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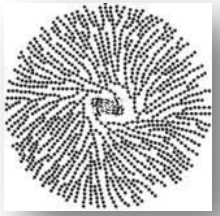
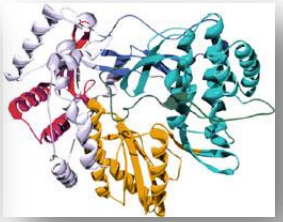
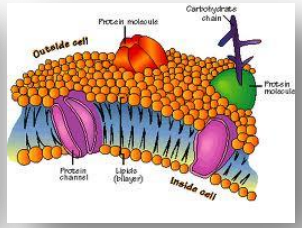
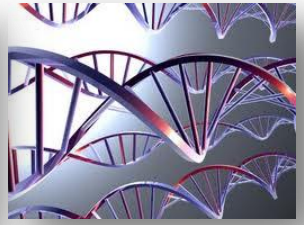
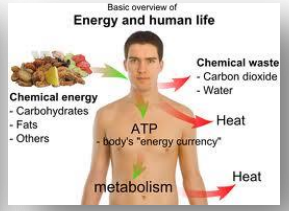
BIOC201W1

Introduction to Biomolecules

Dr MS Islam
Lecturer of Biochemistry
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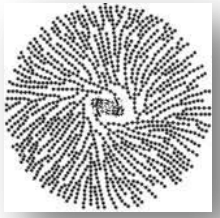
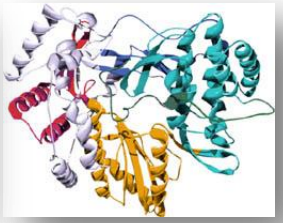
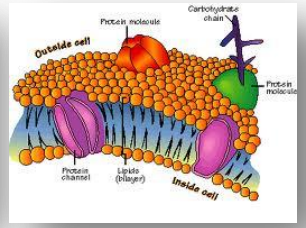
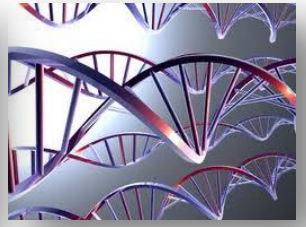
LIPIDS

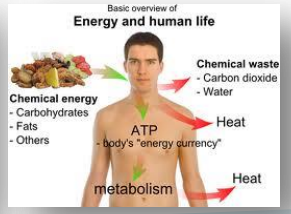
Structure & Chemistry







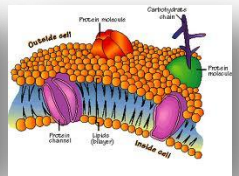


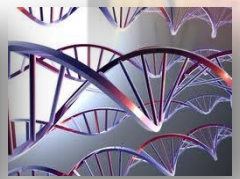


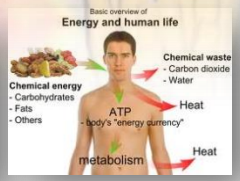
What is lipid?

- Lipids are organic molecules which are not soluble in water but soluble in organic solvents such as- ether, chloroform, benzene, ethanol, methanol etc.
- One of the 4 major classes of biomolecules e.g.
  - Lipids
  - Carbohydrates
  - Proteins and
  - Nucleic acids

- Lipids are essential components of all living organisms e.g. animals, plants, insects, bacteria, fungi etc.
- Basis on the weights, lipids are lighter than carbohydrates and proteins but contribute more than double energy compared to them such as-
  - 1 g lipid or fat provides 9 kcal energy whereas,
  - 1 g carbohydrate or protein provides about 4 kcal

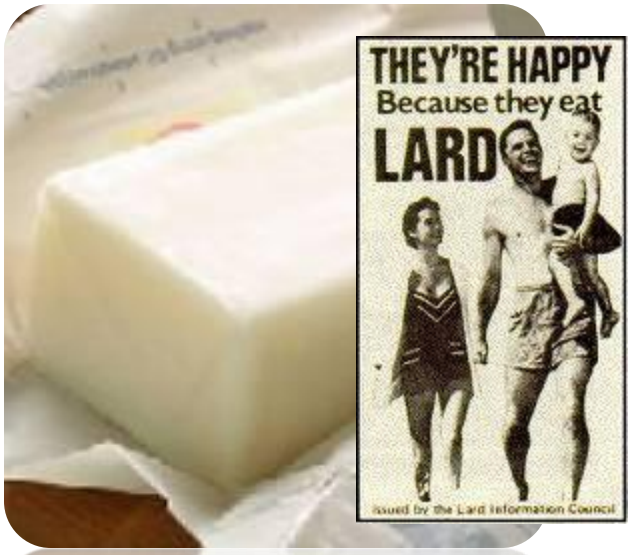


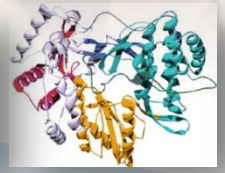


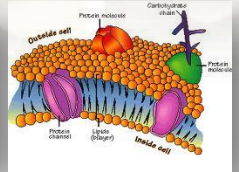


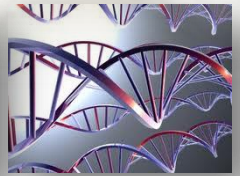
Who are lipids?

