - **ACTH**
  - **Mineralocorticoids**
  - **Glucocorticoids**
  - **Sex Hormones: Androgens, Progesterone, Estrogen and Testosterone**

Bile Acids and Bile Salts

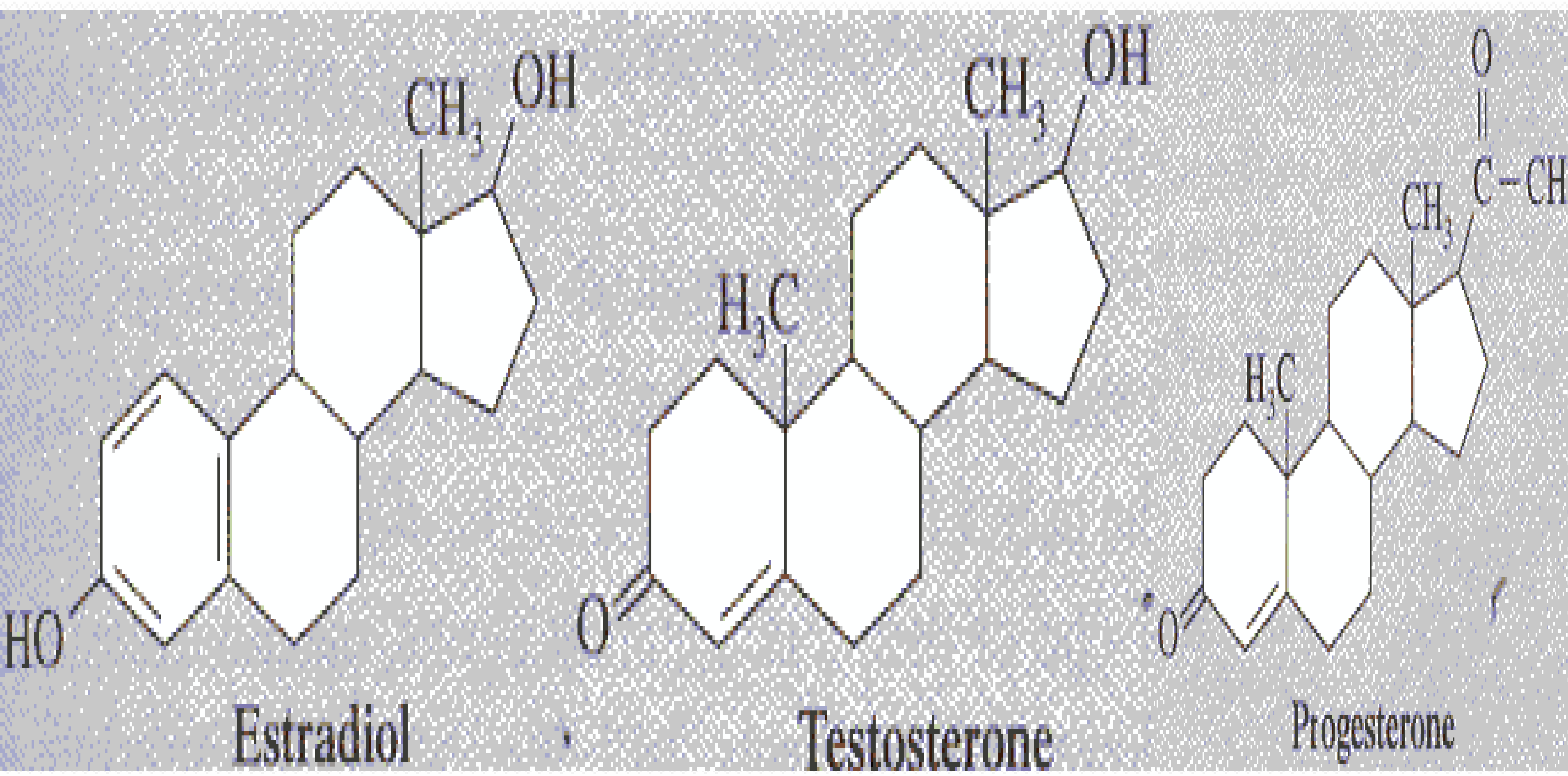


Sodium glycocholate



Sodium taurocholate

Steroids Hormones



Disorders Related To Cholesterol

- **Serum Total Cholesterol** of a Healthy human body is **150-200 mg%**

Hypercholesterolemia

- **Causes for Hypercholesterolemia**
- **High intake** of dietary cholesterol(animal origin) is a exogenous source of Cholesterol.
- Elevated endogenous Cholesterol **biosynthesis** when a very **rich Carbohydrates is ingested.**
- **Defect in** Cholesterol **transport by Lipoproteins** in blood retains Cholesterol in blood.

- **Hypercholesterolemia** leads to :
  - Deposits of **excess of Cholesterol in blood vessels.**
  - **Atherosclerosis** and atheroma /**plaque formation**.
  - Increased risk of **ischemia** and **Myocardial infarction and Stroke.**

• Cholesterol Summary

- Cholesterol is **exclusively found only in animals.**
- Exogeneous Cholesterol comes from diet
- **Endogeneous** Cholesterol is **biosynthesized** by the **Liver from Glucose product Acetyl-CoA.**
- Cholesterol is an important **component of biomembranes, steroidal hormones, bile acids and Vitamin D**

Study Of
Simple Lipids/Neutral Lipids

Fats/Oils

- **Fats and Oils** are **simple /Neutral lipids**

- **Fats/Oils are** chemically esters of **Fatty acids** with **Alcohol Glycerol** (**Trihydric Alcohol**).

- Chemically Fat/Oil is **Triacylglycerol (TAG).**

Fatty acids are Stored as components of Triacylglycerols

- **Fatty acids** are **not stored in free form** in living beings.
- **Fatty acids** are **stored** in **bound form** as **TAG.**
- Thus **TAG** is a **storage form of Fatty acids** .

- **Fatty acids** are **linked** to an Alcohol **Glycerol by** ester bonds to form **Triacylglycerol** (TAG).

- **Three Fatty acids same or different** (Acyl Chains) are esterified
- With **three hydroxyl groups** of a **Glycerol** to form **Triacylglycerol (TAG)/Triglycerides(TG).**

- **Hydrolytic Products Of TAG**
- **Monoacylglycerol (MAG) /(Monoglycerides):** A Glycerol esterified with one fatty acid.
- **Diacylglycerol (DAG) (Diglycerides):**
- A Glycerol esterified with two fatty acids.

- **MAG and DAG are derived Lipids.**
- **Monoacylglycerol** and **Diacylglycerol** are hydrolytic products of **Triacylglycerol.**
- These are produced during **TAG metabolism** in the body.

Most Common Fatty Acids in Triacylglycerol

Fatty acid	Carbon:Double bonds	Double bonds
Myristic	14:0	
Palmitic	16:0	
Palmitoleic	16:1	*Cis*-9
Stearic	18:0	
Oleic	18:1	*Cis*-9
Linoleic	18:2	*Cis*-9,12
Linolenic	18:3	*Cis*-9,12,15
Arachidonic	20:4	*Cis*-5,8,11,14
Eicosapentaenoic	20:5	*Cis*-5,8,11,14,17
Docosahexaenoic	22:6	*Cis*-4,7,10,13,16,19

$$CH_3(CH_2)_n COOH$$

Differences In Fat and Oil

- Fat and Oils are **different** in **Physical Characteristics**

- **Fat is solid at room temperature.**
- **Oil is liquid at room temperature.**

- **Chemical Name of Both Fats and Oils is Triacylglycerols:**

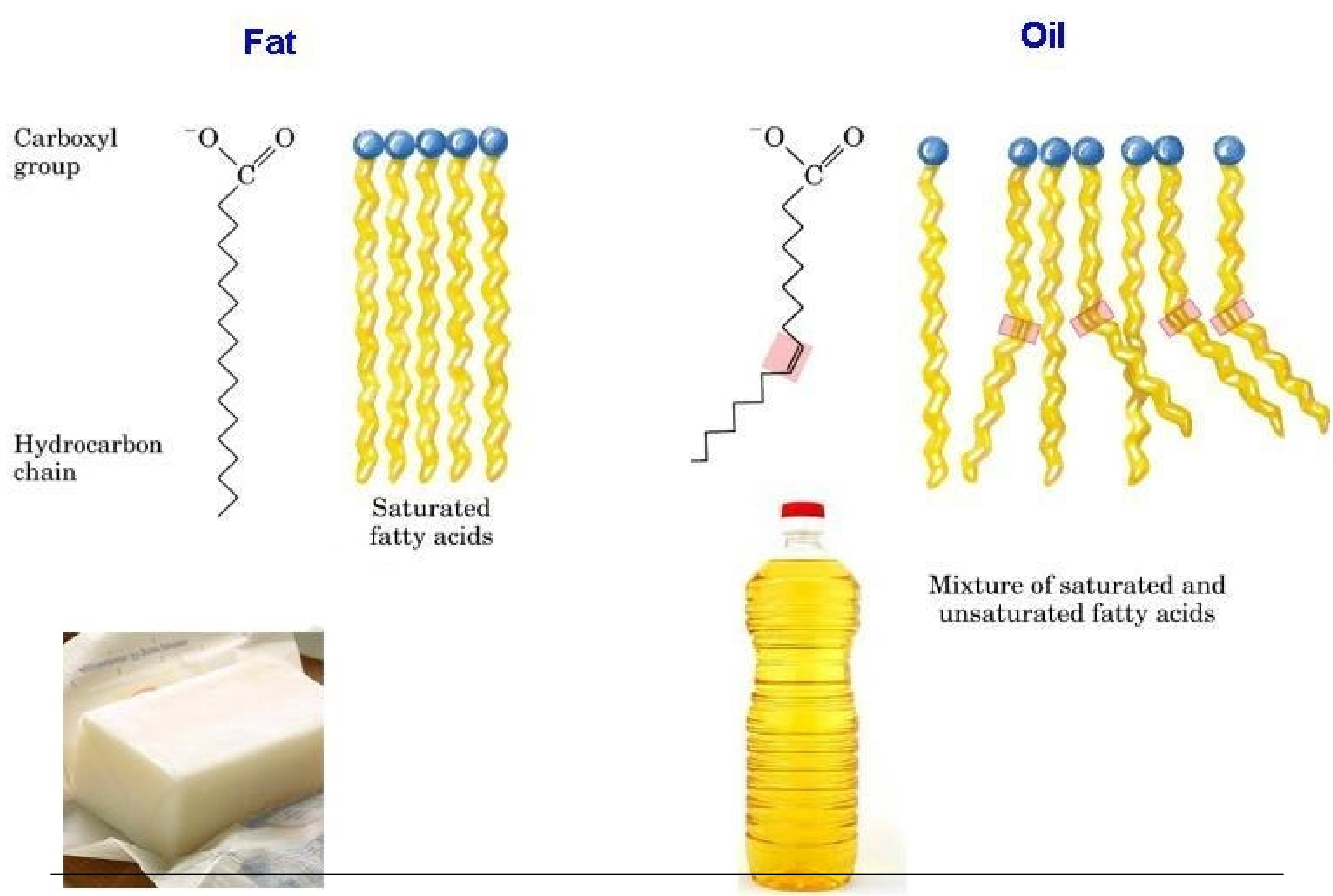
- **TAG of Fat is solid** since chemically composed of **long and saturated fatty acids**.
- **Source of Fat is Animal foods**.

- **TAG of Oil is liquid** as composed of **short and unsaturated fatty acids.**
- **Source of Oil is plant**.

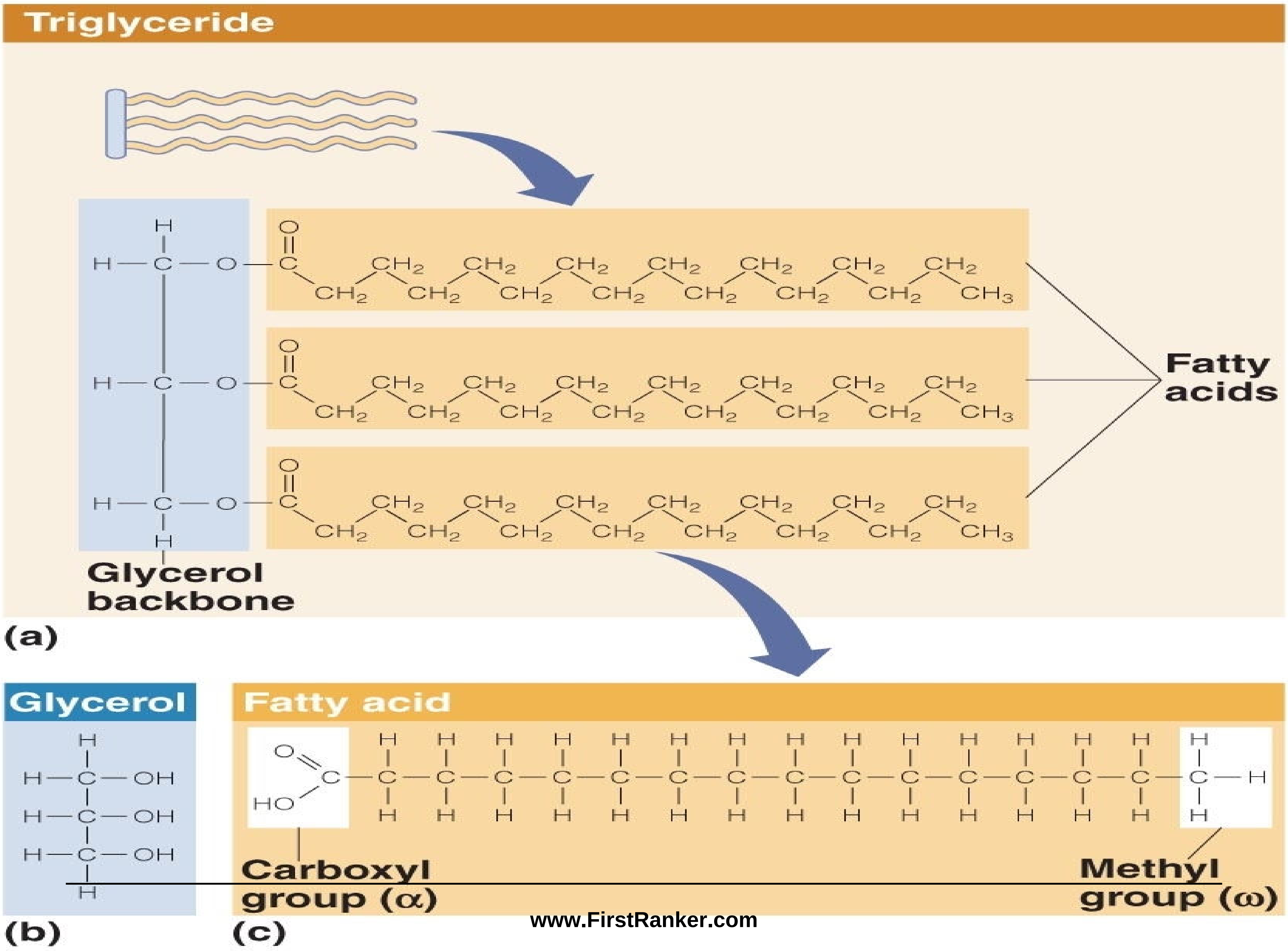
Chain Length Of Fatty acids IN TAG affects Melting Point

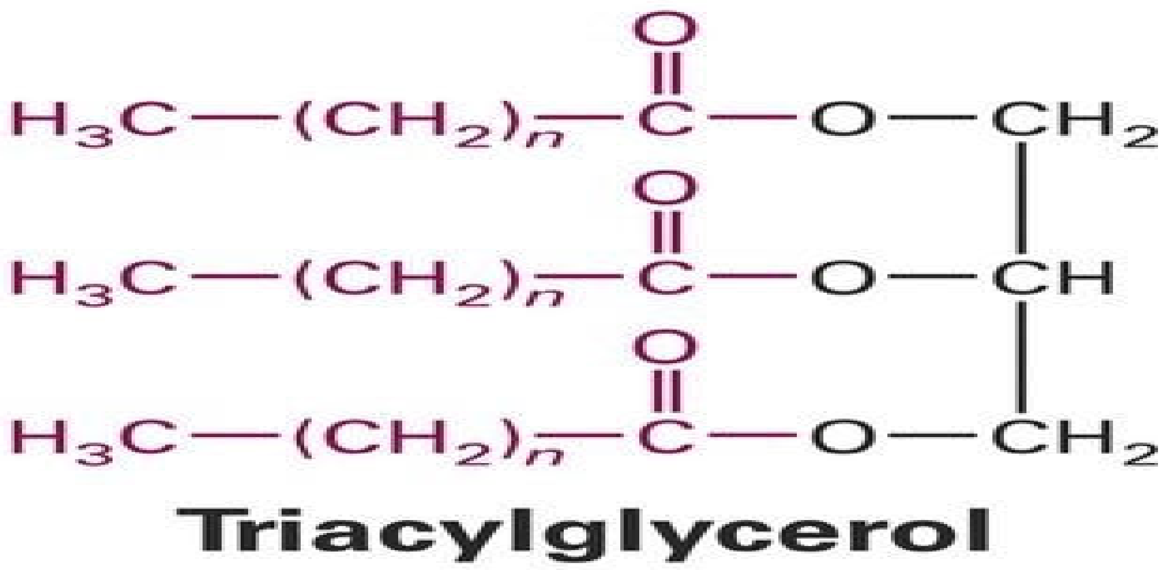
- The chain length of the majority of Fatty acids will determine the "hardness" of the Fat/TAG.
  - <10 carbons in FA = liquid
  - >20 carbons in FA = solid

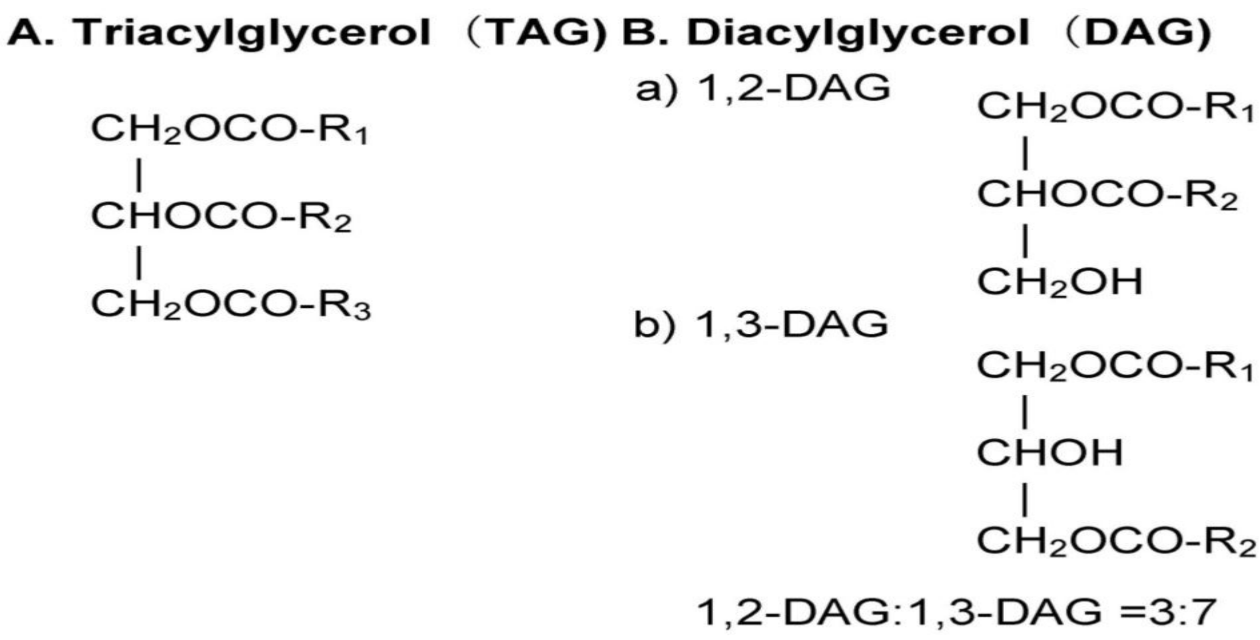
Acetic Acid (2 C)	Vinegar	Liquid
Stearic Acid (18 C)	Beef Tallow	Solid
Arachidic Acid (20 C)	Butter	Solid



Chemical Structures Of Triacylglycerol (TAG)







- Triacylglycerol is formed by linking of
- **Three same or different fatty acids** **to a Glycerol** molecule by ester bonds.
- The **Carboxyl group of each fatty acid interacts with hydroxyl group of Glycerol**(Trihydric Alcohol) to form **Ester bond of TAG**.

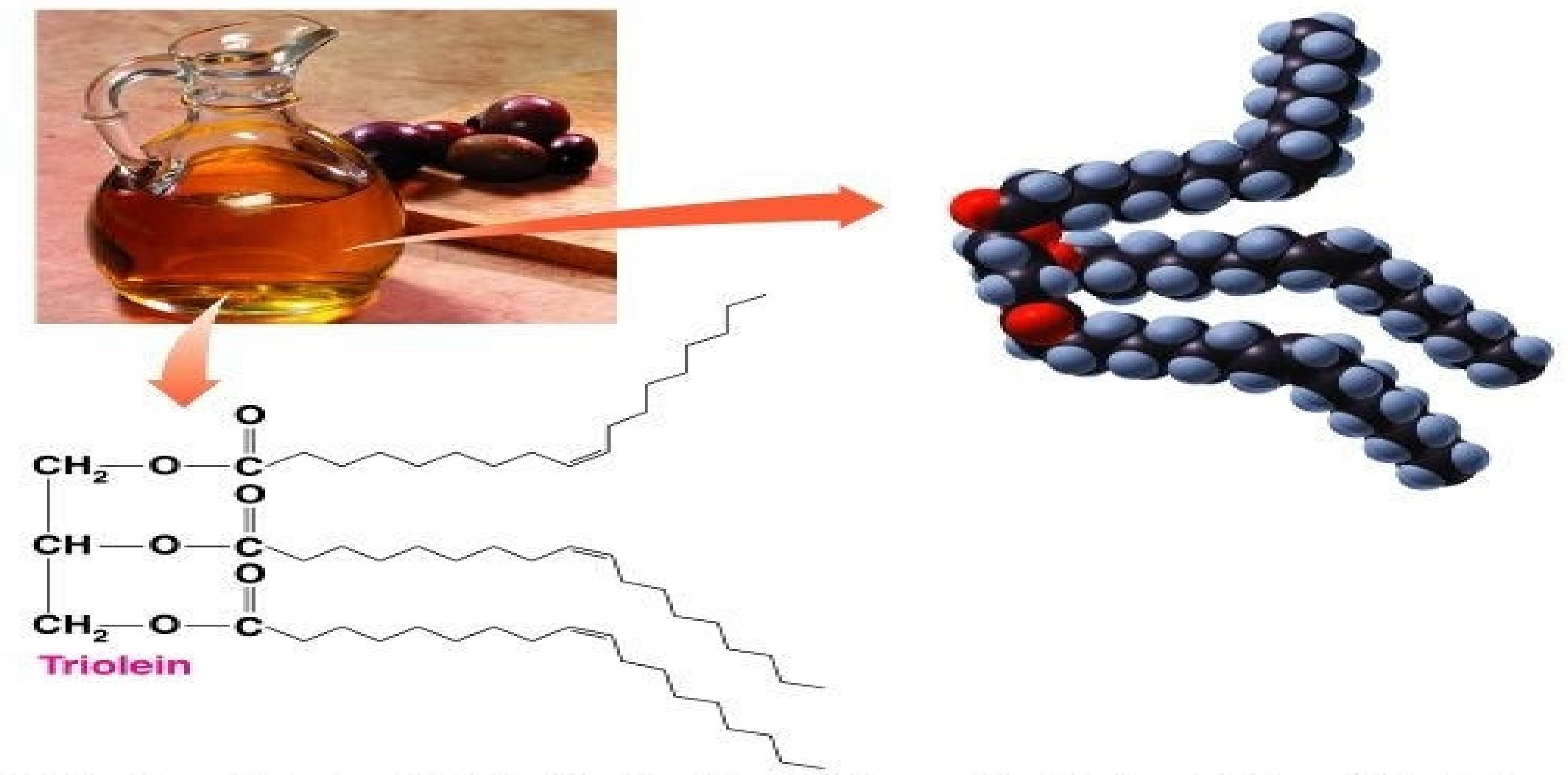
Types Of Triacylglycerol

- Simple TAG
- Mixed TAG

- **Simple TAG: Three same Fatty acids** are esterified to Glycerol to form simple TAG.
- **Examples of Simple TAG:**
  - TriPalmitin
  - TriStearin
  - TriOlein

Olive Oil Rich In Simple TAG

- Olive oil contains mostly TAG as **Triolein, which has three Oleic acids.**



Timberlake, *General, Organic, and Biological Chemistry*. Copyright © Pearson Education Inc., publishing as Benjamin Cummings

- **Mixed TAG:**
- The 3 **different Fatty acids** esterified to Glycerol to form a mixed TAG.
- Mixed TAG's are **more predominant in nature**.

- **In a Mixed TAG**
- **First Carbon C_1** -has **Saturated Fatty acid**
- **Second position C_2**-has **Unsaturated Fatty acid-PUFA**
- The **3 rd position C_3 Fatty acid** in TAG has- **either Saturated/Unsaturated fatty acid**

- **TAG is Neutral or Non polar lipid.**
- Since **TAG structure** has **no charged/polar group** in its structure.

Sources OF Triacylglycerol To Human Body

- **Exogenesis source of TAG :**
  - **Dietary Fat/Oil**
- **Endogenous source of TAG :**
  - **Liver Lipogenesis in well fed condition**
  - **Using Glucose product Acetyl-CoA.**

Dietary Sources Of TAG

- Animal Fat (Solid)
- Plant Oils (Liquid)

Fats (solid Triacylglycerol)
Oil (a liquid Triacylglycerol)

Occurrence/Distribution Of TAG

- TAG is a most widely distributed abundant natural lipid.

- The **predominant Lipid** form in **Human diet** is **TAG 98%.**
- **95** % of human body **Lipid** is **TAG.**

Storage form of **Lipid** in human body is **TAG.**

- **Because of insolubility of TAG in aqueous phase:**
- Body TAG are mostly found in **isolated compartments as droplets.**
- **TAG in anhydrous form** is packed in **Adipocytes (Depot Fat)**

Transportation Of TAG in blood is By Lipoproteins

- **Chylomicrons** :
- Transports exogenous dietary TAG
- **VLDL:**
- Transports endogenous TAG

Biomedical Importance Of TAG

- Triacylglycerol is the **predominant form of dietary Lipid** (99%).

1.TAG Serves As Source Of Energy

- TAG serve as **secondary source of energy** when body Glucose get lowered.

- TAG has **high calorific value (9Kcal/gram)** more than Carbohydrates (4 Kcal/gram).

2.TAG Reservoir Of Energy

- **TAG When excess serves** as an **energy reservoir** **stored in Adipocytes** as :
  - **Unlimited amount**
  - **Concentrated**
  - **Anhydrous form**

- Stores of TAG are utilized in **between meals** and **starvation phase**.

- A **good storage of depot Fat** can suffice for **2-3 months** in **starvation condition.**

- TAG is **highly reduced and anhydrous** form.
- Hence chosen as energy reserve of the body.

3.Store House Of TAG is High In Comparison To Glycogen Stores

- **TAG** is **stored** in **anhydrous form .**
- **More content** of **energy** can be stored by TAG in **comparison to Glycogen stores.**

- **1 gm** of **anhydrous TAG stores more than 6 times** as much as **energy** as **1 gm of hydrated Glycogen.**

- **Hydrated molecules requires more space.**
- **TAG stored in anhydrous** form requires **less space.**
- In contrast **Glycogen being hydrated** requires more space.

(1 gm of Glycogen binds with 2gm of water)

- The stored TAG is used as **long term energy source for body activities.**
- In **long marathon race** energy for muscle activity is provided by the **hydrolysis of depot TAG.**

4. TAG Regulates Body Temperature

- The **subcutaneous Fat** layer is a TAG
- TAG is a **bad conductor of heat and electricity** and serves as a **thermal and electrical insulator.**
- Which prevents loss of heat from the body and plays important role in **regulating body temperature.**

5.TAG Protects Internal Visceral Organ and Systems

- A presence of **Fatty** (TAG) **pad** around the **soft delicate** internal **visceral organs**
- **Protects from mechanical trauma or injury** by **acting as a shock absorber.**

- TAG provides **shape to body and keep the skin smooth and supple.**

- **Remember TAG is not associated to biomembranes.**

Tests To Check Purity Of Fat and Oil

- Several laboratory tests are employed to:
  - **Check the purity**
  - **Degree of adulteration** of fats and oils.

- **These tests also determine the biological value of Fat.**

Iodine Number

- Iodine number is **Grams/Number of Iodine absorbed by 100 gram of Fat /Oil .**
- Iodine Number is calculated by method of **Iodometry.**

Use Of Iodine Number

- Iodine number is useful to know
- The **index of unsaturation** and **content of unsaturated fatty acids** present in the Fat/Oil.

- Iodine number is **directly proportional** to the **unsaturated bonds of PUFAs** in a Fat/Oil.

- **High value of Iodine number** of oil **indicates more content of Unsaturated Fatty acids** in it.

Name Of Oils	Iodine Number
Coconut Oil Butter	7-10 (**Least**) 25-28
Ground Nut Oil	85-100
Sunflower Oil Soya bean Oil	125-145 135-150
Linseed Oil /Flax seed Oil	175-200 (**Highest**)

- Determination of Iodine number **helps in knowing the degree of adulteration** of tested oil sample.

- If **Linseed oil is adulterated** with an oil whose content is high in **saturated fatty acids** will **give lower Iodine number than the reference values.**

Saponification Number

- Saponification number is **milligram/number of KOH molecules required to hydrolyze and saponify one gram of Fat/Oil**.

- The saponification number gives the **idea of molecular size/chain length of Fatty acids** present in 1 gram of Fat.

- 1 gram **Fat/Oil with long chain fatty acids has low saponification** number.
- Since in 1 gram of Fat has few -COOH groups of fatty acids to react with KOH.

- 1 gram Oil with **short chain fatty acids** has **higher saponification number.**
- Since it has more COOH groups for KOH reaction.

- 1 gram of Fat/oil with **long chain fatty acids** has **lower saponification number.**
- As compared to an 1 gram of oil containing short chain fatty acids.

Oils	Saponification Number
Coconut Oil	250-260
Butter	230-250
Jojoba Oil	69- 80
Olive Oil	135-142

Acid Number

- Acid number is **milligram of KOH required for complete neutralization** of **free fatty acids present in one gram of Fat/Oil.**
- Acid number checks the **purity of Refined oils.**

- Refined oils are free from free fatty acids and has zero Acid number.
- Increased Acid number of refined oil suggests bacterial/chemical contamination and unsafe for human consumption.

Reichert Meissl (RM)Number

- RM number is **0.1 N KOH required for complete neutralization of soluble volatile fatty acids distilled from 5 gram of Fat .**

- **R.M Number** of Butter is 25-30.

- The R.M number of other **edible oils is less than 1.**

- **R.M number is useful in testing the purity of butter**
- Since it **contains good concentration of free volatile fatty acids** viz: **Butyric, Caproic and Caprylic acid.**

- **Adulteration of butter reduces its R.M number.**

Chain Length Of Fatty acids Of TAG affects Melting Point

- The chain length of the majority of fatty acids will determine the "**hardness**" of the Fat/TAG.
  - < 10 carbons in FA = liquid
  - >20 carbons in FA = solid

Acetic Acid (2 C)	**Vinegar**	**Liquid**
Stearic Acid (18 C)	**Beef Tallow**	**Solid**
Arachidic Acid (20 C)	**Butter**	**Solid**

Hydrogenation Of Fat/Oil

- **Treatment of Oils(TAG) rich in PUFAs with Hydrogen gas, (H_2).**
- **Catalyst required (Nickel).**
- **Adding Hydrogen at double bonds of PUFAs.**
- **It is also called "Hardening of Oils"**
- **Hydrogenation also converts PUFAs with cis form to trans form.**
- **Margarine**
  - **Vanaspati Dalda Crisco, Spry, etc.**

Advantages and Disadvantages Of Hydrogenation Of Fat /Fatty acids

Advantage Of Hydrogenation

- Commercially Oils with Unsaturated Fatty acids are **Hydrogenated to Saturated Fatty acids.**

- Hydrogenation makes the unstable ,unsaturated , liquid TAGs:
  - To stable , saturated, solid TAGs
  - **Increases shelf life**
  - **Reduces risk of Rancidity**
  - Example : Vanaspati Dalda ,Margarine.

- **Double bond** containing /Unsaturated Fatty acids are **unstable** and **ready** for **peroxidation and rancidity.**
- **Single bond** containing/Saturated Fatty acids are **stable and less peroxidized and made rancid**.

Disadvantage Of Hydrogenation Of Fat/Fatty acids

- During Hydrogenation some of the **Cis form Fatty acids** are **transformed to Trans Fatty acids.**

Trans Fats increases the risk of Atherosclerosis and CVD.

- Hydrogenated trans Fatty acids are **more stable.**
- Body has **no enzyme system** to oxidize and **metabolize trans fatty acids.**

- Thus trans Fats containing trans Fatty acids are:
- **Less metabolized in body.**
- More retained in the body.
- Leading to **Atherosclerosis and CVD.**

- **Remember Hydrogenated Fats are Bad for Health.**

- **Note**
- Try eat natural Fats.
- Avoid Processed Fats.

- **Summary Of Hydrogenation:**
- Hydrogen atoms are added to unsaturated Fatty acids
  - Make liquid oils more solid and more saturated.
  - Create *trans* fatty acids.
  - Reduce oxidation of Fatty acids.
  - Resist rancidity.
  - Increase risk of cardiovascular disease.

Rancidity Of Fats/Oils

Rancidity

- Rancidity is a **physico chemical** phenomenon
- Which **deteriorates Fats and Oils**
- Resulting in **unpleasant taste ,odor and color of Fat/Oil**

(Rancid Fat/oil)

- Rancid Fat is **inedible**

Factors Causing Rancidity

Causes Of Rancidity

- Fats and Oils get **Rancid on Ageing**.
- Various **Factors aggravates rancidity** of Oils and Fats:
- **Improper handling by exposure to:**
  - **Light**
  - **Air**
  - **Moisture**
  - **Microbes**

Oxygen is favorable for Rancidity

PUFAs are more prone to Rancidity

Types and Mechanism Of Rancidity

Types Of Rancidity

- Oxidative Rancidity
- Hydrolytic Rancidity
- Ketonic Rancidity

- **Oxidative Rancidity**:
- PUFAs having **double bonds** are easily oxidized to form its peroxides.
- By the action of **Oxygen Derived Free radicals (ODFR).**

- The cellular Lipids are also likely to get peroxidized by Free radical action causing damage to biomembranes.

- **Hydrolytic Rancidity**:
- Long Chain Saturated fatty acids are **hydrolyzed** by **bacterial Enzymes** .
- To produce **Dicarboxylic acids**, **Aldehydes**, **Ketones** etc which make the Fat rancid.

Ketonic Rancidity

- It is due to the **contamination** with certain **Fungi** such as **Asperigillus Niger on Oils** such as Coconut oil.
- **Ketones, Fatty aldehydes, short chain fatty acids** and **fatty alcohols** are formed.
- **Moisture accelerates Ketonic rancidity.**

- Rancidity gives bad odor and taste to rancid Fats/oils.
- **Due to Dicarboxylic acids ,Ketones , Aldehydes** Produced during the process of

Prevention Of Rancidity

- Rancidity can be prevented by **proper handling of oils**
- By keeping fats or oils in **well closed containers in cold, dark and dry place**.

Prevention Of Rancidity

- **Avoid** exposure to **direct sunlight, moisture and air.**
- **Avoid over** and **repeated heating** of oils and fats.

- **Removal** of catalysts such as **Lead** and **Copper** from Fat/Oils that **catalyzes rancidity** prevents rancidity.

Antioxidants Prevent Rancidity

- Antioxidants are chemical agents which prevent the peroxidation and Hydrolysis of Fats/Oils.

- **Examples Of Antioxidants:**

- Tocopherol(Vitamin E)
- Vitamin C
- Propyl Gallate
- Alpha Napthol
- Phenols
- Tannins
- Hydroquinone's.
- Butylated Hydroxy Anisole(BHA)
- Butylated Hydroxy Toluene (BHT)

- **The most common natural antioxidant is vitamin E that is important in vitro and in vivo.**

- **Vegetable oils** are associated with **high content** of **natural antioxidants (Vitamin E),**
- Hence **oils do not undergo rancid rapidly**
- As compared to **animal fats** which are **poor in naturally** associated **antioxidants .**

- Addition of Anti-oxidants prevents peroxidation in fat (i.e., rancidity).

- Rancidity of Fats and Oils is prevented by adding Antioxidants.
- **Thus addition of Antioxidants increases shelf life of commercially synthesized Fats and Oils.**

Avoidance of Rancidity of Fat/Oil By

- Good storage conditions
- Less Exposure to light
- Low Oxygen, moisture
- No very High temperatures
- No Bacteria or fungal contamination
- Addition of Antioxidants

Hazards of Rancid Fats:

1. Rancidity **destroys the content of polyunsaturated essential fatty acids.**
2. Rancidity causes **economical loss** because **rancid fat is inedible.**
3. The products of rancidity are **toxic**, i.e., **causes food poisoning and cancer.**
4. Rancidity **destroys the fat-soluble vitamins** (vitamins A, D, K and E).

RANCIDITY

- The condition reached in certain foods as the lipid material (fat) undergoes oxidation reactions producing aldehydes, hydroxyl acids, keta acids, and other compounds which are responsible for the odor and off-flavor producing stale foods
- Foods high in lipids
  - potato chips
  - peanut butter
  - crackers
- Factors causing rancidity
  - light
  - oxygen
  - trace elements (i.e.—iron, zinc)
  - salt
  - water
  - bacteria
  - mold

(Courtesy, Agricultural Research Service)

Lipid Peroxidation
Is a source of Free Radicals

- **Lipids** undergo **peroxidation**(autoxidation) when exposed to **Oxygen.**
- The oxygen derived free radicals (RO.,OH.,ROO.) with **unpaired electrons** leads to chain reactions of lipid peroxidation.

- **Steps of Lipid peroxidation reaction:**
  - **Initiation**
  - **Propagation**
  - **Termination**

- **Lipid peroxidation Provide** continuous **Free radicals.**
- Thus has potentially **devastating effects in the body.**

- **In vitro peroxidation of Lipids deteriorates the quality of Fats and Oils**
- Makes the Fat/Oil **rancid and in edible.**
- Fat/oil has **bad taste and odor**
- **Decreases the shelf life** of Fats and Oils.

- **In vivo peroxidation of membrane Lipids damages the tissues.**
- Lipid peroxidation has devastating effects on body Lipids.
- Increases risk of Inflammatory diseases
- Ageing
- Cancer

- **Antioxidants** control and **reduces** In vivo and In vitro **Lipid peroxidation**
- Naturally occurring antioxidants are :
  - Vitamin E
  - Vitamin C
  - Beta Carotene

- **In Vivo Enzymes as Antioxidants:**
  - Catalase
  - Glutathione Peroxidase
  - Superoxide Dismutase
- **In vivo other Substances as Antioxidants:**
  - Urate
  - Bilirubin

- **Food Additives as Antioxidants:**
  - Alpha Naphtol
  - Gallic Acid
  - BHA
  - BHT

- **Preventive Antioxidants:**
- Reduces the rate of Chain initiation of Lipid peroxidation
  - **Catalase**
  - **Peroxidase**
  - **EDTA**
  - **DTPA**

- **Chain Breaking Antioxidants:**
- Interferes the chain propagation of Lipid peroxidation.
  - Vitamin E
  - Urate

Differentiation Between Fats And Oils

Fats	Oils
Fats are TAGs composed of **Long and Saturated Fatty acid.**	**Oils** are TAGs composed of **short and Unsaturated Fatty acids.**
Fats solid at room temperature Fat has **high melting point**	**Oils liquid** at room temperature Oils have **low melting point**
Fats -animal In Origin **Example: Lard (pork Fat)**	**Oils -Plant in Origin** **Example: Safflower Oil**
Fats **has low antioxidant content** and **get easily Rancid**	Oils have **high antioxidant** content and **do not get easily Rancid**
Fats are **more stable** Fats are **less metabolizable** in body.	Oils **are less stable** Oils are **readily metabolizable** in the body.
High content of dietary **Fats has high risk for Atherosclerosis.**	Oils have **low risk for Atherosclerosis.**

Study Of Compound Lipids

Compound Lipids

- Compound lipids are **class of Lipids**
- Which are chemically **Esters of Fatty acids with Alcohols attached** with **Additional groups.**

- **Additional Groups** in **Compound Lipids** may be either of these:
  - **Phosphoric acid**
  - **Nitrogenous Base**
  - **Carbohydrate moieties**
  - **Proteins**
  - **Sulfate groups**

3 Main Compound Lipids

- **Phospholipids**
- **Glycolipids**
- **Lipoproteins**

Phospholipids

Phospholipids (PL)

- **Phospholipids (PL)** are compound lipids.

- **Phospholipids Chemically Possess:**
- **Fatty acids** esterified to **Alcohol** and
- **Phosphoric acid** attached with **Nitrogenous /non nitrogenous base.**

Types Of Phospholipds

- **Based upon the Alcohol present in Phospholipid structure**
- **Two Types of Phospholipids are :**

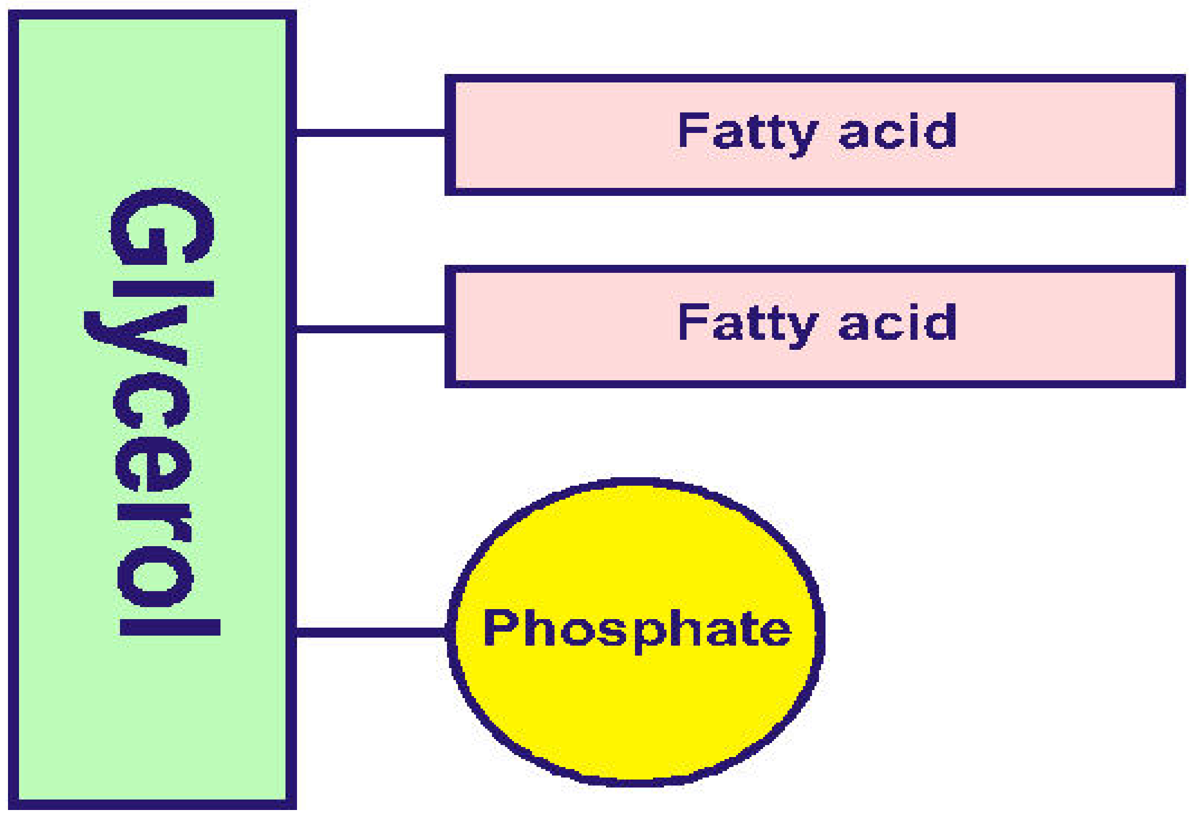
  - **Glycerophospholipids:**
    Glycerol containing Phospholipids

  - **Sphingophospholipids:**
    Sphingosine/ Sphingol containing Phospholipids.

Glycerophospholipids/ Glycerophosphatides

Simplest Glycerophospholipid

PHOSPHATIDIC ACID



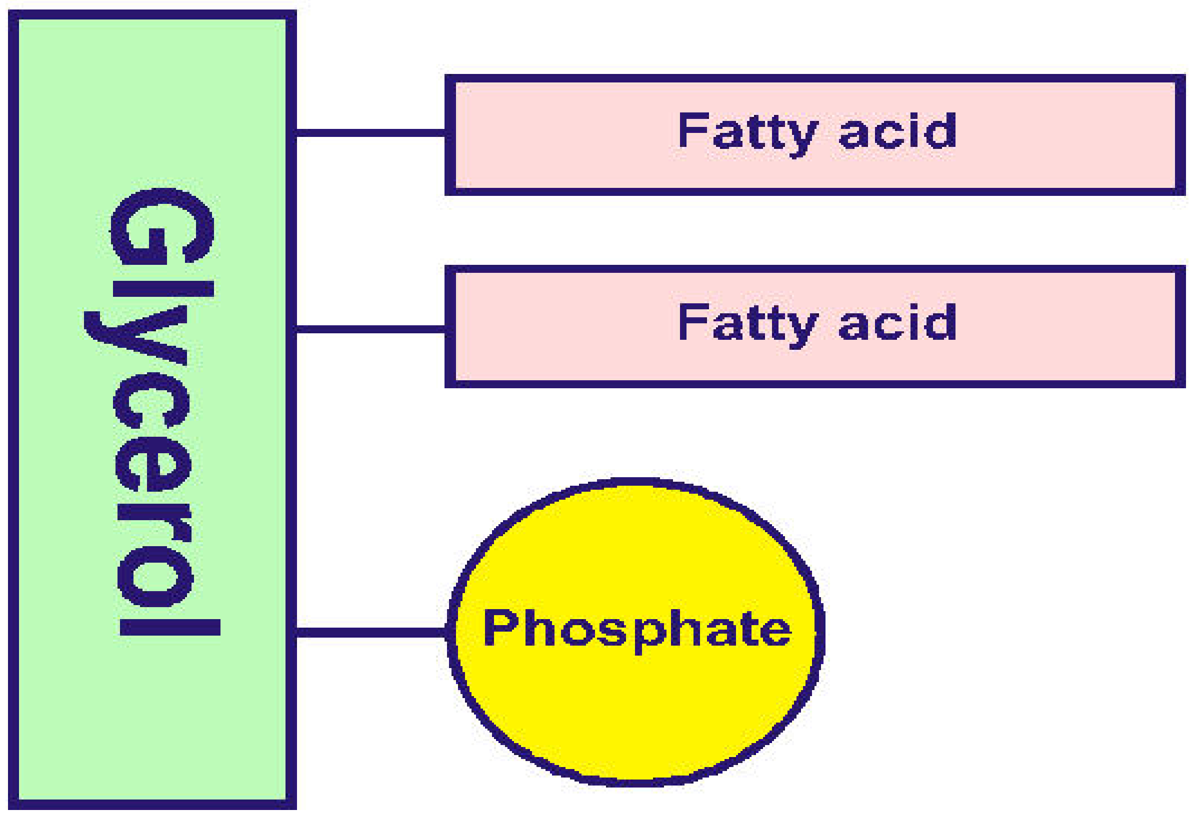
- Depending upon the Nitrogenous and Non nitrogenous moiety attached.
- Examples of 7 Glycerophospholipids are:
  1. Phosphatidic Acid (Simplest PL)
  2. Phosphatidyl Choline (Lecithin)
  3. Phosphatidyl Ethanolamine (Cephalin)
  4. Phosphatidyl Serine
  5. Phosphatidyl Inositol/ Lipositol
  6. Phospatidal Ethanolamine/ Plasmalogen
  7. DiPhosphatidyl Glycerol /Cardiolipin

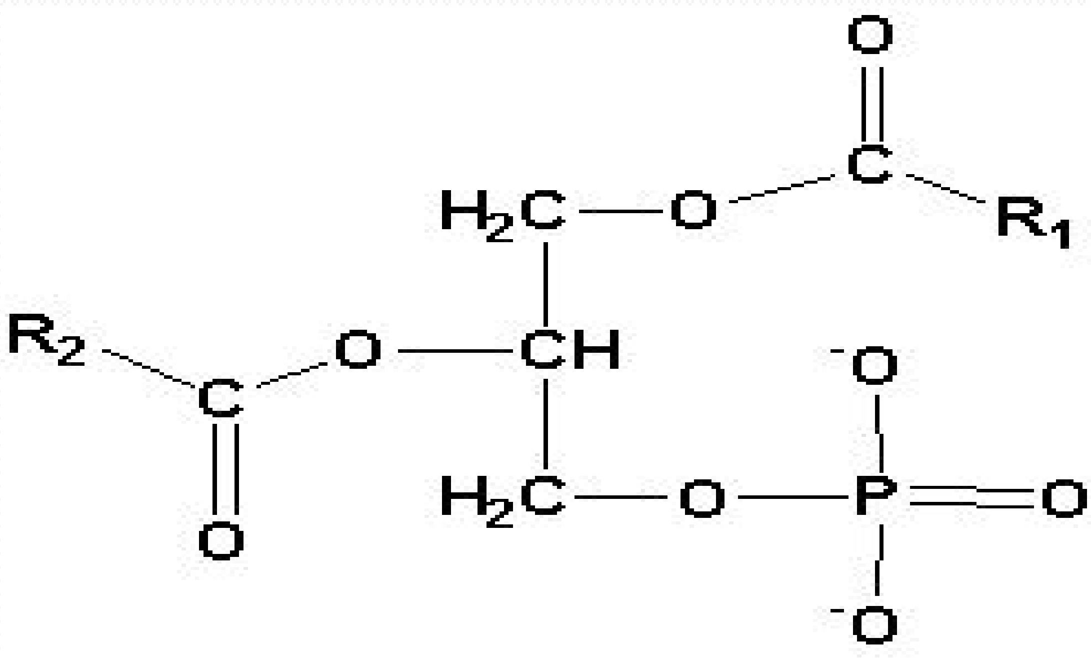
Structures OF Glycerophospholipids

Phosphatidic Acid

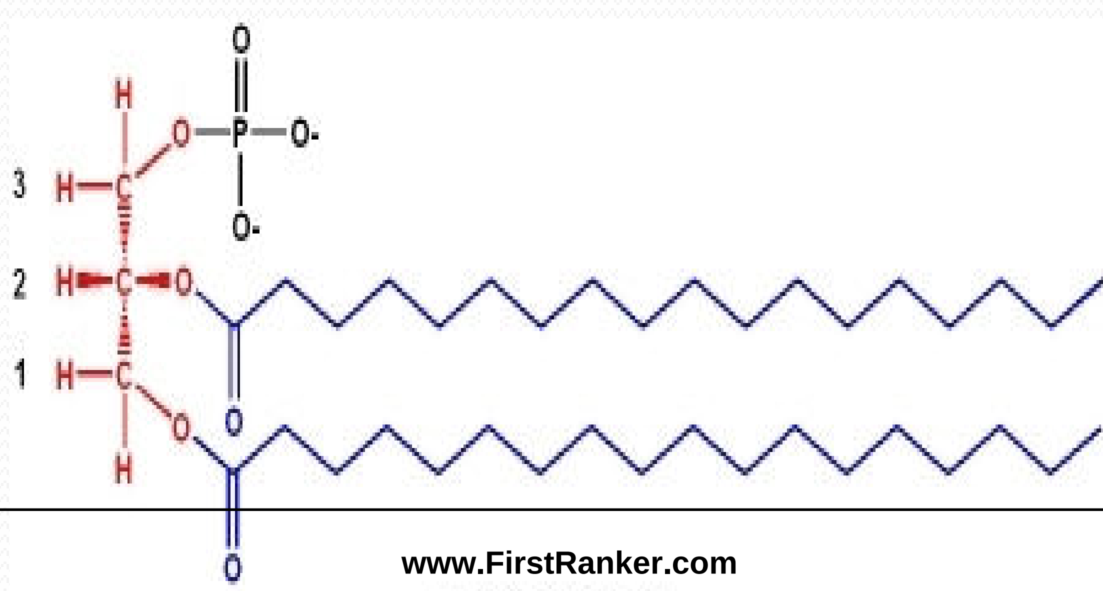
- **Phosphatidic acid** is a **simplest GlyceroPhospholipids.**
- Phosphatidic acid has Glycerol esterified with **two Fatty acids at C_1 and C_2 .**
- C_3 is esterified with **Phosphoric acid.**

PHOSPHATIDIC ACID





Phosphatidic Acid



Phosphatidic Acid

- **Phosphatidic acid serve as a precursor for the synthesis of a**ll other **Glycerophospholipids**
- Either by linking of Nitrogenous or a Non nitrogenous base.