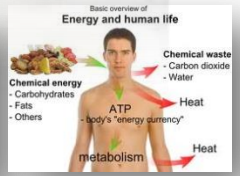
- Vegetable oil, butter, margarine, grease, wax etc.
- Steroid hormones, fat soluble vitamins, prostaglandins, thromboxanes, leukotrines are also the lipids or lipid derivatives.











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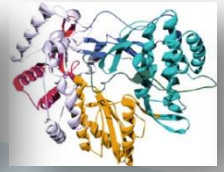
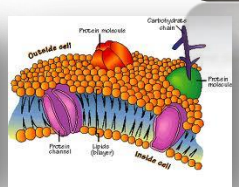
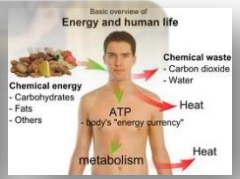
Functions of lipids?

- **Insulation:**
- **In mammals, especially in aquatic mammals, have most fat deposited subcutaneously which act as an insulating materials to protect their body from extreme heat or extreme cold.**

- **Energy:**
- **Major source of energy in living system.**
- **In Camel, the hump on Camel's back is largely a deposition of fat (mostly triacylglycerol or triglyceride) which provides energy and water during long-term starvation. (1 g fat provides 9 kcal energy and 1 g of water)**







Page 2 in Handouts

Functions of lipids?

- **Creams:**

  Lipid containing creams prevent the loss of moisture from our skin.

- **In birds:**

  Lipid coating in bird feathers protects feathers of birds to render them not wetting

- **In plants:**

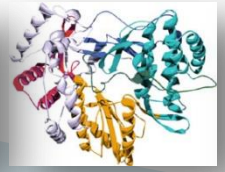
  Coat the leaves of plants to protect them against abrasion and curb the loss of moisture by evaporation

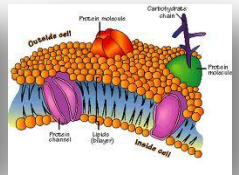
- **Hormones and vitamins:**

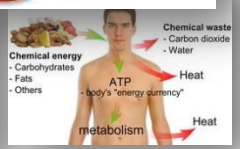
  They work as a precursor of several hormones and some fat soluble and anti-oxidant vitamins (A, D, E and K)

- **Plasma membrane:**

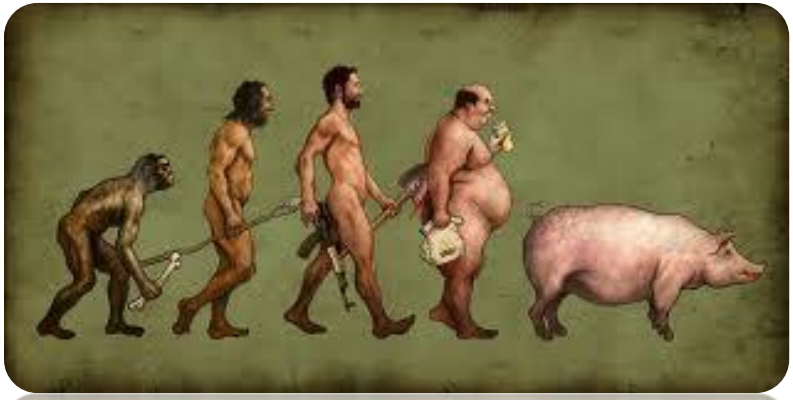
  Crucial part of cell membrane







Lipids in humans?



- **In organs:**

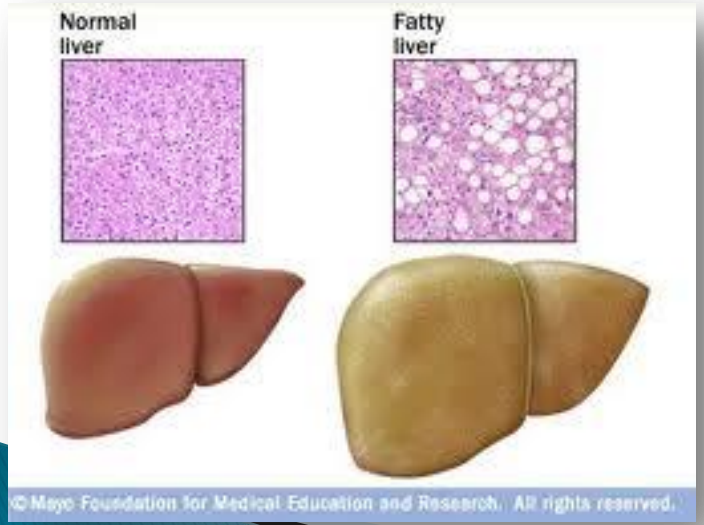
  Present in kidneys, heart, liver etc

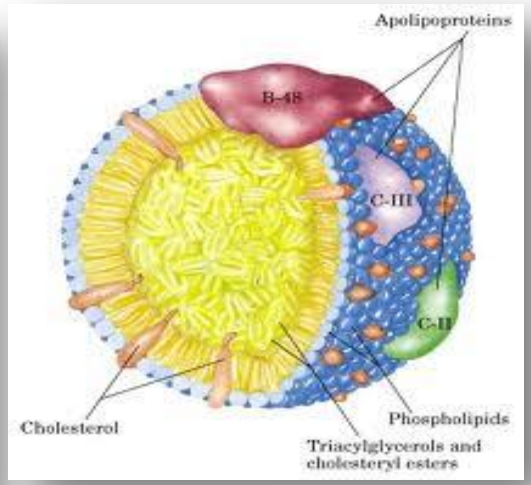
- **In blood:**

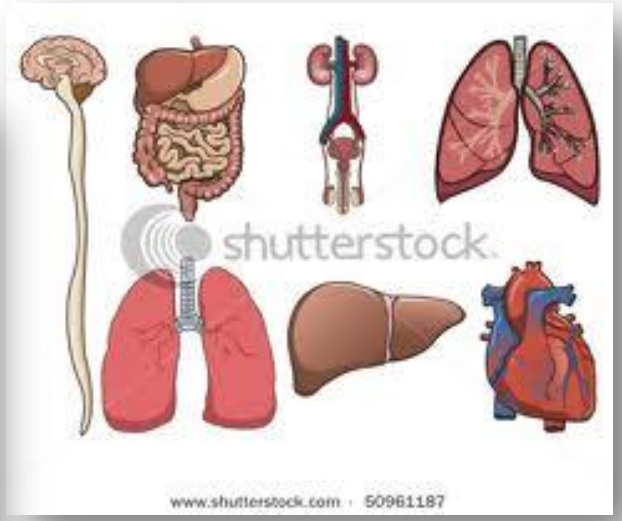
  Lipids are found in associate with protein called lipo-proteins, which works as transporters of lipids

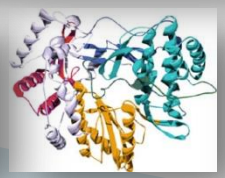
- **In cell membrane:**

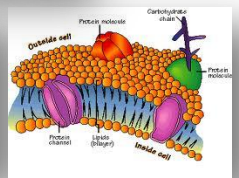
  Lipids is a integral part of cell membrane

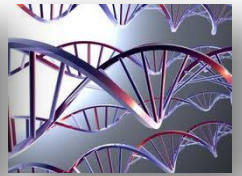


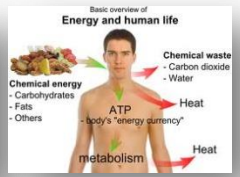






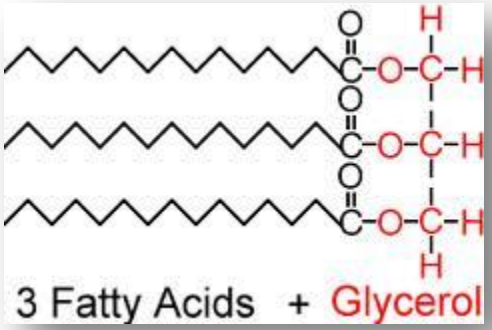




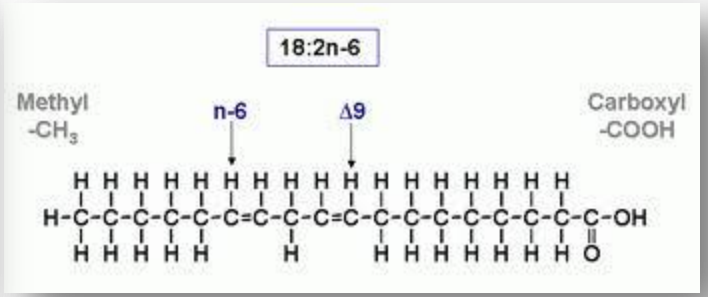


Classification of lipids?

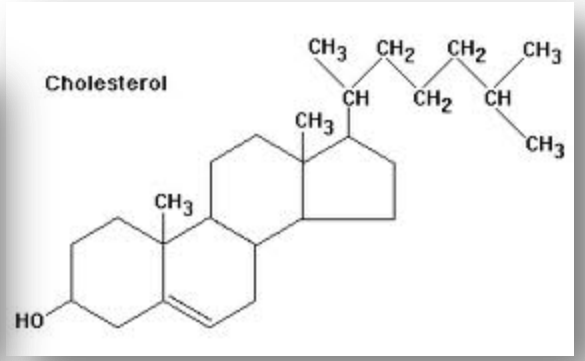
- Based on the physical property lipids are classified into 5 major classes:
  1. Fatty acids and their derivatives
  2. Neutral esters of fatty acids and glycerols (Glycerides)
  3. Ionic esters of fatty acids, glycerols and phosphoric acids (Phospholipids)
  4. Lipids without glycerols (Sphingolipids)
  5. Lipids combined with proteins e.g. lipoproteins, glycolipids, cholesterol etc.