Phosphatidyl Choline/Lecithin

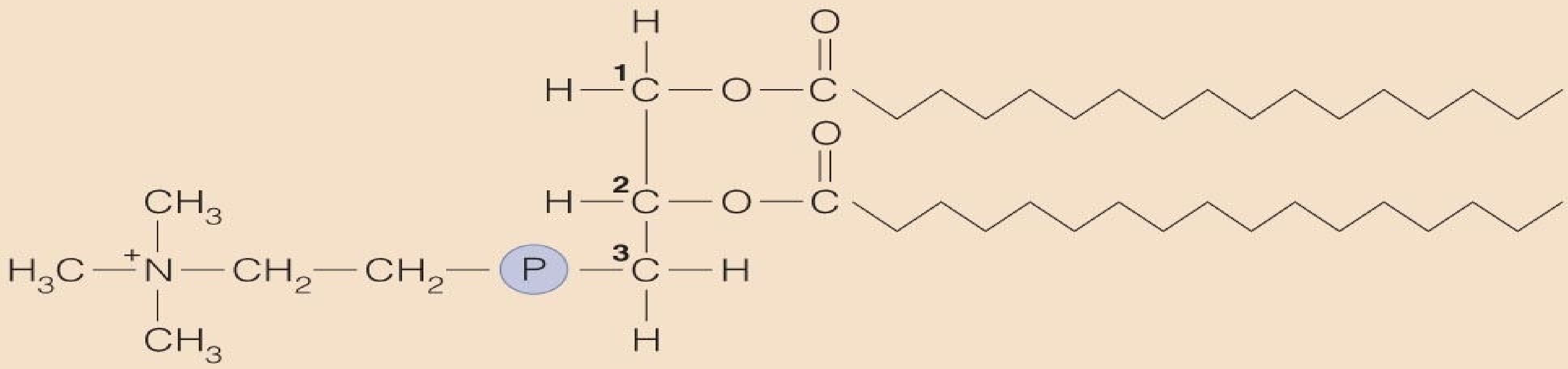
- **Phosphatidyl Choline** (**Lecithin**) is the most **commonest** and **abundant** **Glycerophospholipid** in body.

- Phosphatidyl Choline is commonly called as **Lecithin.**

- Derived from word '**Lecithos**' **meaning Egg Yolk.**

- **Phosphatidic acid** is linked to a Nitrogenous base Choline to form **Phosphatidyl Choline.**

Phospholipid



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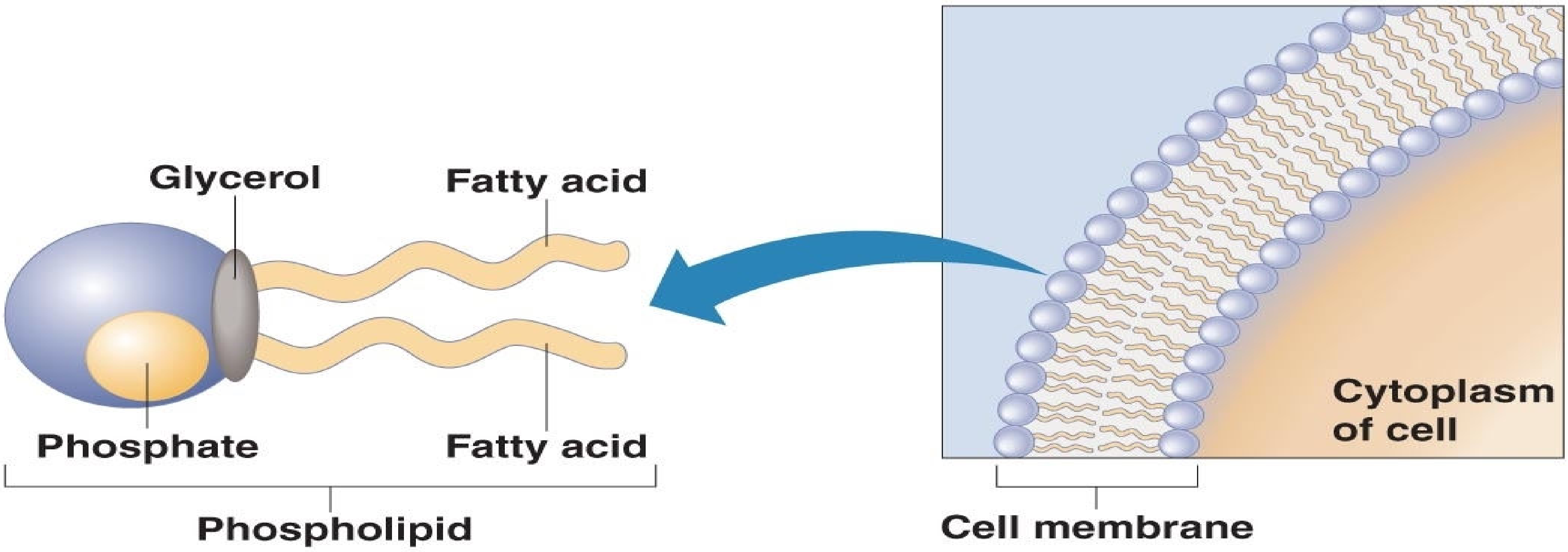

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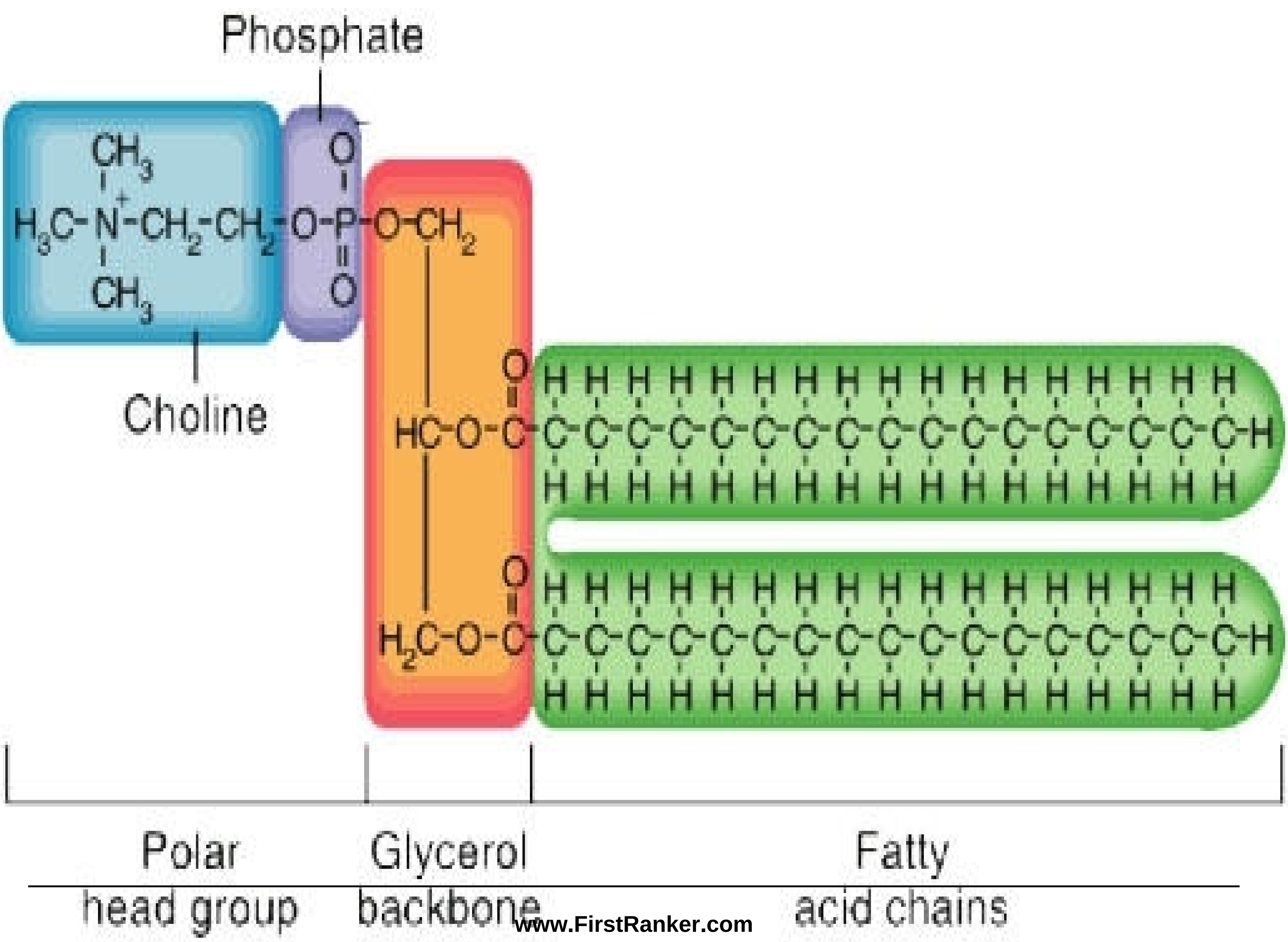
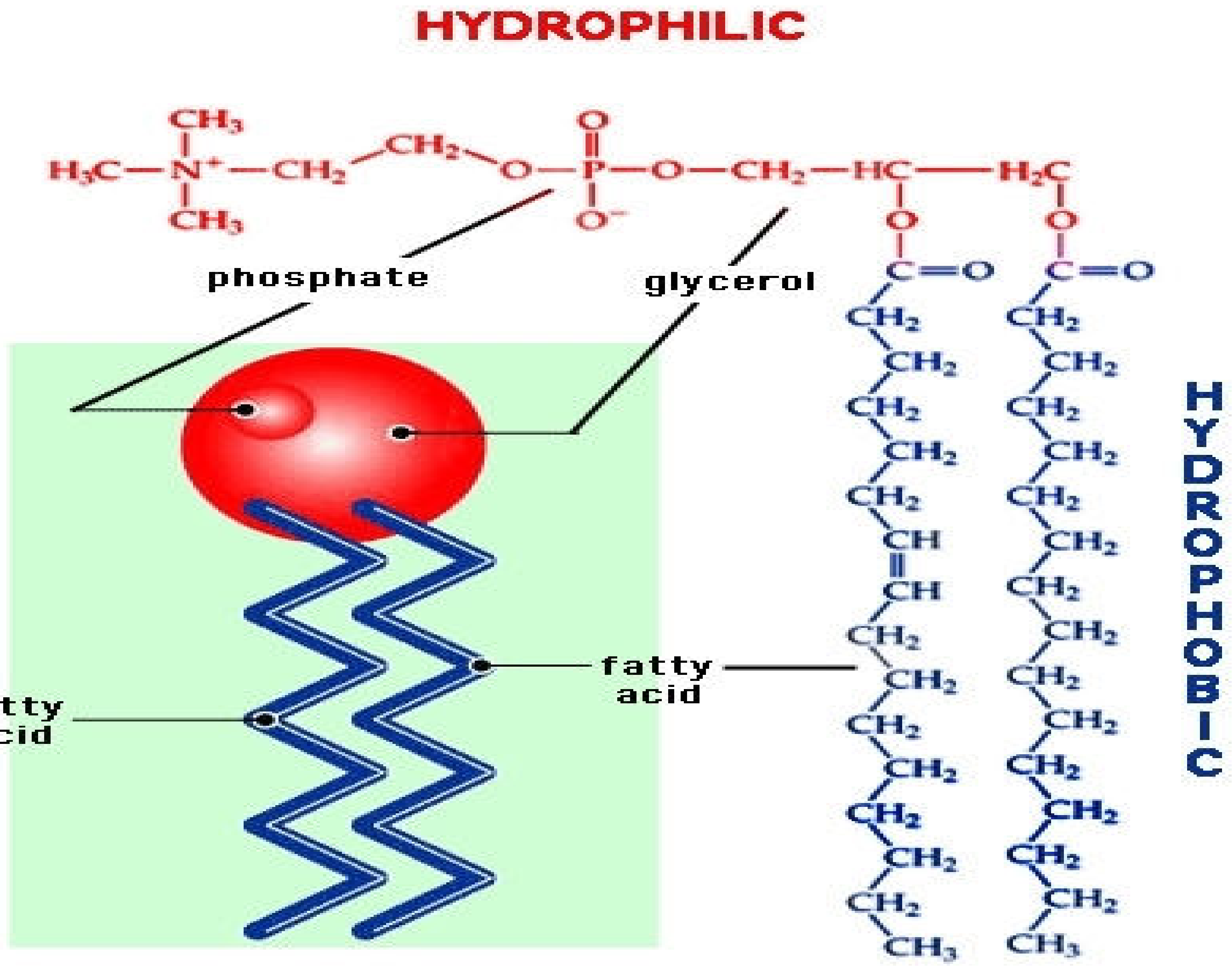
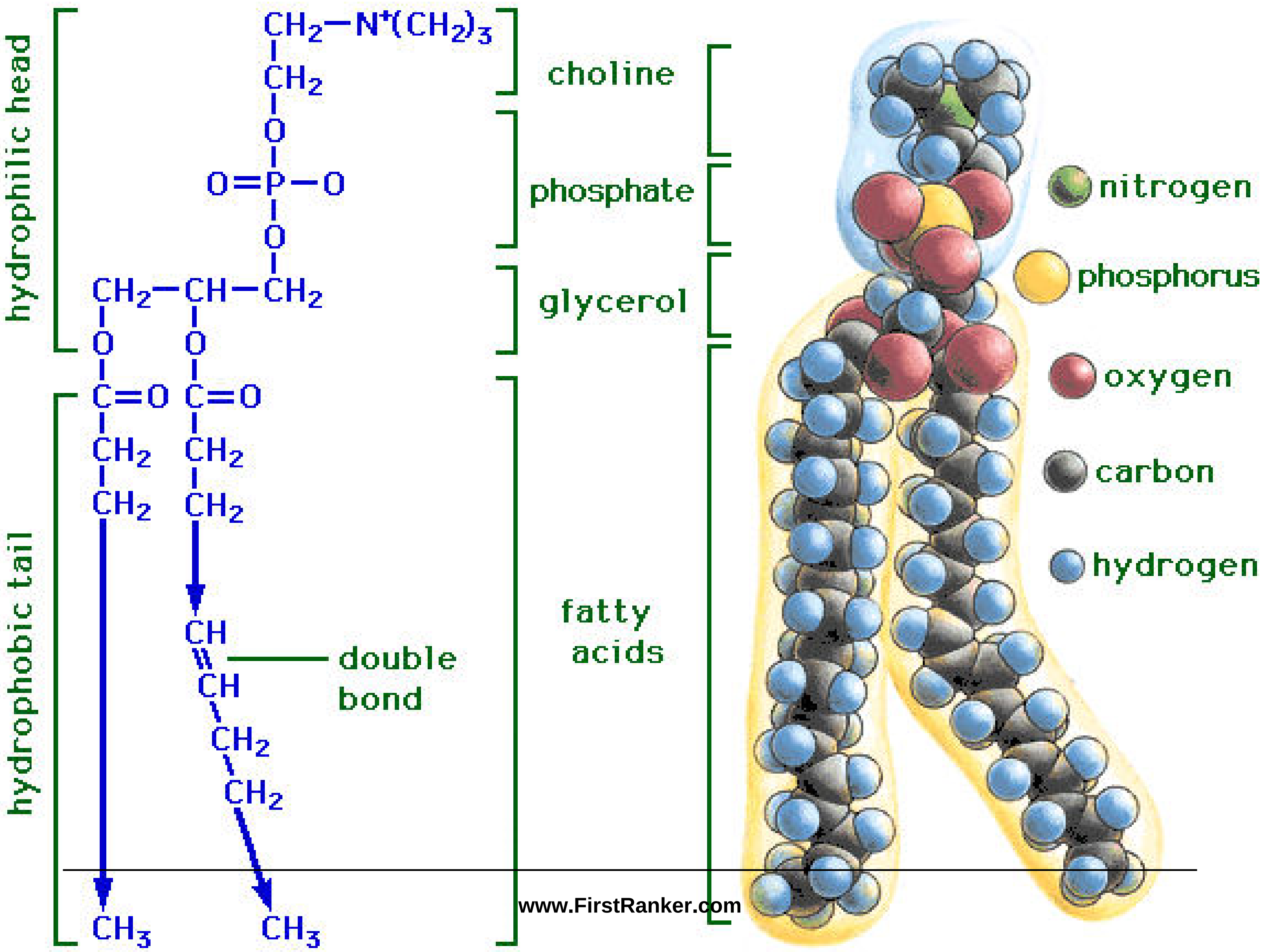
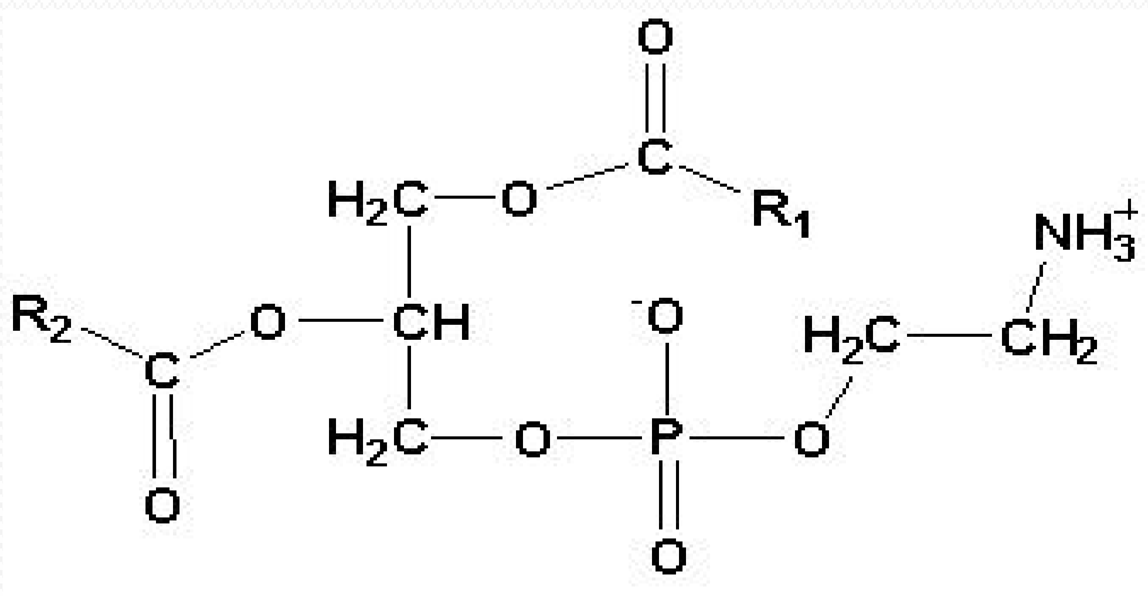


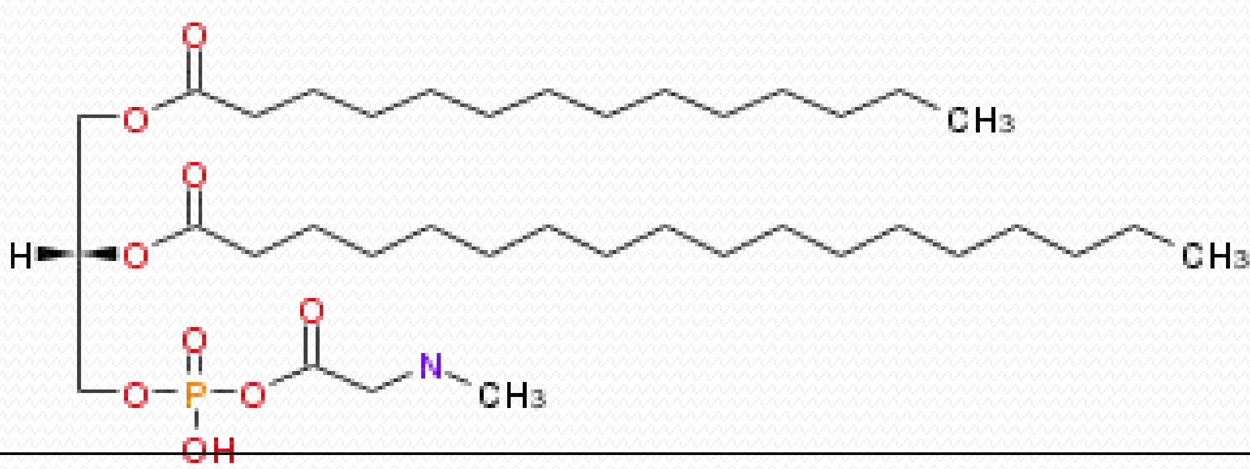

HYDROPHILIC
phosphate
glycerol
fatty acid
fatty acid
HYDROPHOBIC


hydrophilic head
hydrophobic tail
choline
phosphate
glycerol
fatty acids
double bond
nitrogen
phosphorus
oxygen
carbon
hydrogen

Phosphatidyl Ethanolamine/ Cephalin

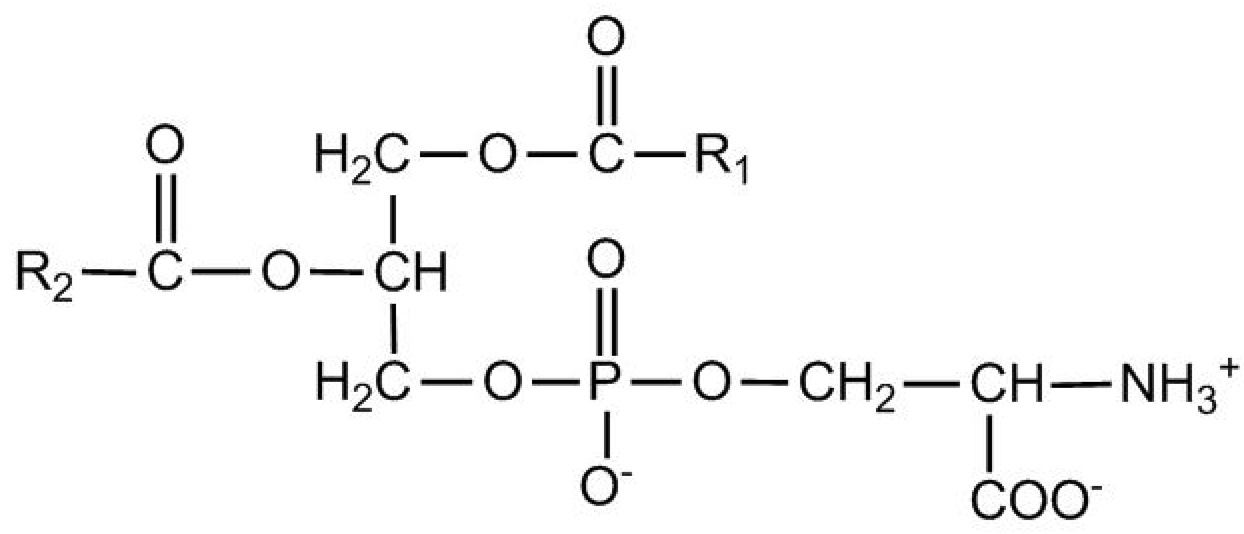


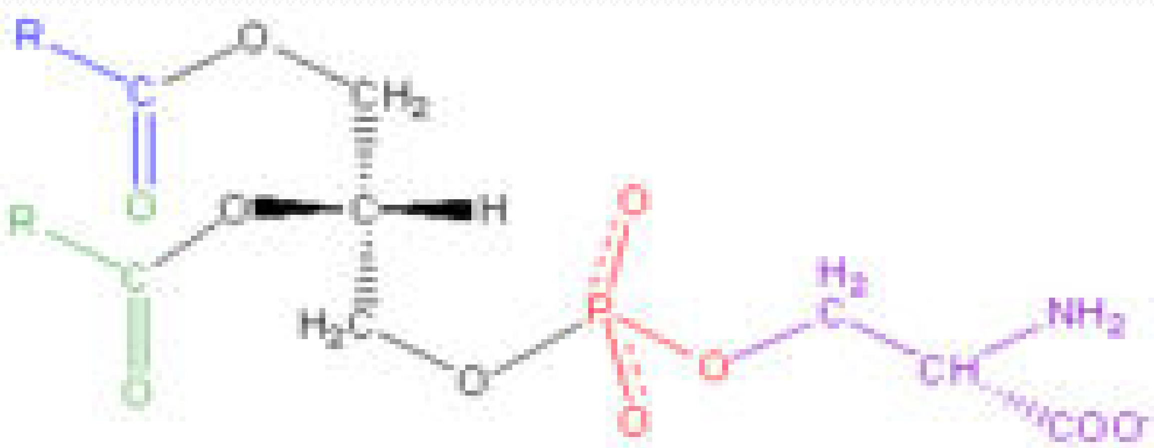
Phosphatidylethanolamine



Phosphatidyl Serine

- An Amino acid **Serine** linked to **Phosphatidic acid** forms **Phosphatidyl Serine.**



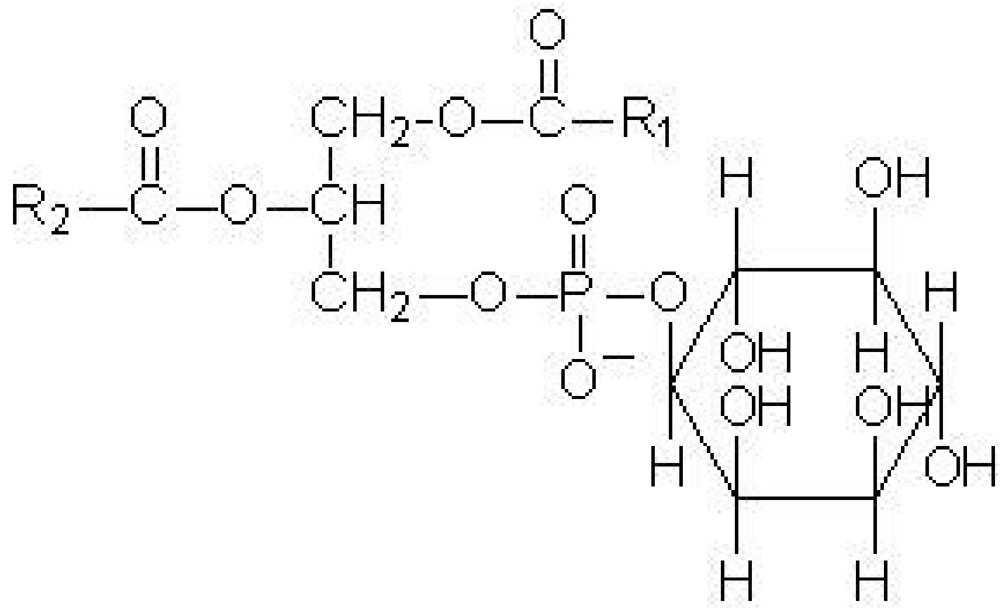


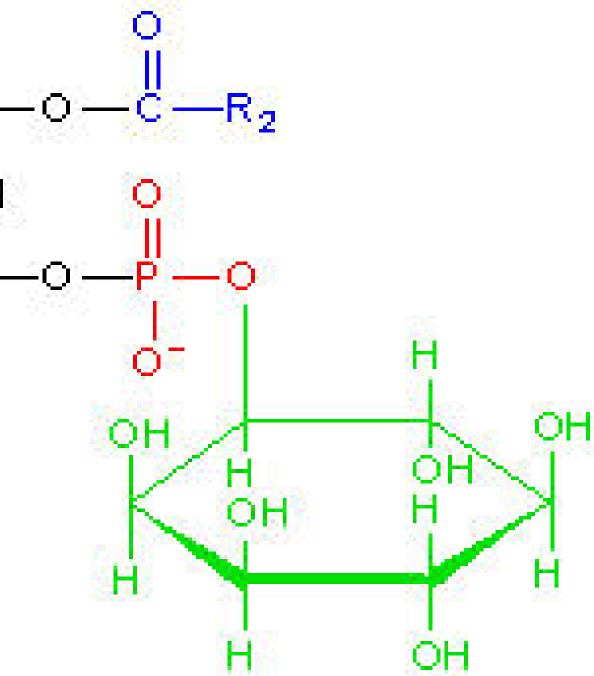
Cephalins

- Type of Glycerophospholipids
- Nitrogen base is Ethanolamine or Serine.
- Phosphatidylethanolamine and Phosphatidylserine are **Cephalins**.

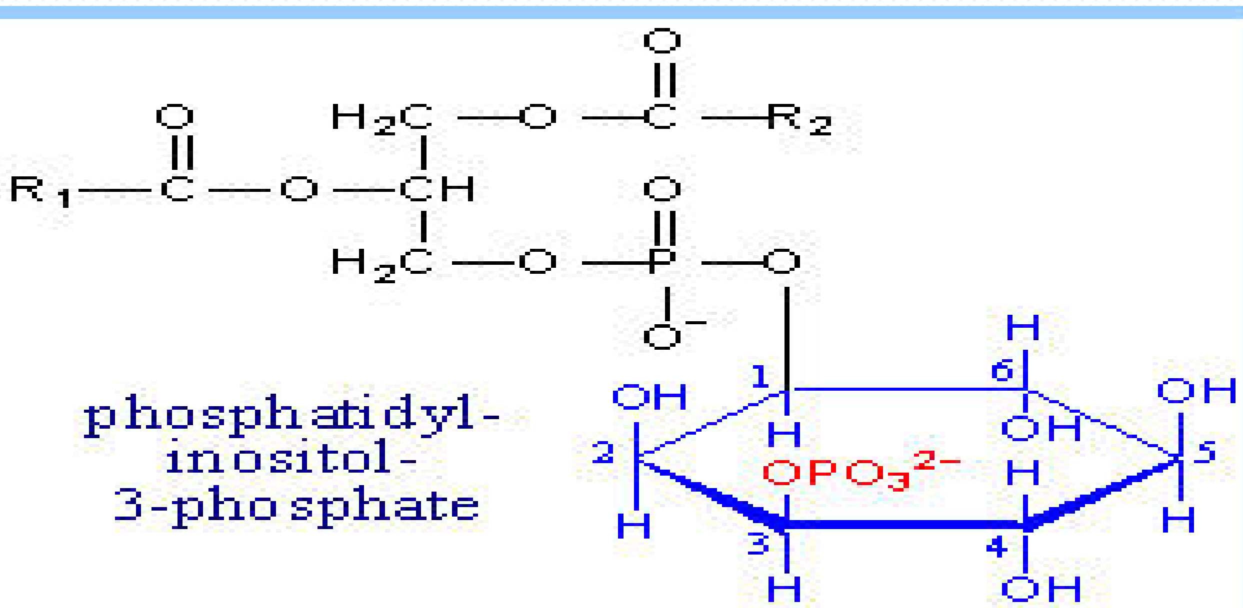
Phosphatidyl Inositol/Lipositol

- **Inositol** a **Polyol derived from Glucose**
- It is a **Non Nitrogenous , Carbohydrate Derivative.**
- Inositol linked to Phosphatidic acid forms **Phosphatidylinositol.**

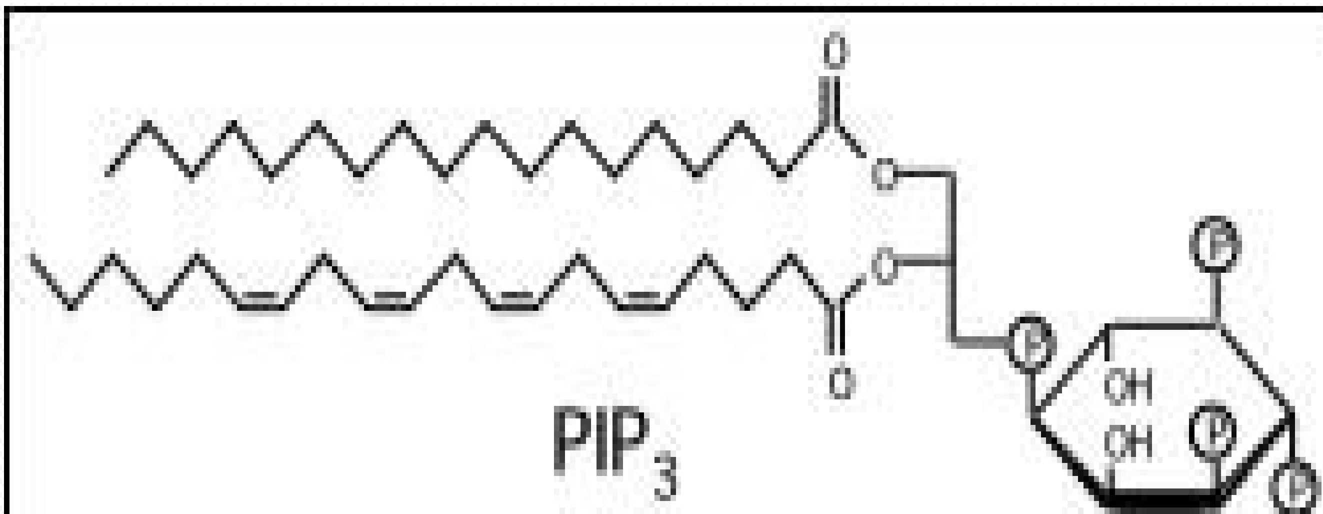




phosphatidyl inositol



phosphatidyl-inositol-3-phosphate



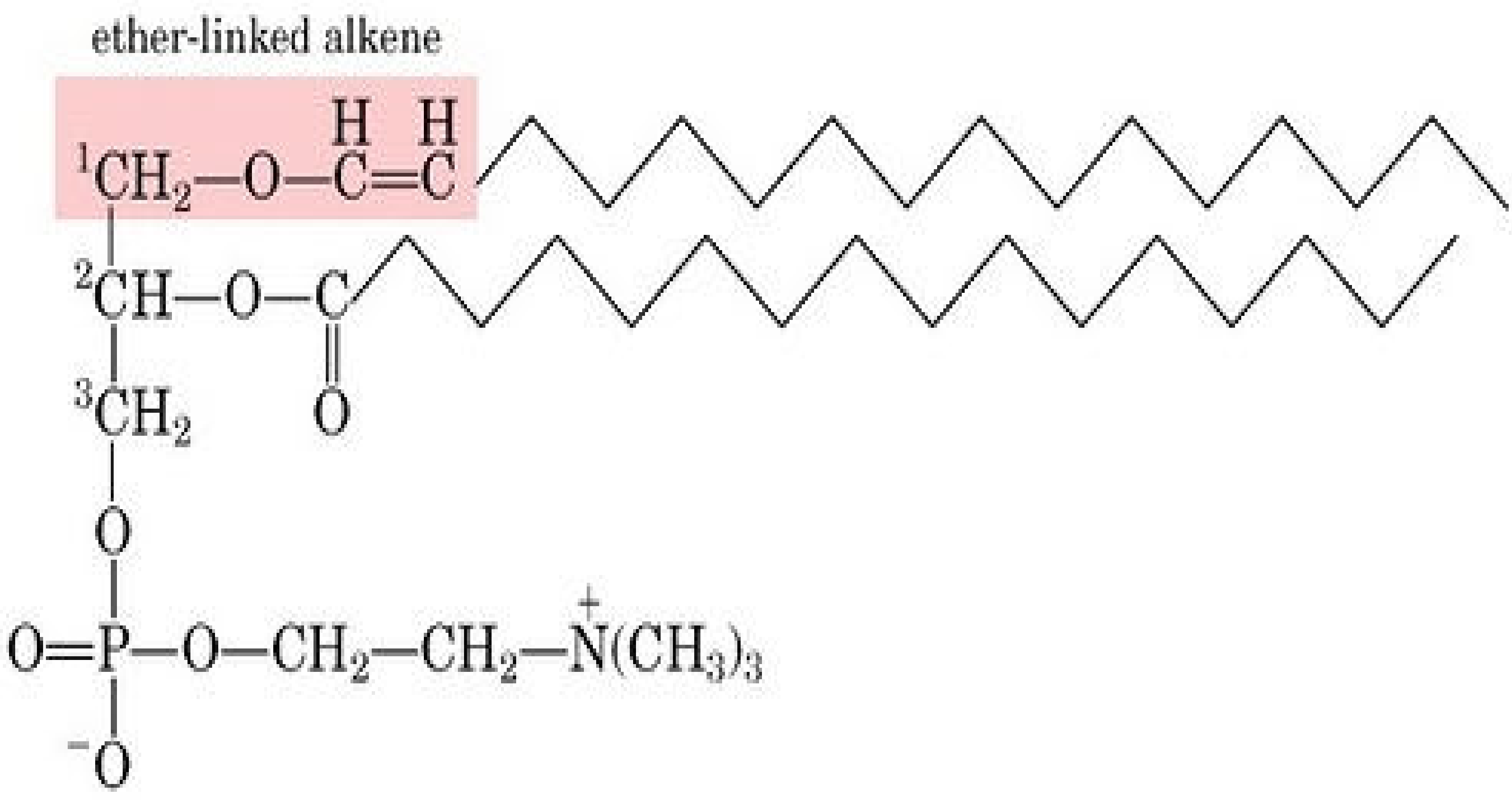
PIP_3

(Phosphatidylinositol 3,4,5-trisphosphate)

- **Phospahatidyl Inositol 3,4,5 Tri Phosphate** (PIP3) in presence of enzyme **Phospholipase C**
- Generates **Diacyl Glycerol** and **Inositol Tri Phosphate.**

Phosphatidalethanolamine/ Plasmalogen

- **Plasmalogen** possess an **Ether linkage at C1.**
- **Fatty acid** is linked to **C1 of Glycerol**, by an **Vinyl(CH=CH2) Ether (C-O-C)linkage** instead of usual Ester bond.
- Nitrogen base linked are **Ethanolamine/Choline.**



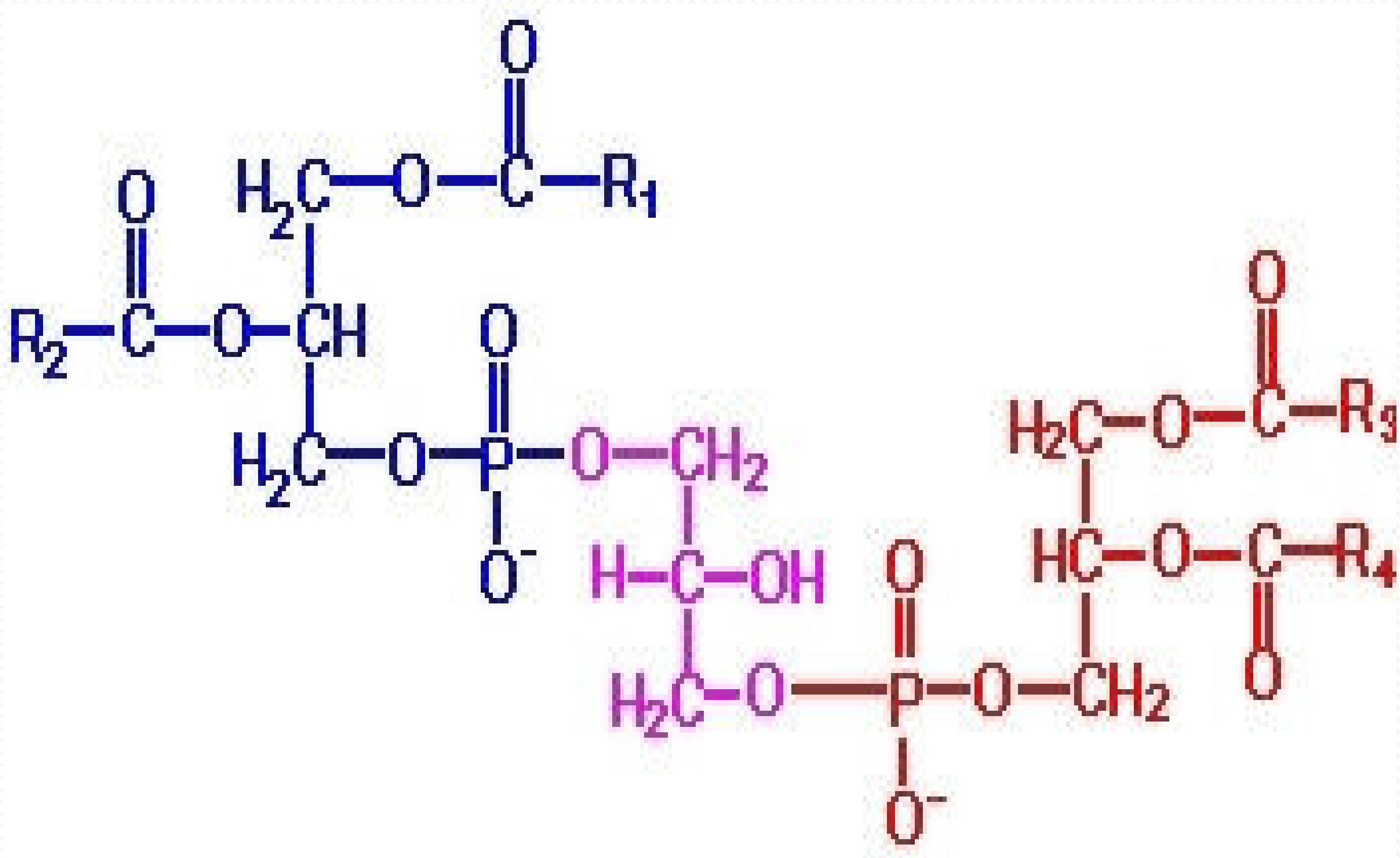
Plasmalogen

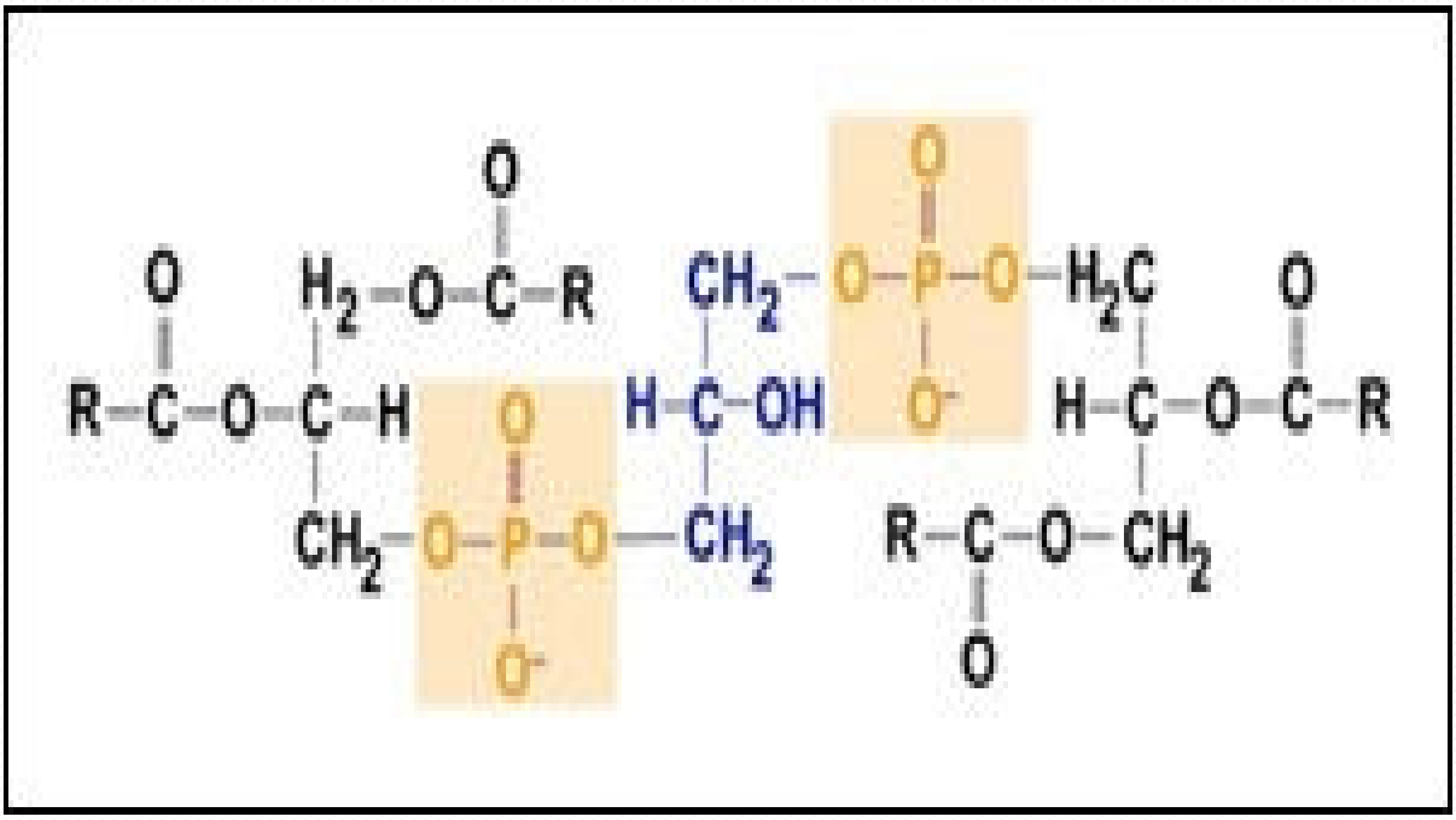
Diphosphatidylglycerol/ Cardiolipin

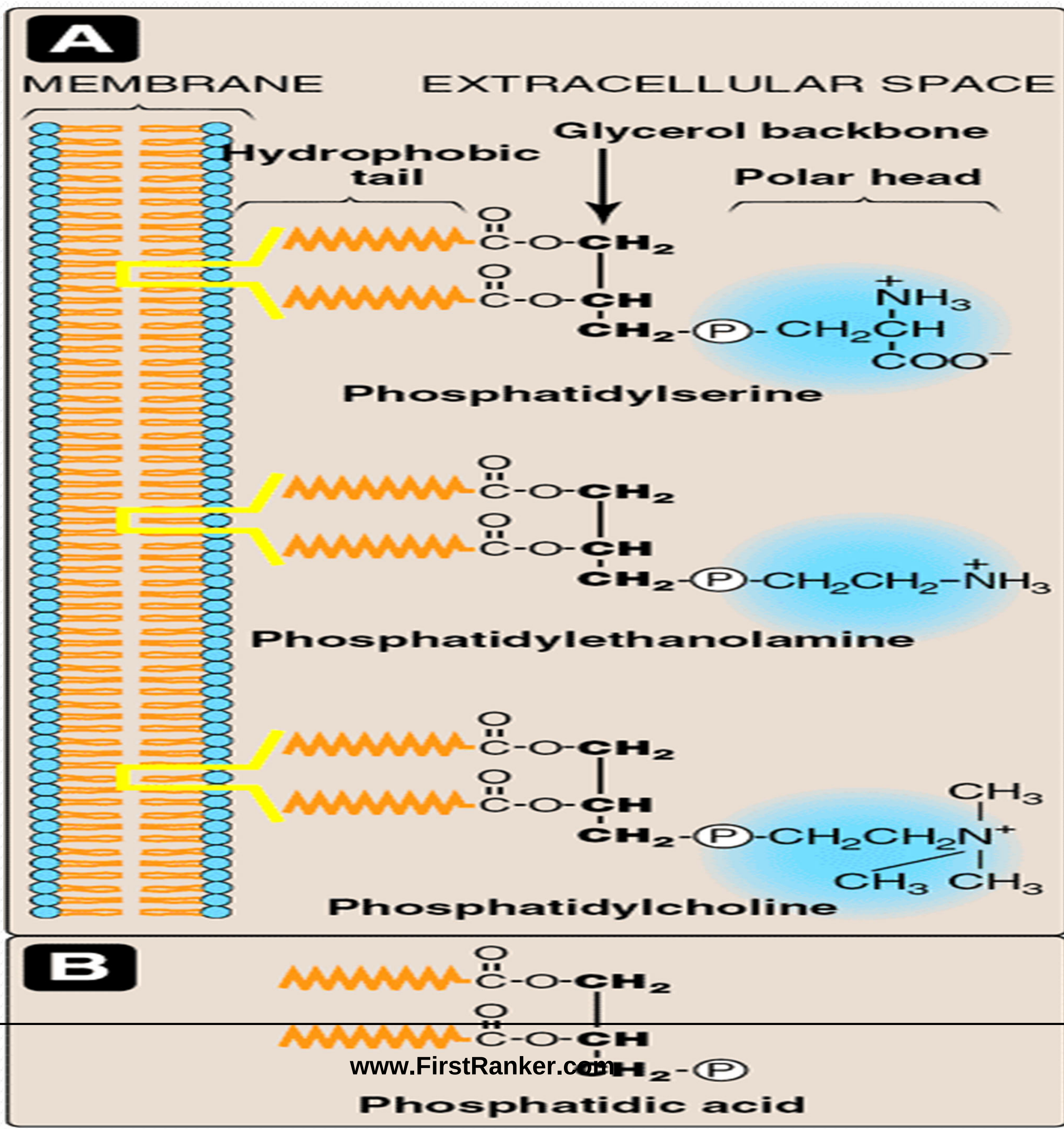
- **Cardiolipin** was first isolated from **Cardiac Muscles of Calf** and hence the name derived.