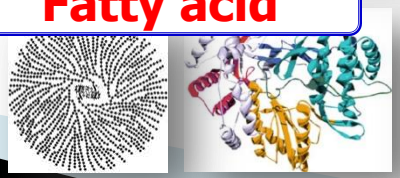
Triglycerides

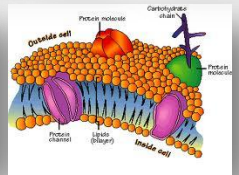


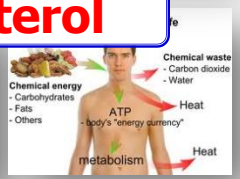
Fatty acid



Cholesterol







Classification of lipids?

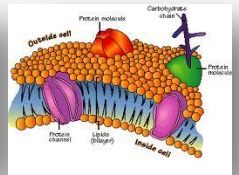
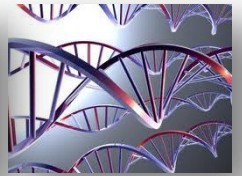
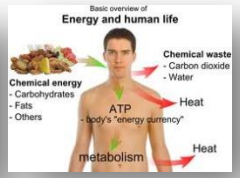
1. Fatty acids/ criteria of fatty acids:

- Must have a carboxylic (-COOH) group
- Fatty acids are contain two ends – one hydrophilic / polar end and another hydrophobic / non-polar end
- Hence, fatty acids are called AMPHIPHILIC (hydrophilic and hydrophobic) compound
- Carboxylic group (-COOH) is located in the hydrophilic end and a hydrocarbon tail in the hydrophobic end which may contains carbon-carbon single (-C-C-) or double (-C=C-) bonds
- Hydrocarbon tail varies based on the number of carbons (12-20) and the number and positions of carbon-carbon double bonds

$$R\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}COOH$$

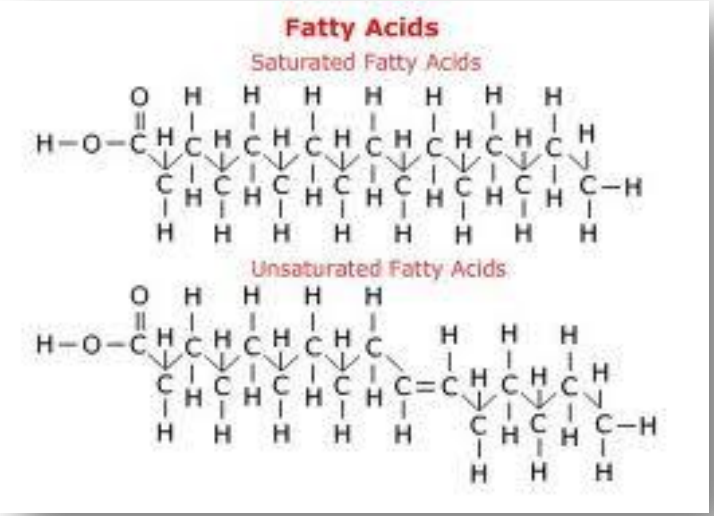
Fatty acid



Classification of FAs?

- Based on the type of carbon-carbon bond (-C–C-) in the hydrophobic part, fatty acids are classified in two major classes:



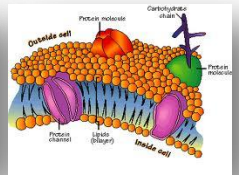
Fatty acids

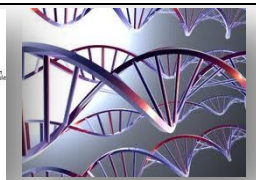
Saturated fatty acids

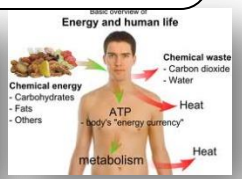
Unsaturated fatty acids

Monounsaturated fatty acids (MUFA)

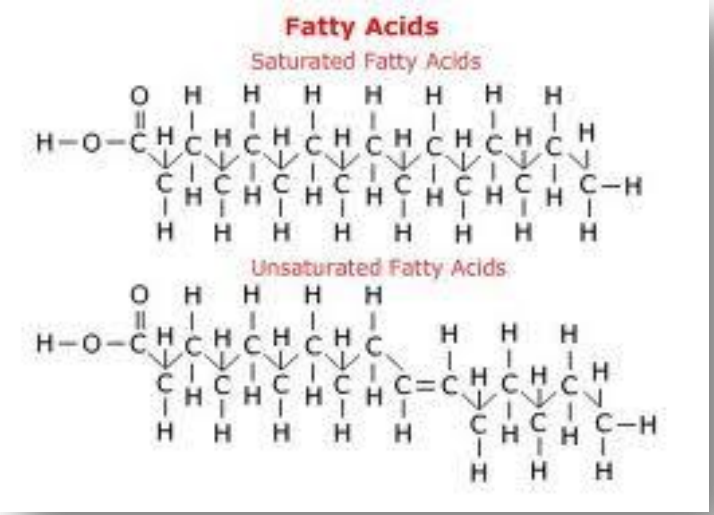
Polyunsaturated fatty acids (PUFA)







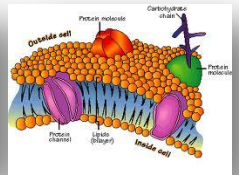
Classification of FAs?