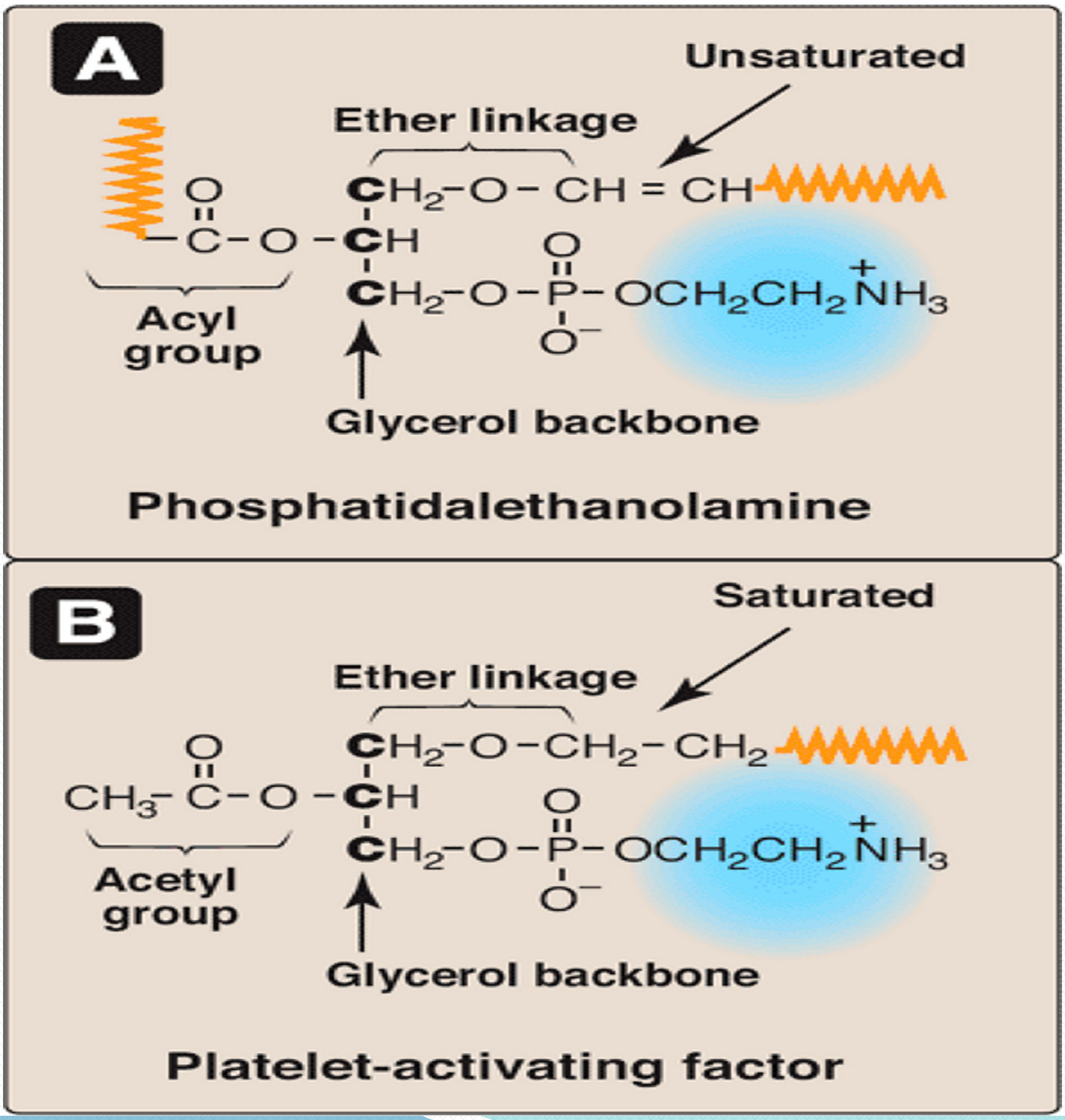
- Diphosphatidylglycerol/Cardiolipin is chemically composed of

- **Two molecules of Phosphatidic acid linked to one Glycerol .**






A
MEMBRANE
EXTRACELLULAR SPACE
Glycerol backbone
Hydrophobic tail
Polar head
Phosphatidylserine
Phosphatidylethanolamine
Phosphatidylcholine
B
Phosphatidic acid

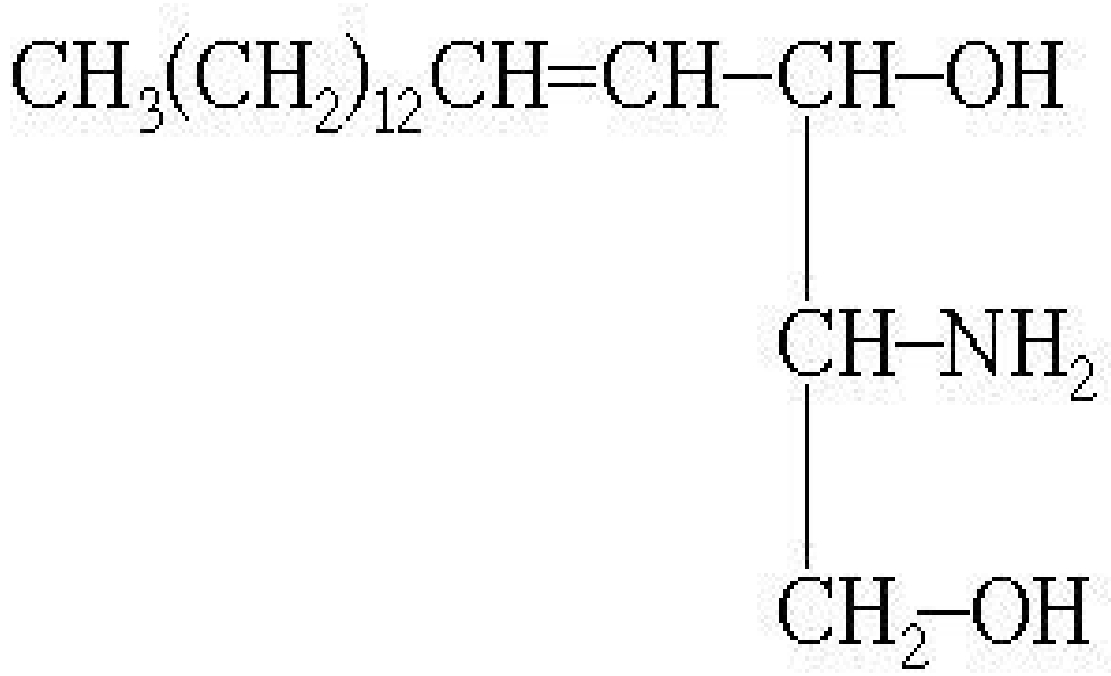


SphingoPhospholipids/ Sphingophosphatides

- **Sphingophospholipid** is a type of Phospholipid.
- **Sphingophospholipid** is **Sphingosine based Lipid**
- Which has an **C18 Dihydric Amino Alcohol– Sphingosine**.

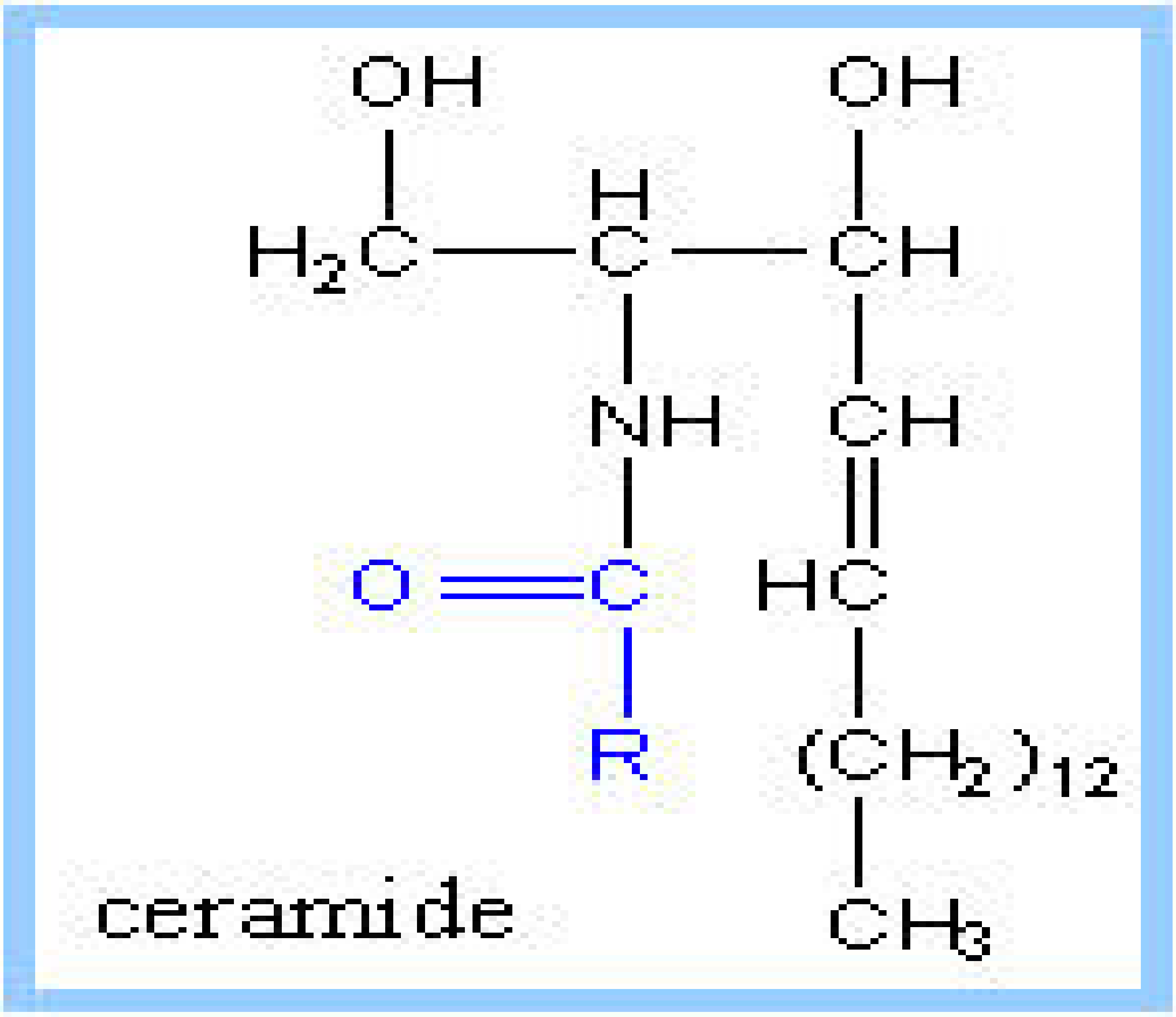
Sphingolipids

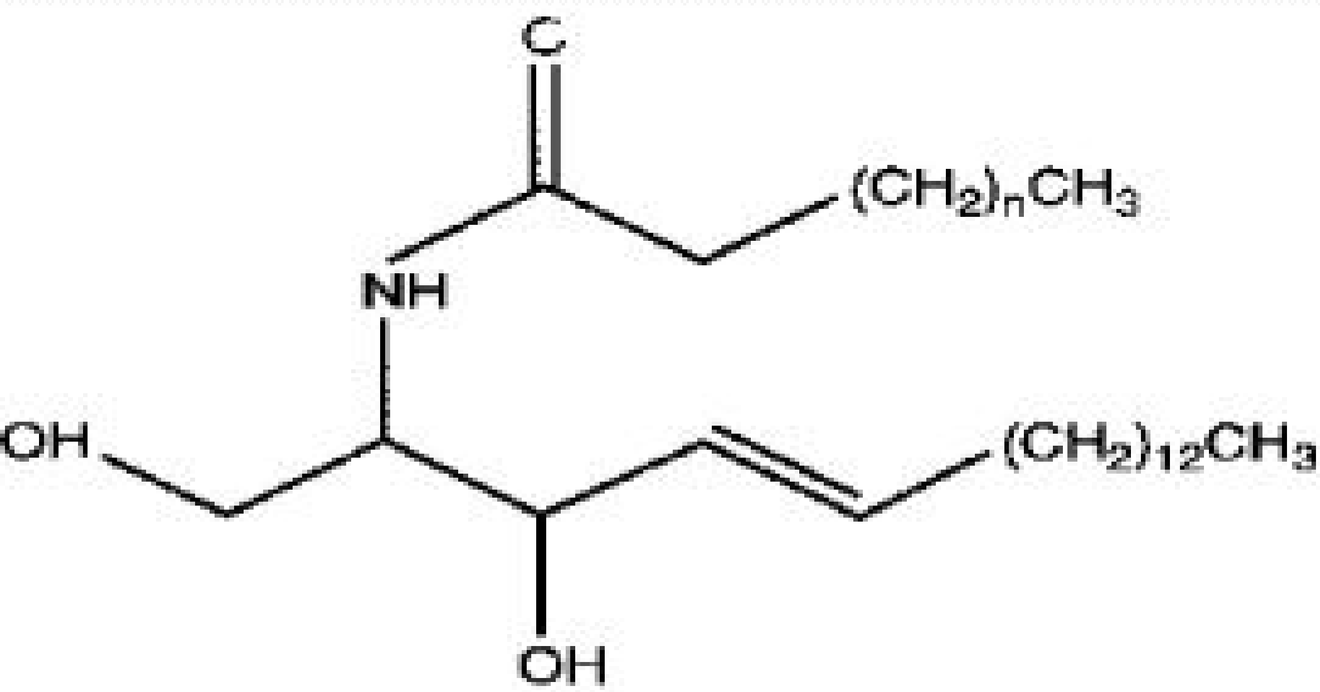
Sphingosine



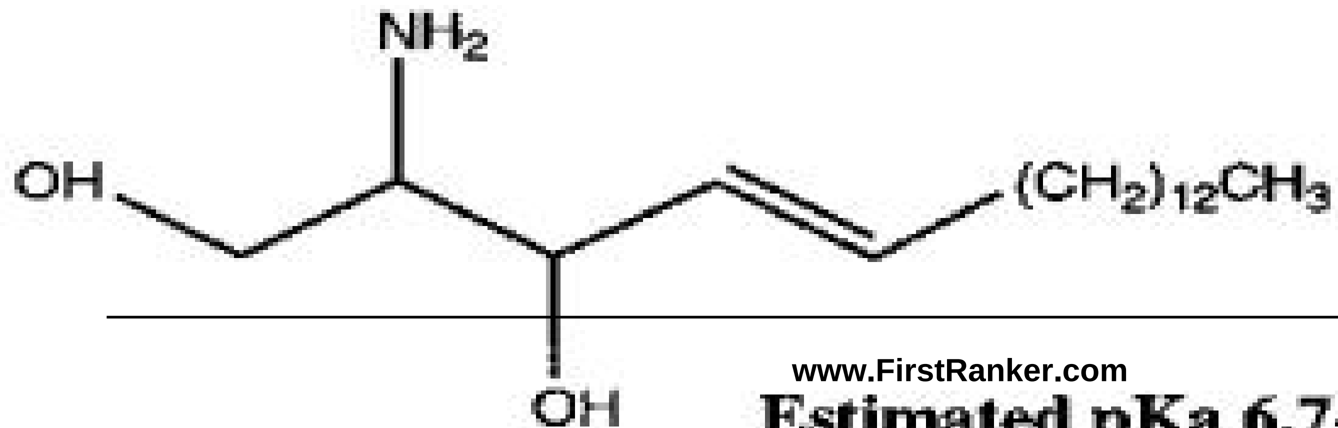
- **Sphingomyelin** is an example of **Sphingophospholipid**.

- **Sphingosine** is linked with a Fatty acid by an **amide linkage** to form **Ceramide.**
- **Ceramide is then** linked to **Phosphoric acid and Choline to form Sphingomyelin.**



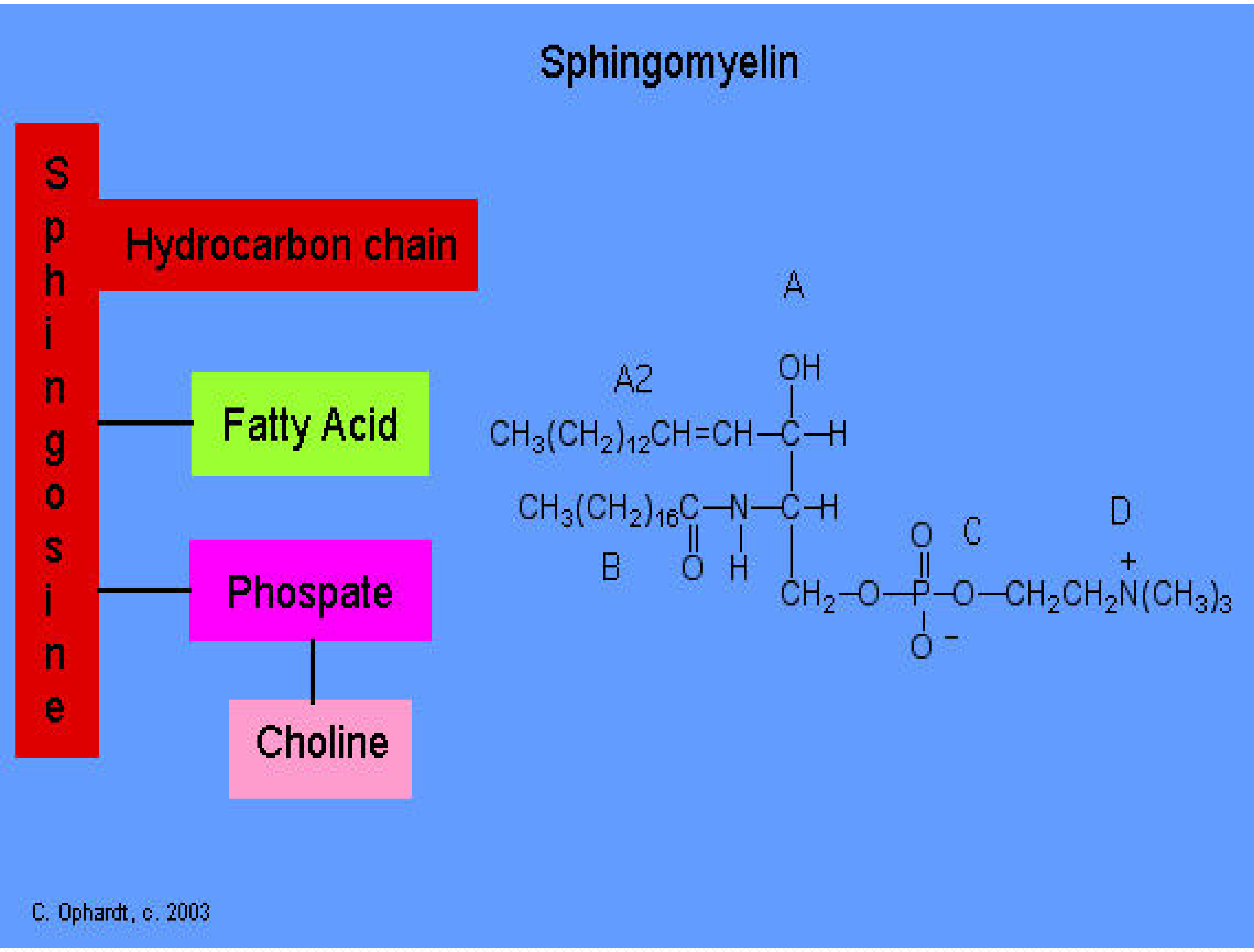


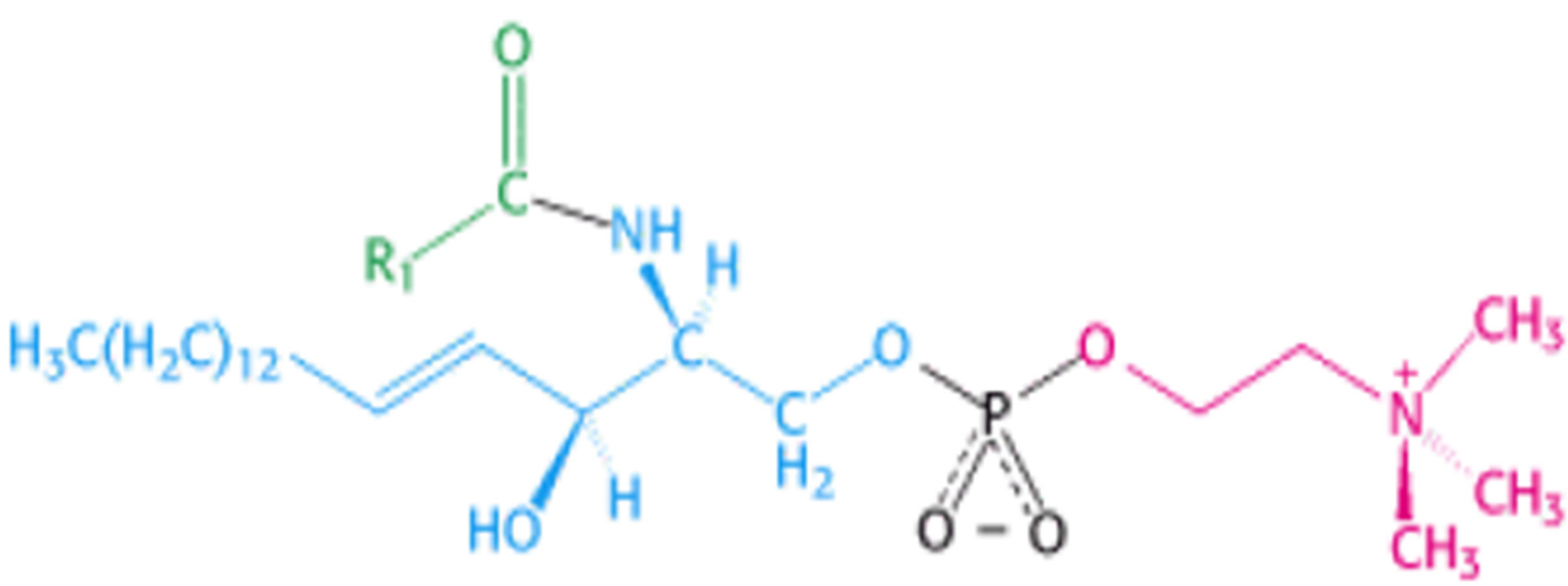
Ceramide



Sphingosine

Estimated pKa 6.7-8.4





Sphingomyelin

Properties Of Phospholipids

Amphipathic Nature Of PL

- **Phospholipds** are **Amphipathic/ Amphiphillic** in nature.
- Since the structure of PL possess **both polar** and **nonpolar groups.**

- **Hydrophilic/Polar groups of Phospholipids:**
  - **Phosphoric acid**
  - **Nitrogenous groups**
- **Hydrophobic/non polar groups of Phospholipids :**
  - **Fatty acid/Acyl chains**

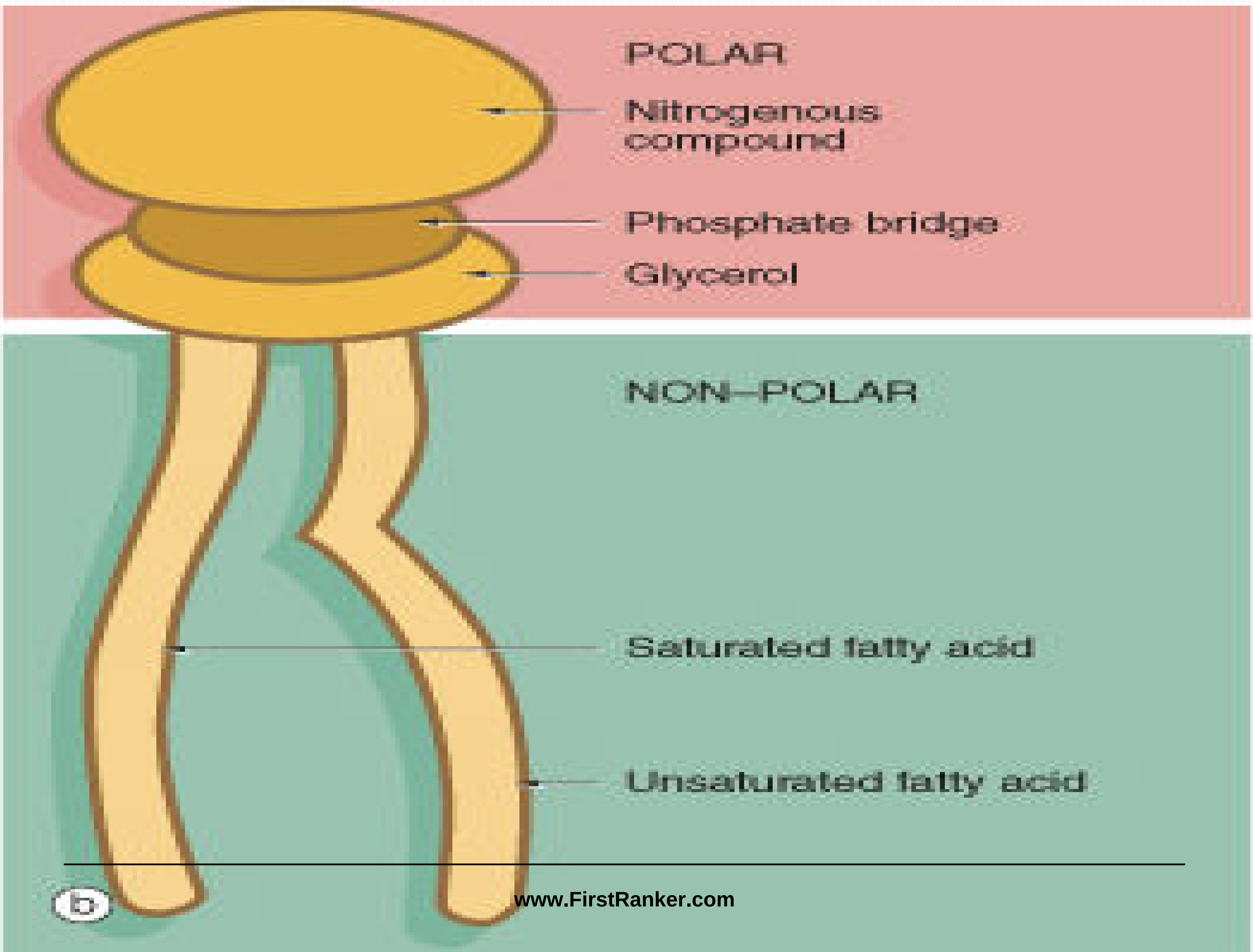
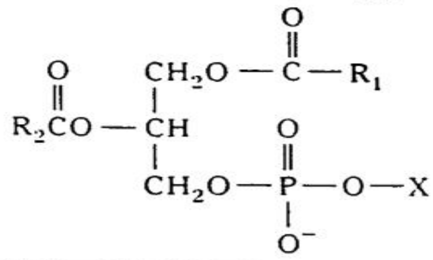
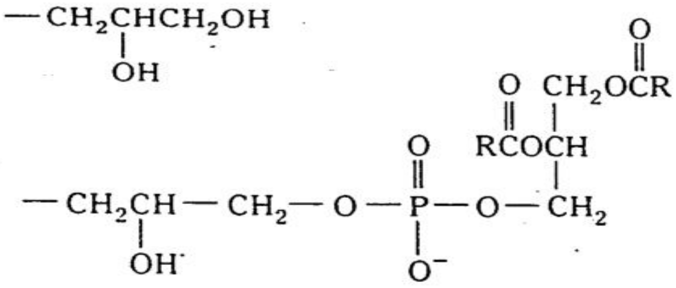
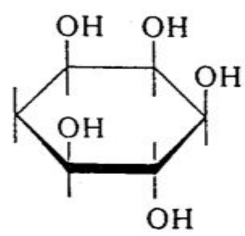
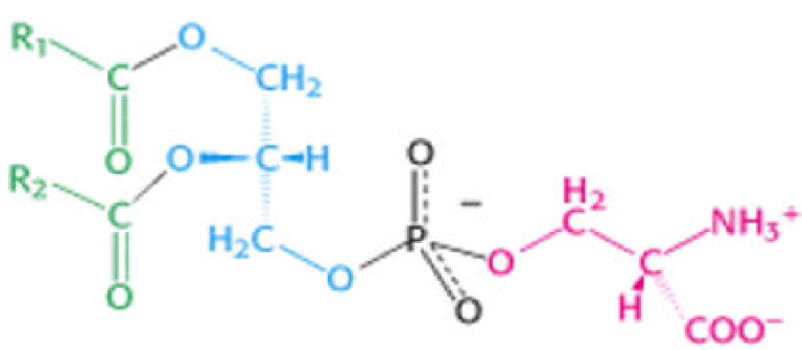


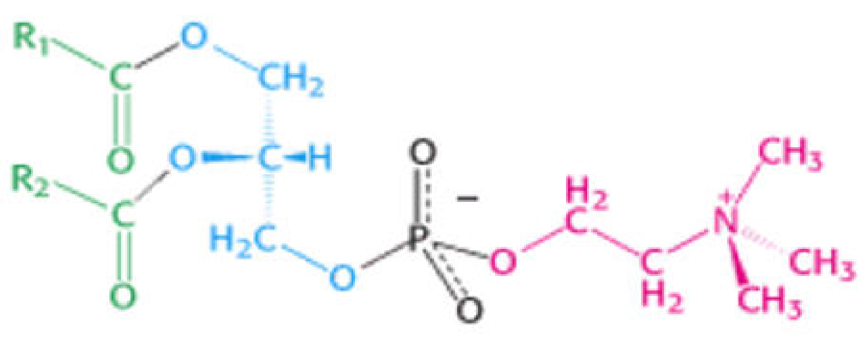
TABLE 10.2 **Major Classes of Phosphoglycerides**



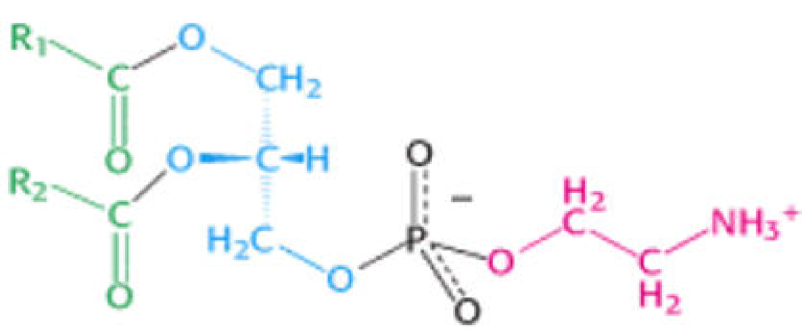
X Substituent: Name of X-OH	X Substituent: Formula of X	Name of Phospholipid
Water	$-H$	Phosphatidic acid
Choline	$-CH_2CH_2\overset{+}{N}(CH_3)_3$	Phosphatidylcholine (lecithin)
Ethanolamine	$-CH_2CH_2\overset{+}{N}H_3$	Phosphatidylethanolamine (cephalin)
Serine	$-CH_2-CH(NH_3)-COO^-$	Phosphatidylserine
Glycerol	$-CH_2CH(OH)CH_2OH$	Phosphatidylglycerol
Phosphatidylglycerol		Diphosphatidylglycerol (cardiolipin)
Inositol		Phosphatidylinositol



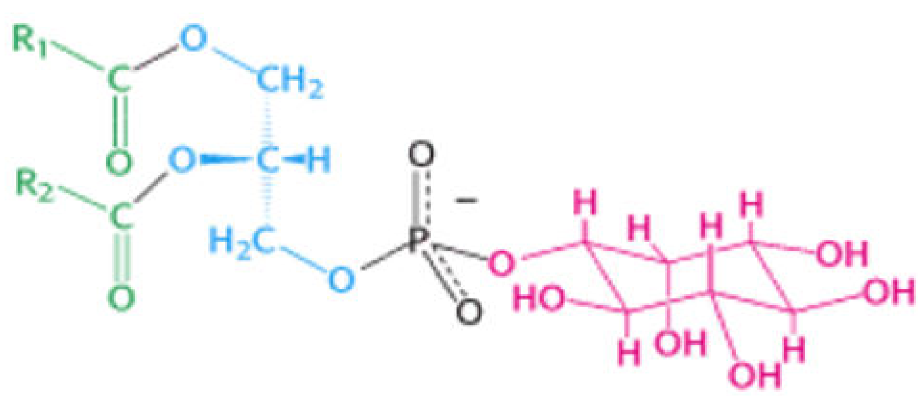
Phosphatidyl serine



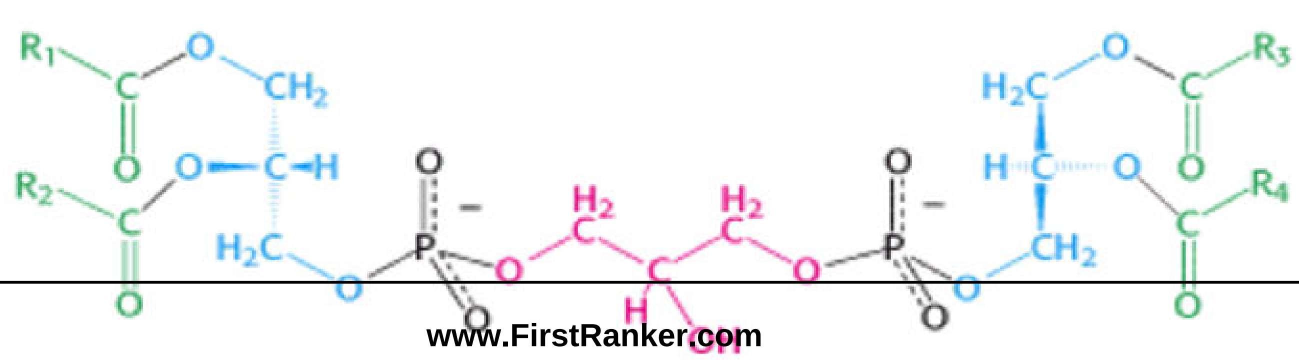
Phosphatidyl choline



Phosphatidyl ethanolamine



Phosphatidyl inositol



Diphosphatidyl glycerol (cardiolipin)

Functions Of Phospholipids(PL)

1. Biomembrane Components
2. Lung Surfactant Role
3. Lipid Digestion and Absorption
4. LCAT activity for Cholesterol Esterification and Excretion
5. Lipotropic Factor
6. Clotting Mechanism
7. Cardiolipin role
8. Coenzyme Role
9. Choline from Lecithin Methyl Donor
10. Detoxification role of Lecithin
11. Eicosanoids biosynthesis
12. Nerve Impulse Conduction
13. Second Messenger of Hormone Regulation

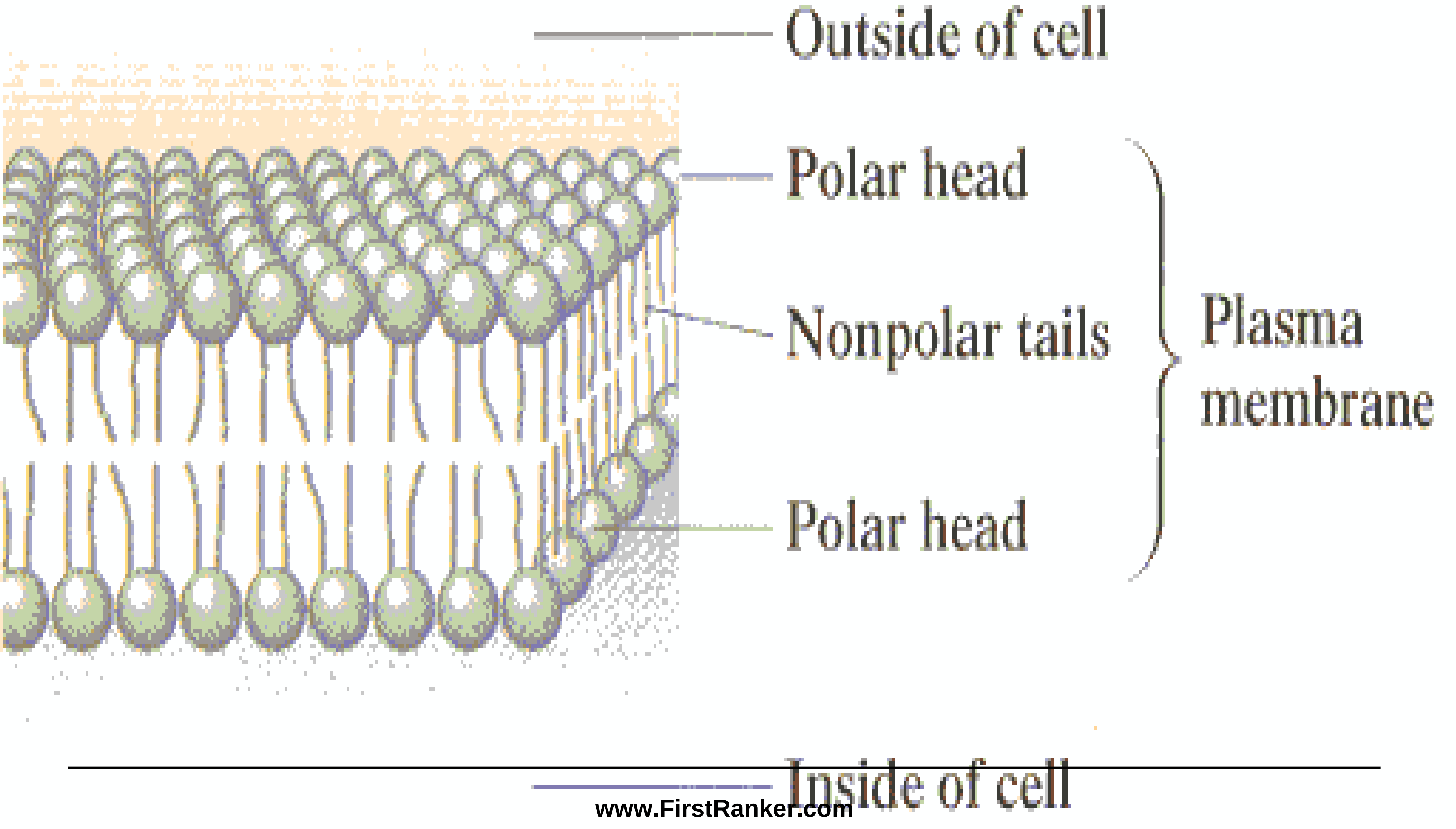
Glycerophospholipid Functions

1. Phospholipids Components Of Biomembranes

Role Of Lecithin

- The **Glycerophospholipid Lecithin** is the major **structural components of biomembranes**.
- The **Amphipathic phospholipid bilayer** has polar head groups of PL directed outwards.

Lipid bilayer of plasma membrane



- **Membrane Phospholipid bilayer ,constituent of cell membranes imparts:**
  - **Membrane Structural Integrity**
  - **Membrane Fluidity**
  - **Membrane Flexibility**
  - **Selective Permeability**

- **Phospholipids** may have fatty acids which are **saturated or unsaturated**.
- This affects the properties of the resulting bilayer/cell membrane:

- Most membranes have phospholipids derived from **unsaturated** fatty acids.
- **Unsaturated fatty acids** add **fluidity to a bilayer** since **'kinked' tails do not pack tightly together.**

- Phospholipids (PL) derived from unsaturated phospholipids **allow faster transport of nonpolar substances across the bilayer**.
- **Polar substances are restricted** to cross the membrane .
- **PL bilayer in membranes protect the cell from an entry of polar reactive and interfering substances and serve as security guards of cells.**

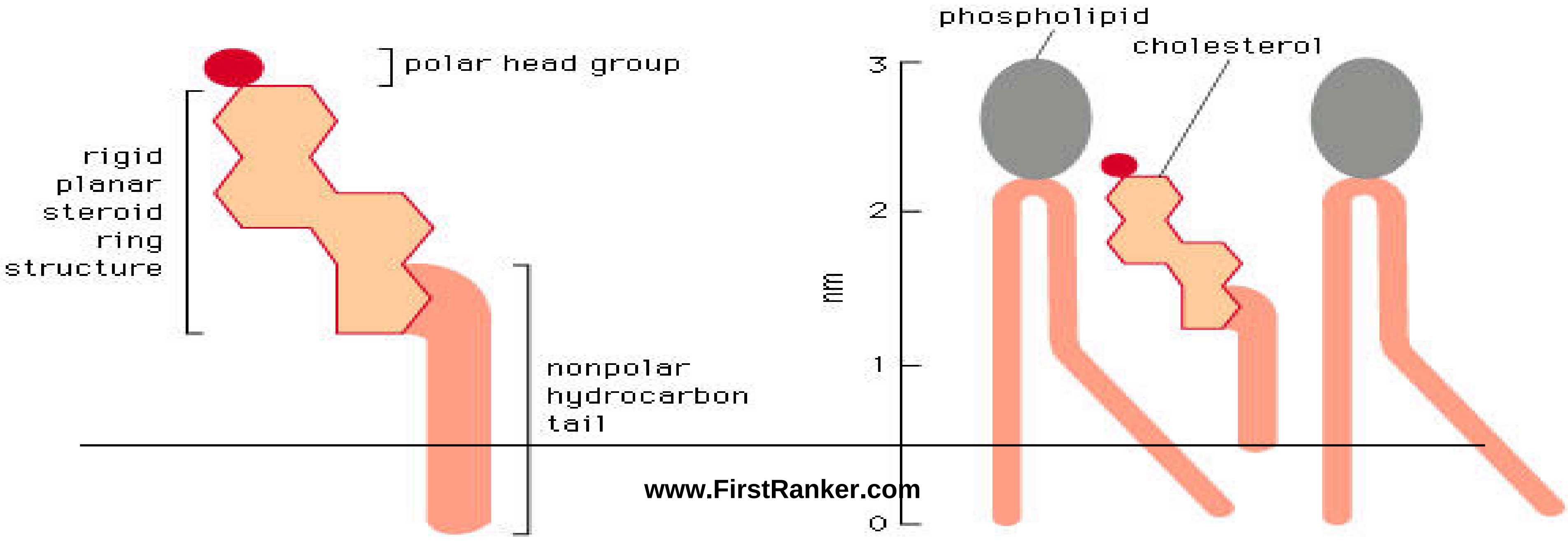
- **Membranes of nerve cells,** which are **stiffer** contain a much higher percentage of **phospholipids derived** from **saturated fatty acids**.

- They also contain **high levels of cholesterol** which **stiffens membrane** structure.

Cholesterol intercalates among the Phospholipids.

Cholesterol fills in the spaces left by the kinks of PUFAs .

Cholesterol stiffens the bilayer and makes membrane **less fluid and less permeable**.