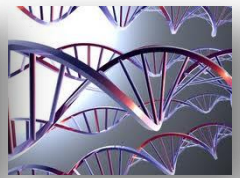
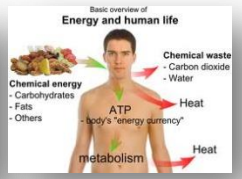


Saturated fatty acids:

- Solid and waxy at room temperature
- Rich in animal originated fat
- General formula is [$(C_nH_{2n+1})COOH$]
- Contain only carbon-carbon single bonds (-C–C-)
- Most of them are present in esterified form with glycerols
- Fatty acids which are not in esterified form called free fatty acids (FFA)
- Carbon number in saturated fatty acids are 2-24 but <10 carbons fatty acids are not normally found in animal lipids with one exception of butyric acid (CH_3-CH_2-CH_2-COOH)
- Example – Palmitic acid (C16:0), Stearic acid (C18:0)



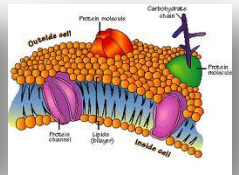


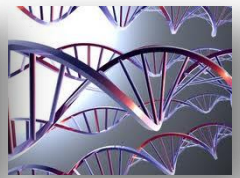
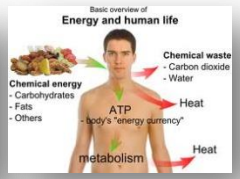



Example of saturated fatty acids

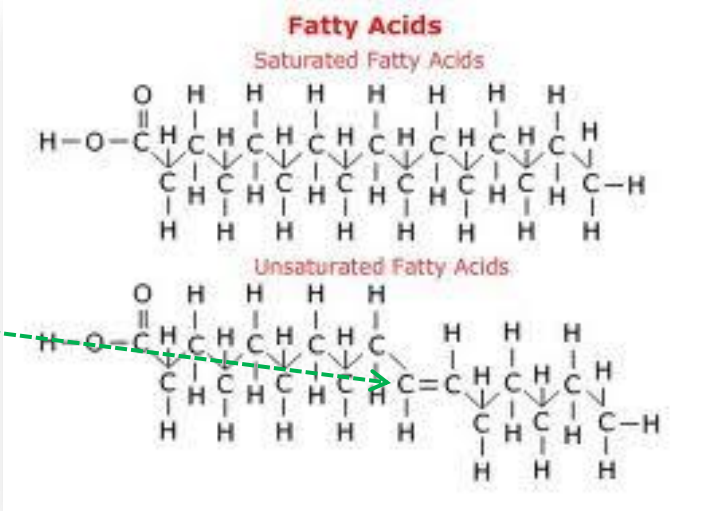
Systemic name	Common name	Molecular formula	Short note	m.p. (oC)	Occurrences
	Acetic acid	CH_3COOH	2:0	16	Intermediate in metabolism
	Propionic acid	C_2H_5COOH	3:0	-22	
	Butyric acid	C_3H_7COOH	4:0	-8	Butter fat
Dodecanoic acid	Lauric acid	$C_{11}H_{23}COOH$	12:0	44	
Tetradecanoic acid	Myristic acid	$C_{13}H_{27}COOH$	14:0	54	
Hexadecanoic acid	Palmitic acid	$C_{15}H_{31}COOH$	16:0	63	Common in all animal and plant fats
Octadecanoic acid	Stearic acid	$C_{17}H_{35}COOH$	18:0	70	
Eicosanoic acid	Arachidonic acid	$C_{19}H_{39}COOH$	20:0	77	
Dicosanoic acid	Behenic acid	$C_{21}H_{43}COOH$	22:0	80	
Tetracosanoic acid	Ligonceric acid	$C_{23}H_{47}COOH$	24:0	86	Cerebrosides





Unsaturated fatty acids



Double bonds:

- Fatty acids which contain at least one carbon-carbon double bond is called unsaturated fatty acid

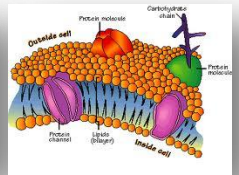
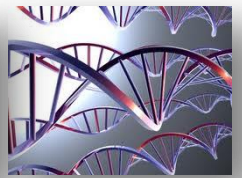
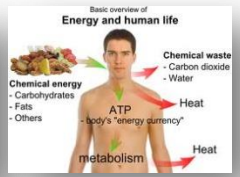
Melting and boiling points:

- Their melting or boiling points are lower than those of their saturated counter parts
- The higher the double bonds the lower the melting or boiling points

Solubility:

- Solubility of unsaturated fatty acids in a non-polar solvents are also better than their saturated counter parts



Unsaturated fatty acids

Physical property:

- **All common unsaturated fatty acids are liquid at room temperature**

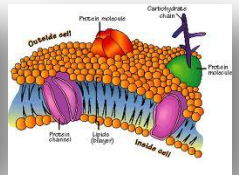
Number of double bonds:

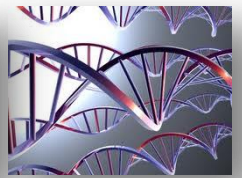
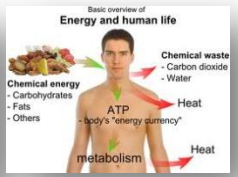
- **Unsaturated fatty acids may contain one, two, three, four or more carbon-carbon double bonds**

Unsaturation:

- **The total number of carbon-carbon double bonds denotes the degree of unsaturation**





Class of unsaturated fatty acids

- **Based on the number of carbon-carbon double bond (-C=C-) in the hydrophobic part, unsaturated fatty acids are classified in two major classes:**

Unsaturated fatty acids

Monounsaturated fatty acids (MUFA)

Polyunsaturated fatty acids (PUFA)

1. Dienoic series (two – C-C – double bonds)
2. Trienoic series (three – C-C – double bonds)
3. Tetranoic series (four – C-C – double bonds)
4. Pentanoic series (five – C-C – double bonds)
5. Hexanoic series (six – C-C – double bonds)

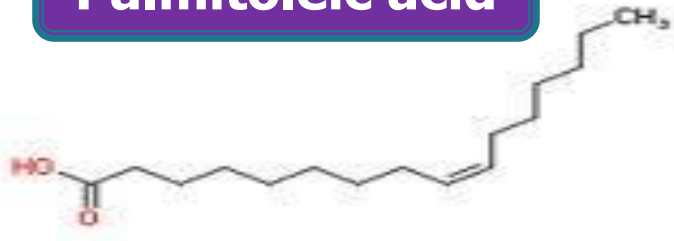
Class of unsaturated fatty acids

Monounsaturated fatty acids (MUFA):

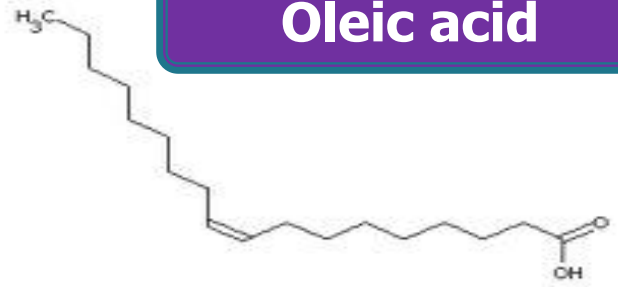
- Contains one carbon-carbon double bond
- This fatty acids are present in the lipids of prokaryotic cell membranes
- Example –

Common name	Molecular formula	Shorthand notation	Melting point (oC)
Plamitoleic acid	$C_{15}H_{31}COOH$	C16:1Δ^9 cis	-0.5
Oleic acid	$C_{17}H_{33}COOH$	C18:1Δ^9 cis	16

Palmitoleic acid



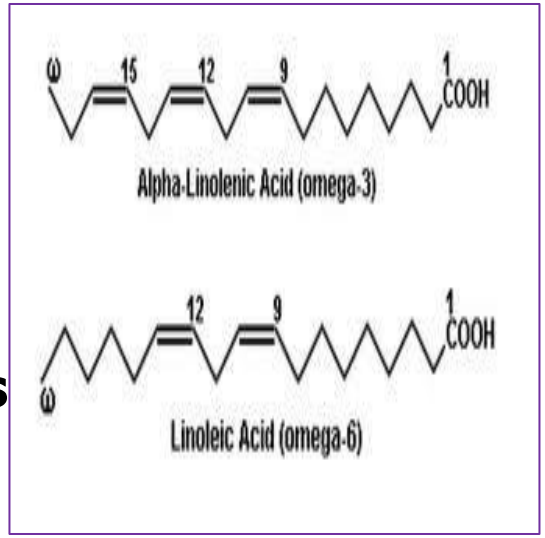
Oleic acid



Class of unsaturated fatty acids

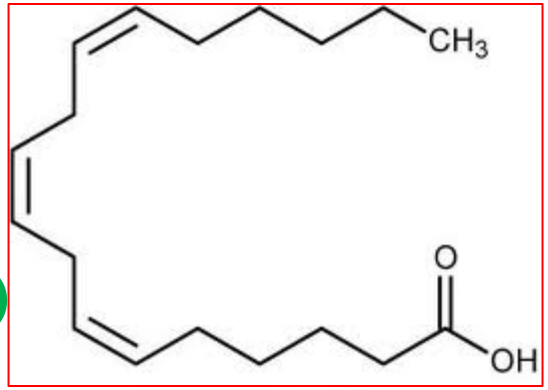
1. Dienoic series:

- Contain two carbon-carbon double bonds
- Such as- Linoleic acid (C18:2, $\Delta^{9,12}$)
- Melting point is -5 °C



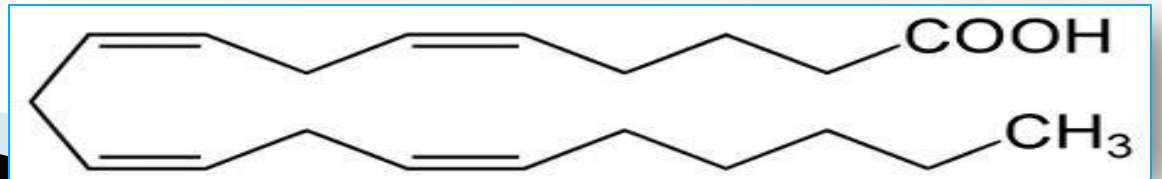
2. Trienoic series (ω3/ ω6 fatty acids):