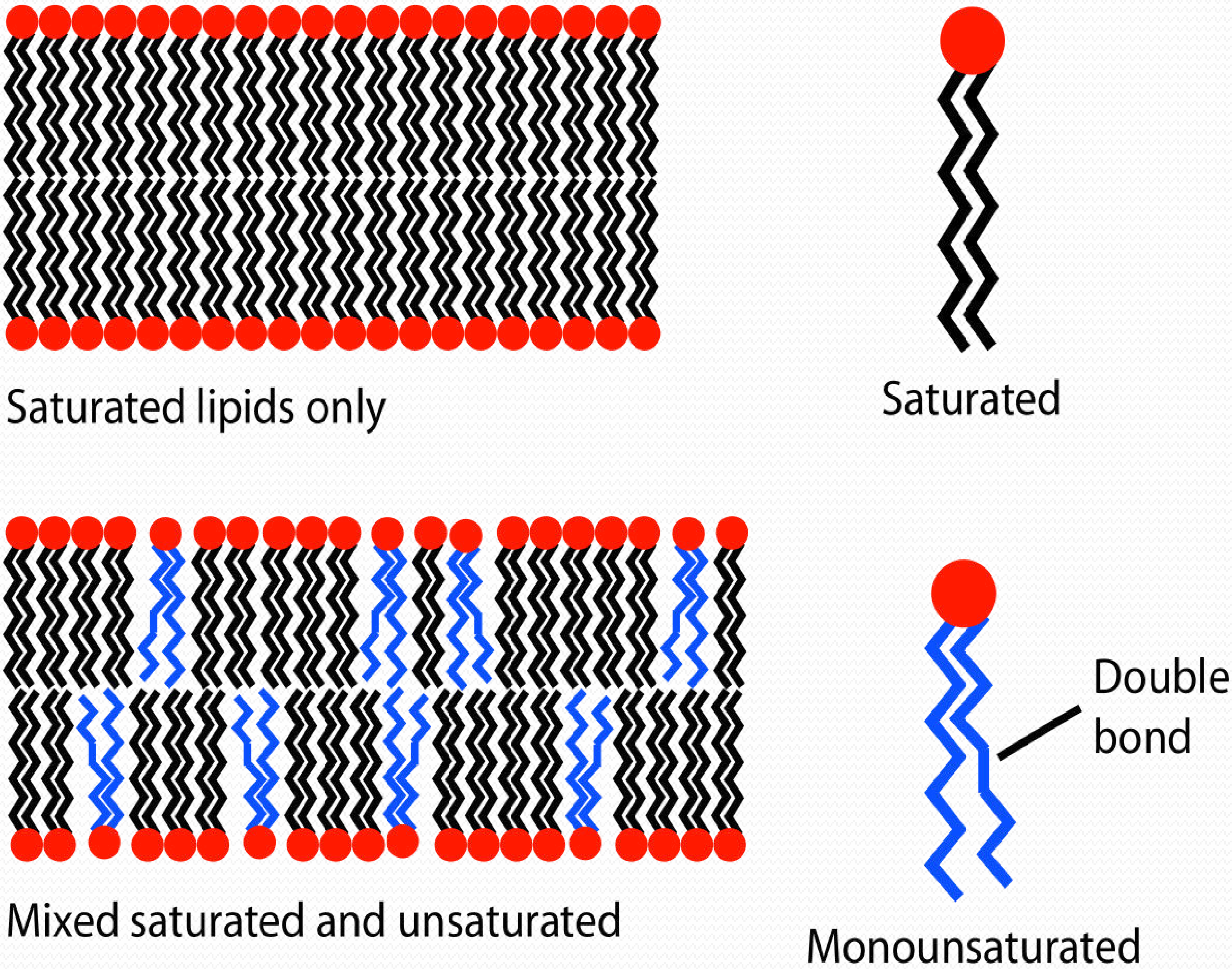
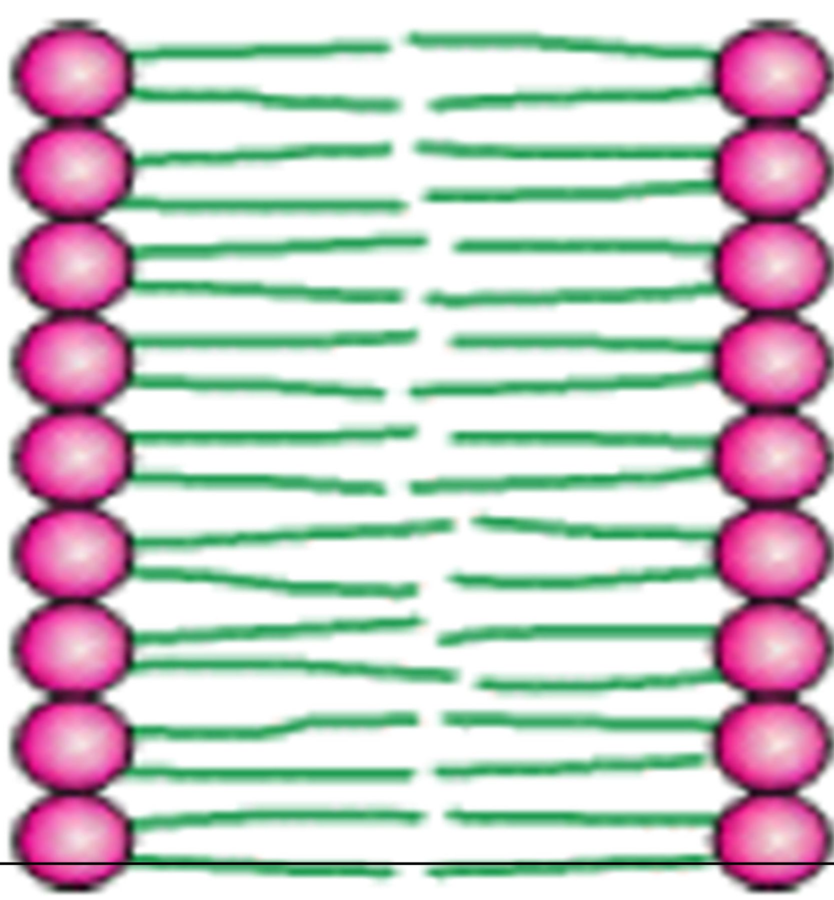
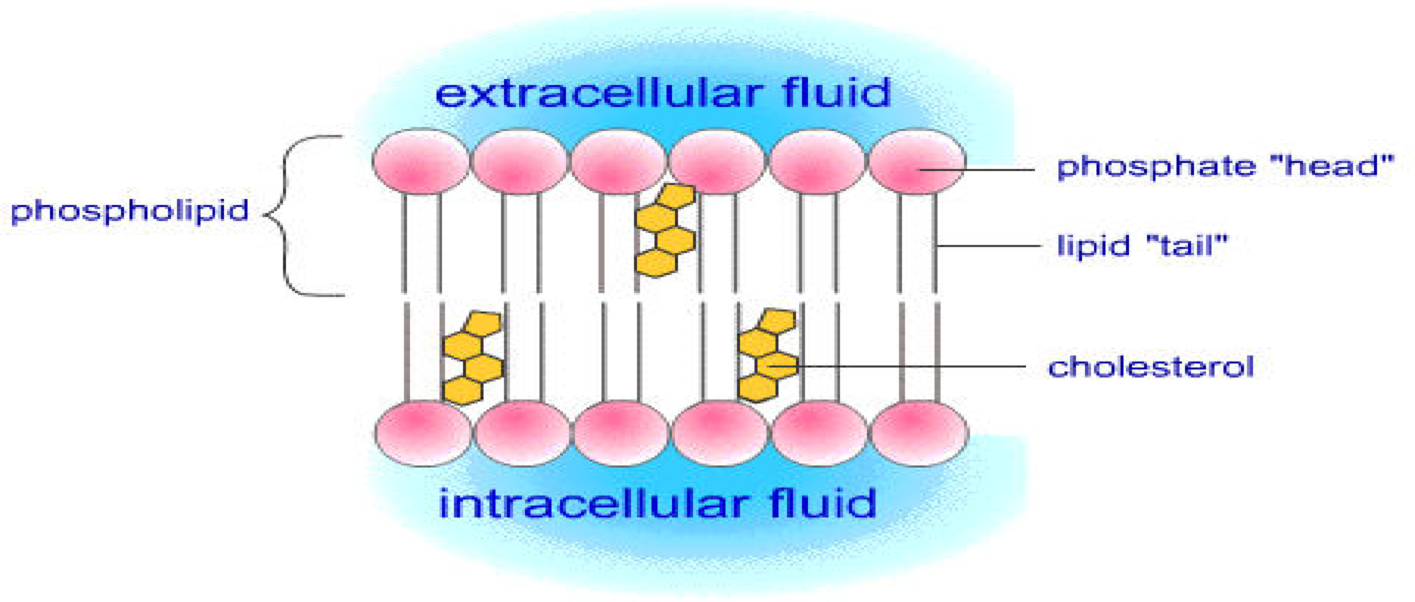
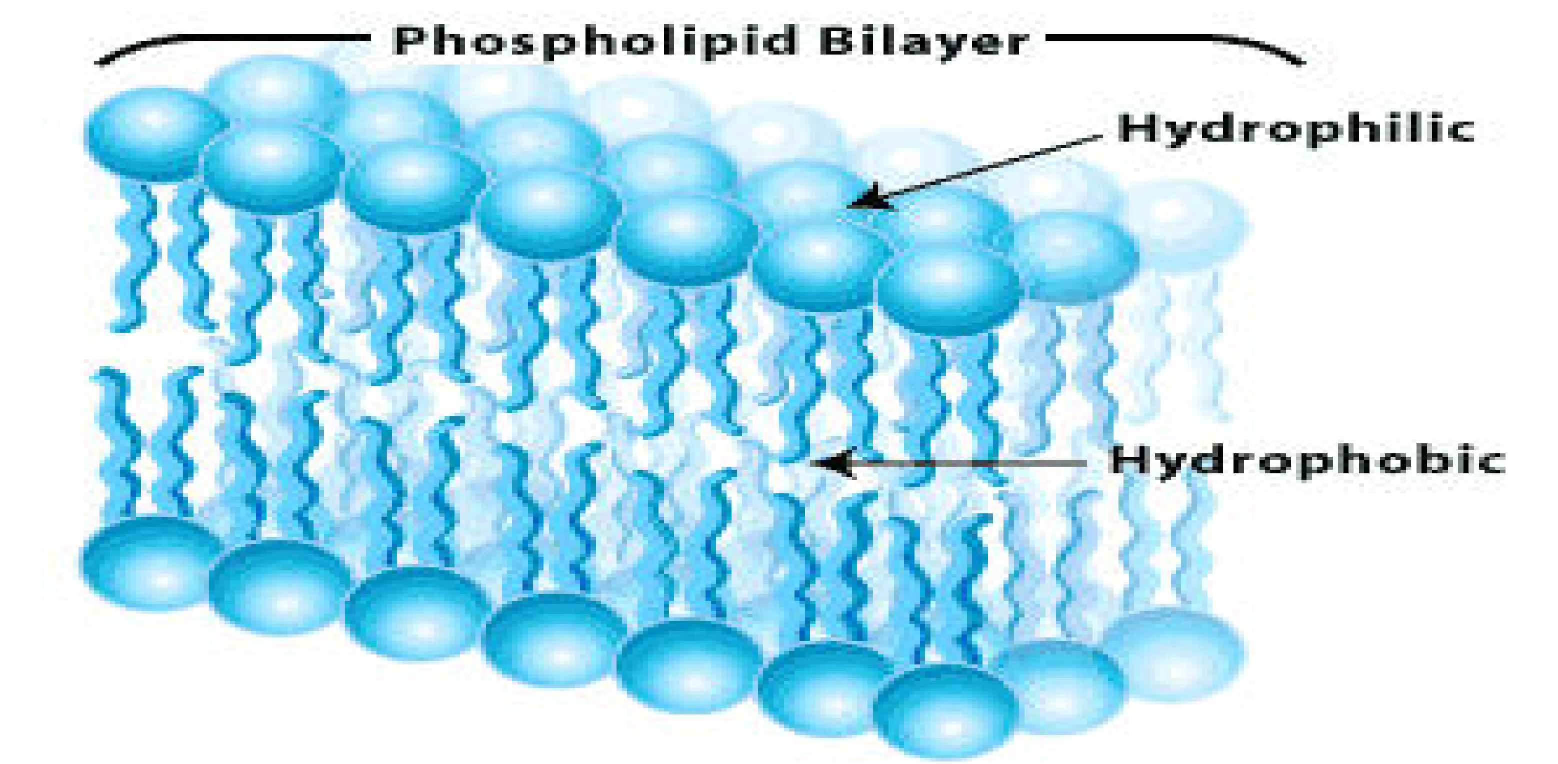


Diagram of a section of a bilayer membrane.







2.Phospholipid As Lung Surfactant

- **DiPalmitoyl Phosphatidyl Choline** serve as an **Lung surfactant.**
- It **lowers the surface tension** and keeps the **alveoli of lungs blown. (prevent adherence of alveoli)**
- This **enables effective exchange** of **gases** (Oxygen) in Lungs.

- After expiration of air the alveoli gets deflated.
- The **lung surfactant** reduces the surface tension and allow the **alveolar walls to reinflate**.

- The **Phospholipid** as **Lung surfactant** prevent the body to suffer from **Respiratory Distress Syndrome.**

3.Phospholipids
Help In Digestion And Absorption Of Dietary Lipids

- **Phospholipids being amphipathic** in nature act as good **emulsifying agents.**

- **Along with Bile Salts** they help in **digestion and absorption** of non polar **dietary Lipids.**

4.Phospholipids Helps In Cholesterol Excretion

- **Lecithin** helps in **Cholesterol Esterification by LCAT activity.**
- **Cholesterol Ester is later** dissolved in Bile and further **excreted it out**.

- **Lecithin** serve as a **storage depot of Choline.**
- **Choline** is a store of **labile Methyl groups**
- Hence **Choline** participate in **Transmethylation reactions .**

- **Choline** is used for generation of neurotransmitter '**Acetyl Choline**" which helps **in nerve impulse transmission.**

- **Choline** serve as **Lipotropic factor** hence helps in Lipoprotein formation in Liver to mobilize out Lipids and **prevent from Fatty Liver.**

6. Phospholipids Releases Arachidonic Acid For Eicosanoid Biosynthesis

- **Lecithin** at 2nd carbon has **Arachidonic acid(PUFA).**
- **It donates Arachidonic acid** which is a precursor for **Eicosanoid biosynthesis.**

- Phosphatidyl Inositol **also provides Arachidonic acid** for Eicosanoids biosynthesis.

- Lecithin helps CYT450 system for **drug detoxification**.

8. Phospholipids Has Role In Blood Coagulation

Role Of Cephalin

- Phosphatidyl Ethanolamine has **role in blood coagulation.**
- It converts clotting factor **Prothrombin to Thrombin by factor X.**

- Phosphatidyl Serine has **role in Apoptosis** (Programmed Cell death).

10.Role Of Phospholipids In Hormonal Action

- **Role Of Phosphatidylinositol**
- **Phosphatidyl Inositol Triphosphate (PIP3)** is a constituent of **cell membrane** and **mediate hormone action** and **maintain intracellular Calcium.**

- **Inositol tri phosphate** and **Diacylglcerol** are released from **PIP3** by membrane bound **Phospholipase C**

- **The Inositol triphosphate and DAG** serve as **second messenger** to **hormones Oxytocin and Vasopressin**

- **Plasmalogen** associated to **brain and muscles** helps in Neural functions.

- **Role Of Cardiolipin**

- **Cardiolipin** is rich in **inner mitochondrial membrane** and supports **Electron Transport Chain and cellular respiration.**

- **Cardiolipin** exhibits antigenic properties and used in **VDRL serological tests** for diagnosis **Syphilis**.

- Phospholipid serve as **Coenzyme for certain Enzymes :**
  - **Lipoprotein Lipase**
  - **Cytochrome Oxidase**

Functions OF Sphingophospholipids

- **Sphingomyelins** are rich in **Myelin sheaths** which surrounds and **insulate the axons of neurons.**

- Sphingomyelin helps in **nerve impulse transmission.**

Disorders Related To Phospholipids

- **Respiratory Distress Syndrome (RDS)**
- Suffered by premature born infants.
- Caused due to **deficiency** of **Lung surfactant DiPalmitoyl Phosphatidyl Choline.**

- Since Lung is the last organ to mature.
- **Premature babies** has **insufficient lung surfactant** lining in the alveoli walls.
- Which supports **no normal respiration.**
- Has respiration difficulties due to **alveolar collapse.**

- **Sign And Symptoms Of RDS**
- Low ATP production
- Weakness ,Lethargy
- Low Cellular Functions
- Poor Coordination

L/S ratio of Amniotic Fluid Diagnostic Criteria For RDS

- Lecithin /Sphingomyelin (L/S) ratio of **amniotic fluid** is a good indicator to evaluate **fetal lung maturity.**

- Prior to 34 weeks of gestation the concentration of Lecithin and Sphingomyelin in amniotic fluid is equal.
- **In Later weeks of gestation the Lecithin levels are markedly increased.**

- At full term L/S ratio is 5.

- **In pre term infants L/S ratio is 1 or < 1 resulting to suffer from RDS.**

- **Old** age **persons** and **Adults** with Lung damage
(Due to Smoking/ Infections)

- Who **unable to biosynthesize the lung surfactant** may also **exhibit RDS.**

Membrane Related Disorders Due To Defective Phospholipds

- Deranged Cellular Environment
- Cell membrane Damage
- Tissue Necrosis
- Cell Death

Mitochondrial ETC Defects due to Phospholipid Deficits

Defect In Sphingomyelins affect Nerve Impulse Conduction

Fatty Liver due to Phospholipid Defects.

Glycolipids

Glycolipids

- Glycolipids are type of **compound Lipids.**
- **Chemically Esters of Fatty acids with Alcohol and additional group as Carbohydrate moieties**

Types OF Glycolipids Based on Alcohol

1. **Glycoglycerolipids**
   Glycerol as Alcohol
   (Less in Animals and Human)
2. **Glycosphingolipids**
   Sphingosine as Alcohol
   (Predominant in Animals and Human)

Glycosphingolipids

Predominant Animal Glycolipids

- **Types of Glycolipids** chemically composed of **Ceramide linked with one or more sugar residues /there derivatives**

Types Of Glycosphingolipids

1. **Based on Number and Type of Carbohydrate moiety and there derivatives linked to a Ceramide**

2. **Based on Fatty acid in Ceramide**

Types Of Glycosphingolipids

All has Ceramide in Their Str

1) Cerebrosides
2) Gangliosides
3) Globosides
4) Sulfatides

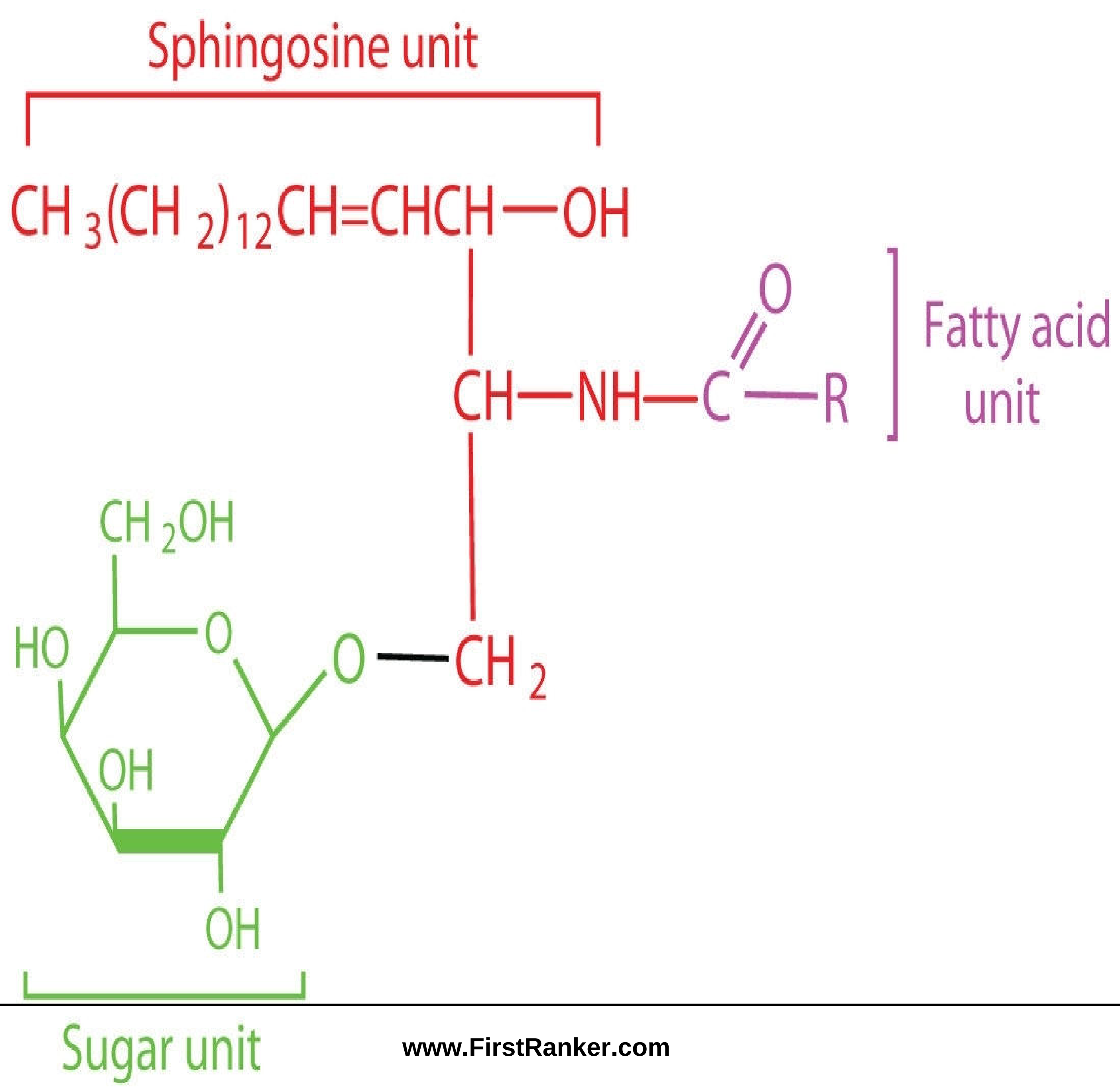
Cerebrosides

Simplest GlycoSphingolipids

Monoglycosylceramide

Cerebrosides

- **Cerebrosides** are **type of Glycosphingolipids**
- **Ceramide linked with one sugar residue**

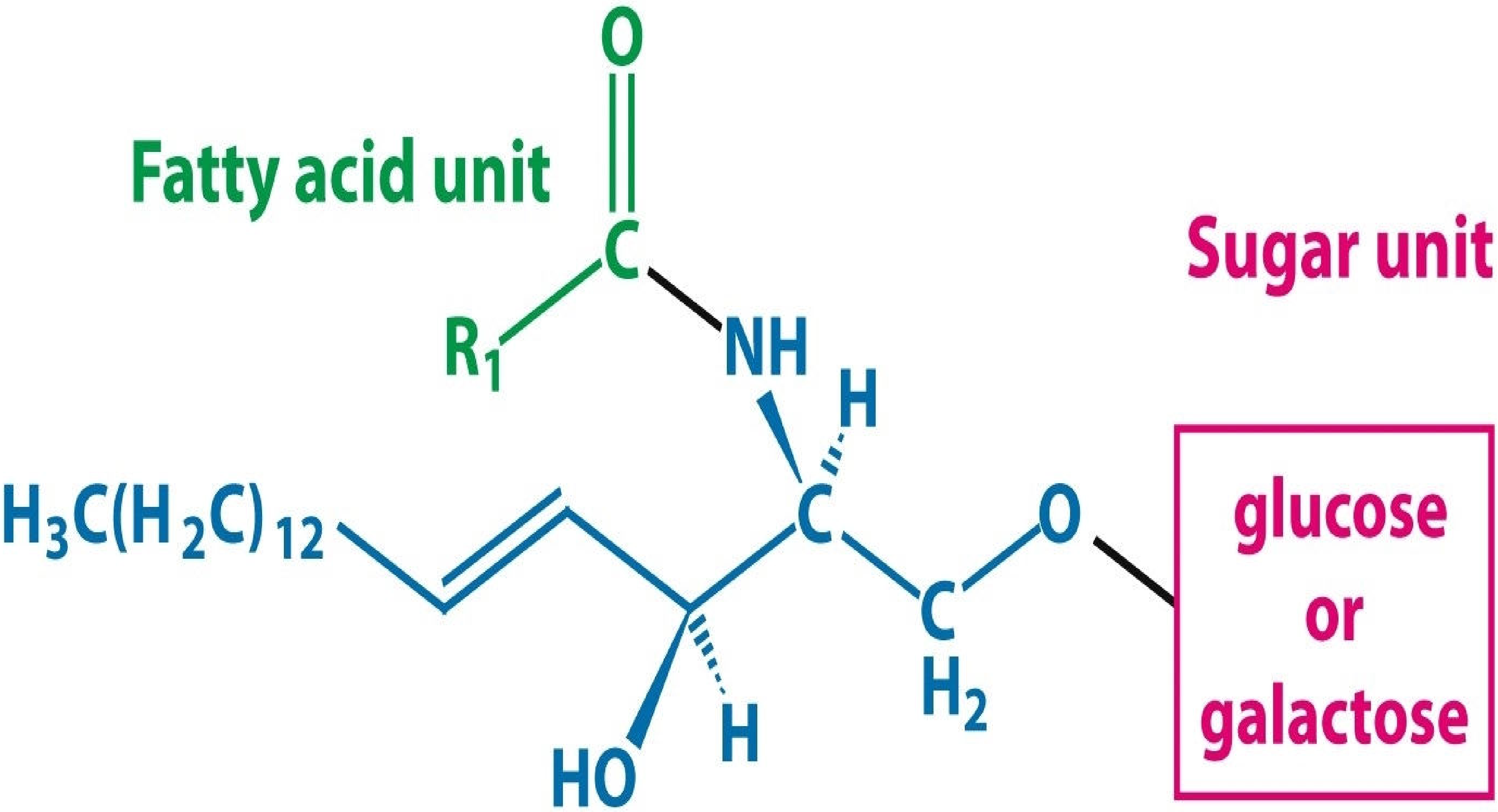


Types of Cerebrosides

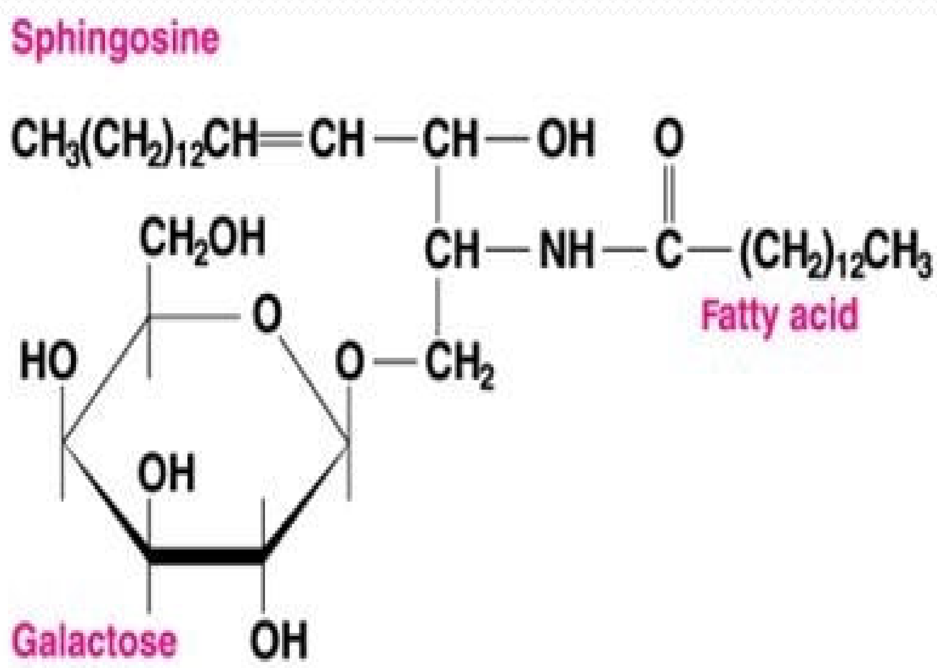
- **Depending upon** the **Carbohydrate** moiety **Types of Cerebrosides** are:

  - **Glucocerebrosides**
  (In Extra neural/Other tissues)
  - **Galactocerebrosides**
  (In Neural)

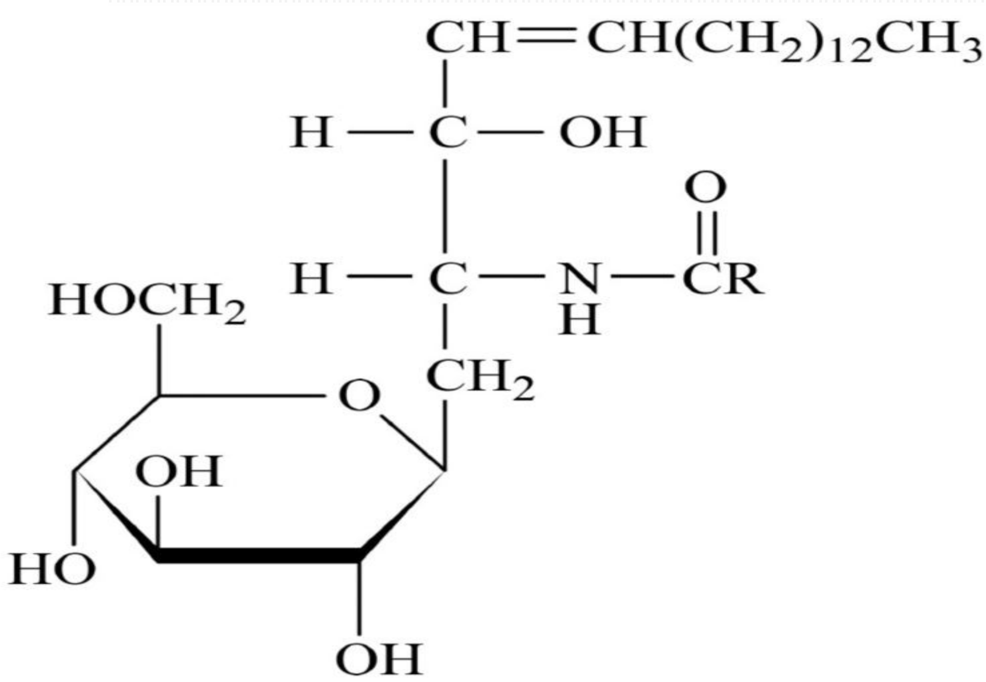
Structures Of Cerebrosides



Cerebroside (a glycolipid)

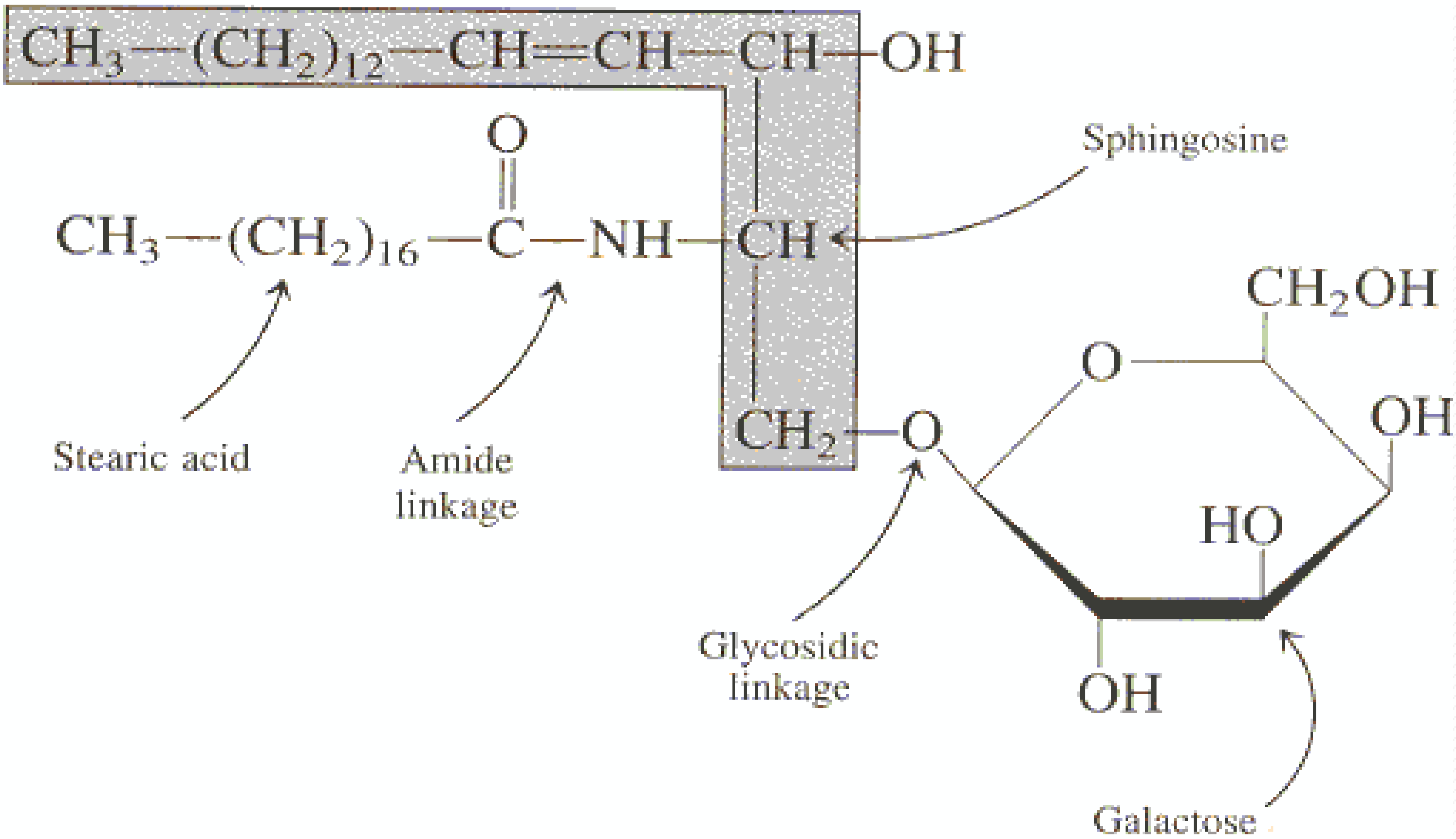


Galactocerebroside, a glycosphingolipid



A Glucocerebroside

Galactocerebroside

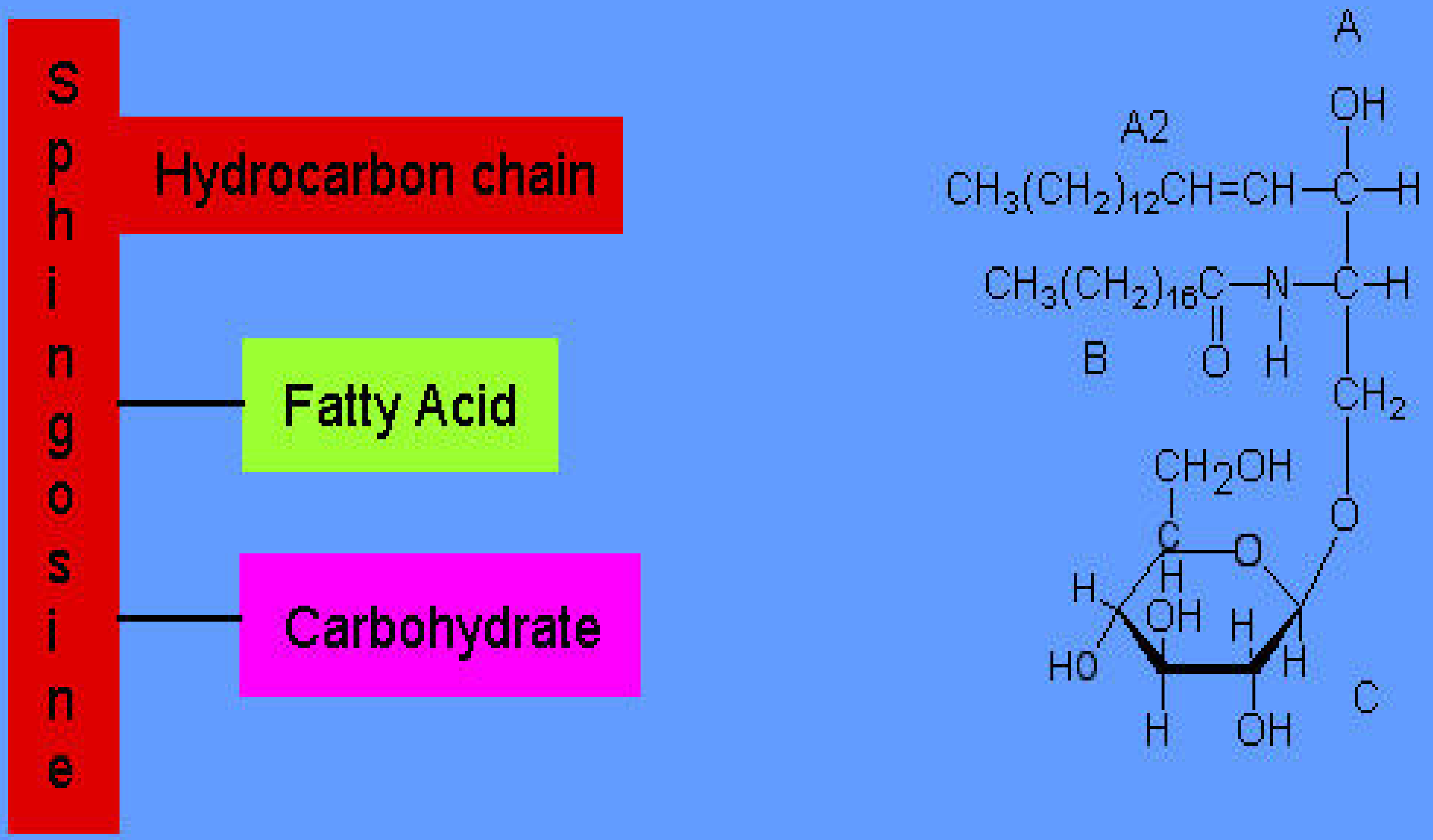


- Depending upon the **Fatty acids** **Types of Cerebrosides** are:

  - **Kerasin-Has Lignoceric acid**
  - **Cerebron-Has Cerebronic acid**
  - **Nervon-Has Nervonic acid**
  - **Oxynervon - Has Oxynervonic acid**

 www.FirstRanker.com

Glucocerebroside



C. Ophardt, c. 2003

Gangliosides

Complex Glycosphingolipids

Gangliosides

- **Gangliosides** are **Type of Glycosphingolipids**
- In comparison to **Cerebrosides, Gangliosides are more complex.**

NANA in Gangliosides

- Characteristic feature of Gangliosides is
- Its structure contains **one or more N-Acetyl Neuraminic Acid (NANA)/Sialic acid residues**

- **NANA**/Sialic acid is derived from **N-Acetyl Mannose and Pyruvate**.

- **Gangliosides** structure has Carbohydrate moieties as
  - **Glucose**
  - **Galactose**
  - **N-Acetyl Galactosamine**
  - **N-Acetyl Neuraminic Acid (NANA)/Sialic acid**.

Types Of Gangliosides

- Based on Number and Position of NANAs in Ganglioside structure
- Various types and subtypes of Gangliosides are existing in human body

Types of Gangliosides

- **Gangliosides with one NANA residue**
  - **GM1**
  - **GM2**
  - **GM3**
- **Gangliosides with two NANA residues**
  - **GD**
- **Gangliosides with three NANA residues**
  - **GT**

Types Of Gangliosides

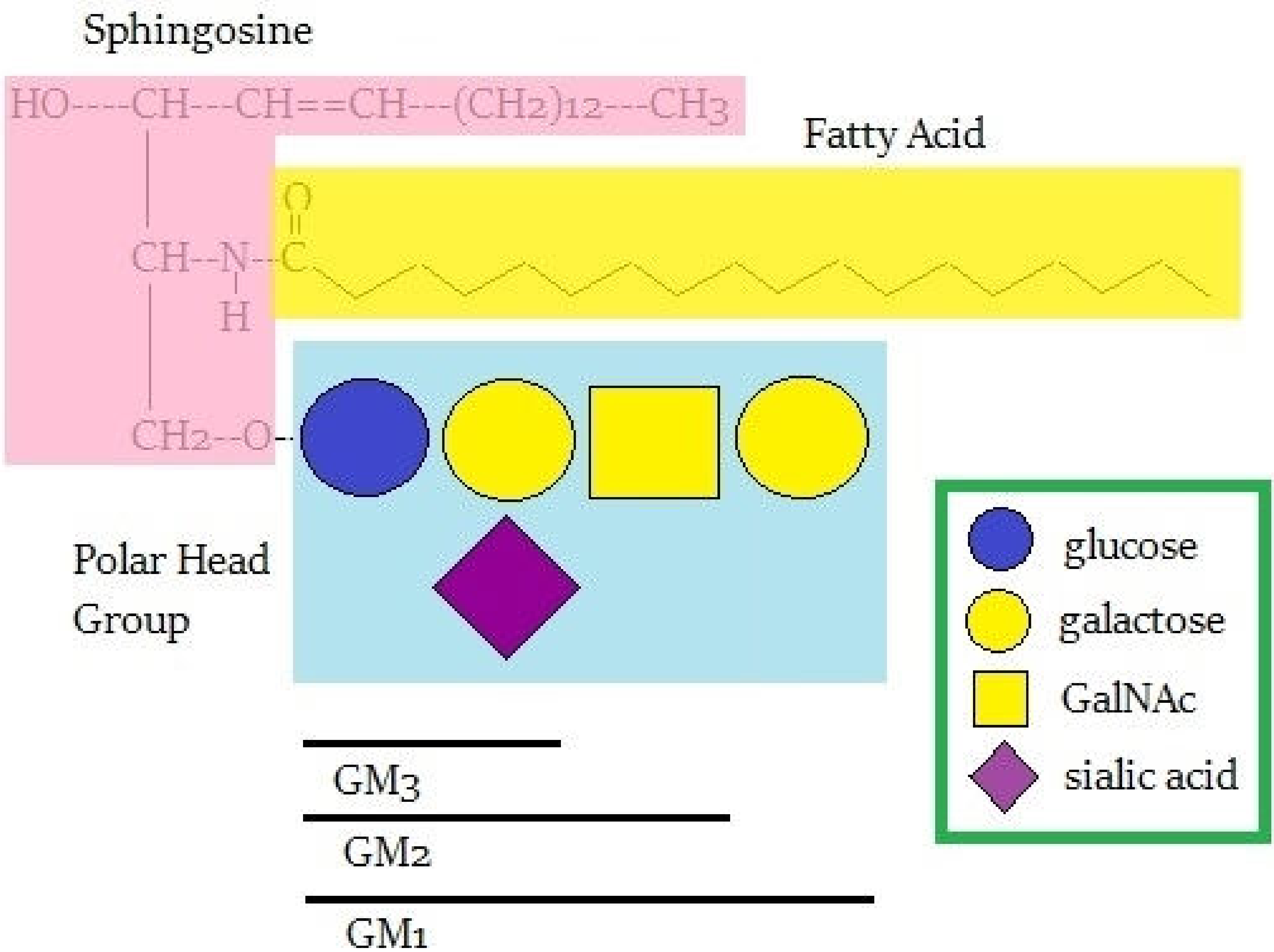
- Depending upon the Chemical structure and Chromatographic separations
- More than 30 Types of Gangliosides are isolated:

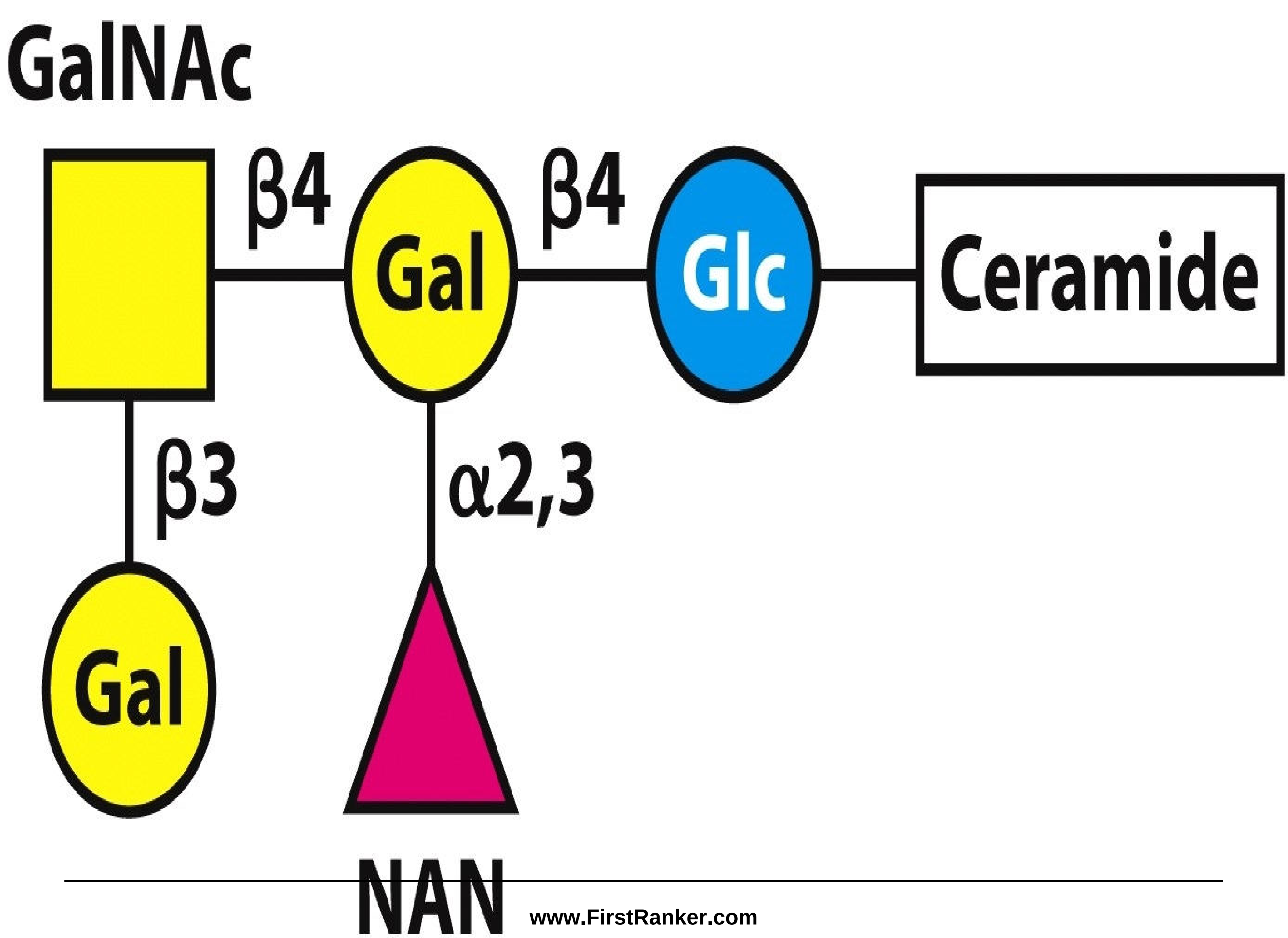
Structure Of Gangliosides

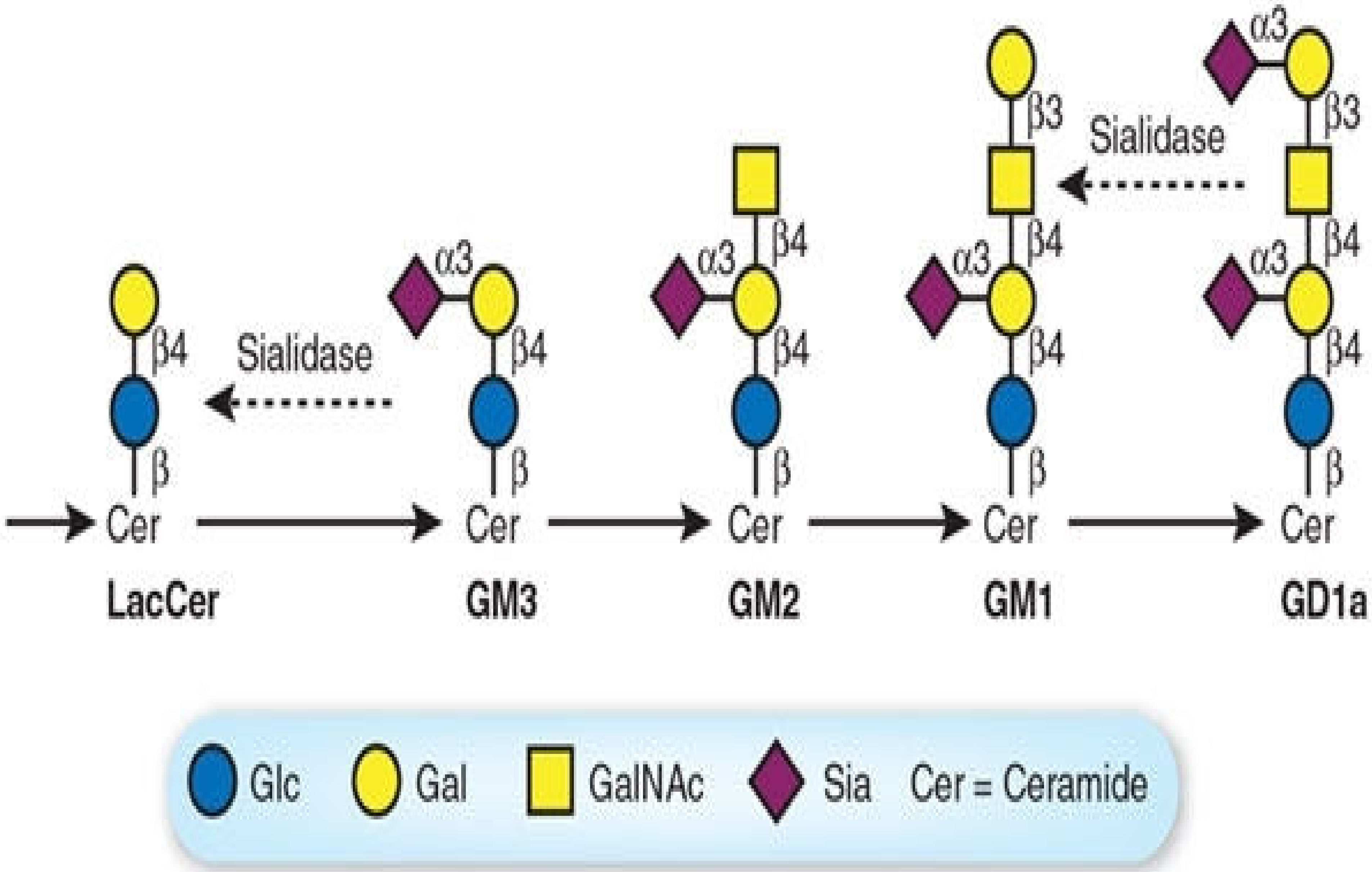
- **GM3 is more common and simplest Ganglioside.**
- GM3 has single Sialic acid.

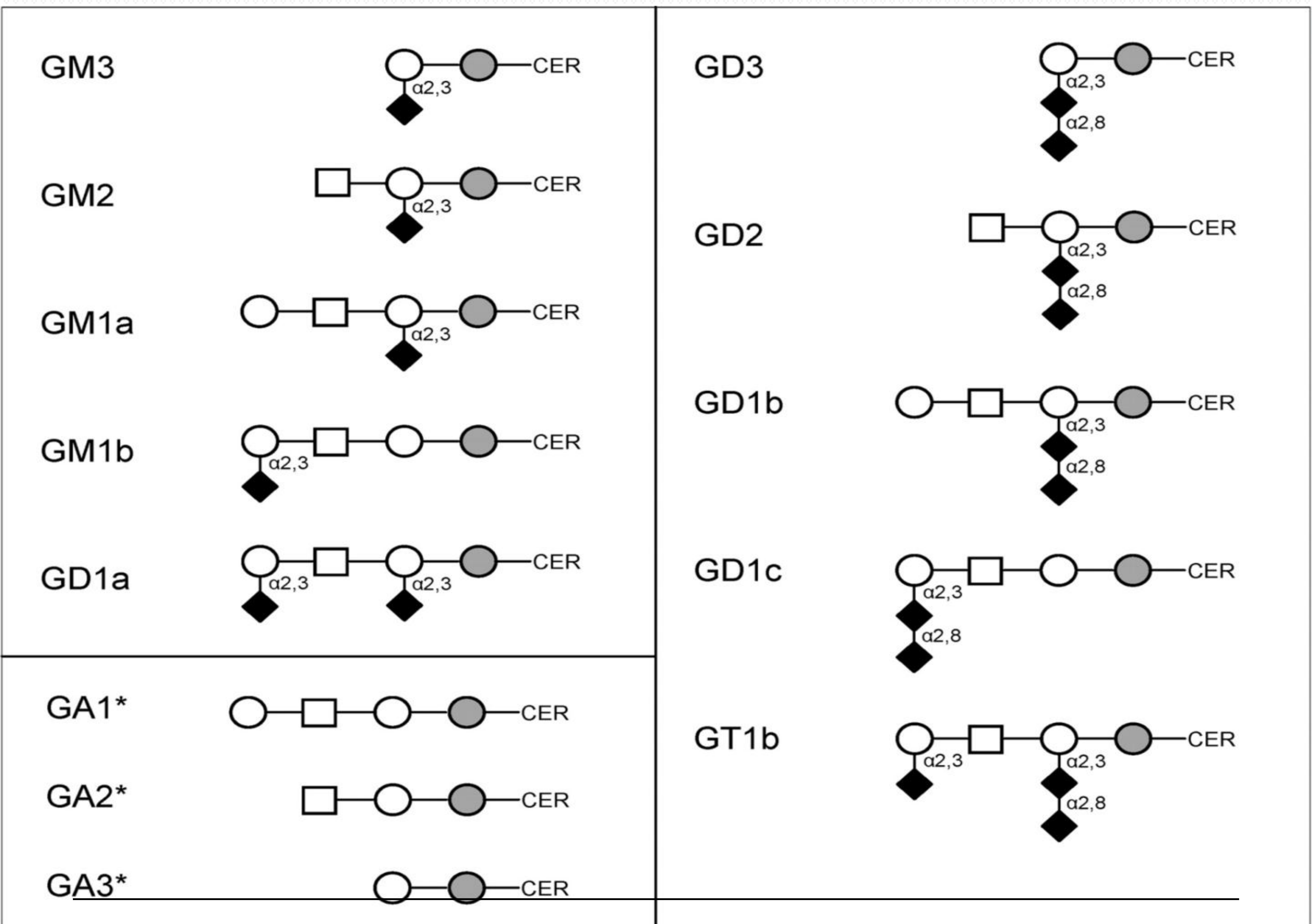
- **GM1** is a **more complex Ganglioside.**

- **GM1 is obtained from GM3.**

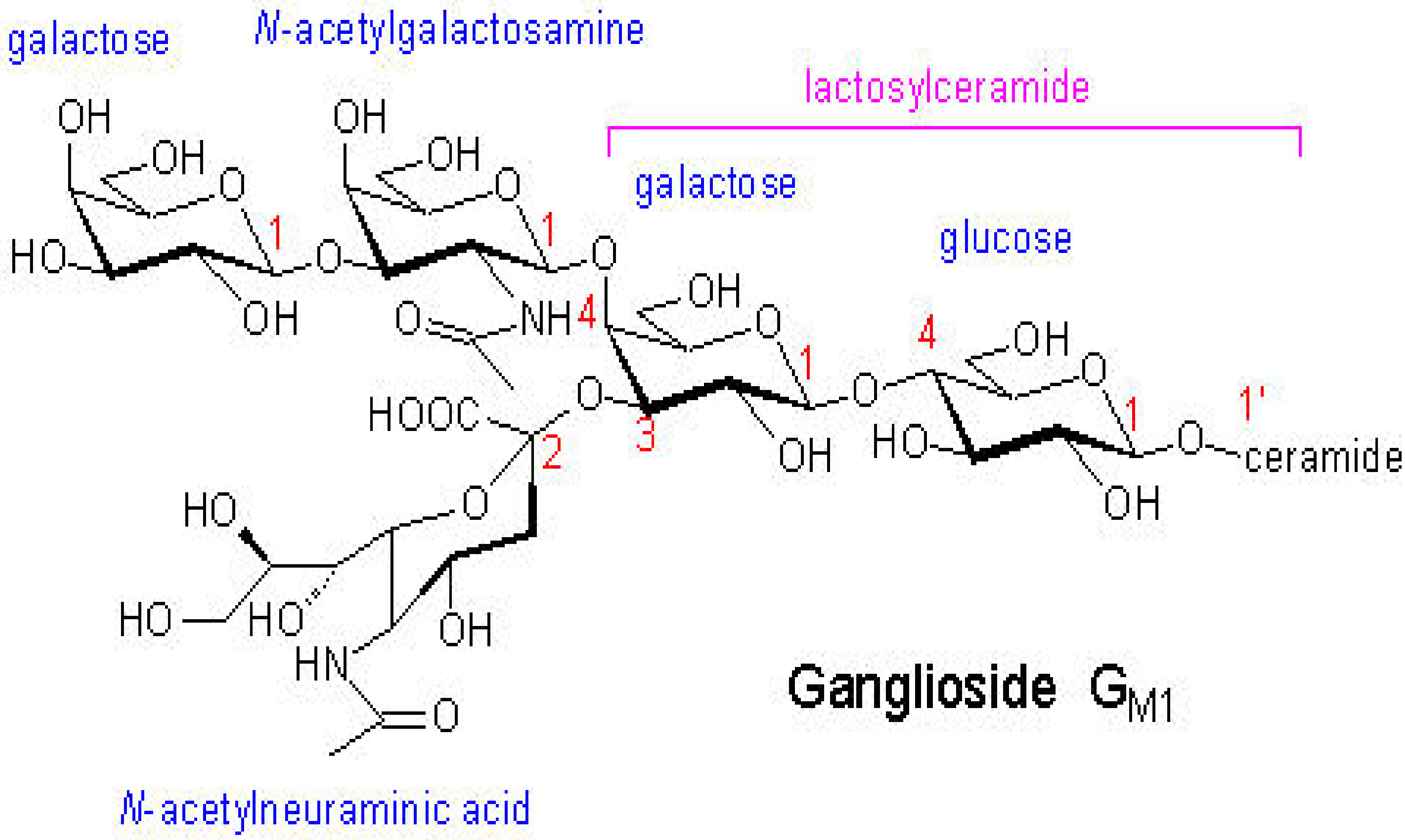

Sphingosine
HO---CH---CH==CH---(CH2)12---CH3
Fatty Acid
CH--N--C
H
O
CH2--O-
Polar Head Group
glucose
galactose
GalNAc
sialic acid
GM3
GM2
GM1

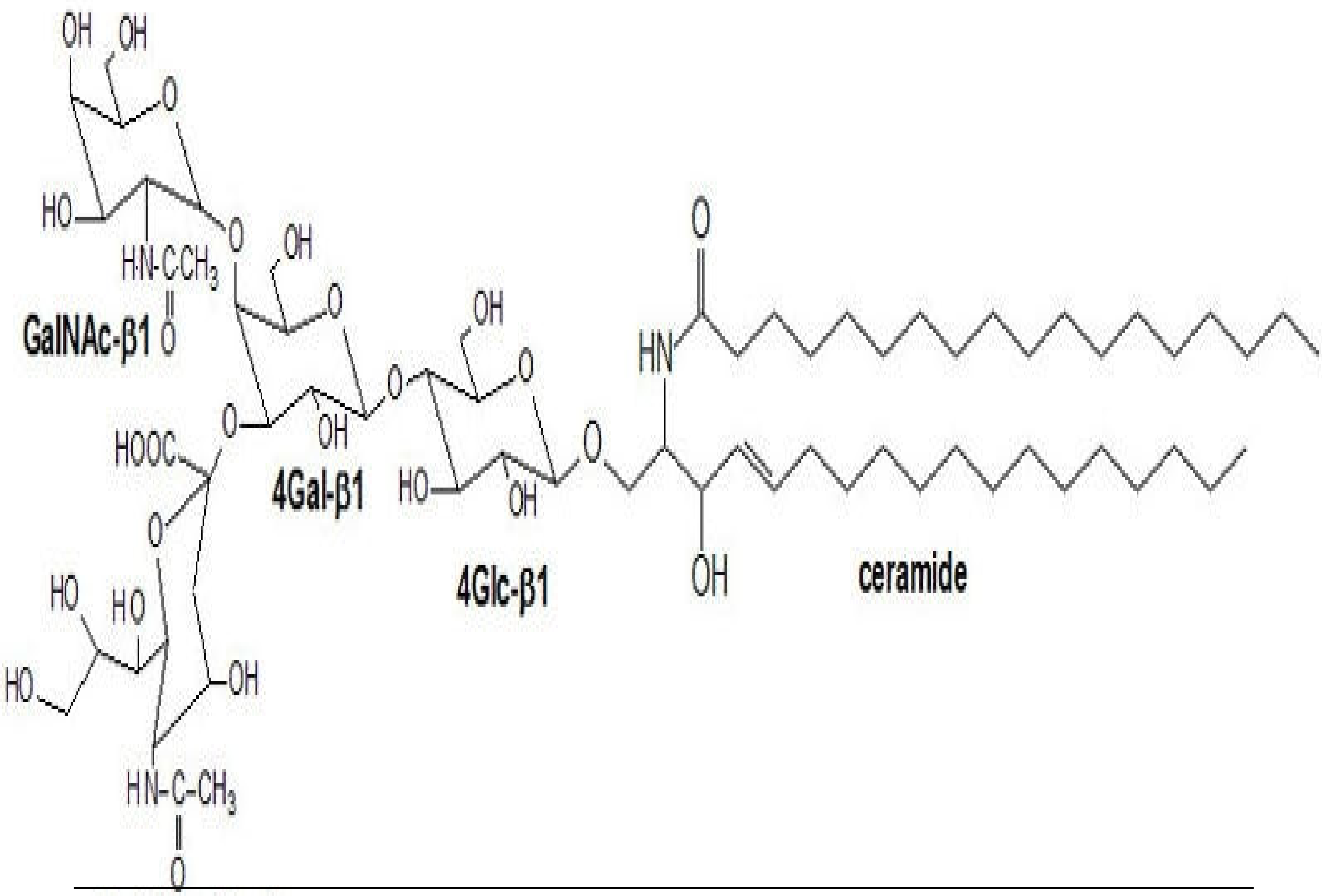

GalNAc
β4
Gal
β4
Glc
Ceramide
β3
α2,3
Gal
NAN





○ galactose, □ N-acetyl-galactosamine, ● glucose, ◆ sialic acid, CER = ceramide





2-sialic acid-α3

Occurrence Of Glycolipids

- **Glycosphingolipids** are widely distributed
- In **every cell and tissue of human body**
- They are **richly present in nervous cells.**
- **Occur particularly in outer leaflet of Cell membrane.**

- **Glycolipids** occur on the outer surface of every cell membrane as component of **Glycocalyx** /(**Cell raft**).

- **Cerebrosides**: Richly present in
  - **White matter of brain**
  - **Myelin sheath**

- **Gangliosides:** Predominantly present in
  - **Grey matter of brain**
  - **Ganglions and Dendrites**

Functions Of Glycolipids

- Glycolipids are **richly present in nervous tissue**, they help in:
- **Development** and **function of brain**.
- **Nerve impulse conduction**

- **Glycolipids present in cell membranes Serve as :**
  - **Antigens** viz **Blood group Antigens, Embryonic Antigen**.
  - **Receptor sites for Hormones.**

- Glycolipids of cell membrane serve as:
- Markers for cellular recognition which helps in:
  - Cell Functioning
  - Cell Growth and Differentiation
  - Cell-Cell interaction
  - Cell Signaling/Signal Transduction
  - Anchoring sites for Antigens, Toxin and Pathogens

- GM1 serve as receptor /anchoring site to :
  - Cholera toxin
  - Tetanus toxin
  - Influenza viruses

- The **Cholera toxin** on binding to intestinal cells
- **Stimulates secretion of Chloride ions into gut lumen.**
- **Resulting in copious diarrhea of Cholera.**

- In various malignancies dramatic **changes** in **membrane Glycolipid** composition are noted.

Lipid Storage Disorders Related To Glycosphingolipids

Disorders Of Glycolipids

- Gaucher's Disease
- Tay Sach's Disease

Gaucher's Disease:

- **Defect:** Due to deficiency of Cerebroside degrading enzyme **Glucocerebrosidase.**
- **Biochemical Alteration:** Abnormal **accumulation of Cerebrosides** in the tissues.
- **Consequences:** **Affect normal function** of tissues where it is accumulated.

Tay Sach's Disease:

- **Defect:** Due to deficiency of Ganglioside degrading enzyme: **Hexoseaminidase-A.**
- **Biochemical Alteration:** Abnormal **accumulation of Gangliosides** in the tissues.
- **Consequences: Affect normal function of tissues.**

Similarities and Dissimilarities Of Cerebrosides and Gangliosides

Similarities Of Cerebrosides and Gangliosides

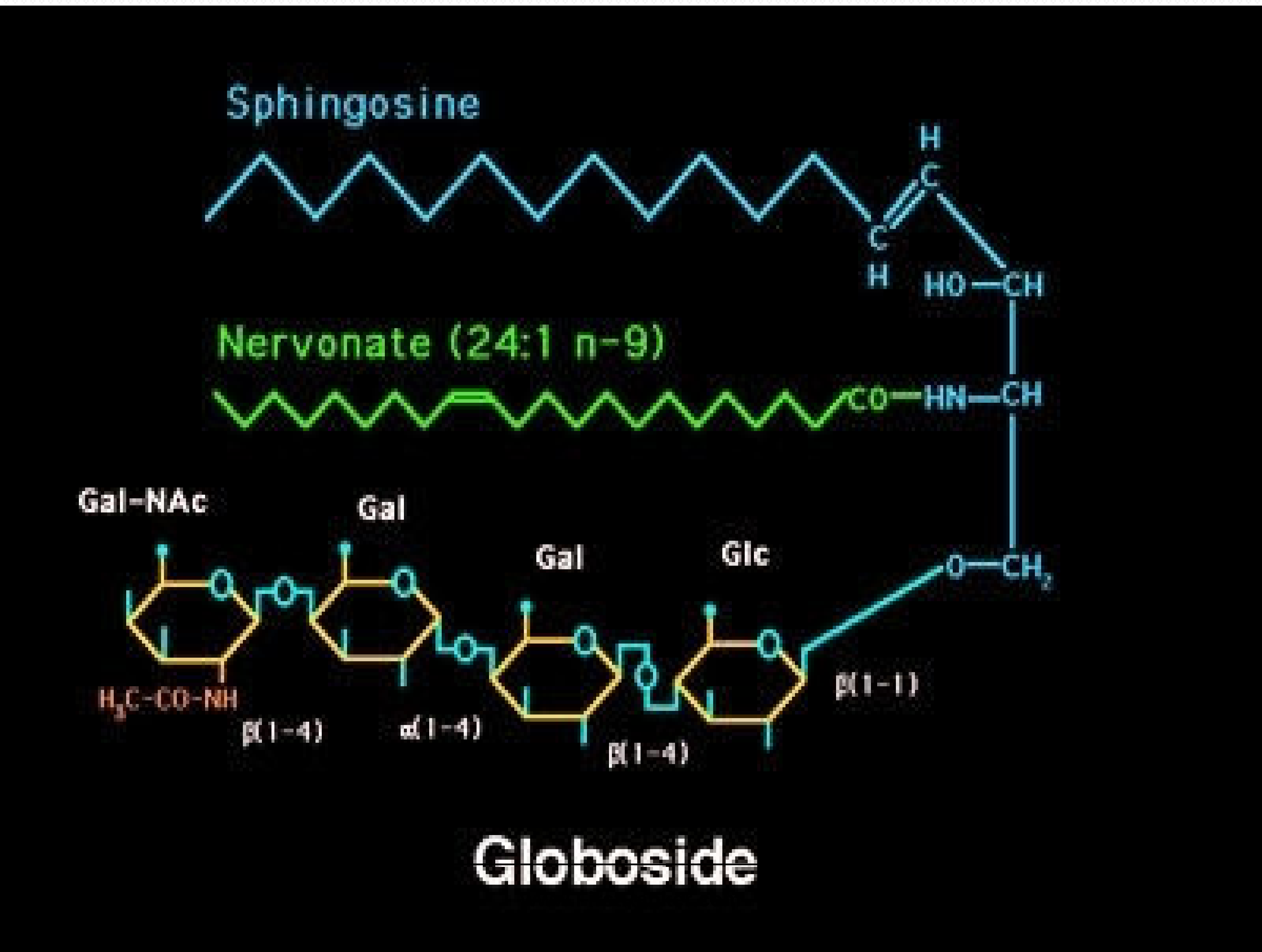
- **Both are Glycolipids** containing Carbohydrate moieties.
- Both contain **Sphingosine/Ceramide** in their structures.
- Both are richly present in **Nervous tissue.**

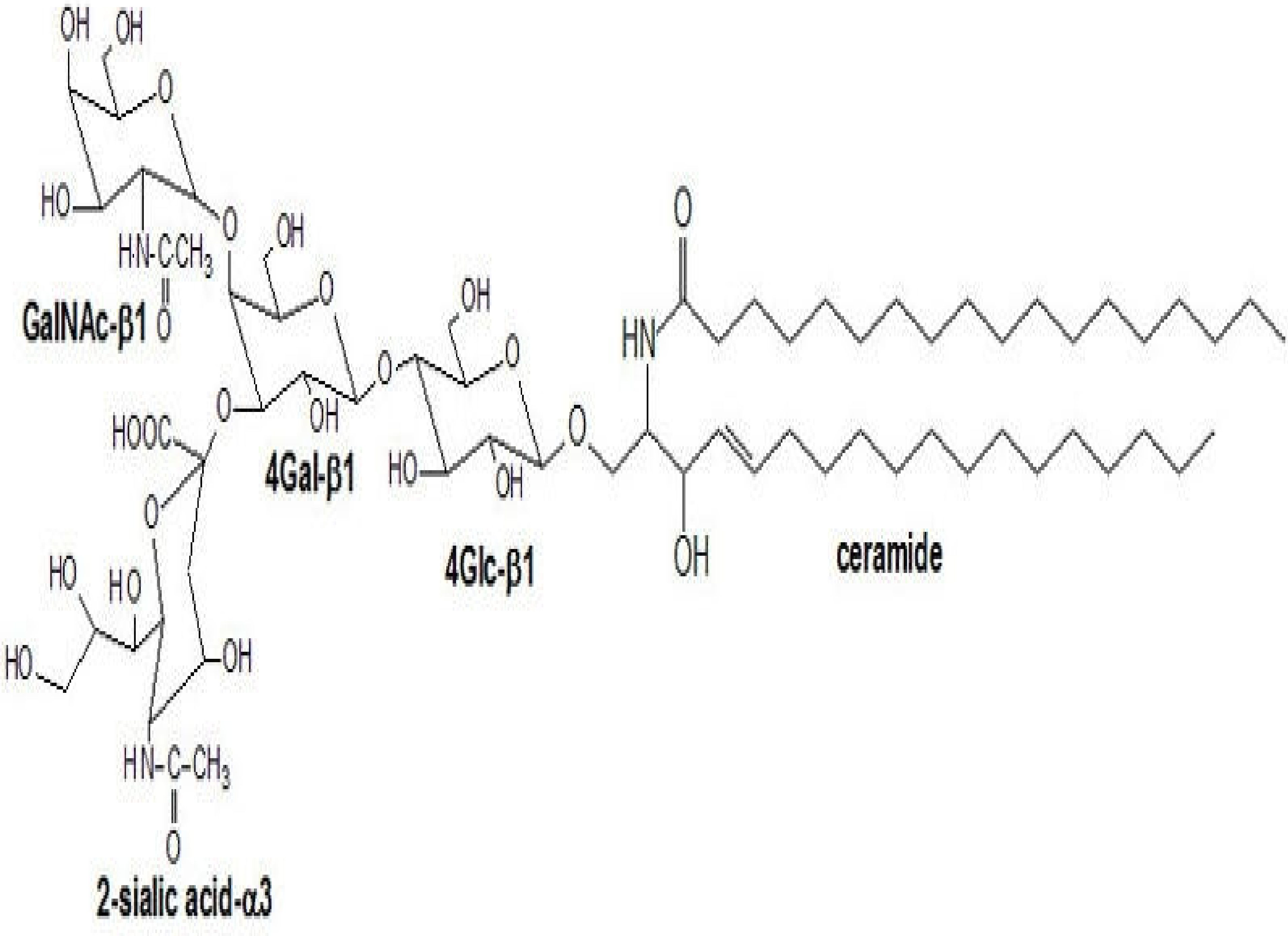
Dissimilarities Of Cerebroside and Gangliosides.

S.No	Cerebrosides	Gangliosides
1	**Structurally Simple** Ceramide linked with Glucose or Galactose.	**Structurally complex** Ceramide linked to Glucose, Galactose , NAGalactosamine ,and NANA
2	Occur in **White matter** of brain and **Myelin Sheaths.**	Occur in **Grey matter** of brain and **Ganglions**.
3	Types : Glucocerebrosides Galactocerebrosides	Types : GM1,GM2, GM3,GM4
4	Function : Conducts nerve impulse	Transfer Biogenic Amines
5	Related Disorder: **Gauchers Disease**	Related Disorder: **Tay Sachs Disease**

Globosides

- Globosides are **type of Glycolipids.**
- Structurally **Ceramide linked with Oligosaccharide** is Globosides.

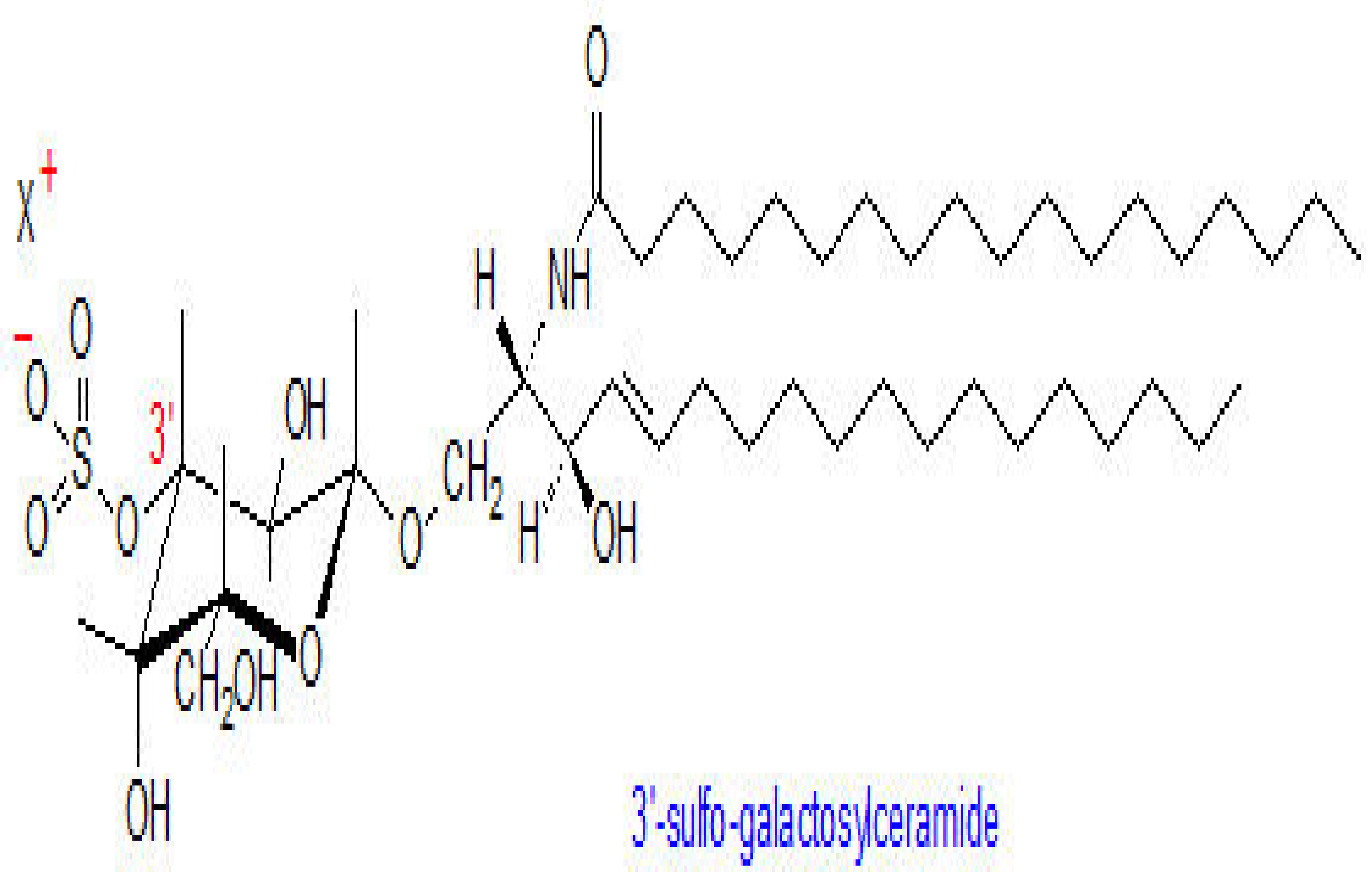


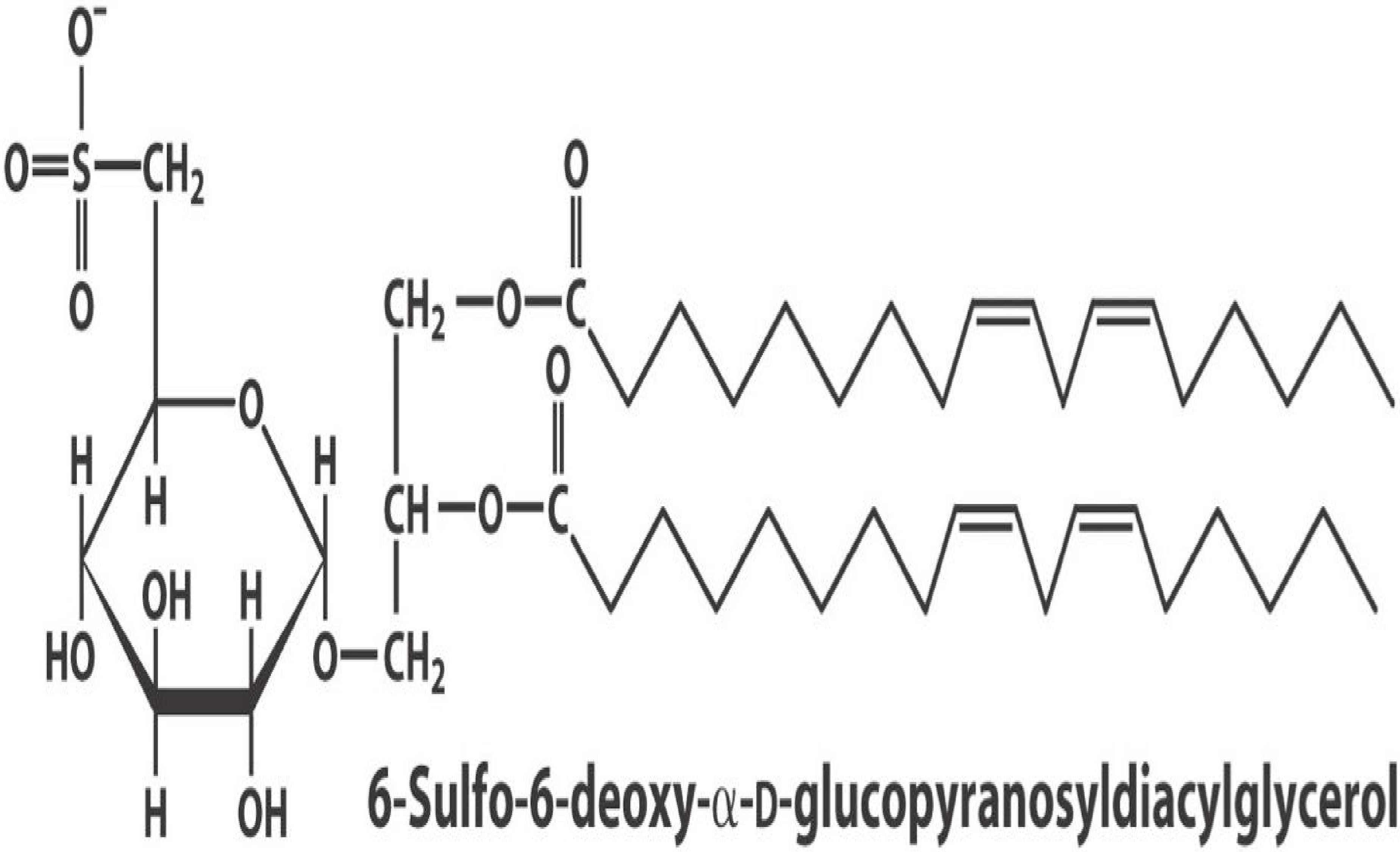


Sulfatides/Sulfolipids

- **Sulfolipids** are **compound Lipids**.
- **Sulfolipids** are **Ceramide** linked to **Sulfated sugar units/ Oligosaccharides**.

- Structurally Sulfolipids may also has Glycerolipids containing **Sulfate groups**.
- Sulfolipids are component of **nervous tissue.**





6-Sulfo-6-deoxy-α-D-glucopyranosyldiacylglycerol
(a sulfolipid)

Lipoproteins

Lipoproteins

- Lipoproteins are types of **Compound Lipids** /**Conjugated Proteins**.

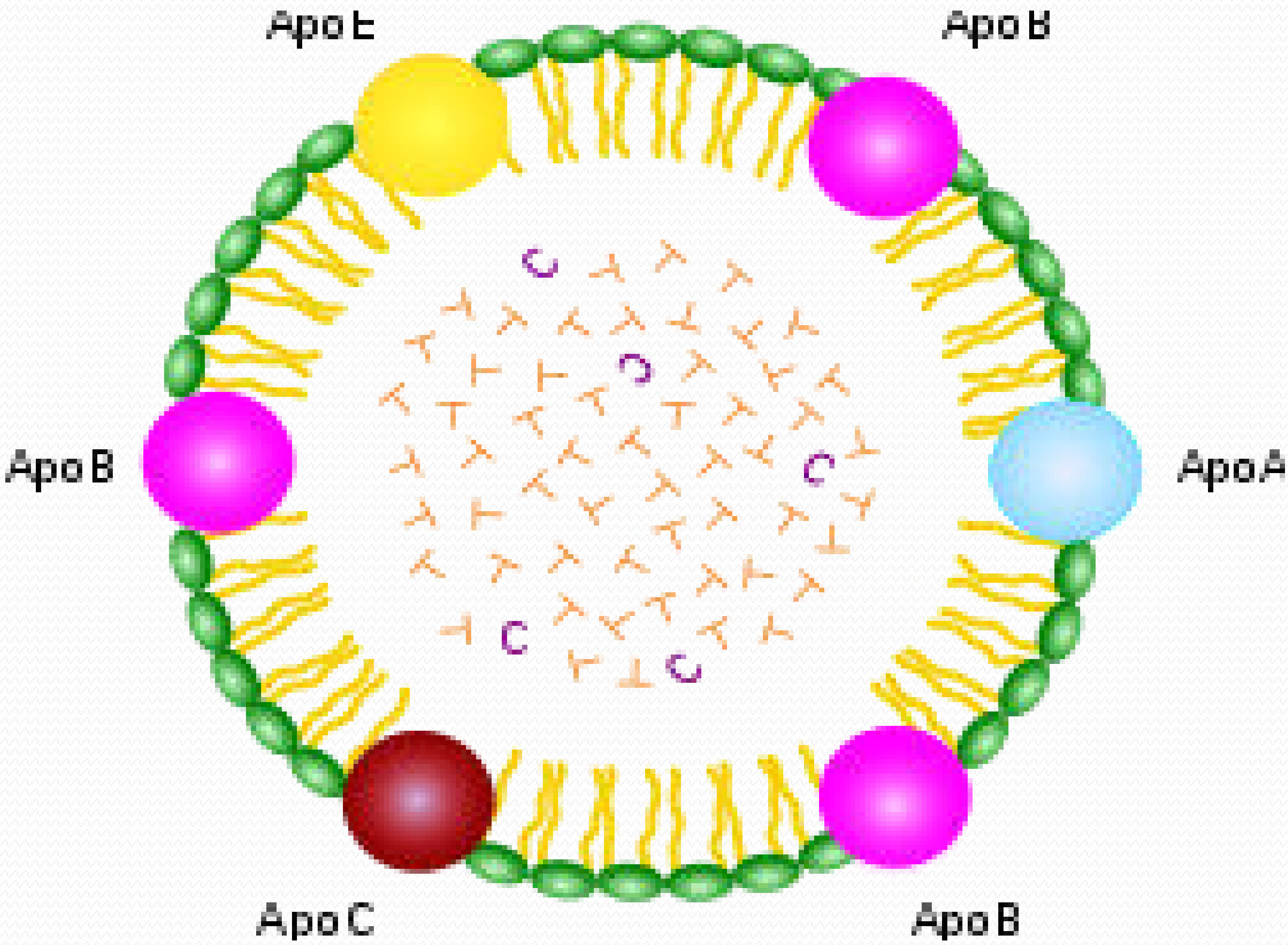
- **Lipoproteins** are **macromolecules** formed by aggregation of **:**
- **Lipids** (polar and nonpolar)
- **Proteins**(Apoprotein) in the human body.

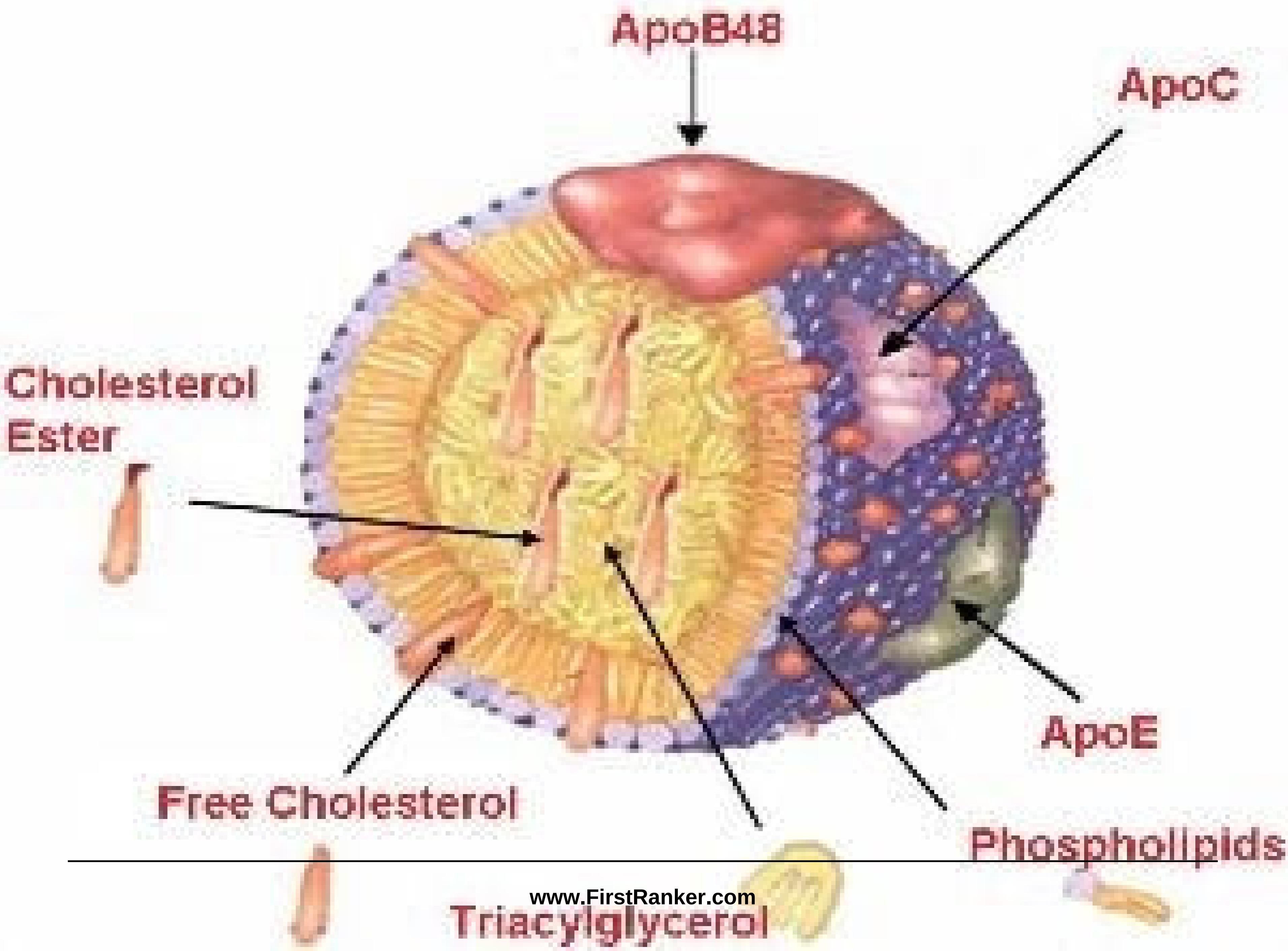
- **Lipoproteins acquire polarity** (Hydrophilic Property)

- **Lipoprotein** serve as **vehicles for transportation** of **non polar and polar Lipids** through aqueous media **blood and lymph.**

- Lipoproteins are **biosynthesized within the cells of tissues**.
- By aggregation of various forms of Lipids and Apoproteins.

Structure Of Lipoproteins

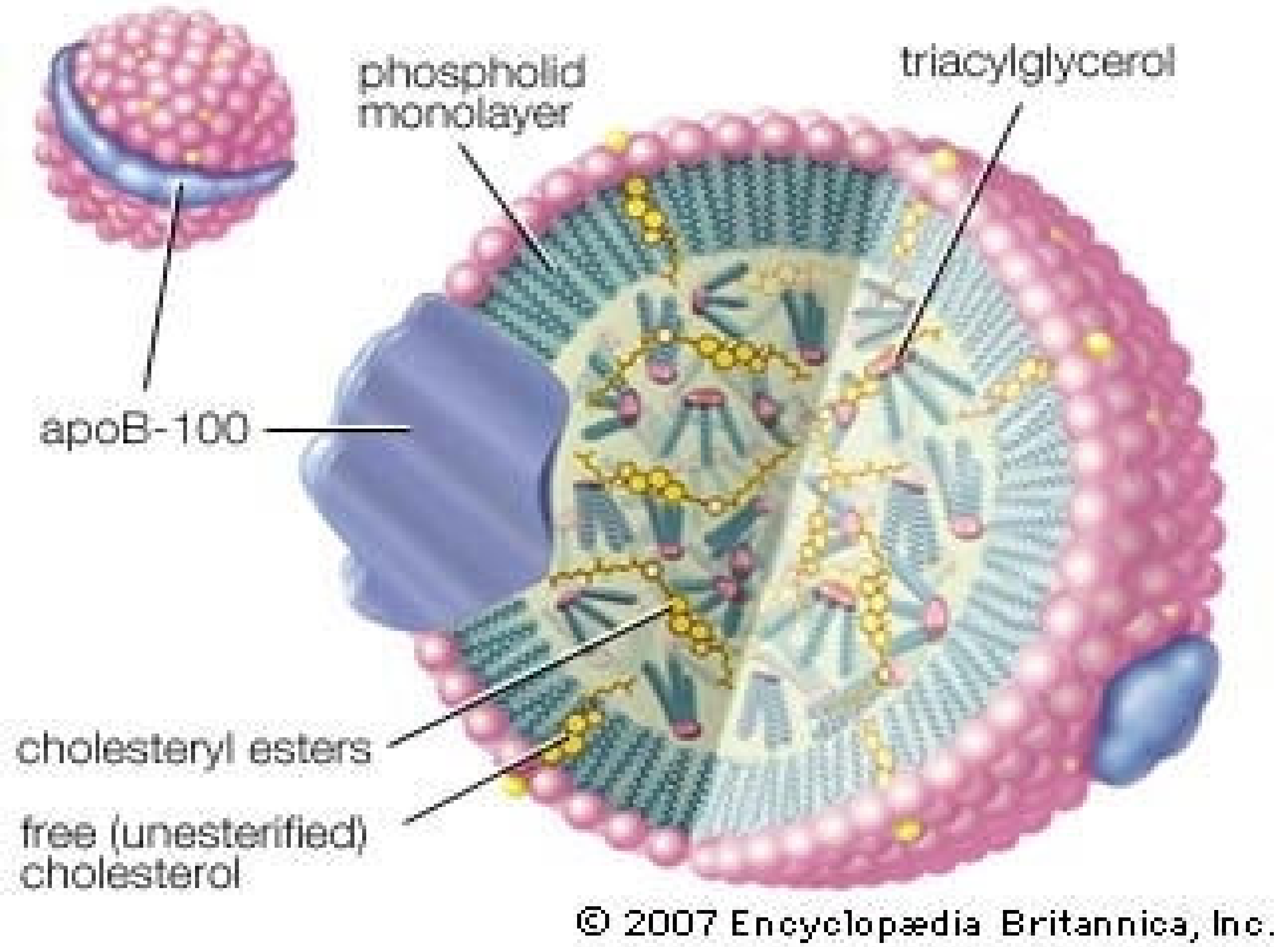

Apo E
Apo B
Apo B
Apo A
Apo C
Apo B

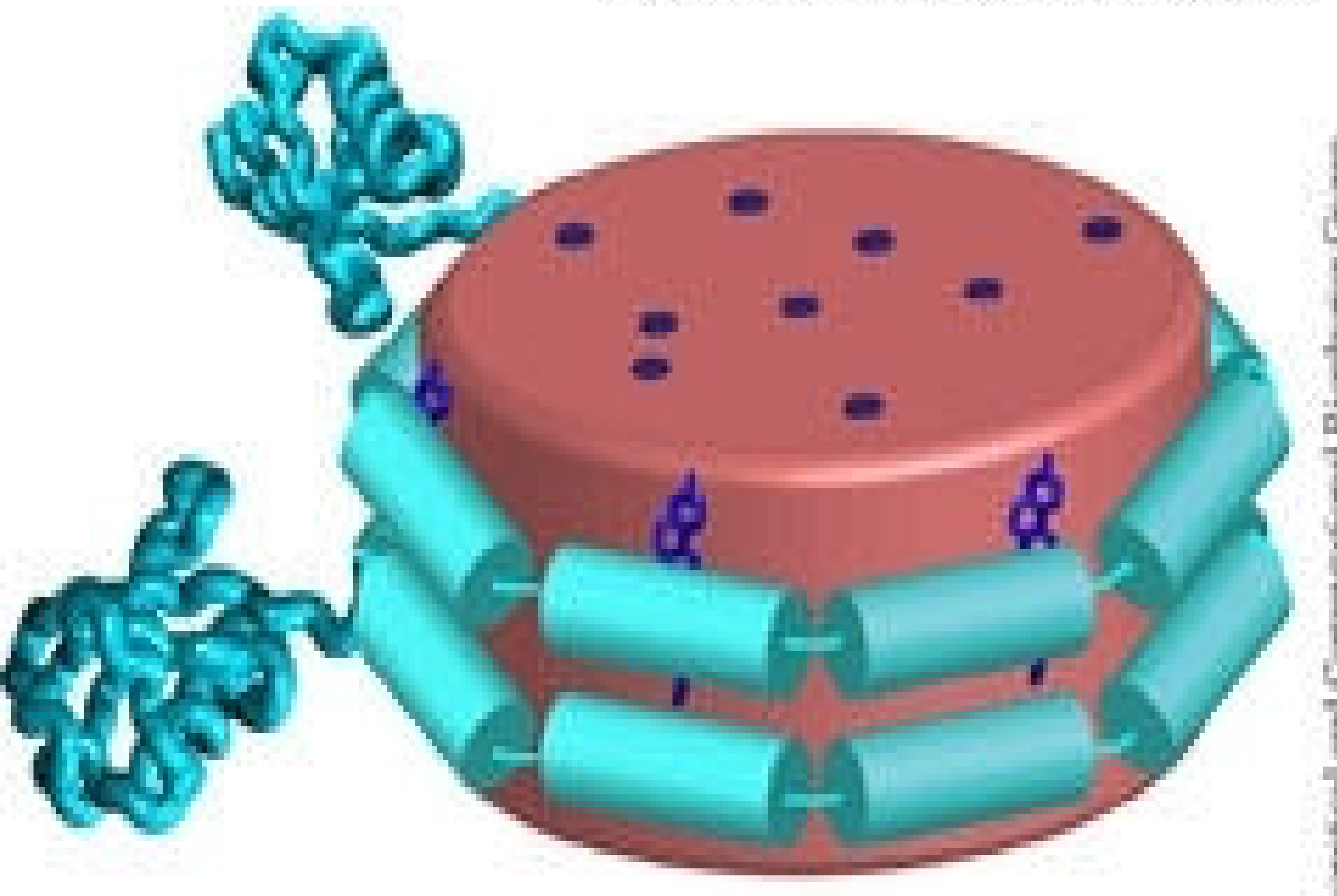

ApoB48
ApoC
Cholesterol Ester
ApoE
Free Cholesterol
Phospholipids
Triacylglycerol

Structure of Lipoproteins

- The non polar /hydrophobic Lipids **TAG and Cholesterol Ester** are **gathered centrally** to form the core of LipoProtein particle.
- At the **periphery of Lipoprotein are Apoprotein and Amphipathic Lipids** viz **Phospholipids and Cholesterol**.

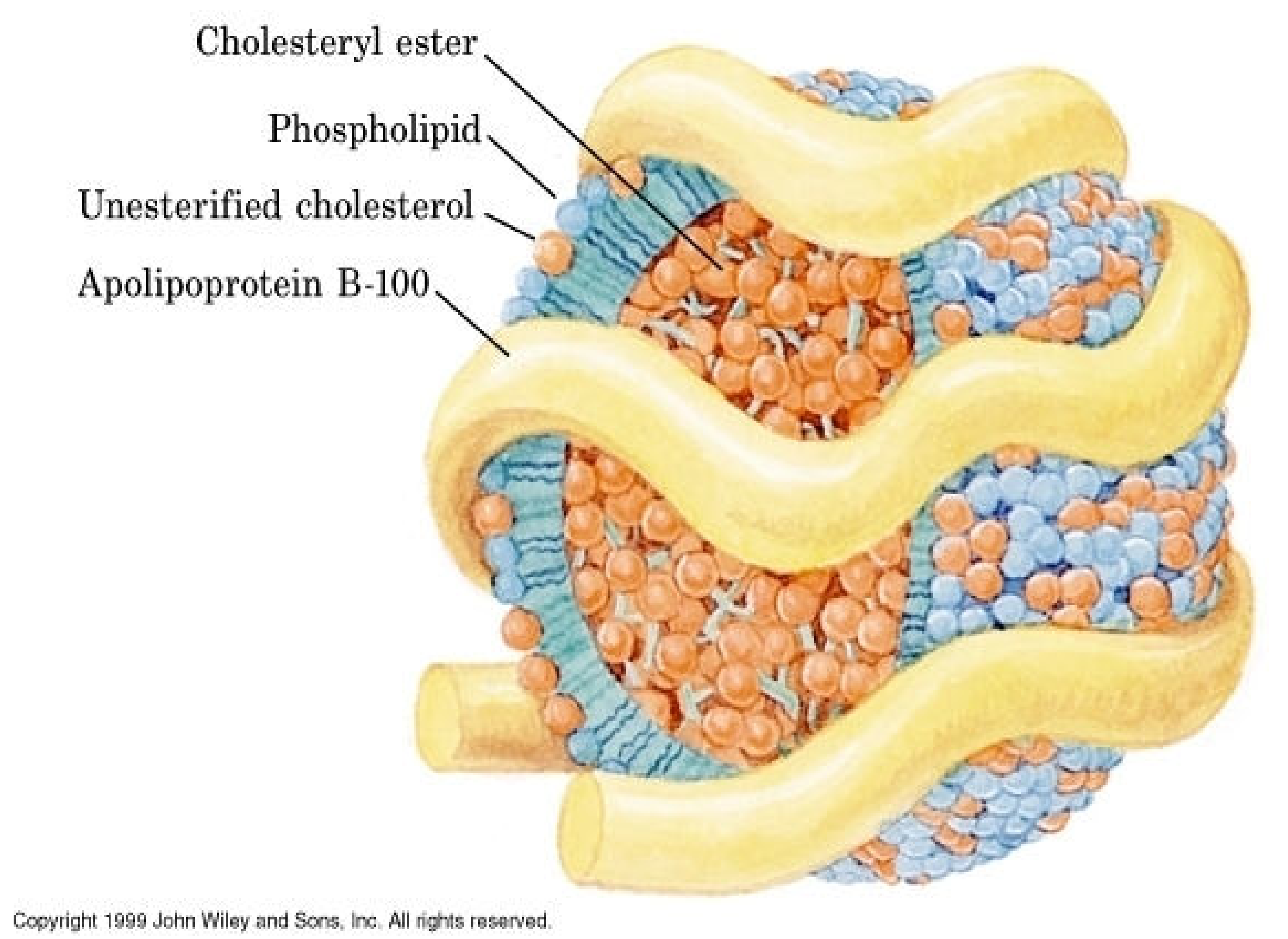
- The Apoprotein and polar groups of Amphipathic Lipids **impart hydrophilic property** to Lipoprotein molecules
- This **helps in transportation** of **Lipids**
- **From site of origin to site of utilization through blood**.