- Contain three carbon-carbon double bonds
- Such as- α-Linolenic acid (C18:3, $\Delta^{9,12,15}$)
- γ-Linolenic acid (C18:3, $\Delta^{6,9,12}$)
- Melting point is -10 °C



3. Tetranoic series (ω6 fatty acids):

- Contain four carbon-carbon double bonds
- Such as- Arachidonic acid (C20:4, $\Delta^{5,8,11,14}$)
- Melting point is -50 °C



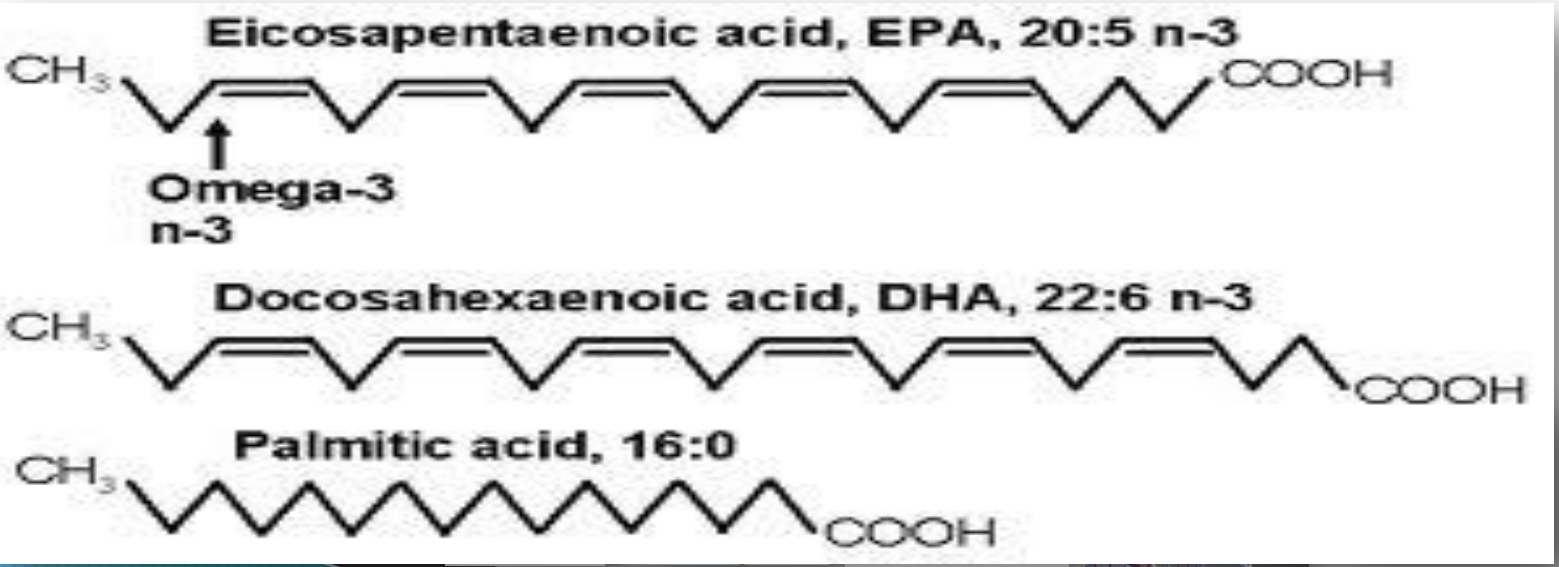
Class of unsaturated fatty acids

4. Pentanoic series:

- Contain five carbon-carbon double bonds
- Such as- Eicosapentanoic acid (20:5, $\Delta^{5,8,11,14,17}$)
- Melting point is -50 ^{o}C

5. Hexanoic series (ω6 fatty acids):

- Contain six carbon-carbon double bonds
- Such as- Docosahexanoic acid (22:6, $\Delta^{4,7,10,13,16,19}$)
- Melting point is -50 ^{o}C



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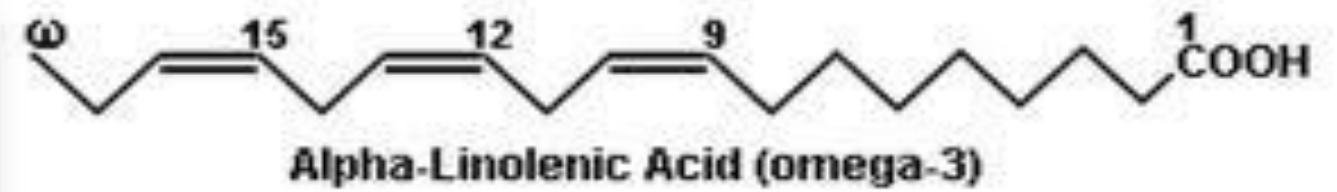
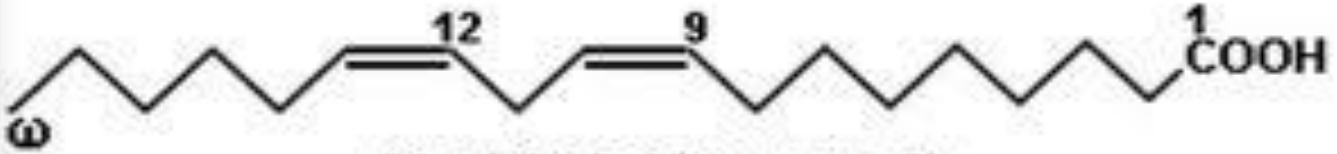
Essential and Non-essential FAs