Discoidal HDL

Cholesterol Transported as Lipoprotein Complex (LDL)



Functions Of Lipoproteins

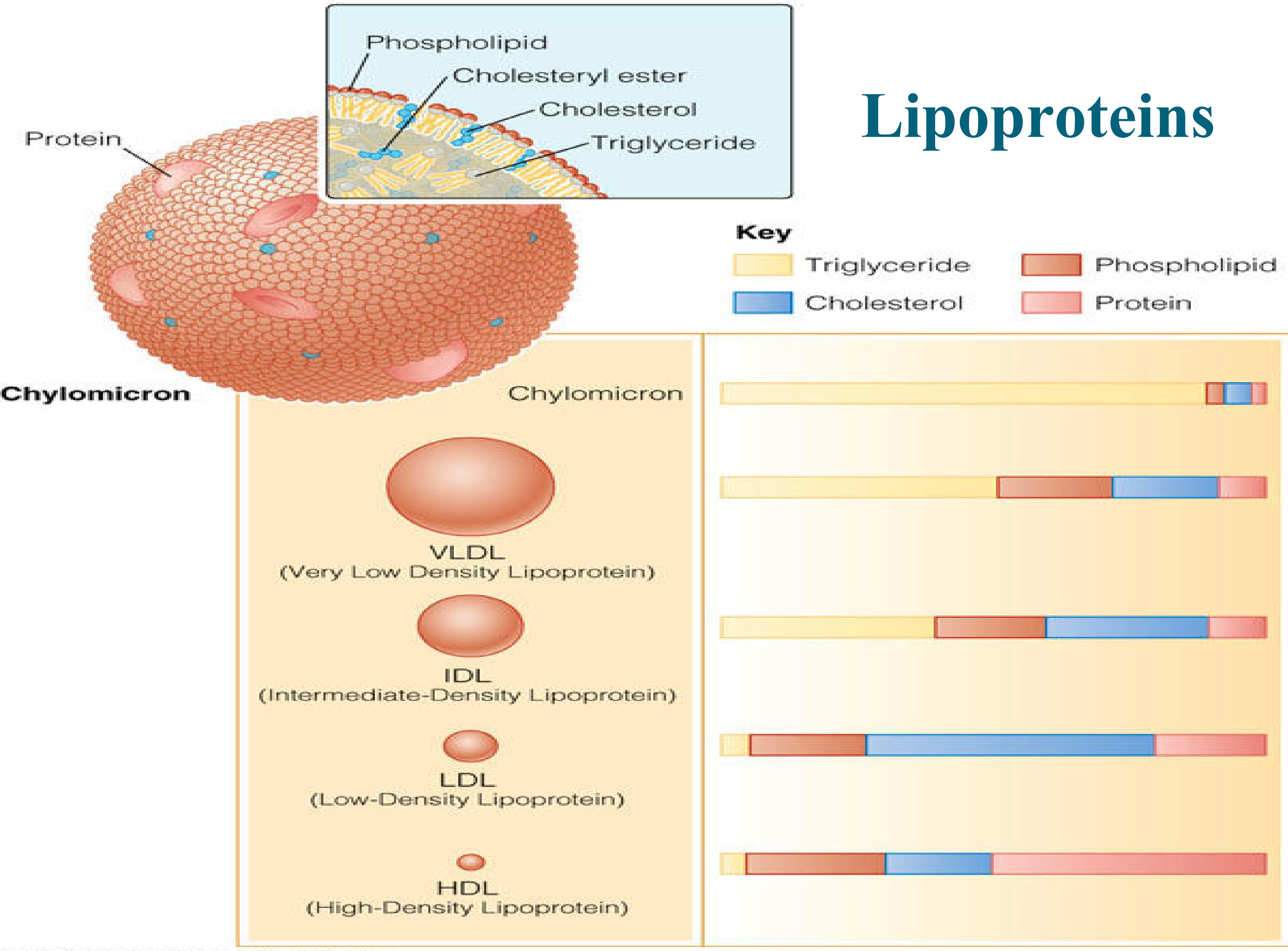
- Lipoproteins serve as a **vehicle in transportation** of non polar Lipids

- From the **site of its biosynthesis to the site of utilization** through aqueous media of blood or lymph.

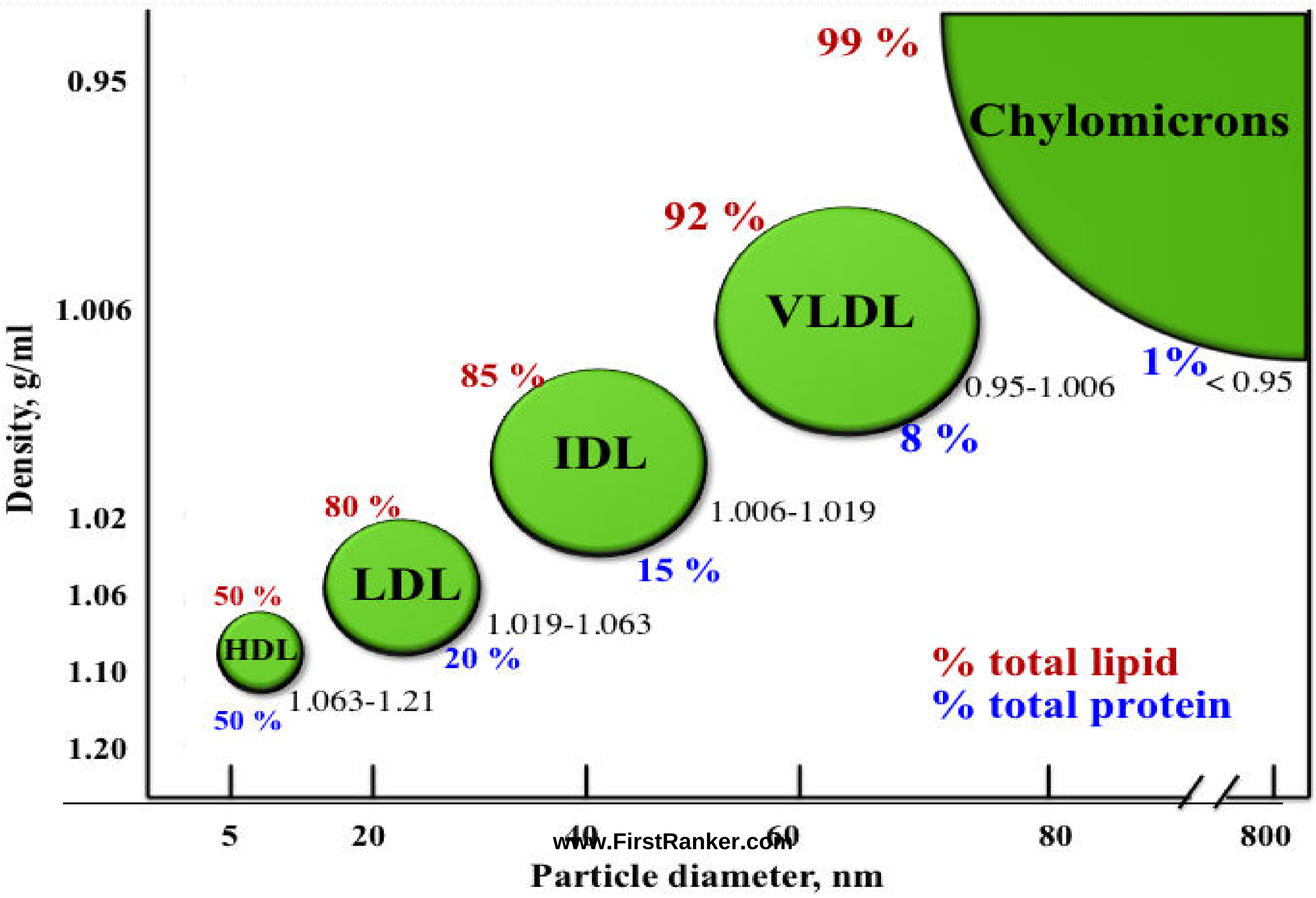
Types Of Lipoproteins

- Depending upon the **composition** and other **properties** following are **the types of Lipoproteins:**
  - **Chylomicrons (CM)**
  - **Very Low Density Lipoprotein (VLDL)**
  - **Low Density Lipoproteins (LDL)**
  - **High Density Lipoproteins (HDL)**
  - **Free Fatty acid -Albumin**

Lipoproteins



Lipoproteins



CHYLOMICRON (CM)

- **Site Of Synthesis of Chylomicron:**
  Small Intestine
- **Percentage of Lipids in CM:**
  99 % (CM is least dense due to high Lipids)
- **High concentration of associated Lipid in CM:**
  Triacylglycerol (Exogenous Origin)
- **Percentage of Protein in CM:**
  1%
- **Associated Apoproteins in CM:**
  Apo B48, Apo CII and Apo E.

- **Source Of Lipids in CM :**
  Exogenous /Dietary origin

- **Role of Chylomicron (CM) :**
  CM Transports dietary exogenous Lipids from Intestine to Liver through lymph and blood

VLDL

- Site Of Synthesis of VLDL:
  Liver (80%) and Small Intestine (20%).
- Percentage of Lipids in VLDL : 92%
- High concentration of associated Lipid in VLDL is: Endogenous Triacylglycerol
- Percentage of Protein in VLDL: 8%
- Associated Apoproteins in VLDL:
  Apo B100, Apo CI, Apo CII and Apo E

- Source Of Lipids to VLDL : Endogenously biosynthesized Lipids in Liver and Intestine.
- Role Of VLDL:

VLDL Transports Endogenous lipids from Liver to Extra Hepatic tissues.

LDL

- **Site Of LDL Synthesis:**
  In **Blood circulation from VLDL**
- **Percentage of associated Lipids in LDL:**
  80%
- **High concentration of associated Lipid in LDL is: Cholesterol**
- **Percentage of associated Protein in LDL:**
  20%
- **Associated Apoproteins of LDL:**
  Apo B100, Apo CI, Apo CII and ApoE

- **Source Of Lipids in LDL:**
  Endogenously biosynthesized Lipids in Liver

- **Role Of LDL:**

LDL transports Endogenous Cholesterol from Liver to extra hepatic tissues.

HDL

- **Site of nascent(new) HDL Synthesis:**
  In Liver
- **Percentage of associated Lipids in HDL: 50%**
- **High concentration of associated Lipid in HDL: Phospholipids**
- **Percentage of associated Protein in HDL**: **50%** (HDL is more dense due to high content of **Proteins**)

- **HDL Associated Apoproteins:**

Apo A I, Apo A II

Apo C I, Apo C II

Apo D and Apo E

HDL Is Associated With Enzyme LCAT Responsible For Cholesterol Esterification And Its Excretion

- **Role Of HDL** :

Transports extra ,non functional Cholesterol present in blood circulation to Liver for its excretion.

- **HDL** has **scavenging role with protective mechanism.**

- **HDL Transports Cholesterol from**

Extrahepatic tissues back to Liver for its excretion.

HDL Has Role as Reverse Transport of Cholesterol

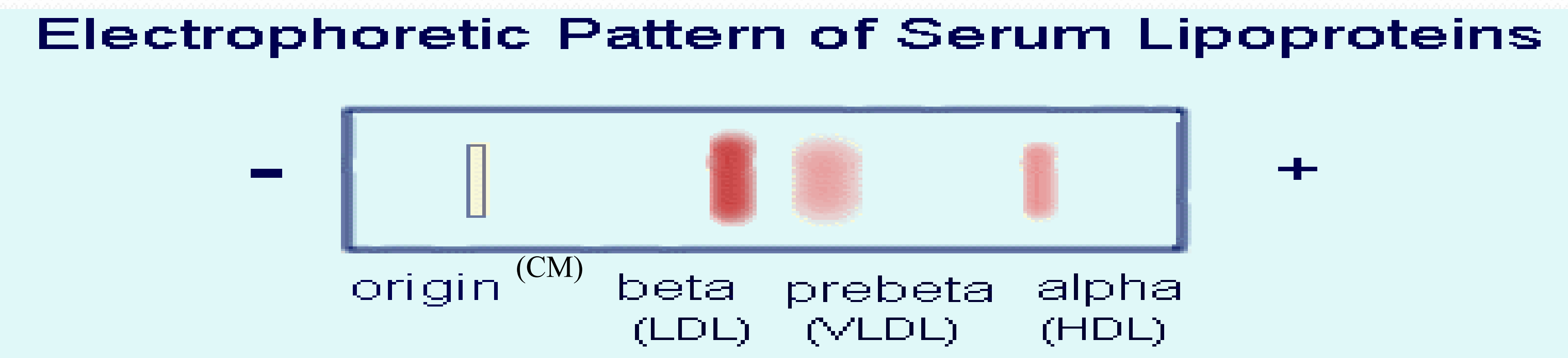
- **HDL reduces risk of Atherosclerosis**.

- **HDL clears the body Lipids** and **do not allow accumulation of Lipids in blood.**

- Thus when the levels of HDL are **within normal range**
- **Cholesterol** associated with **HDL** is termed as **Good Cholesterol**

- **Based on Electrophoretic pattern** the **Lipoproteins** are **termed as:**
  - **LDL: Beta Lipoproteins**
  - **VLDL: Pre Beta Lipoproteins**
  - **HDL: Alpha Lipoproteins**

Classification of plasma Lipoproteins according to their electrophoretic mobility



α-lipoprotein (HDL)

Pre-β-Lipoprotein (VLDL)

β-lipoprotein (LDL)

CM

Types of Lipoprotein

(all contain characteristic amounts TAG, cholesterol, cholesterol esters, phospholipids and Apoproteins – NMR Spectroscopy)

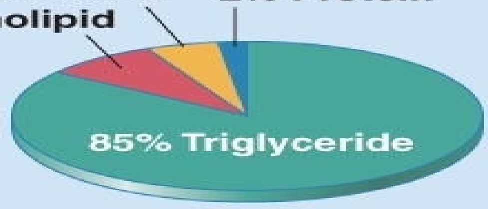
Increasing density

Class	Diameter (nm)	Source and Function	Major Apoliproteins
Chylomicrons (CM)	500 Largest	Intestine. Transport of *dietary* TAG	A, B48, C(I,II,III) E
Very low density lipoproteins (VLDL)	43	Liver. Transport of ***endogenously*** synthesised TAG	B100, C(I,II,III) , E
Low density lipoproteins (LDL)	22	Formed in circulation by partial breakdown of IDL. Delivers cholesterol to peripheral tissues	B100
High density lipoproteins (HDL)	8 Smallest	Liver. Removes "used" cholesterol from tissues and takes it to liver. Donates apolipoproteins to CM and VLDL	A, C(I,II,III), D, E

Lipoprotein class	Density (g/mL)	Diameter (nm)	Protein % of dry wt	Phospholipids %	Triacyl-glycerols % of dry wt
HDL	1.063-1.21	5 – 15	50	29	8
LDL	1.019 – 1.063	18 – 28	25	21	4
IDL	1.006-1.019	25 - 50	18	22	31
VLDL	0.95 – 1.006	30 - 80	10	18	50
Chylomicrons	< 0.95	100 - 500	1 - 2	7	84

Chylomicron

- Formed in the gut after a meal
- Released into the lymph system and then into the blood
- Largest of the lipoproteins, with the lowest density
- Taken up by the liver once triglycerides are removed



Transports dietary fat into the blood and to the tissues of the body

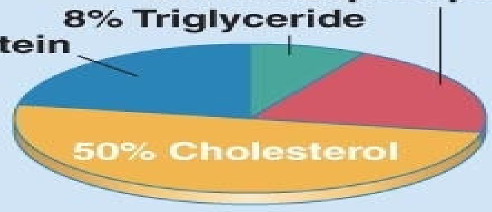
VLDL (Very-low-density lipoprotein)

- 80% formed in the liver
- 20% formed in the intestine

Transports endogenous lipids, especially triglycerides, to the various tissues of the body

LDL (Low-density lipoprotein)

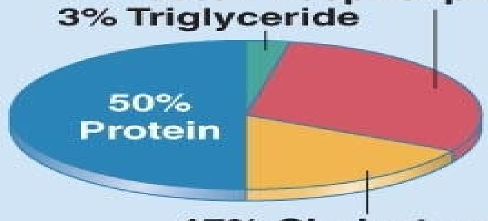
- Formed in blood from VLDL (transformation from VLDL to LDL occurs as the triglycerides are removed from the VLDL)



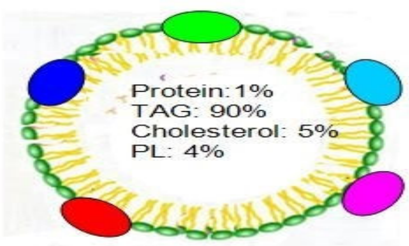
Transports cholesterol to the cells of the body

HDL (High-density lipoprotein)

- Synthesized in liver and released into the blood
- Transported by the blood throughout the body, picking up free cholesterol

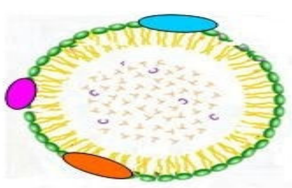


Transports cholesterol from tissues back to the liver



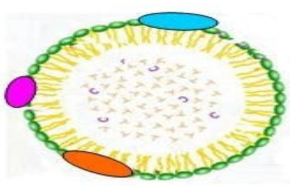
Lipoprotein type: Chylomicron
Density: <0.950 g/mL
Diameter: 80-1000 nm
Major lipids: dietary triacylglycerols
Apolipoproteins: B48, A1, A2, C, E

Protein: ~1%
Triglyceride: ~90%
Cholesterol: ~5%
Phospholipids: ~4%



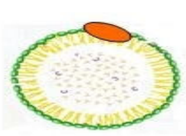
Lipoprotein type: VLDL
Density: 0.950-1.006 g/mL
Diameter: 30-80 nm
Major lipids: endogenous triacylglycerols
Apolipoproteins: B100, C, E

Protein: ~10%
Triglyceride: ~65%
Cholesterol: ~13%
Phospholipids: ~13%



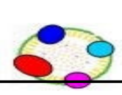
Lipoprotein type: IDL
Density: 1.006-1.019 g/mL
Diameter: 25-30 nm
Major lipids: endogenous triacylglycerols and cholesterol
Apolipoproteins: B100, C, E

Protein: ~18%
Triglyceride: ~34%
Cholesterol: ~22%
Phospholipids: ~22%



Lipoprotein type: LDL
Density: 1.019-1.063 g/mL
Diameter: 20-22 nm
Major lipids: cholesterol and cholesteryl ester
Apolipoproteins: B100

Protein: ~20%
Triglyceride: ~10%
Cholesterol: ~45%
Phospholipids: ~23%



Lipoprotein type: HDL
Density: 1.063-1.090 g/mL
Diameter: 9-15 nm
Major lipids: cholesteryl ester and phospholipids
Apolipoproteins: A1, A2, C, E

Protein: ~50%
Triglyceride: ~20%
Cholesterol: ~18%
Phospholipids: ~30%

Lipoproteins

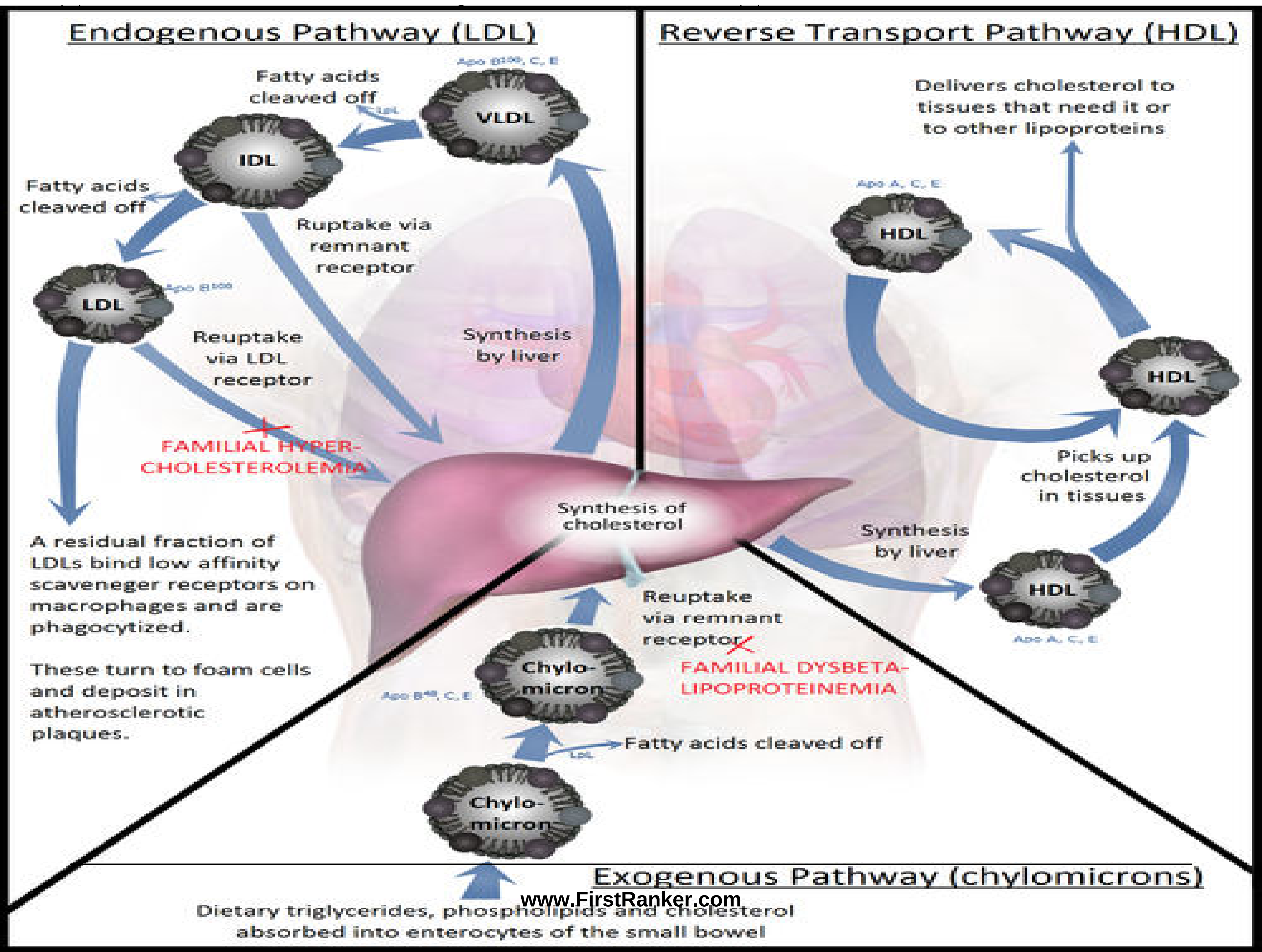
	CM	VLDL	LDL	HDL
Density (g/ml)	< 0.94	0.94-1.006	1.006-1.063	1.063-1.210
Diameter (Å)	6000-2000	600	250	70-120
Total lipid (wt%) *	99	91	80	50
Triacylglycerol	85	55	10	6
Cholesterol esters	3	18	50	40
Cholesterol	2	7	11	7
Phospholipid	8	20	29	46
Apoprotein %	1	9	20	50

Fatty acid compositions (wt% of the total) in the main lipids of human Lipoprotein

	Triacylglycerols			Cholesterol Esters			Phospholipids		
Fatty acid	VLDL	LDL	HDL	VLDL	LDL	HDL	VLDL	LDL	HDL
16:0	27	23	23	12	11	11	**34**	**36**	**32**
18:0	3	3	4	1	1	1	15	14	14
18:1	**45**	**47**	**44**	26	22	22	12	12	12
18:2	16	16	16	**52**	**60**	**55**	20	19	21
20:4 (n-6)	2	5	8	6	7	6	14	13	16

The main properties of the Apoproteins.*

Apoprotein	Molecular weight	Lipoprotein	Function
Apo A1	28,100	HDL	Lecithin:cholesterol acyltransferase (LCAT) activation. Main structural protein.
Apo A2	17,400	HDL	Enhances hepatic lipase activity
Apo A4	46,000	CHYLOMICRON(CM)	
Apo AV(5)	39,000	HDL	Enhances triacylglycerol uptake
Apo B48	241,000	CHYLOMICRON	Derived from Apo B100 – lacks the LDL receptor
Apo B100	512,000	LDL, VLDL	Binds to LDL receptor
Apo C1	7,600	VLDL, CM	Activates LCAT
Apo C2	8,900	VLDL, CM	Activates lipoprotein lipase
Apo C3	8,700	VLDL, CM	Inhibits lipoprotein lipase
Apo D	33,000	HDL	Associated with LCAT, progesterone binding
Apo E	34,000	HDL	At least 3 forms. Binds to LDL receptor
			Linked by disulfide bond



Disorders Of Lipoproteins

Table I Lipid levels (mg/DL) in human beings with known heart disease

Test	Desirable	Borderline	Undesirabl
Total cholesterol	<200	200-240	>240
HDL cholesterol	>45	35-45	<35
Triglycerides	<200	200-400	>400
LDL cholesterol	<130	130-160	>160
Cholesterol/HDL	<4.5	4.5-7.5	>5.5
LDL/HDL	<3.0	3.5	>5.0

- Defect in Lipoprotein metabolism leads to Lipoprotein disorders:
  - **Hyperlipoproteinemias**
  - **Hypolipoproteinemias**

TOTAL CHOLESTEROL

2004	2006	2008	2011
390			
380			
370			
360			
350			
340			
330			
320			
310	Very High		
300			
290			
280			
270			
260	High		
250			
240			
230			
220			
210			
196	198		195
190		188	
180	Good		
170			
160			
150	Very Good		
140			
130			
120			
110			

LDL (bad) CHOLESTEROL

2004	2006	2008	2011
320			
310			
300			
290			
280			
270			
260			
250			
240			
230			
220	Very High		
210			
200			
190			
180	High		
170			
160			
150			
140			
130	131		
120		119	123
110	Good		
100*			
90			
80	Very Good		
70*			
60			
50			
40			

HDL (good) CHOLESTEROL

2004	2006	2008	2011
130			
125			
120			
115			
110			
105			
100			
95			
90			
85			
80			
75			
70	Protective		
65			
60			
55			
49			
45	44	46	45
40			
35	High Risk		
30			
25			
20			
15			
10			
5			
0			

TRIGLYCERIDES

2004	2006	2008	2011
625			
600			
575			
550	Very High		
525			
500			
475			
450			
425			
400			
375			
350			
325	High		
300			
275			
250			
225			
200			
175			
150	Normal		
131			133
100	111	110	
75			
50			
25			
0			

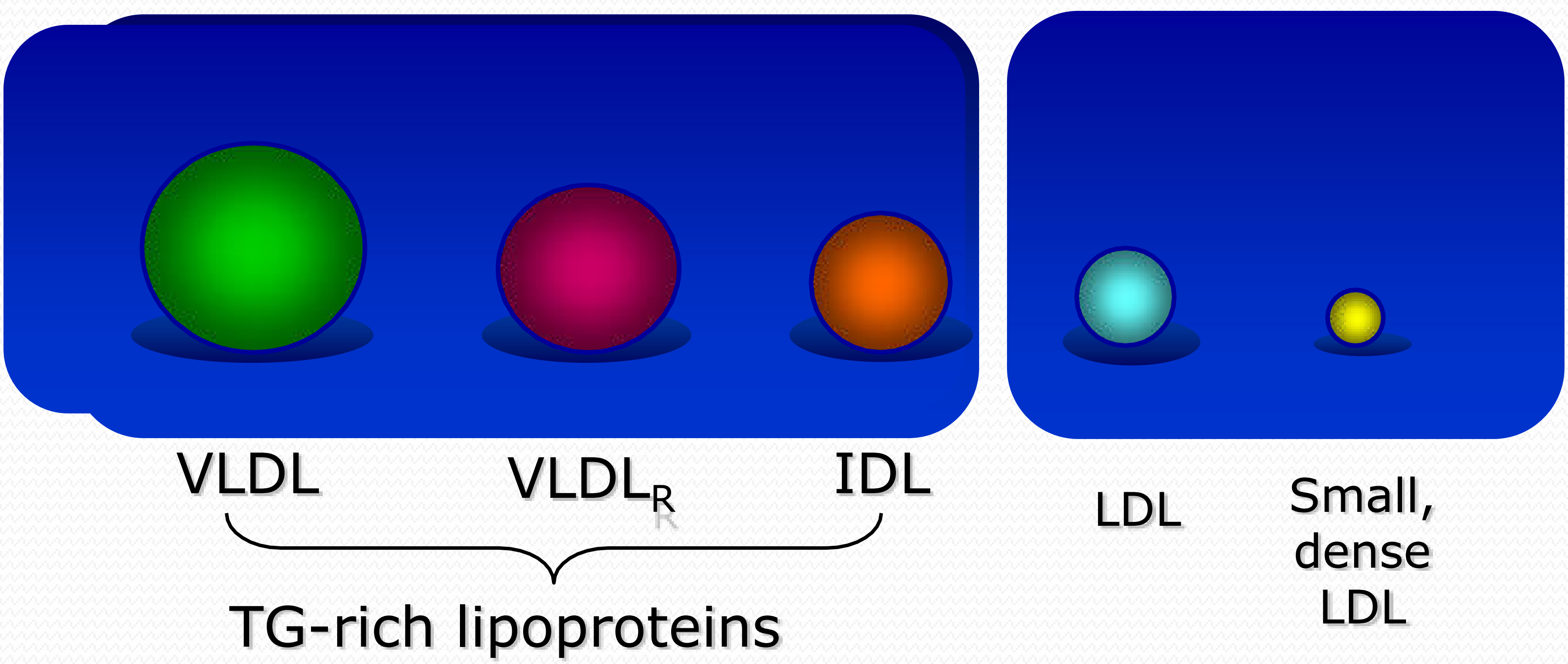
Yellow is Bad
White is Borderline
Green is Good

TOTAL/HDL Cholesterol Ratio

7.0			
6.5	Very High		
6.0			
5.5			
5.0	High		
4.5	4.5		4.3
4.0		4.1	
3.5	Good		
3.0			
2.5			
2.0			
1.5			
1.0			
0.5			
0.0			

Lipoproteins Atherogenic Particles

MEASUREMENTS: Apolipoprotein B
Non-HDL-C



- Defect in the **receptors of Lipoproteins** on specific tissues leads to retention of specific Lipoproteins in the blood circulation.

- Abnormal **high levels of LDL** in blood is **due to LDL receptor defect on extrahepatocytes** bad to body.

- The **Cholesterol associated to high LDL levels** is said to be **bad Cholesterol**.
- **This increases the risk of Atherosclerosis ,Ischemia, MI and Stroke.**

- **Recently** evidenced **high levels of blood HDL are also bad to body.**
- **This increases the risk of Atherosclerosis ,Ischemia, MI and Stroke.**

Proteolipids/ Lipophilin

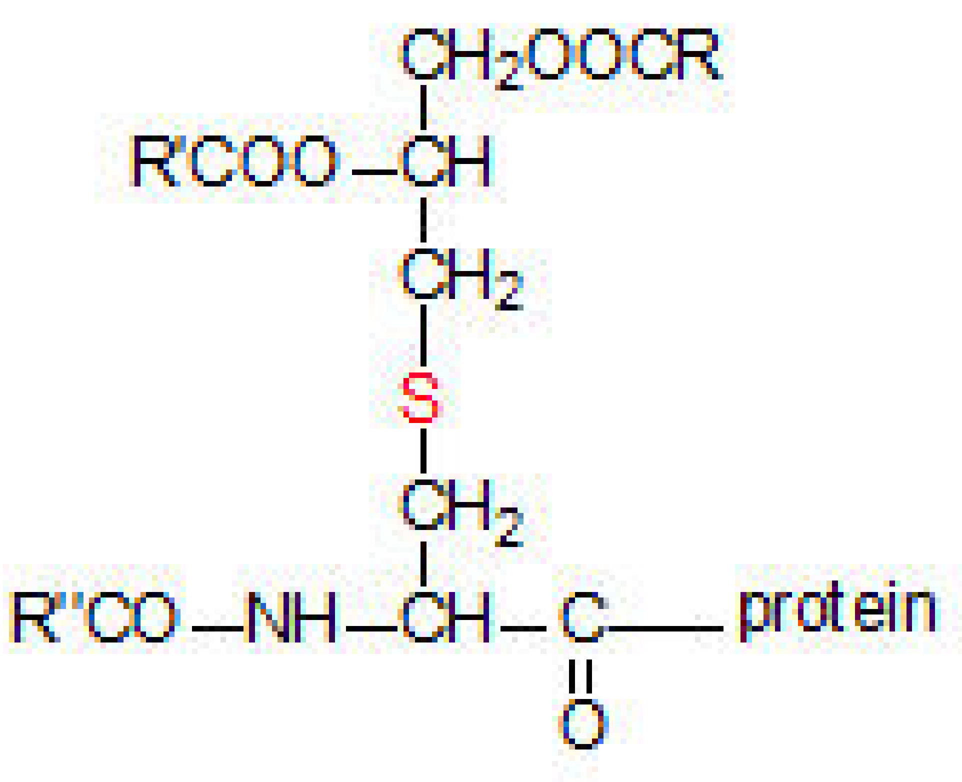
Proteolipids/ Lipophilin

- Proteolipids are compound lipids which have **more content** of **Proteins than Lipids.**

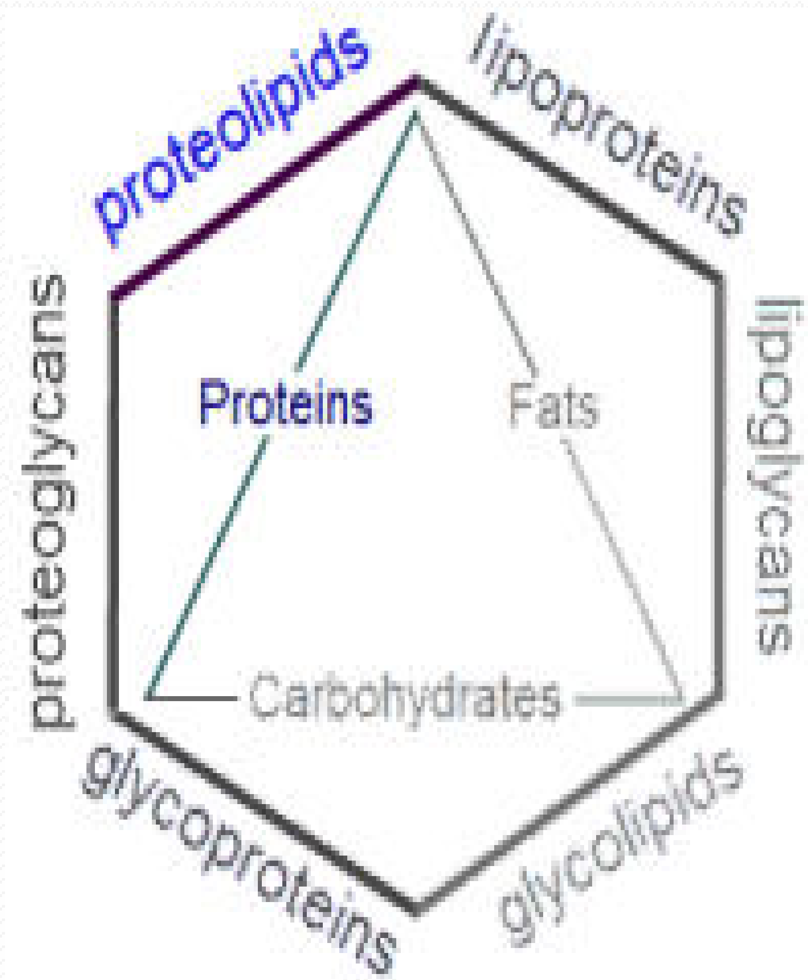
- **Proteolipid** is a **transmembrane domain protein** bound with **Lipids.**

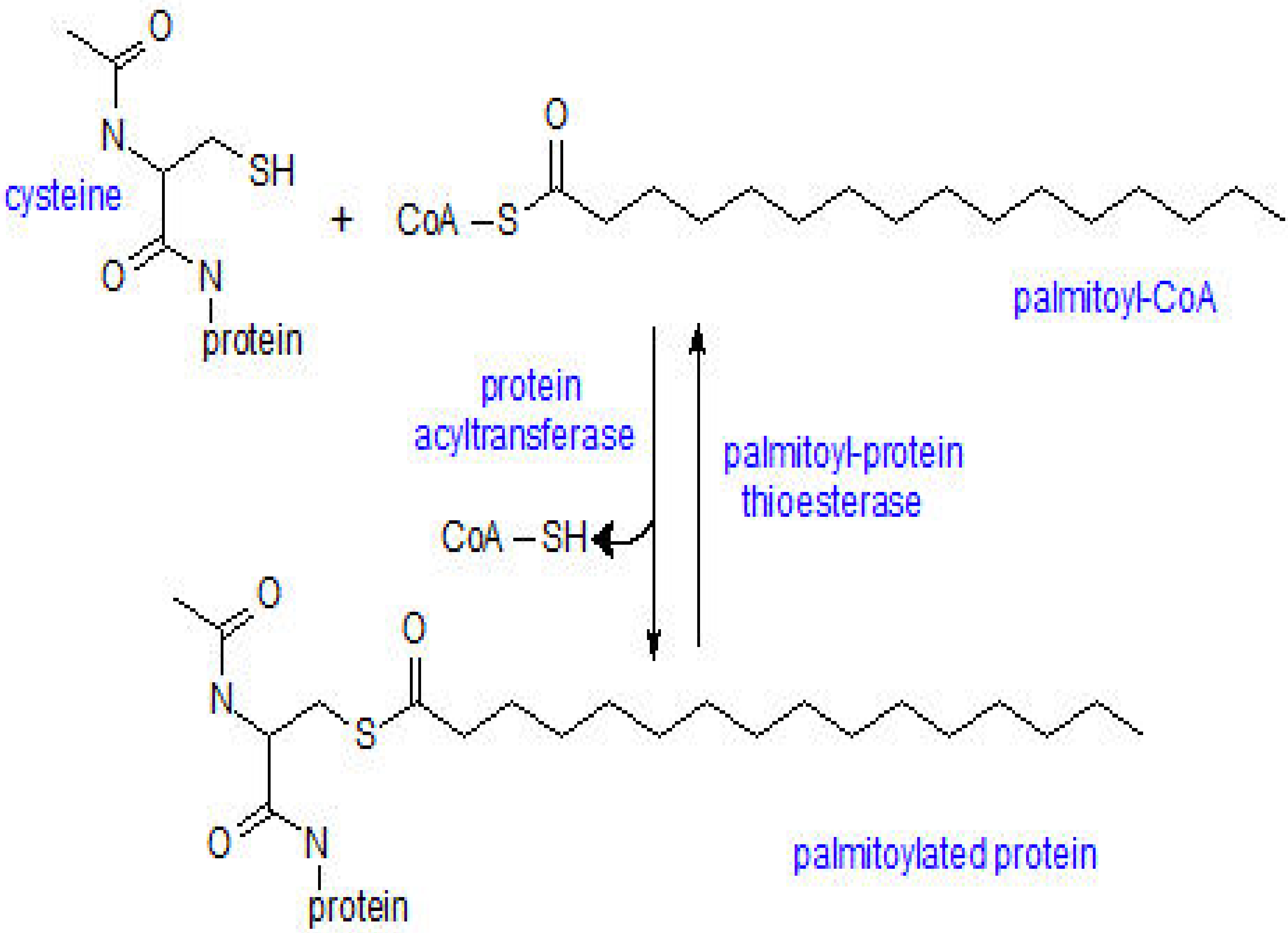
Occurrence Of Proteolipids

- Proteolipids are structural Lipids
- Present on the **extracellular side of the membrane**.
- Proteolipids are also present in **Myelin Sheath.**



bacterial proteolipid





Miscellaneous Lipids

Miscellaneous Lipid

Eicosanoids

- Eicosanoids are Classified under Miscellaneous Lipids.

- **Eicosanoids** is a **generic term collectively** used for
- **Biologically active 20 carbon(Eicosa) Lipid like compounds**

Name Of Eicosanoids

- **Eicosanoids** is a Generic term for the 20 Carbon related compounds like:
  I. **Prostaglandins (PGs)**
  II. **Prostacyclins (PGI_2)**
  III. **Thromboxanes (TX)**
  IV. **Leukotrienes (LT)**
  V. **Lipoxins (LX)**
  VI. **Resolvins**
  VII. **Eoxins**

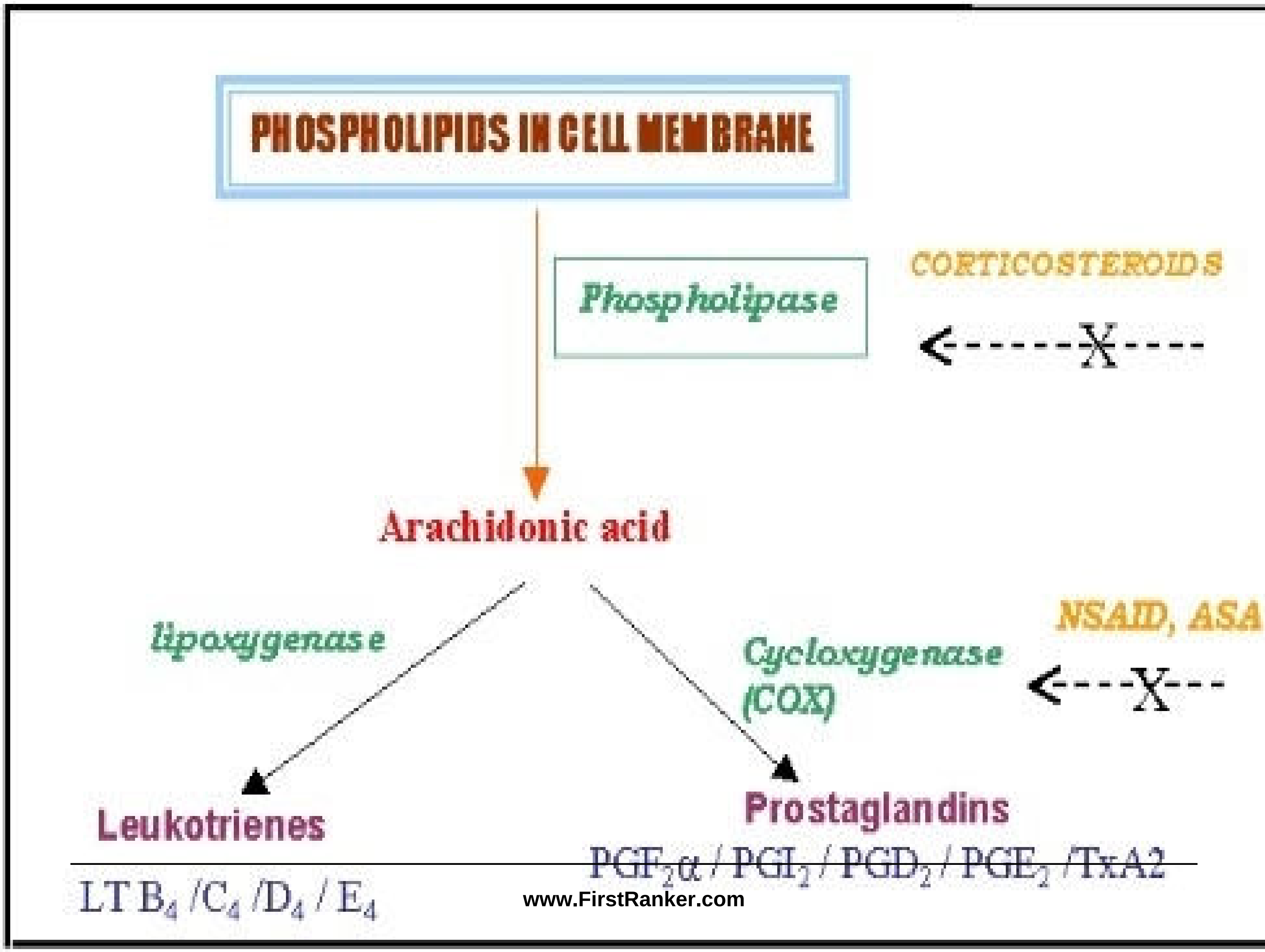
Biosynthesis Of Eicosanoids

- **Eicosanoids** are **derivatives** of **Nutritional Essential Fatty acid/PUFAs**.

- **Eicosanoids** are biosynthesized in the body from **PUFAs**:

1. **Mostly from Arachidonic acid/Eicosatetraenoic acid (PUFA)/Omega 6 Fatty acid**
2. **Minorly from Timnodonic acid/Eicosapentaenoic /Omega 3 Fatty acid**

- **During Eicosanoid Biosynthesis Mostly**
- **Arachidonic acid** is released by **Phospholipids Viz: Lecithin/PIP3**
- **By Phospholipase A2 activity**

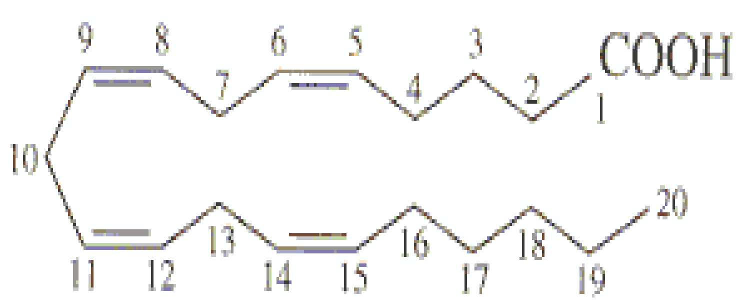


- **Eicosanoids** has **very short half life**
- **From seconds to few minutes**

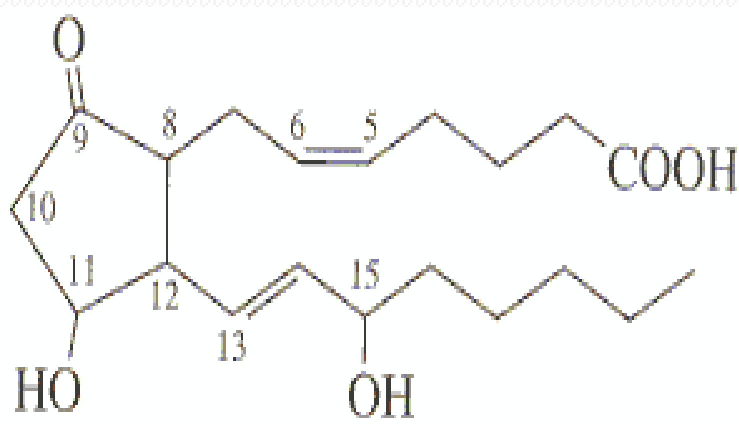
Classification Of Eicosanoids

- **Prostanoids :** Obtained by **Cycloxygenase** System :
  - **Prostaglandin**
  - **Prostacyclins**
  - **Thromboxanes**
- **Leukotrienes** and **Lipoxins** are obtained by **Lipoxygenase** System

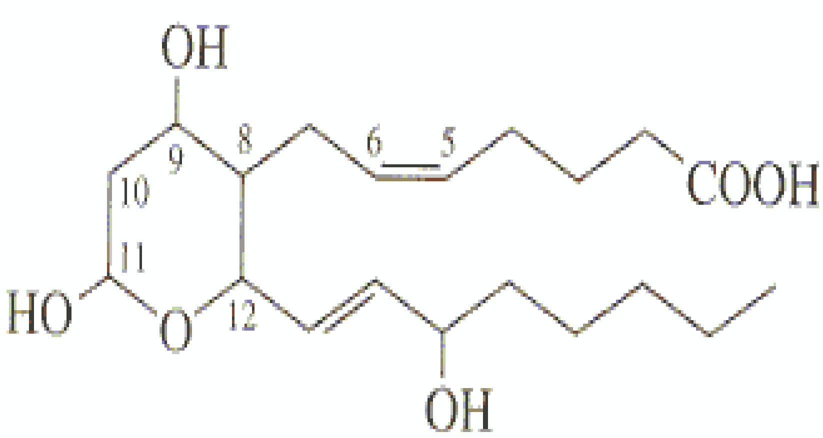
Prostaglandins are Derivative of Arachidonic acid



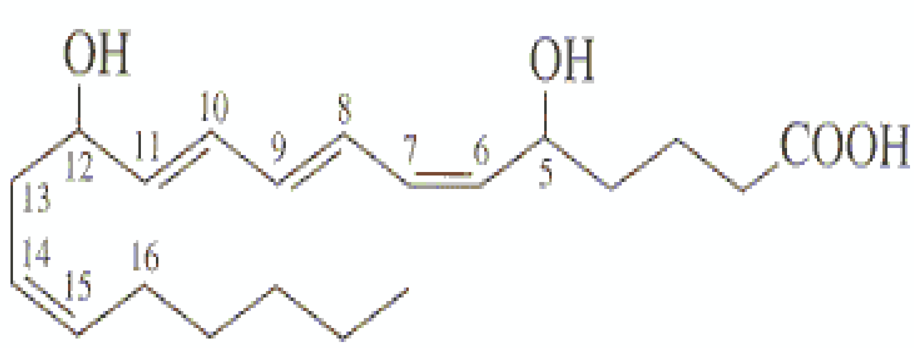
(a) Arachidonic acid



(b) Prostaglandin E_2



(c) Thromboxane B_2



(d) Leukotriene B_4

1. Prostaglandins (PGs)

- **Prostaglandins** are type of **Eicosanoids**.
- **PGs** also termed as **Prostanoids**
- Since they are obtained from parent compound **Prostanoic acid**

Biosynthesis Of Prostaglandins

- **Per day 1 mg** of **Prostaglandins are biosynthesized** in human body.

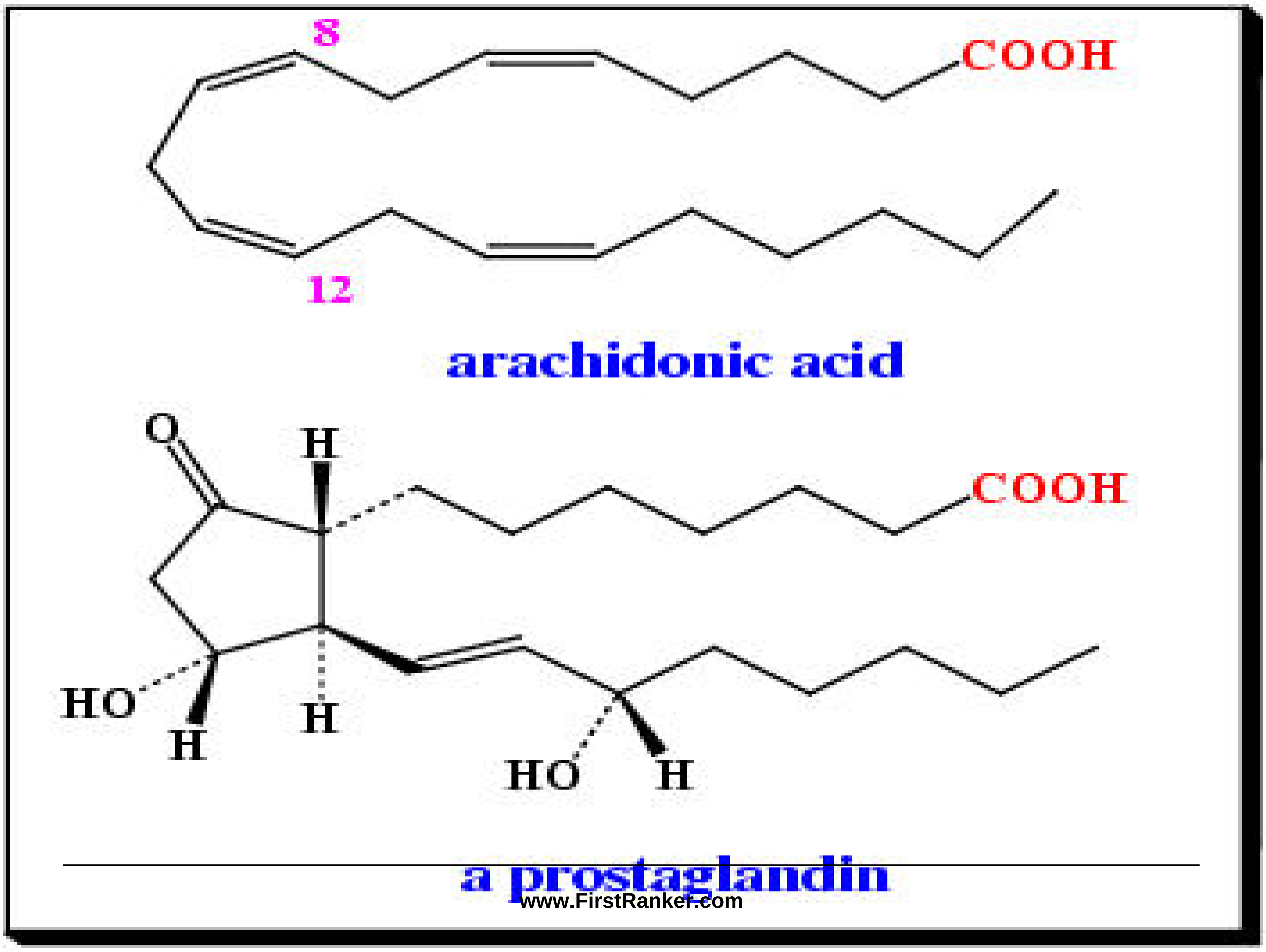
- Prostaglandins are derived from **Arachidonic acid** by **Cycloxygenase system**.

- **Phospholipid Lecithin** releases **Arachidonic acid**
- **Arachidonic acid** is used for **Prostanoic acid synthesis.**
- **Prostanoic acid** then **biosynthesizes Prostaglandin** in human body.

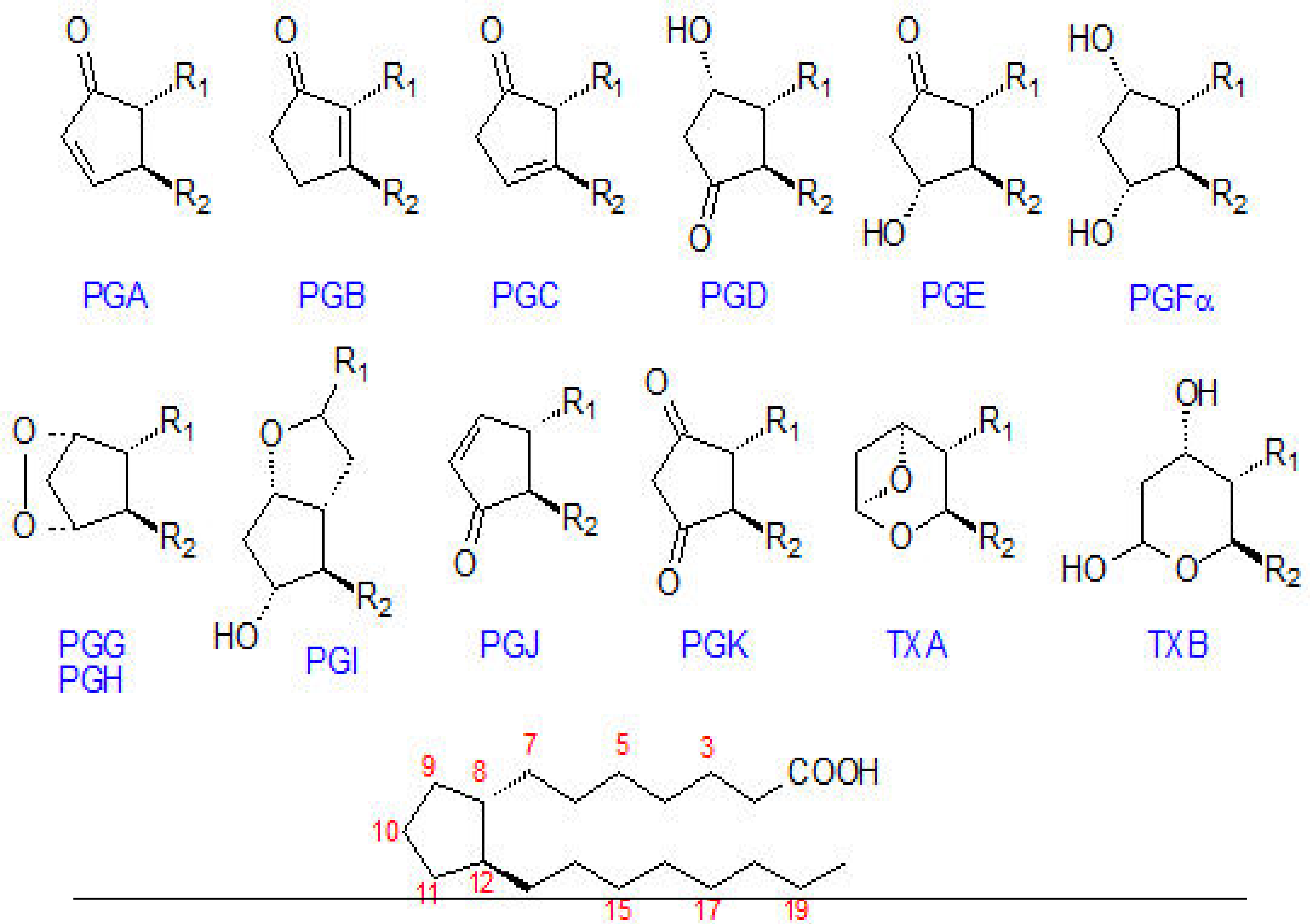
Structure and Types Of PGs

- The Prostaglandin structure is complex and possess:
  - **Cyclopentane ring**
  - **Double bond**
  - **Carboxylic and Hydroxyl groups**

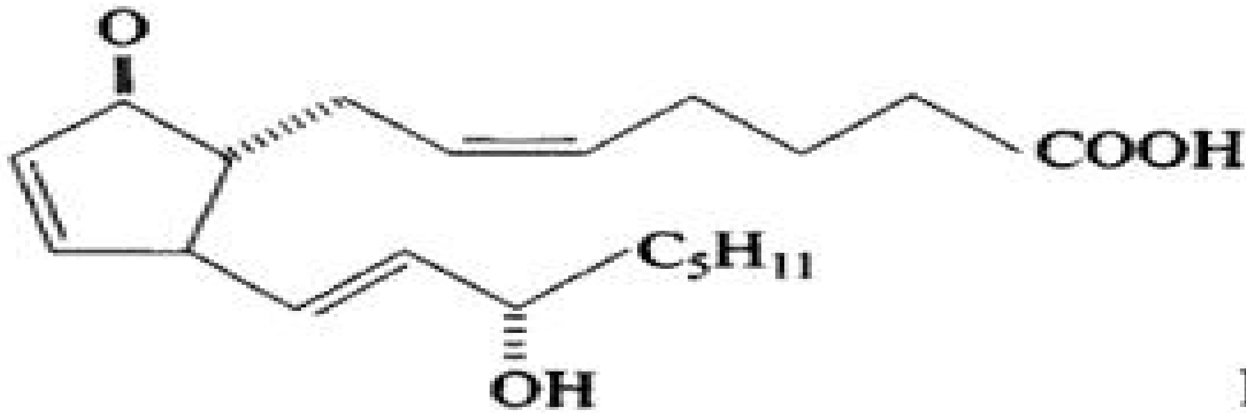
- **Prostaglandins** contains a
- **Cyclopentane ring** with **Hydroxyl groups** at **C11 and C15**



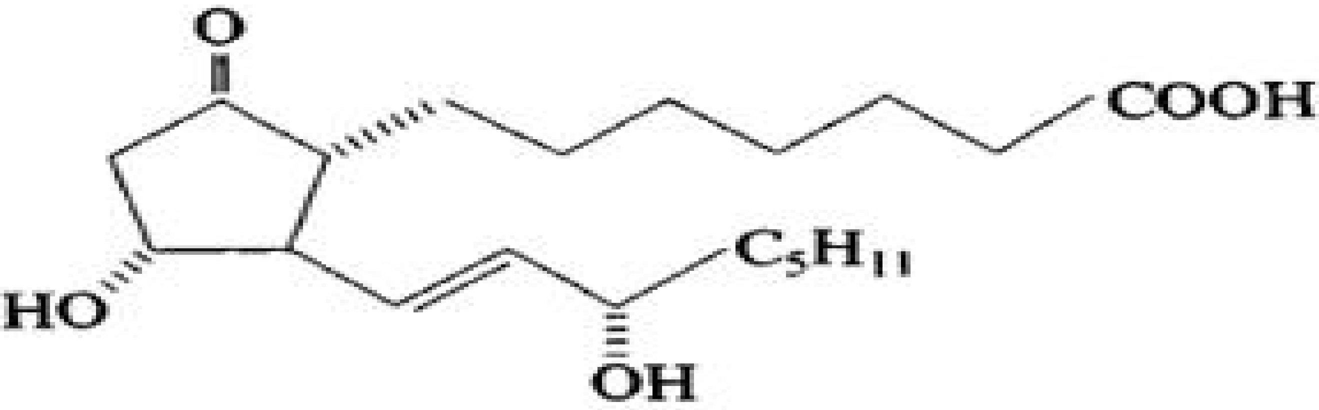
- **Prostaglandins (PG) are of following Types:**
  - **PG A**
  - **PG B**
  - **PG C**
  - **PG D**
  - **PG E**
  - **PG F**
  - **PG G**
  - **PG H**



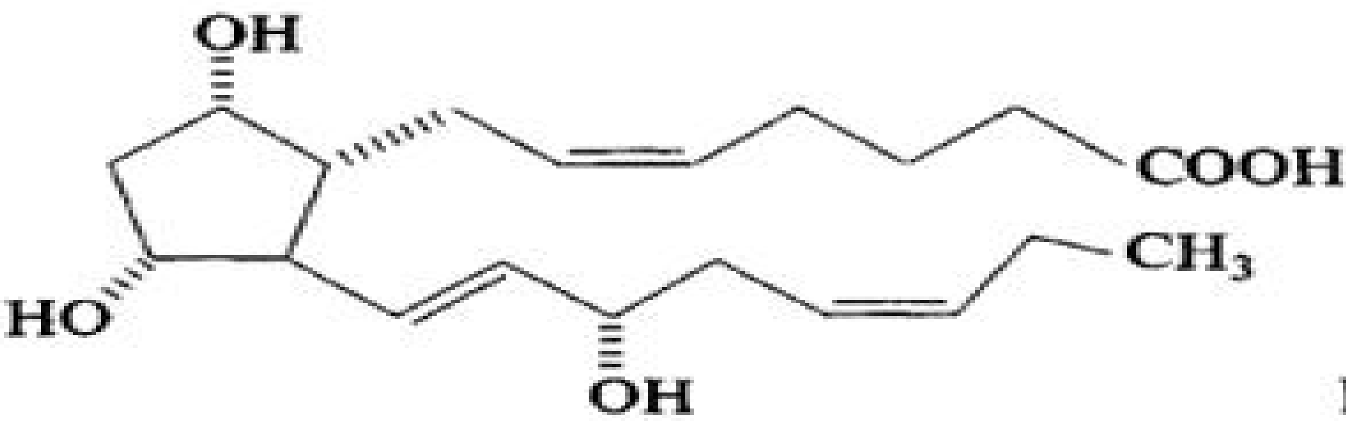
prostanoic acid



Prostaglandin A_2



Prostaglandin E_1



Prostaglandin $F_{3\alpha}$

Occurrence/Distribution Of PGs

Occurrence Of PGs

- Prostaglandin was **first seen** in **Prostatic secretion** and **Semen**.
- **Later** it was **found** that **Prostaglandins** are **ubiquitous**
- Present all over **in the human body tissues.**

Functions OF Prostaglandins

- Prostaglandins serve as Cell Signaling Agents/Local Hormones with.
  - Paracrine in action (act on sites closely where they are produced/ neighboring cells).
  - Autocrine in action that the sites where they are produced.

Prostaglandins have diverse functions on many tissues

- **Action of one PG is different in different tissues.**
- Sometimes PGs bring out **opposing action in same tissue.**

- **PGs exert their function through G-Protein linked membrane receptors.**

1.Role Of PGs In Blood Vessels

PGs Regulate Blood Pressure

- **PG A and PG E** are **Vasodilators.**
- PGs **lowers the blood pressure by:**
  - **Increasing blood flow** and
  - **Decreasing vascular resistance** in blood vessels.

- PGs are used **Therapeutically in treating Hypertension.**

Prostaglandin occur at Platelets

Inhibits Platelet Aggregation

and

Thrombus formation

2. PGs Has Role in Uterus At The Time Of Parturition

- PG naturally **increases uterine contraction of smooth muscles** which **induces** the **delivery of baby**.

- PGs can be **therapeutically used** as **Abortificients** during **Medical Termination of Pregnancies** (MTPs).
- PGs also arrests **postpartum hemorrhage**.

3. Role Of Prostaglandins In Lungs

- PGs in Lungs serve as **Bronchodilators** and **Bronchoconstrictor** of Lungs.
  - **PG E-Bronchodilator**
  - **PG F- Bronchoconstrictor**

- **PG E is used in treatment of Bronchial Asthma.**

4. Role Of Prostaglandin In GIT

- Prostaglandin in stomach **increases its motility** and **inhibits gastric secretion of HCL.**
- PG is used in **treatment of gastric ulcers.**

5. Role Of Prostaglandins in Kidneys

- PGs in Kidneys **increases GFR** and **promotes urine formation** and **urine out put**
- Thus helps in **removing waste out of the body**.

PGs Regulate Sleep and Wake Process

- Use of PG D_2 promotes Sleep

6.Effect Of PGs on Metabolism

- PGs **Decreases Lipolysis** (breakdown of TAG).
- PGs **increases Glycogenesis**.
- PGs **promotes Steroidogenesis** (Biosynthesis of Steroid hormones)
- PGs **promotes mobilization of ionic Calcium** from bones.

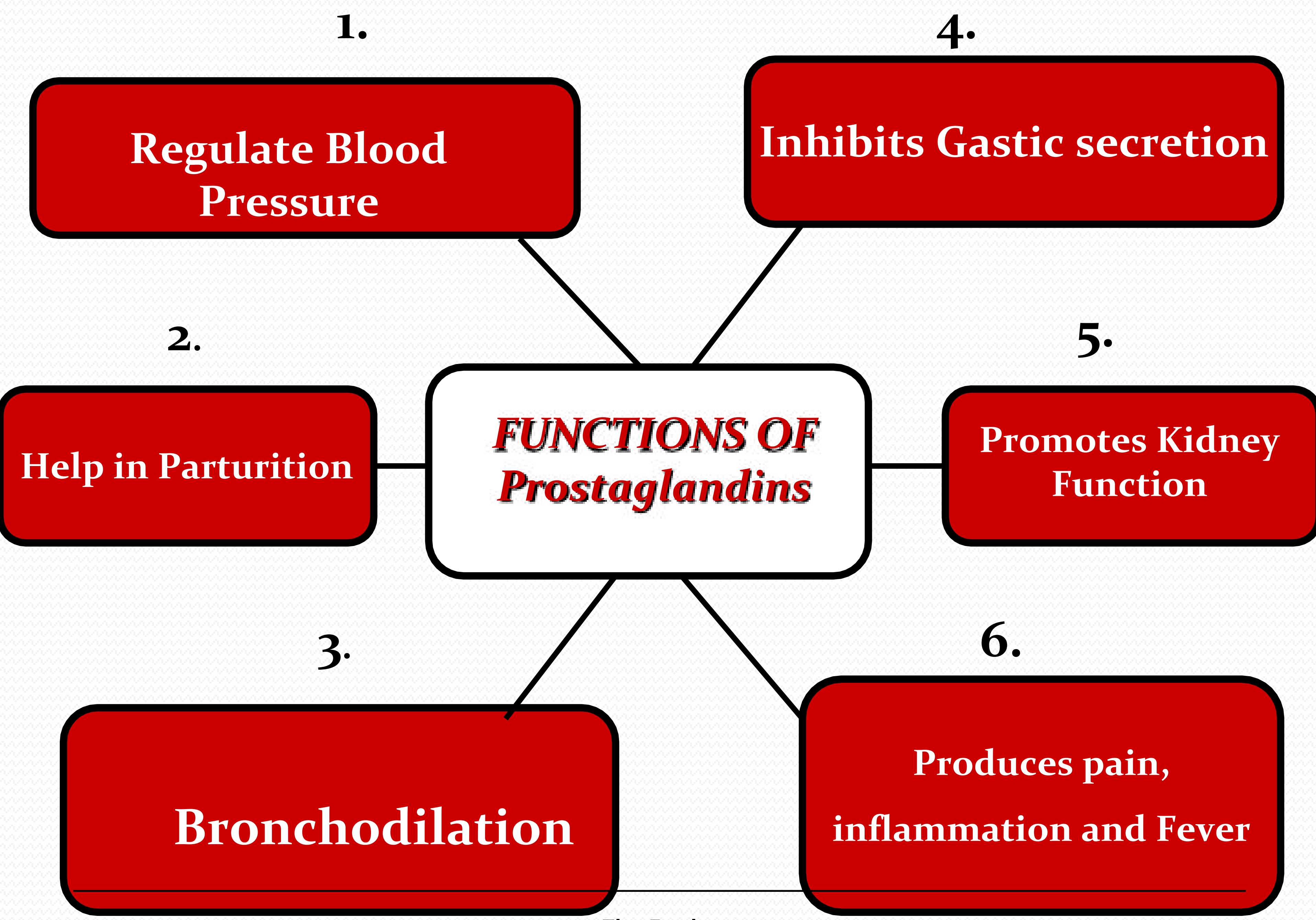
Role Of PGs
In Immunity And Inflammation

- Prostaglandins are produced in more amounts at the time of :
  - **Fever**
  - **Pain**
  - **Nausea and Vomiting**
  - **Inflammation**
- **To provide immunity to body**

Production of PGs Promote Fever , Pain , Nausea Vomiting and Inflammation

- PGs are more produced in inflammatory disorders like **Rheumatoid Arthritis.**

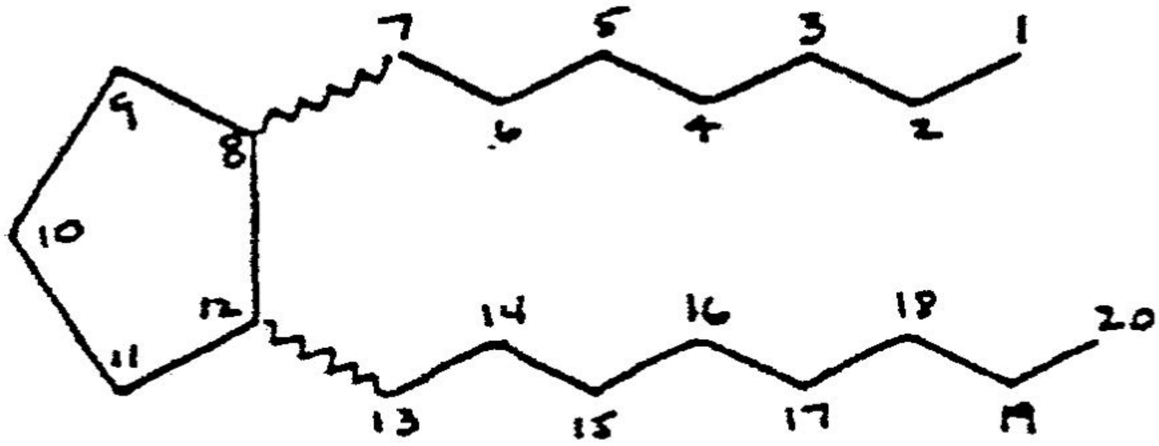
- Drugs like **NSAIDs Aspirin** used in **treating inflammatory disorders.**
- Inhibits the Enzyme of **Cycloxygenase system**
- **Which in turn inhibits** the **biosynthesis of Prostaglandins**.



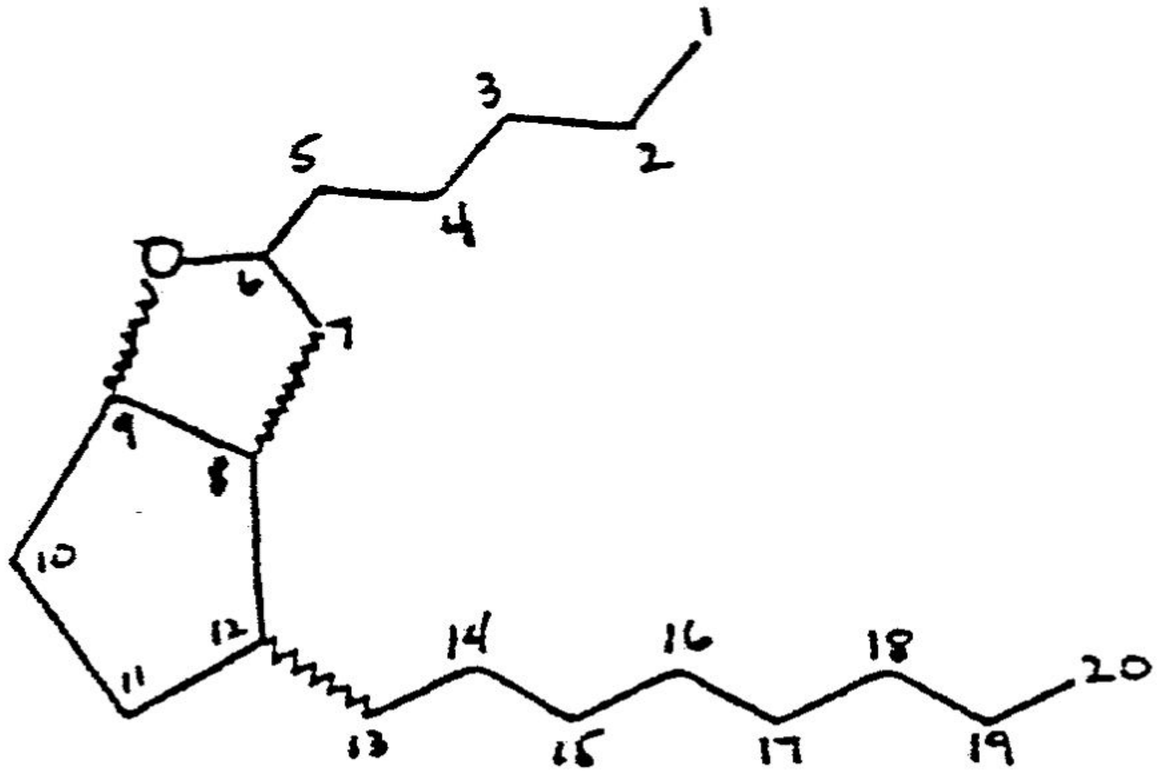
2. Prostacyclins (PGI_2)

Prostacyclins (PGI_2)

- Prostacyclins are type of **Eicosanoids/ Prostanoids.**
- Principally **formed in vascular endothelium**
- **They are Platelet Aggregation Inhibition Factors**
- Biosynthesized by enzyme **Prostacyclin Synthetase**.



Prostaglandin



Prostacyclin

Roles of Prostacyclins

- Prostacyclins are **Vasodilators.**
- Prostacyclins like Prostaglandins **inhibit platelet aggregation.**
- Prostacyclins **prevent Thrombus/clot formation**.

3. Thromboxanes (TX)

Thromboxanes (TX)

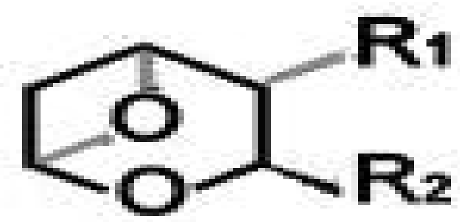
- **Thromboxanes** are also termed as **Platelet Aggregating Factor** (PAF).

- **Thromboxanes are Prostanoids** produced by **Thrombocytes** (platelets)

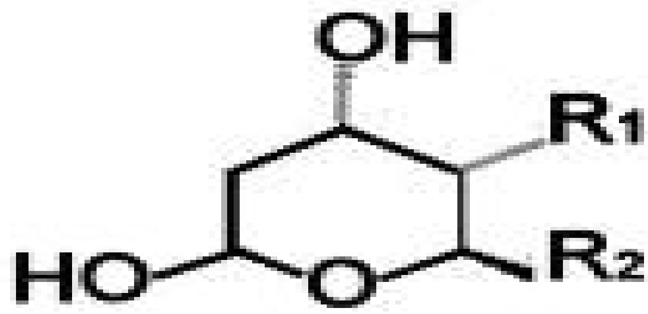
- By **Enzyme Thromboxy Synthase.**

Structure Of Thromboxanes

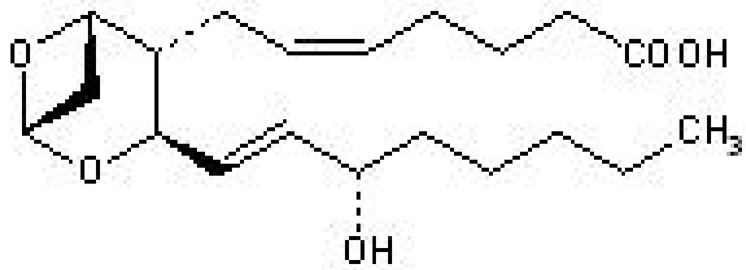
- Thromboxanes possess a **cyclic Ether** in their structures.



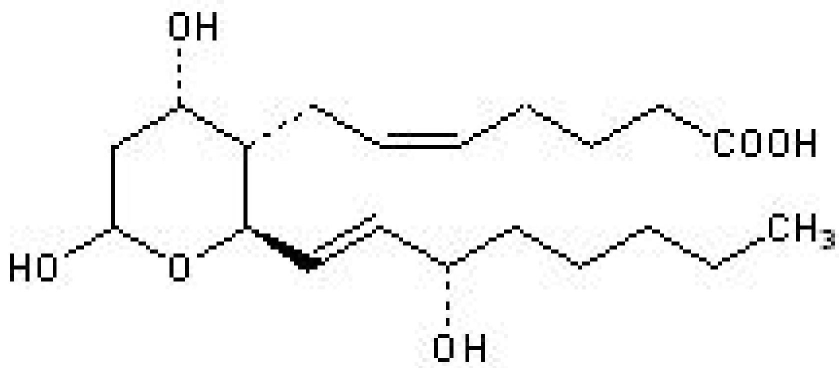
TXA



TXB



Thromboxane A_2



Thromboxane B_2

Types Of Thromboxanes

- **TX A and TX B** are types of Thromboxanes.
- **TXA2** is more prominent in human body.

Functions Of Thromboxanes

- Thromboxanes are **vasoconstrictors.**
- Thromboxanes **enhances platelet aggregation.**
- Thromboxanes **favors blood clot formation** during **blood coagulation**.

- **Thromboxanes** and **Prostacyclins** are **antagonistic to each other** balancing their activities.
- Increased **Thromboxane activity results in Thrombosis.**

4. Leukotrienes

Leukotrienes

- Leukotrienes are **type of Eicosanoids**
- Biosynthesized through **Lipoxygenase system in Leukocytes.**

- **Leukotrienes** are a family of **Eicosanoid**
- **Inflammatory mediators produced in leukocytes.**

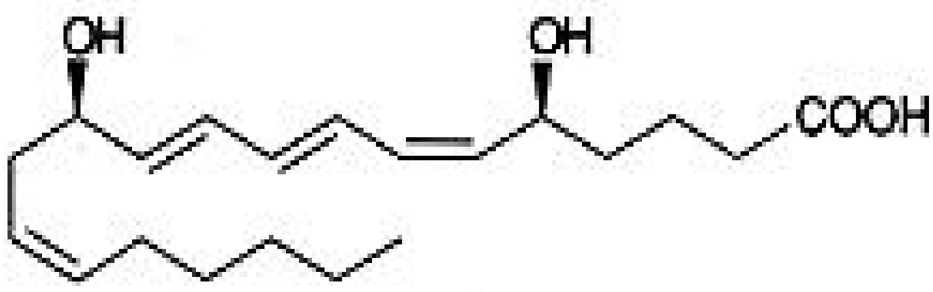
Occurrence Of Leukotrienes

- **Early discovery of Leukotrienes was in Leukocytes.**

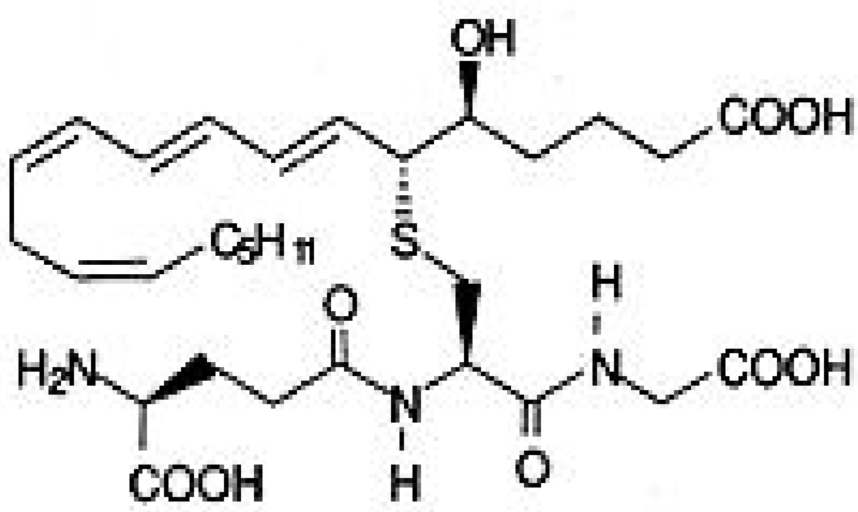
- **Leukotrienes are also produced and present in.**
- **Mast cells**
- **Lung**
- **Heart**
- **Spleen**

Leukotrienes Structure and Types

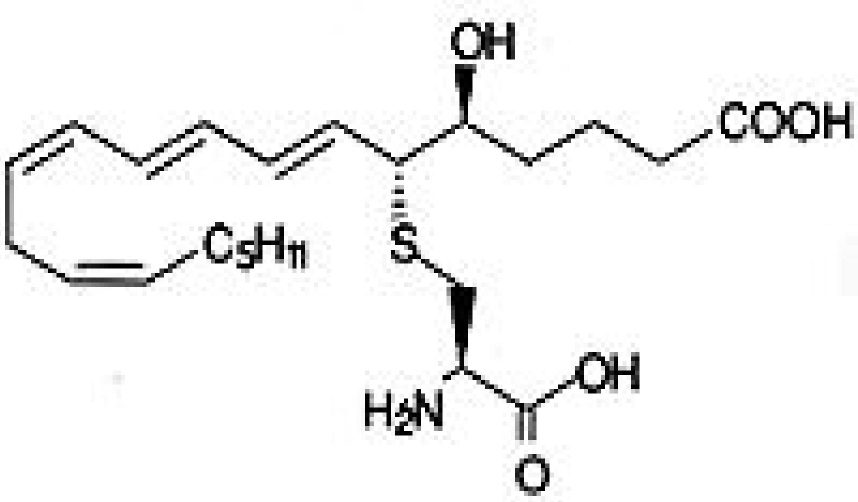
- **Leukotrines** are **Hydroxy derivatives** possessing **conjugated Trienes .**
  - **Types of Leukotrienes:**
- **LTB4, LTC4, LTD4 and LTE4**



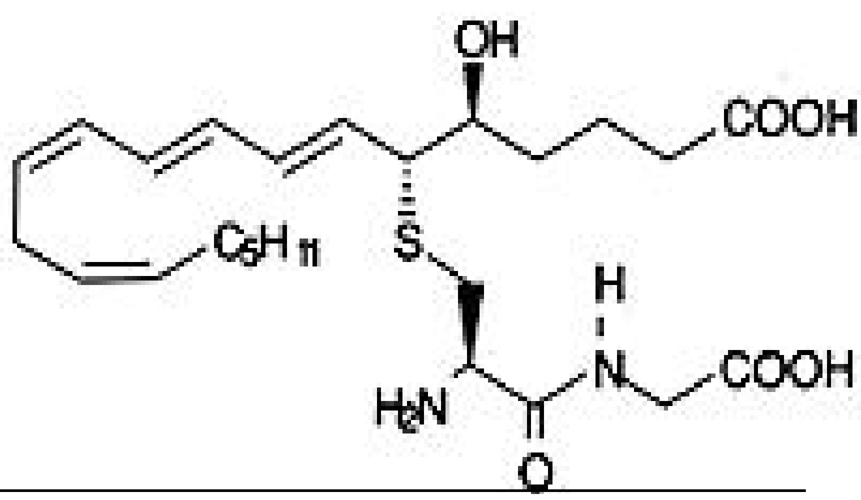
LEUKOTRIENE B_4



LEUKOTRIENE C_4



LEUKOTRIENE E_4



LEUKOTRIENE D_4

Effect Of Leukotrienes

- Leukotrienes are the **component of Slow Reacting Substances (SRS-A).**
- **SRS-A** are released during **Allergic reactions/Anaphylaxis.**

- **Leukotrienes** are 100-1000 times **more potent** than **Histamine** during **allergic reactions.**

- LTB_4 is a potent **chemotactic agent**.

(chemical substance which mediates movement of cells).

- Leukotrienes by action are:
  - **Bronchoconstrictors**
  - **Vasoconstrictors**

- **LTC_4, LTD_4 and LTE_4** are **Slow - Releasing Substance of anaphylaxis** (SRS - A) ,
- **SRS-A** causes fluid leakage from blood vessels to an inflamed area.

- Overproduction of Leukotrienes causes **Asthmatic attacks** /**Anaphylactic shocks.**

- An **Antiasthmatic drug Prednisone inhibits Leukotriene biosynthesis.**

5.Lipoxins

Lipoxins

- **Lipoxins** are Eicosanoids produced in Leukocytes of human body.
- **Lipoxins are**:
  - Vasoactive/Vasodilators
  - Anti-inflammatory
  - Immunoregulatory
  - Chemotactic substances

Omega 6 and Omega 3 Derived Eicosanoids Are Opposite in Body Action

- **Omega 6 Derived Eicosanoids**
- **Prostaglandins:**
  - Promotes Inflammation
- **Omega 3 Derived Eicosanoids**

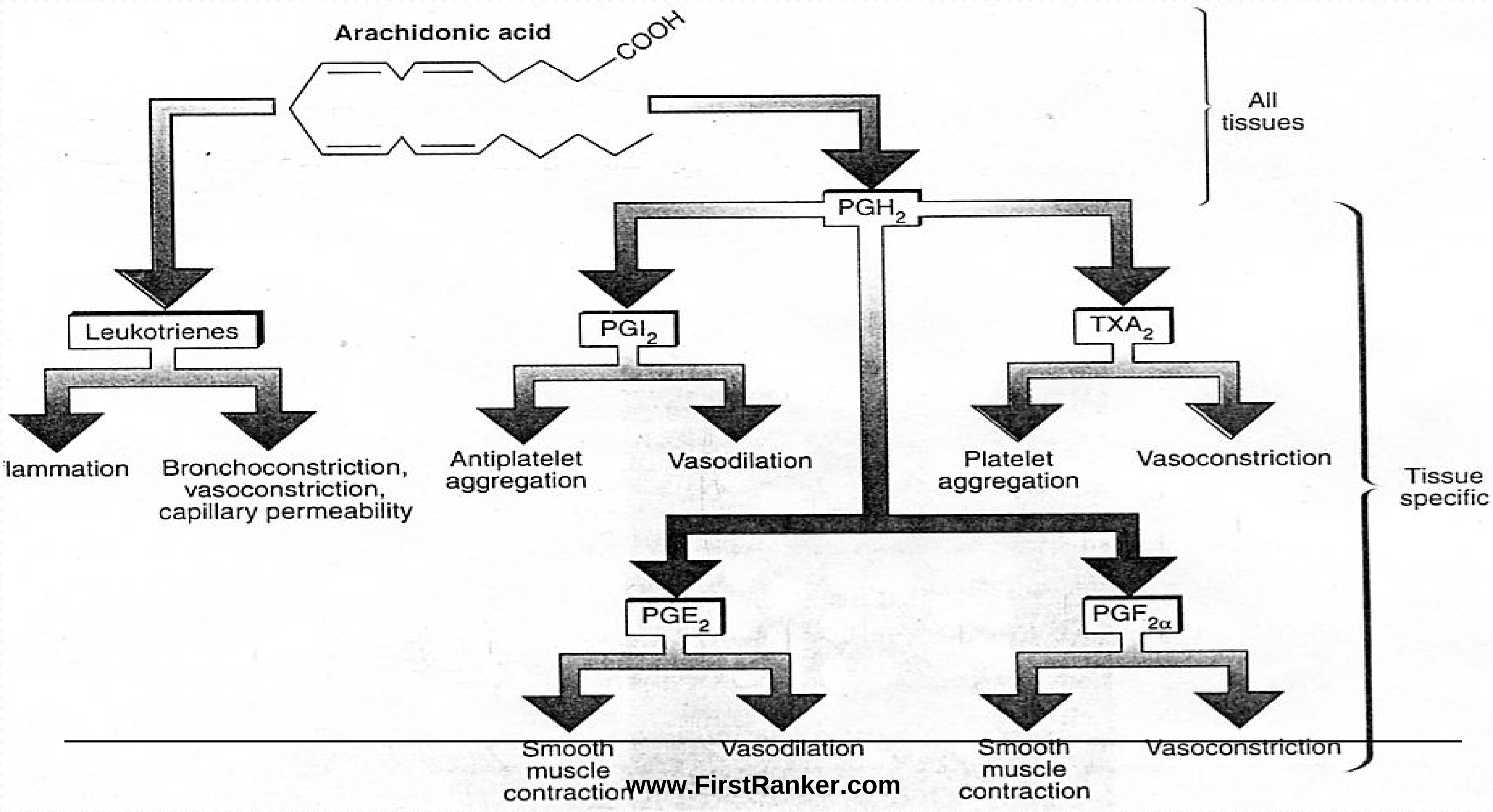
Resolvins and Eoxins are:

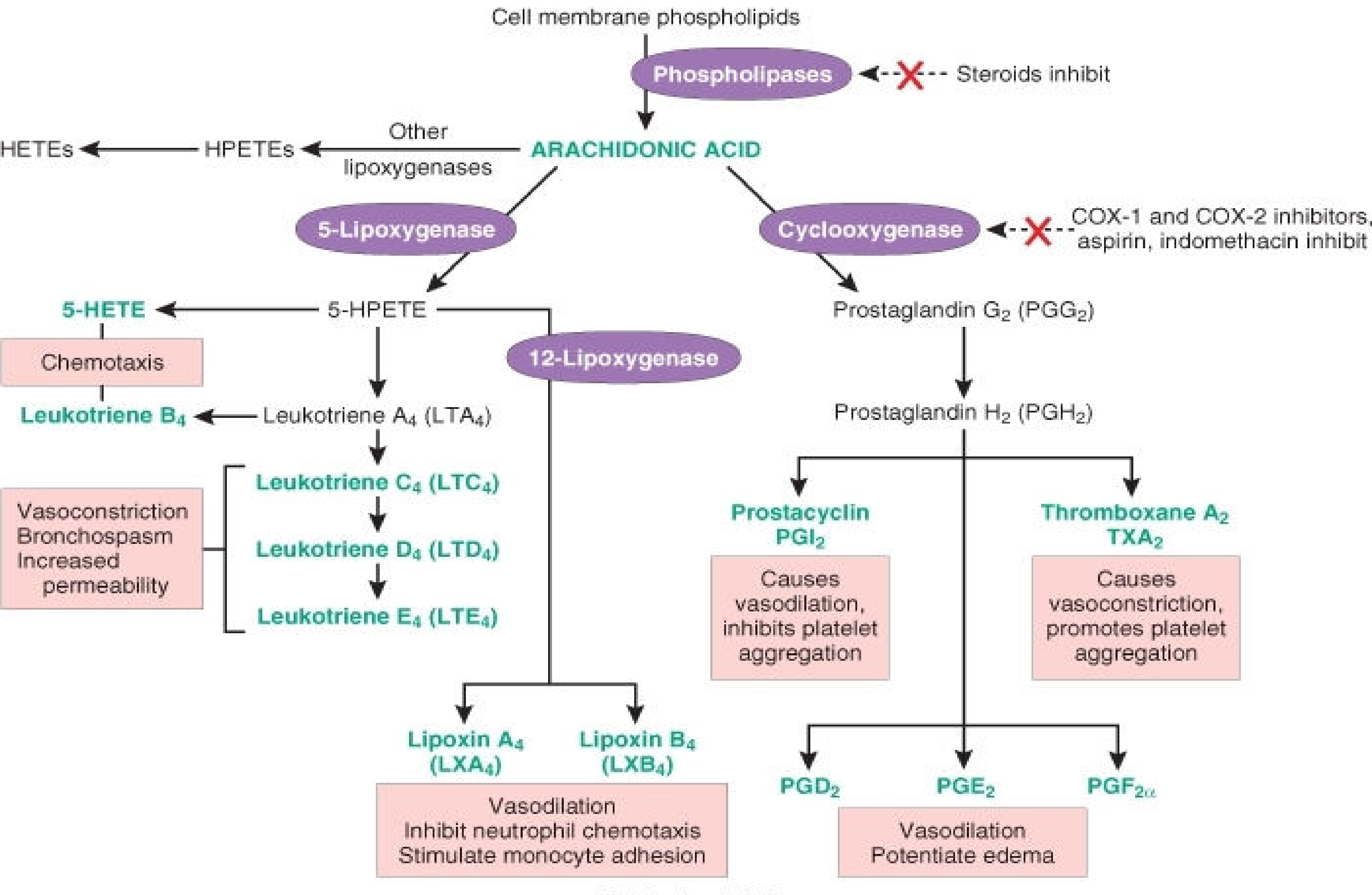
  - Anti Inflammatory
  - Anti Allergy
  - Anti Hypertensive
  - Anti Cancer
  - Anti Atherosclerotic

Adverse effects of Eicosanoids

- Local pain and irritation
- Bronchospasm
- Gastrointestinal disturbances: nausea, vomiting, cramping, and diarrhea.

Biological Actions of Selected Eicosanoid Molecules





Amphipathic Lipids

Amphipathic Lipids

- Lipids structure possessing **both polar and non polar groups** in their structure are **amphipathic Lipids.**

- Amphipathic /Amphiphillic Lipids are **partially soluble** in water due to their **polar hydrophilic groups**

- Amphipathic Lipids become **oriented at oil–water interfaces:**
  - With the **polar group directed** in the **water phase**
  - The **non polar group directed** in **oil phase/away from water.**

Examples Of Amphipathic Body Lipids

- **Phospholipids**
- **Glycolipids**
- **Free Fatty acids**
- **Free Cholesterol**

Role Of Amphipathic Lipids

- **Amphipathic Lipids have following biological Significances in forming:**
  - **Biomembranes:**
  (Phospholipid bilayer, Glycolipids and Cholesterol)
  - **Emulsions:** (In intestine PL help in Lipids Digestion)
  - **Micelles:**(In intestine help in Lipids Absorption)
  - **Lipoproteins:** for transport of nonpolar Lipids
  - **Liposomes**: (Agents for Drug /Gene carrier)

Emulsions

- **Emulsions** are small droplets of **oils miscible in aqueous phase**.
- **Emulsions** are usually formed by Nonpolar and Amphipathic Lipids along with Bile Salts in aqueous phase.

In Human GIT

- **Emulsions are formed as small, miscible dietary Lipid droplets** in aqueous phase of **intestinal juice in intestinal lumen**.

- **Emulsions** are formed during the process of **Emulsification in GIT.**

Requirements For Emulsification

- **Emulsifying agents :**
  - **Bile salts (Major)**
  - **Amphipathic Lipids** (Minor)
- **Mechanical force aids emulsification.**

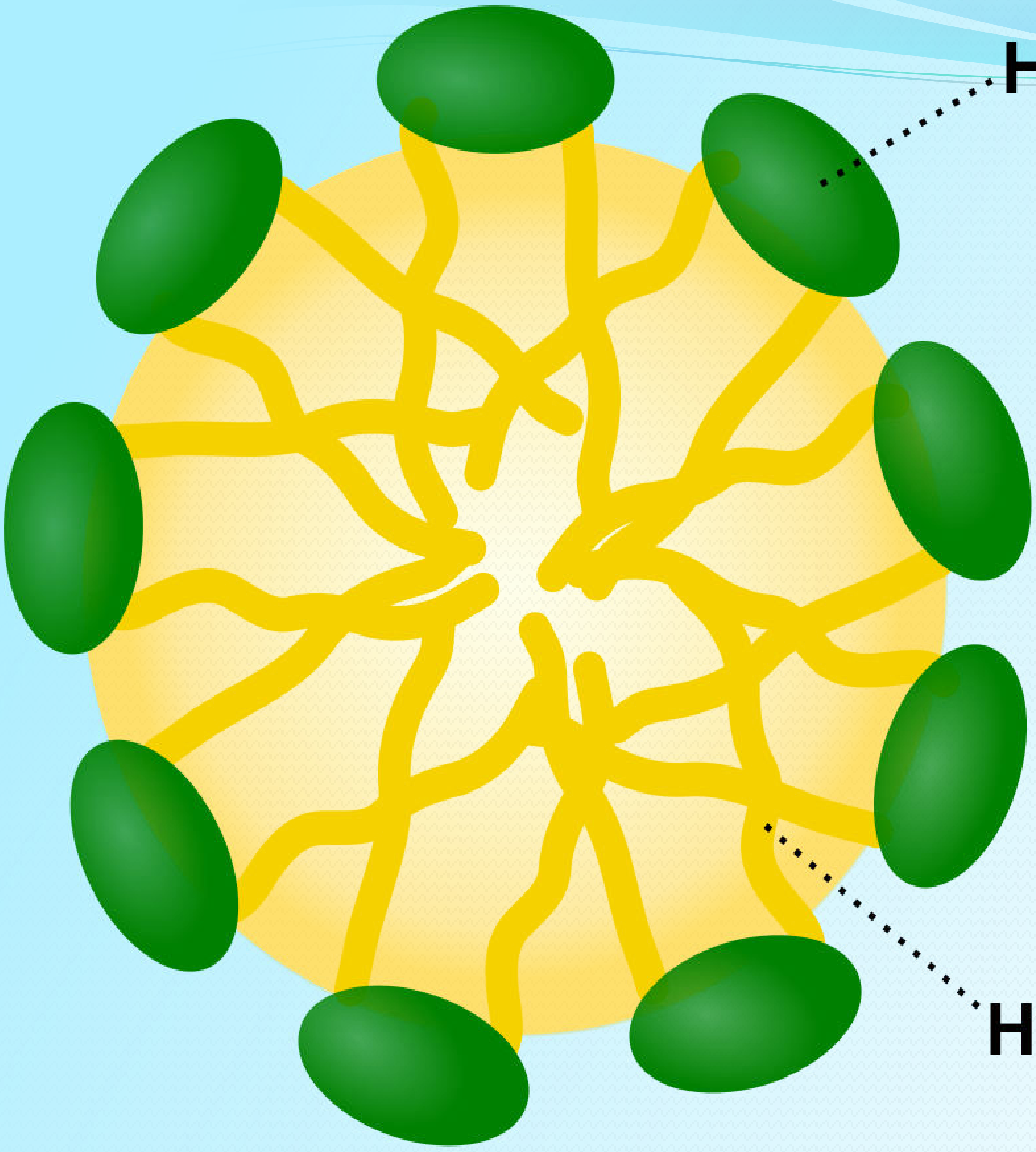
- **Emulsifying agents reduces the surface tension.**
- **Emulsifying agents** form a surface layer of **separating** the main bulk of **nonpolar Lipids** from aqueous phase.

- **Emulsions** are **stabilized** by the **detergent action** of **emulsifying agents.**

Emulsification Process

- **Emulsification** process takes place in an aqueous phase of **intestinal juice in intestinal lumen** and forms **Emulsions**.
- During Emulsification Hydrophobic or **nonpolar dietary Lipids(TAG)** are mixed **with** an **emulsifying agents:**
  - **Bile salts**
  - **Lecithin(Amphipathic Lipids)**

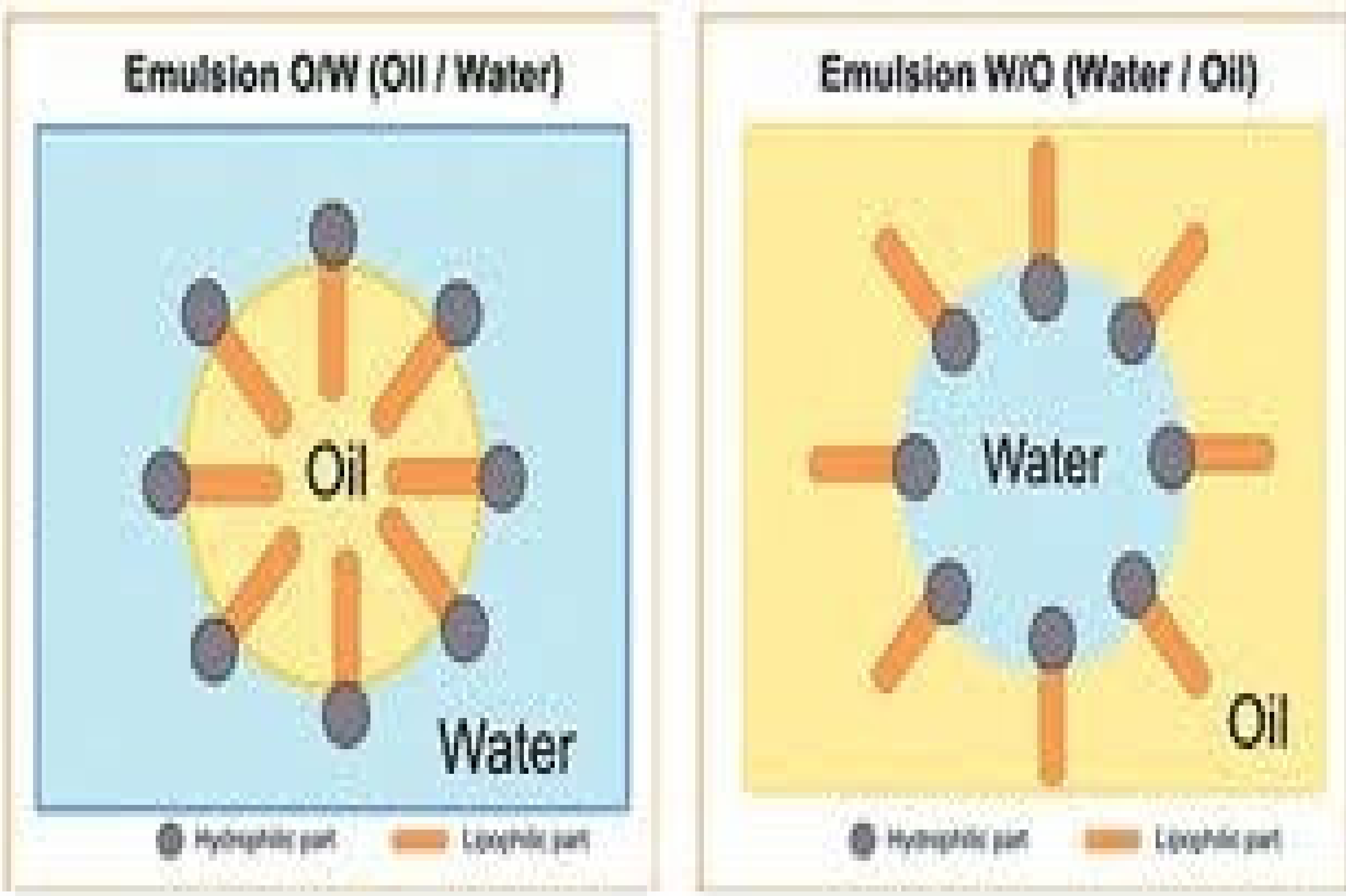
- **Mechanical force(provided by intestinal peristaltic movement) facilitates the process of Emulsification.**



Types Of Emulsions

I. Oil In Water

II. Water In Oil



Significance Of Emulsions

- Emulsions formed in the intestinal lumen **help in the digestion of dietary Lipids.**
- The **dietary large droplets of Fat/Oil** are transformed to **small ,miscible droplets** as **Emulsions.**

- **Emulsions** bring the dietary Lipids in **contact with Lipid digesting Enzymes** present in aqueous phase of **intestinal juice**.

Micelles

- Micelles have a **disc like shape** .
- Critical concentration of **Amphipathic Lipids** in aqueous medium form **Micelles(~200 nm)**.
- **Bile salts** help in forming **Mixed Micelles.**

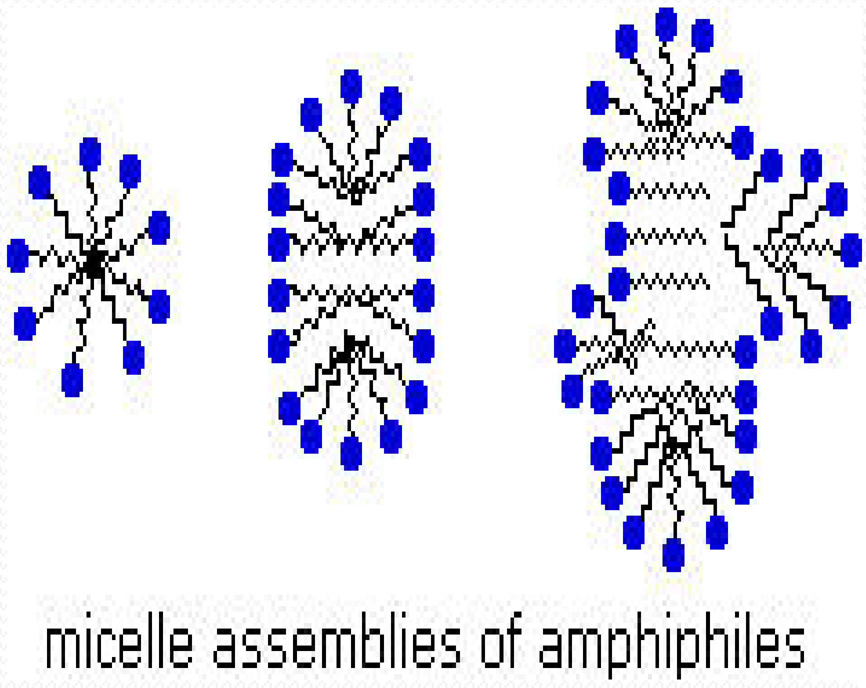
- Mixed Micelles are formed **after digestion** of various forms of dietary Lipids.

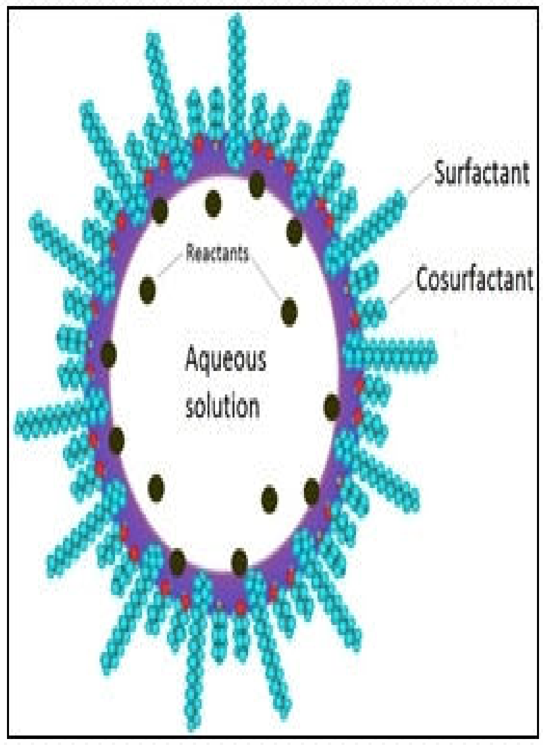
- Aggregation of various **digestive end products** of dietary Lipids covered with a peripheral layer of **Bile salts** form **mixed Micelles in the intestinal lumen.**

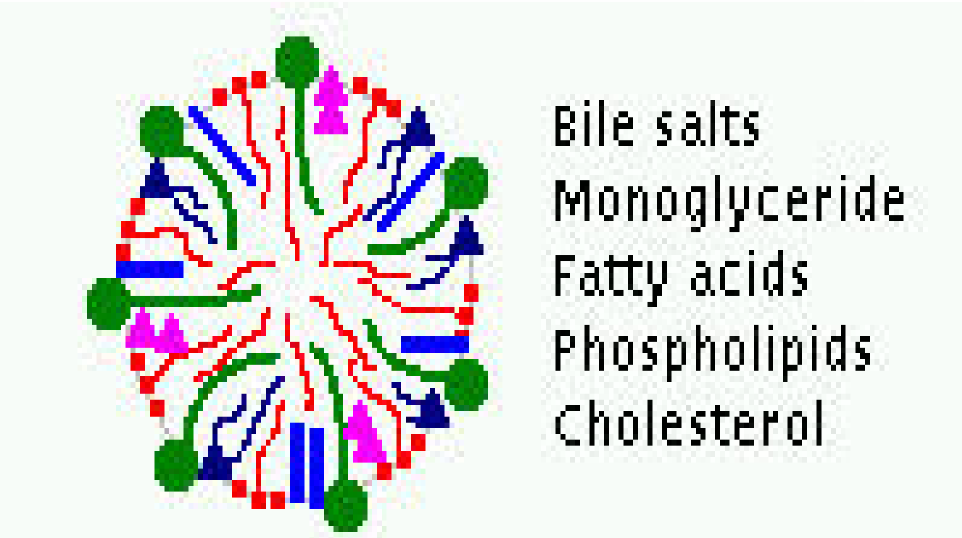
- Mixed Micelles contain the non polar Lipids in the interior portions and polar **Bile salts on the exterior**.

Significance Of Mixed Micelles

- **Mixed Micelles helps** in **absorption** of **dietary Lipids**
- **From intestinal** lumen into intestinal mucosal cells.







Liposomes

- **Amphipathic Lipids** when **exposed** to **high frequency sound waves (Ultra Sonication)** in aqueous medium to agitate particles and **form Liposomes**.
- Liposomes can be prepared by **disrupting biological membranes by ultra sonication(>20 KHz)**

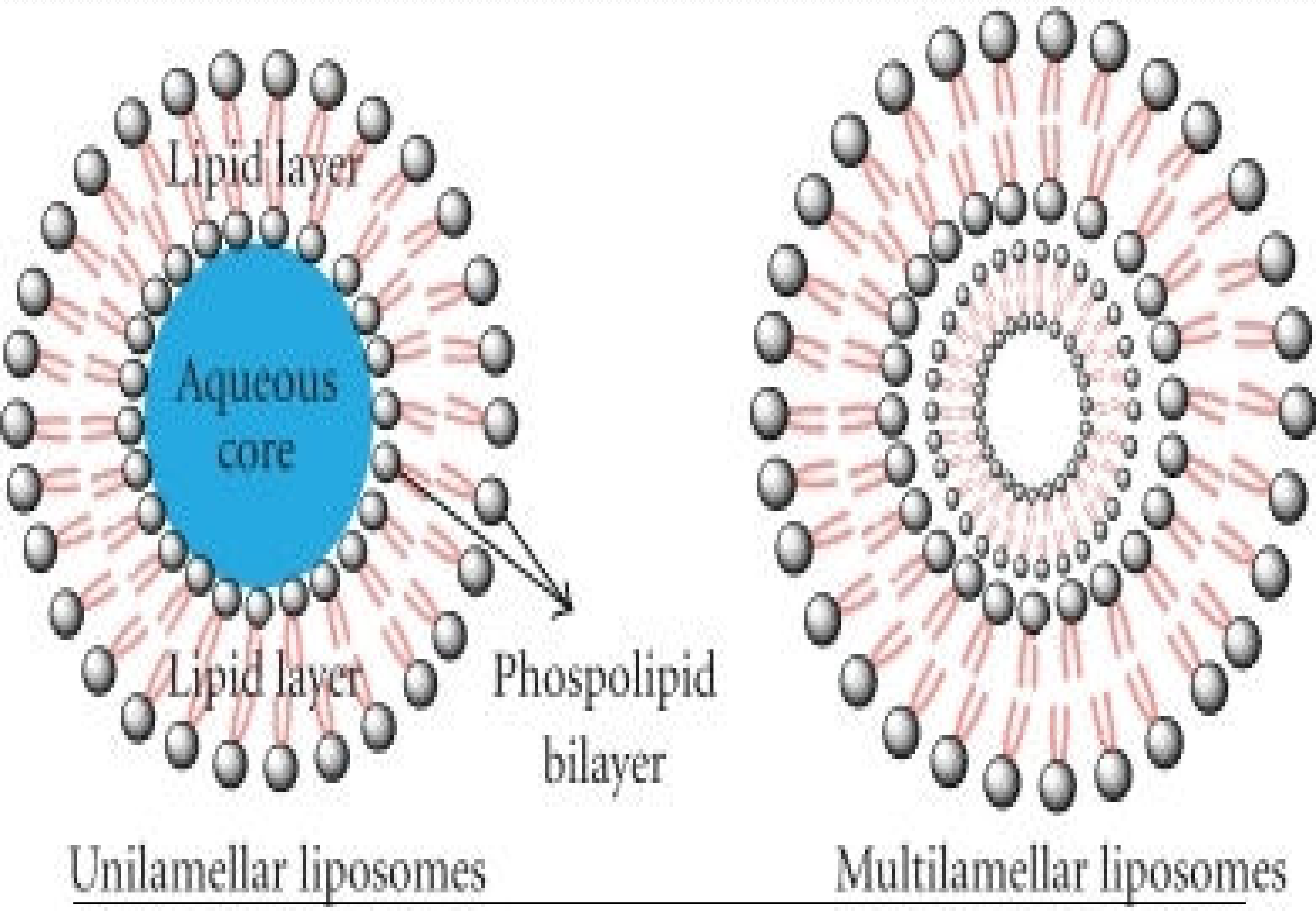
Structures Of Liposomes

- Liposomes are **composite structures made of largely phospholipids** and small amounts of other molecules
- Liposomes has **spheres of one/ many Lipid bilayers.**
- Liposomes contain **aqueous regions**(polar phase) and intermittently **lipid bilayer** (non polar phase).

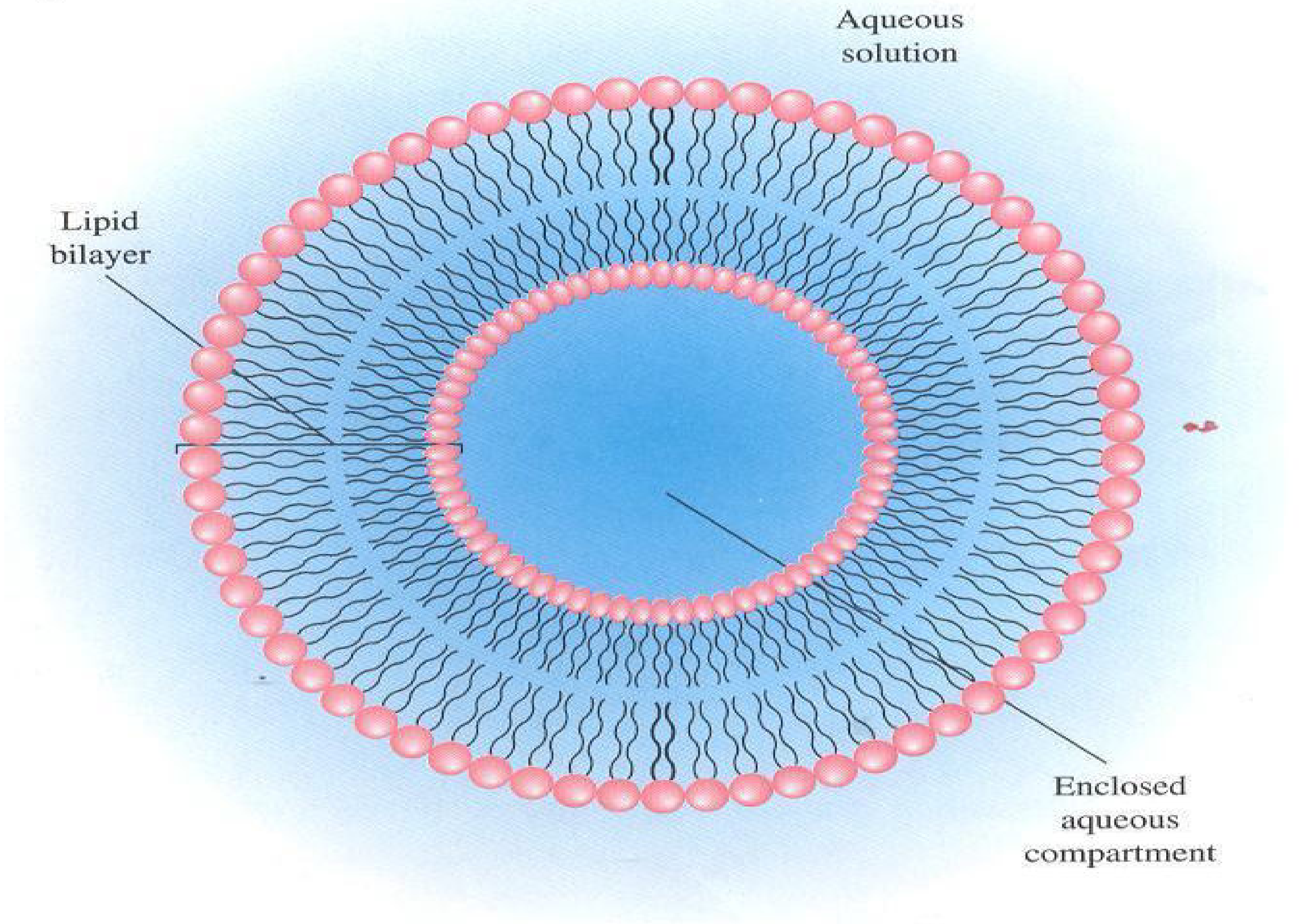
Types Of Liposomes

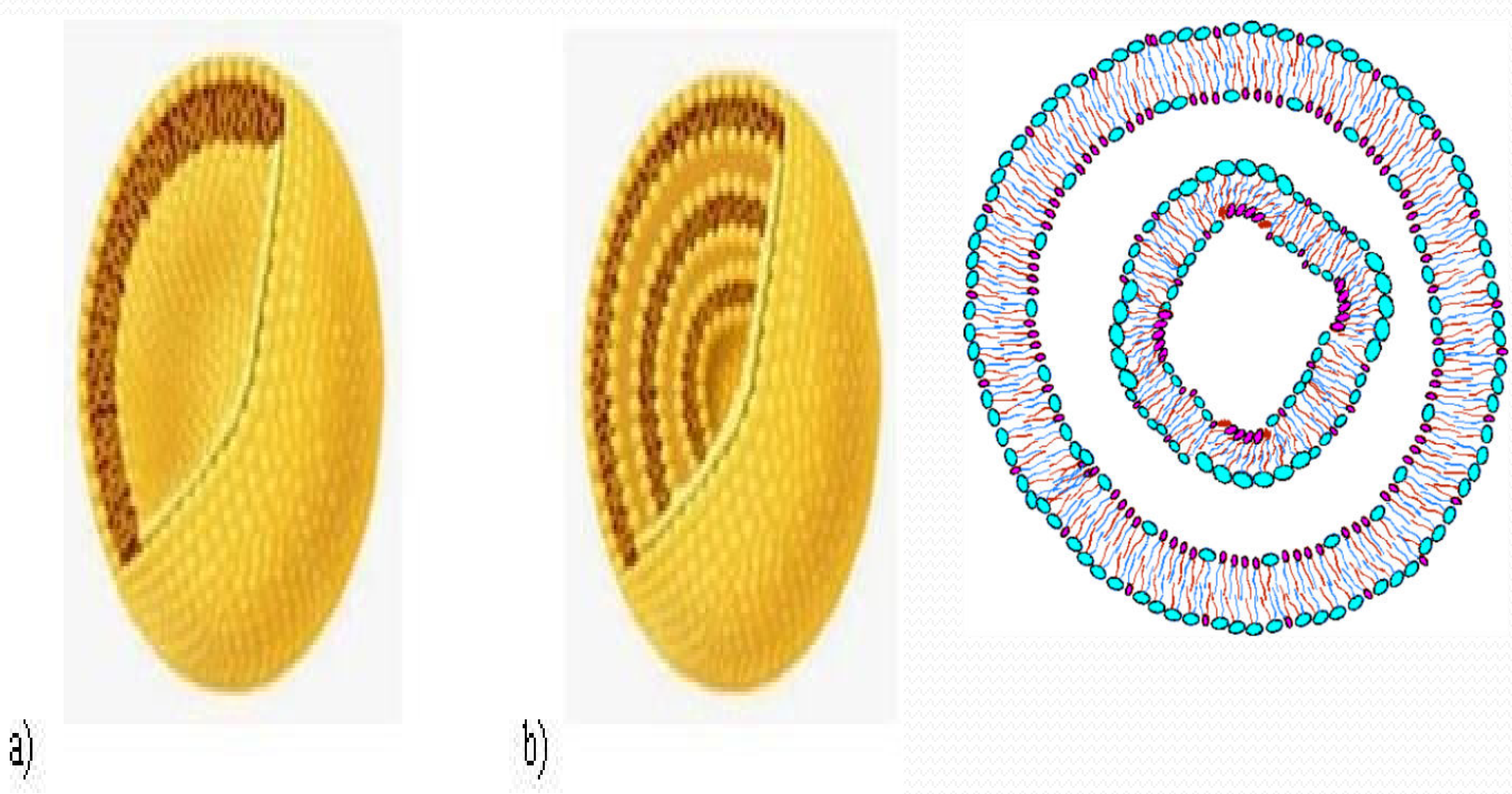
- **Unilamellar Liposome**
- **Multilamellar Liposome**

Structures Of Liposomes



Liposome

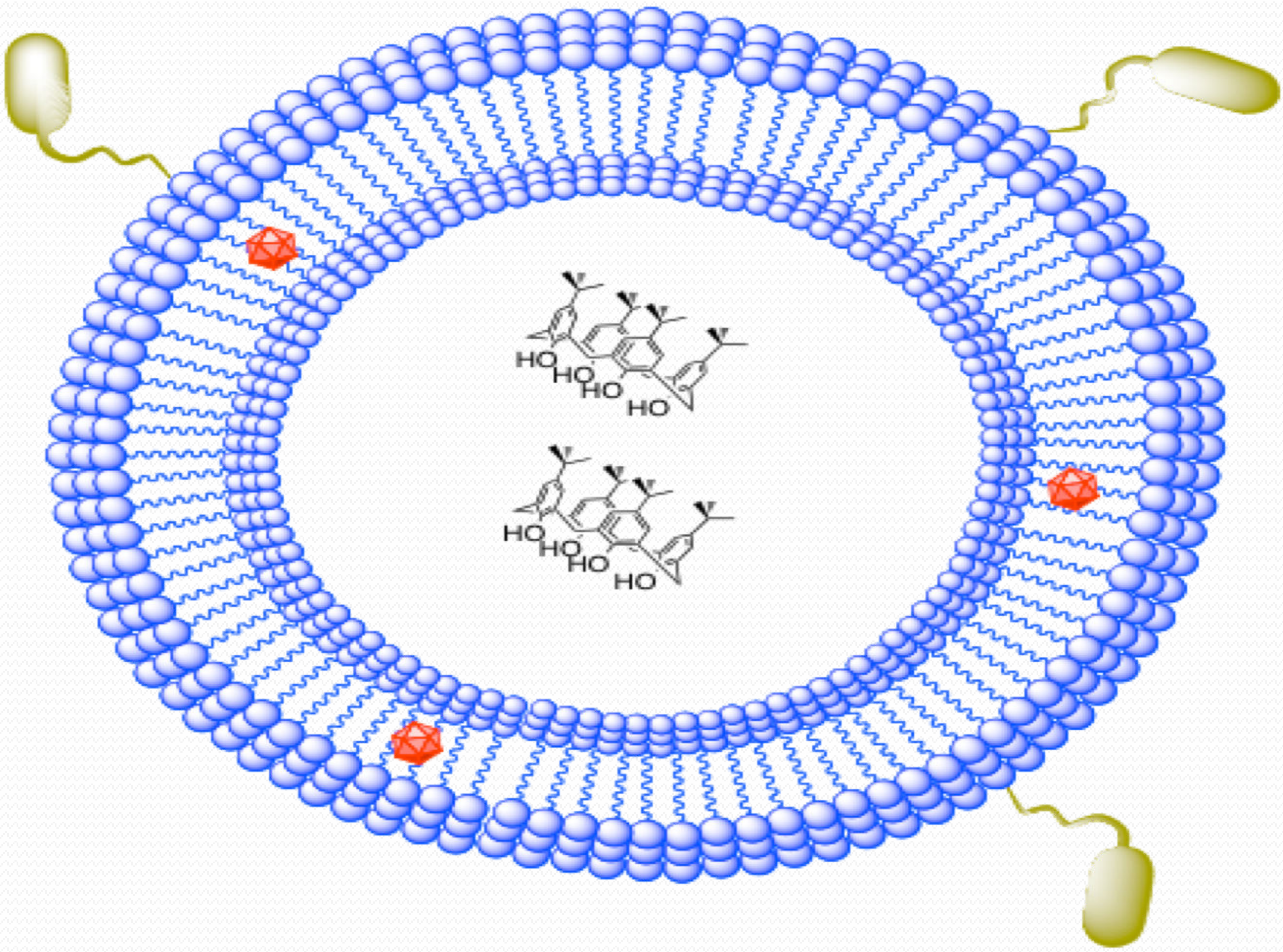

Aqueous
solution
Lipid
bilayer
Enclosed
aqueous
compartment


a)
b)

Role Of Liposomes

- Liposomes are vehicles for administration of **drug** through **blood**, targeted to specific organs.
- Topical **transdermal delivery of drugs.**
- **Transfer of Gene** into **vascular cells**

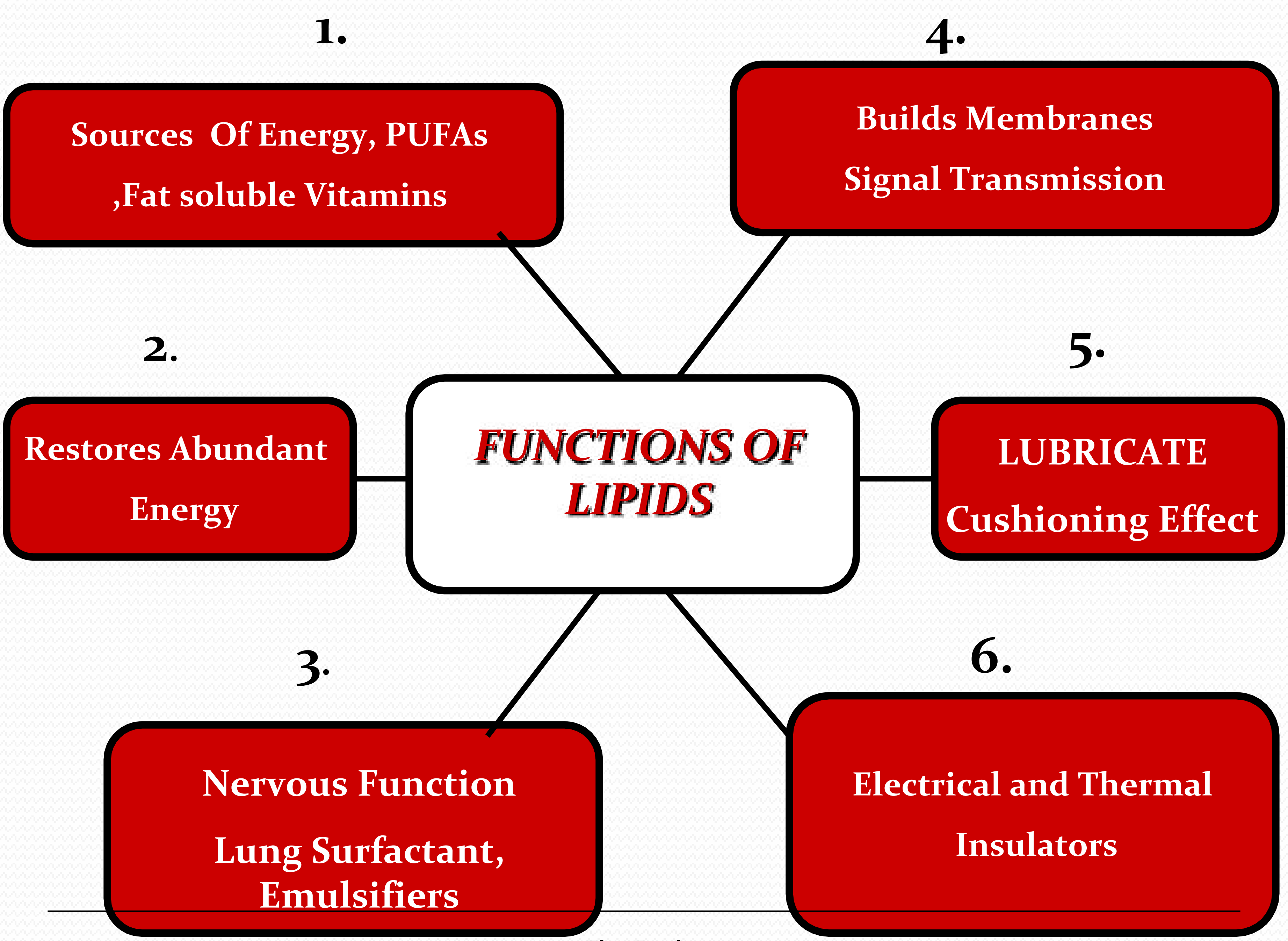
- **Water insoluble drugs** are carried in **Hydrophobic region** of Liposome.
- **Water soluble drugs** are carried in **Hydrophilic region** of Liposomes.



Biomedical Importance Of Body Lipids

The Role of various Body Lipids:

- Triacylglycerol
- Free Fatty acids
- Phospholipids
- Glycolipids
- Lipoproteins
- Cholesterol and Cholesterol Ester
- Eicosanoids

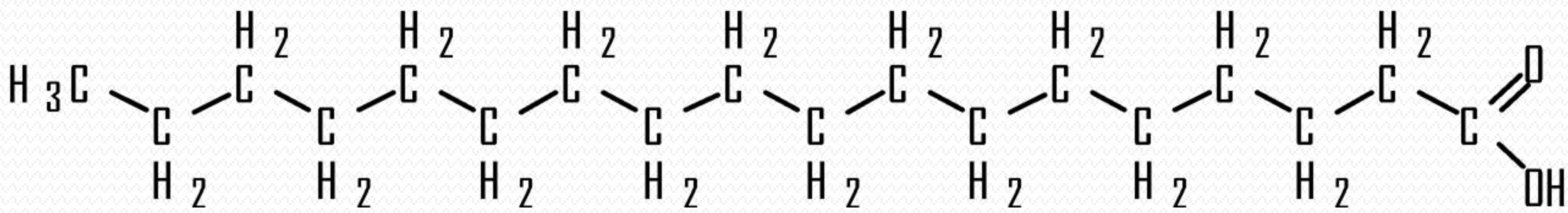


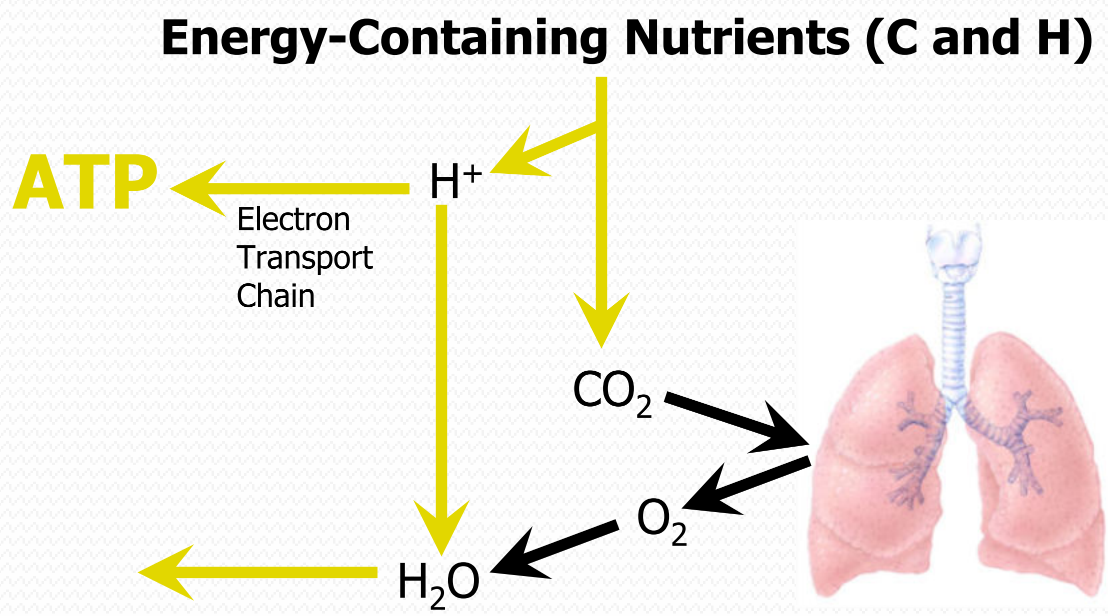
Body Lipids Based On Functions

- Energy Storage Lipids
- Structural Lipids
- Transport Lipids
- Metabolic Regulatory Lipids
- Thermal and Electrical Insulators

1. Lipids are chief **constituents of food** they serve as a **secondary source of energy** (Free Fatty acid oxidation= 9 Kcal/gm).

Fatty acids of TAG is a Source of Energy





- 2.The **TAG** serve as **reserve stores of Lipid as depot fat** in **Adiposecytes.**
- **TAG is stored in concentrated, anhydrous and unlimited form which** supplies energy to muscles for **long term** in between meals and fasting /starvation condition.

3. Dietary Oils and Fat **improve the taste** of recipe, **increases palatability** and **satiety value of foods**.

4.**TAG protect the internal soft visceral organs** ,give mechanical support by **cushioning effect and shock absorber.**

5.The Lipids (TAG) give **shape and contour to body.**

6.Phospholipids, Cholesterol and Glycolipids are structural **components of various biomembranes**.

7.The Lipids of plasma membranes **imparts integrity, fluidity , flexibility and selective permeability.**

8.Dietary Lipids are **sources of essential fatty acids** (PUFAs) which are very essential to bodies function.

9. **Fat soluble Vitamins (A,D,E and K)** are associated with Fatty foods hence become available from fatty diet.

- 10.**Amphipathic Lipids** serve as **surfactants, detergents and emulsifying agents.**
- Dipalmitoyl Phosphatidyl Choline serve as **Lung surfactant and supports good respiration process**.
- Phospholipids in GIT helps in forming **Emulsions and Micelles** helping in **digestion and absorption** of dietary Lipids.

11.Lipids are poor conductor of heat and electricity and serve as **Thermal insulators (Subcutaneous Fat/TAG)** to **regulate body temperature**.

- **12.**Cholesterol,Glycolipids and Sphingophospholipids components of nerve fibers serve as **Electrical insulators and help in conduction of nerve impulse.**

12.Lipids Serve as Metabolic Regulators.

Steroidal hormones derived from Cholesterol.

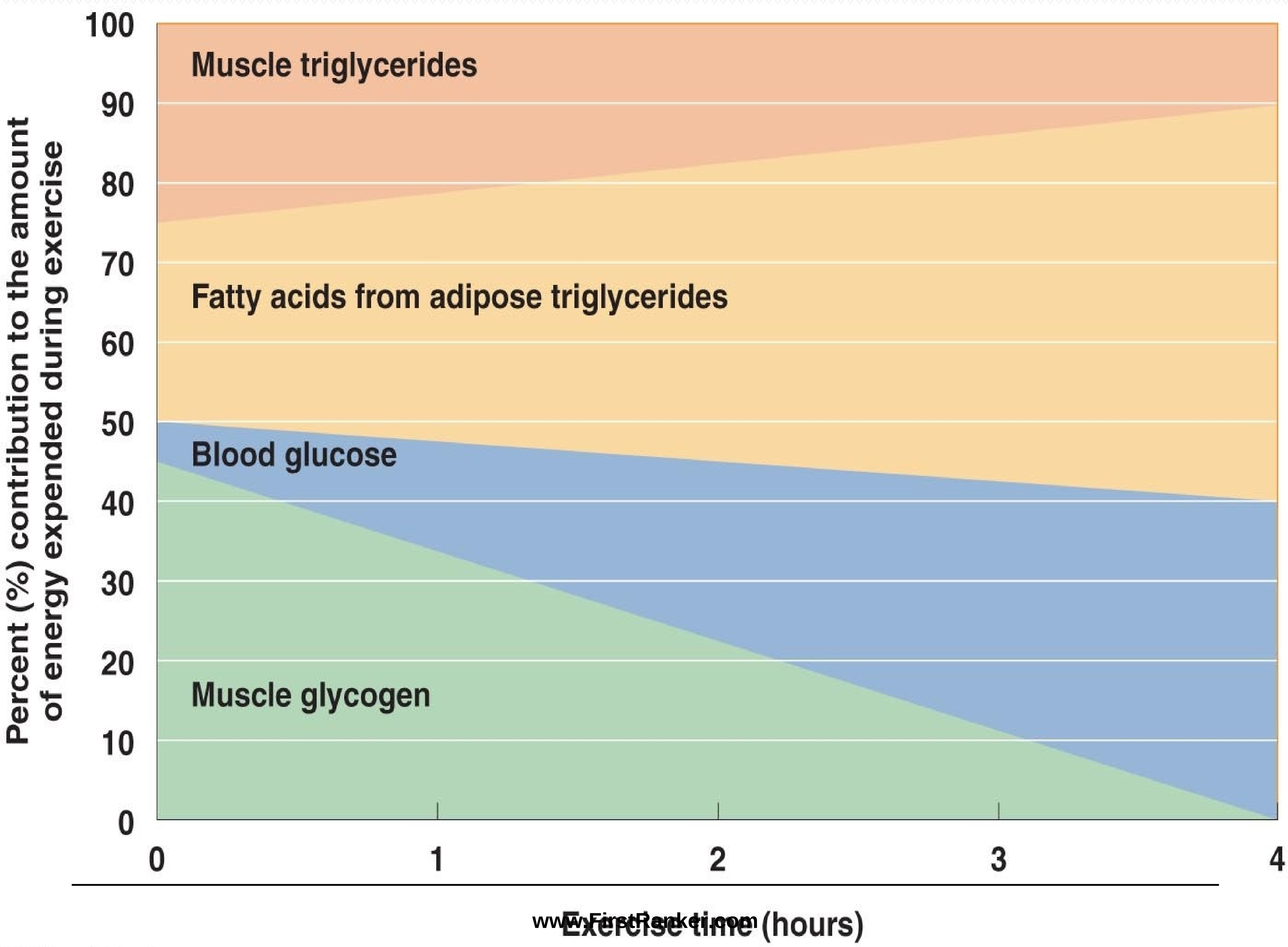
Prostaglandins serve as **Local hormones** regulate various biochemical and physiological processes of body.

13.Cholesterol ester (Human body wax) keep skin lubricated and water proof.

Good About Body Lipids

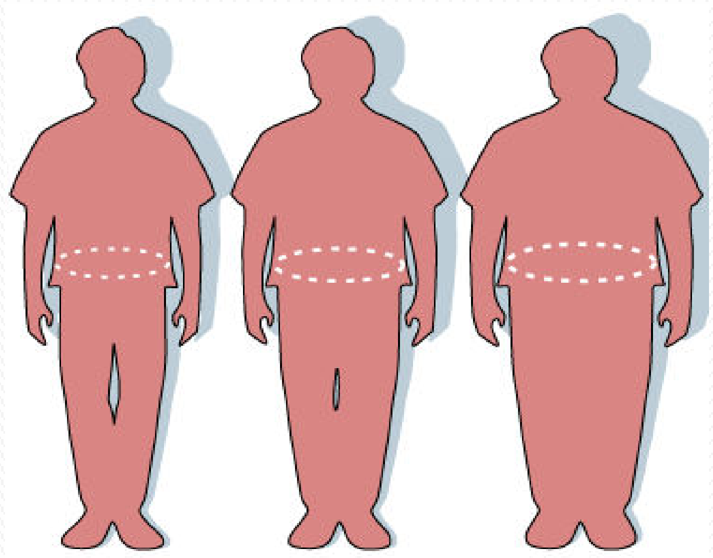
- Liberate 9 kcal per gram of TAG.
- Major fuel at rest
- **Endurance Exercise**
- Stores Energy
- Source of :
  - Essential fatty acids
  - Fat-soluble vitamins

- **Regulates cell function**
- **Maintains membrane structure**
- **Improve nerve function**
- **Provides flavors and textures of foods**
- **Helps us feel satiated**



Bad About : Fats and Oils

- Excess Fat makes Us **Obese**
- Increases risk for **Diabetes Mellitus**
- Leads to Coronary Artery disease
- MI, Stroke
- **Susceptible to Cancer**



Disorders OF Lipids

- Lipid Storage Disorders
- Obesity
- Atherosclerosis
- Respiratory Distress Syndrome
- Fatty Liver
- Hyperlipoproteinemias
- Hypolipoproteinemias
- Necrosis ,Oxidative damage of biomembranes due to Lipid peroxidation

Lipid Storage Disorders

Inborn Errors Of Lipid Metabolism

- **Congenital Defects where deficient of Enzymes**
- Affects an **Abnormal accumulation of Lipid forms**
- In cells and tissues affecting there functionality.

S.No	Lipid Storage Disorder	Enzyme Defect and Abnormal Accumulation of
1	Niemann Picks Disease	**Sphingomyelinase** **Sphingomyelins**
2	Gaucher's Disease	**Beta Glucocerebrosidase** **Glucocerebrosides**
3	Krabbe's Disease	Beta Galactosidase **Galactocerebrosides**
4	Tay Sach's Disease	Hexoseaminidase-A **Gangliosides**
5	Ferber's Disease	Ceramidase **Ceramides**

Table I Lipid levels (mg/DL) in human beings with known heart disease

Test	Desirable	Borderline	Undesirabl
Total cholesterol	<200	200-240	>240
HDL cholesterol	>45	35-45	<35
Triglycerides	<200	200-400	>400
LDL cholesterol	<130	130-160	>160
Cholesterol/HDL	<4.5	4.5-7.5	>5.5
LDL/HDL	<3.0	3.5	>5.0

Source: Medical Essay (1993)

Common Lipids Associated Disorders

- Obesity
- Atherosclerosis
- Coronary Heart Disease
- Hypertension
- Diabetes Mellitus

Disorders Related To TAG

• Obesity

- TAG is stored as reservoir of energy in concentrated and anhydrous form.
- **Adipose tissue** is most predominant in a **subcutaneous layer** and in **abdominal cavity**.

- **Normal Fat content of adult:**
  - **Men 21%**
  - **Women 26%**
- If the **Fat** content of an adult body goes **above the normal** content the condition is termed as **Obesity.**

- Obesity has **excess fat depots.**
- **Truncal/central obesity** is a risk factor for heart attack.

- **Obesity** has abnormal Lipid metabolism.
- Increased Blood Cholesterol and Lipoproteins.

- **Obese persons** has **high risk of Diabetes mellitus, Atherosclerosis and CVD.**

Questions

- **Long Answer Questions**
- **Define Lipids** (Bloor's Definition). Classify Lipids with suitable examples.
- Define **Fatty acids**. **Classify** them with different modes and suitable examples.

- What are **Compound lipids**? Describe chemistry & functions of Phospholipids.
- What are **Sterols**? Describe the structure, dietary sources, properties & functions of Cholesterol.

- **Write Short Notes.**
- Biomedical importance of body Lipids
- Essential fatty acids (PUFAs) & their role in the body.
- Triacylglycerol/Neutral Fats- Structure & Function.

- Rancidity- Causes & Prevention.
- Gycolipids/Cerebrosides/Gangliosides
- Lipoproteins- Chemistry, types & functions
- Eicosanoids/Prostaglandins

- Therapeutic uses of Prostaglandins
- Distinguish between Fats & Waxes
- Nomenclature & Isomerism of fatty acids
- Omega 3 fatty acids and their importance
- Amphipathic nature of lipids and their roles
- Distinguish between Fats & Oils
- Enumerate biomedical important lipids with their classes
- Properties of Fatty acids.

- Simple Lipids with their examples
- Enumerate Compound Lipids & one function of each
- Name the Derived lipids & their functions
- Trans Fats
- Tests to check the purity of fats & oils/Characteristic number of Fats

Revision Questions

- Define Lipids
- Number and Names of Lipid Classes
- Define Derived Lipids
- Examples of Derived Lipids
- Define Fatty acids
- What is Delta and Omega end
- What is Beta Carbon of a Fatty acid
- 6 Modes of Classification of Fatty acids

- Fatty acids with one double bond is:-------------
- Name most predominant Fatty acid of human body-----
- Most easily metabolized fatty acids are :-------------,______________- and _______________
- Fatty acid with odd and even number carbon atoms are:
- PUFAs are Fatty acids with--------------------
- Name PUFAs

- Are Nutritionally Essential Fatty acids and PUFAs same
- Name branched Chain and Odd Number Fatty acids
- Name Cyclic and Hydroxy Fatty acids
- What are Cis and Trans Fatty acids
- Name Omega 3 Fatty acids and 3 Main Roles

- Criteria for Sub classification of Simple Lipids
- Define Simple lipids
- Examples/Subtypes of Simple Lipids
- What is a Class of Fat/Oil and its chemical name
- Define Waxes
- Name body Wax

- Differences of Fats and Oils
- Occurrence and Role of TAG
- Definition Compound Lipids
- Types of Compound lipids
- Sphingophospholipid Examples

- Number and Names Of Glycerophospholipids
- Hormonal role of Phospholipds
- Chemical name of Lung Surfactant
- Which Compound Lipid is a Lipid and Protein?

Biochemistry Department