Essential fatty acids:

- **The fatty acids which cannot be produced in human or animal body are called essential fatty acids**
- **Humans and animals are completely depend on plants for these fatty acids**
- **Only two essential fatty acids found till today, such as-**
  - **Linoleic acid (18:2, $\Delta^{9,12}$)**
  - **α-Linolenic acid (18:3, $\Delta^{9,12,15}$)**



Alpha-Linolenic Acid (omega-3)

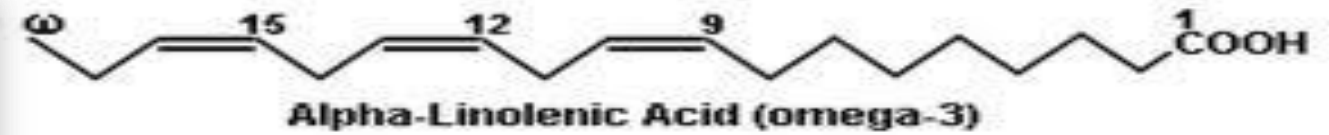


Linoleic Acid (omega-6)

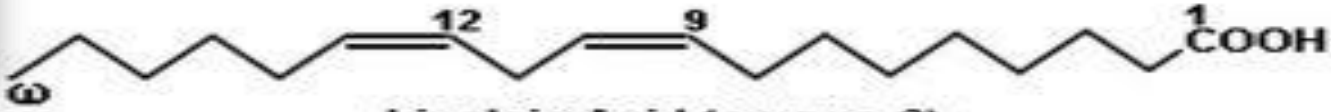
Essential fatty acids

Why plants can but human or animal cannot produce essential fatty acids?

- **Plant desaturase enzymes are capable to provide double bonds at the Δ^{12} and Δ^{15} positions which are not possible by animal desaturase enzymes**
- **Unsaturated fatty acids are synthesize from their saturated equivalents**
- **Saturated fatty acids are biosynthesized first then double bonds are introduced later in various positions**
- **Human and animal system cannot introduce double bonds beyond the Δ^{9} position**

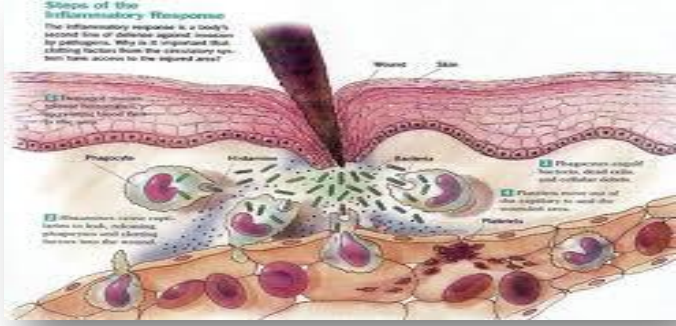


Alpha-Linolenic Acid (omega-3)



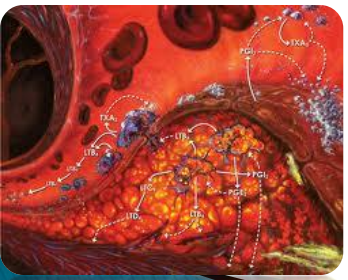
Linoleic Acid (omega-6)

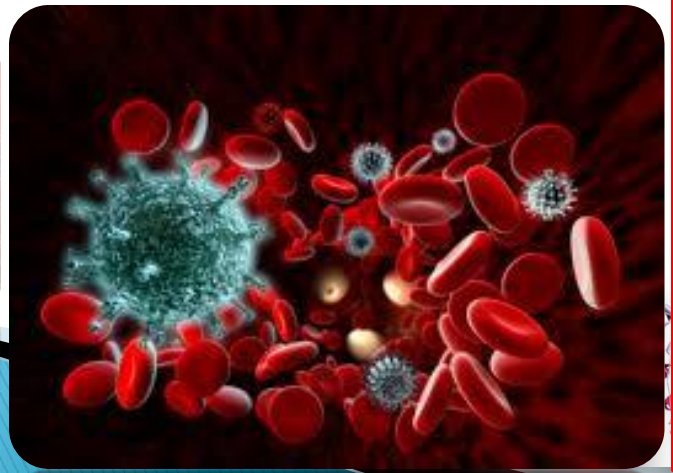
Fatty acid derivatives

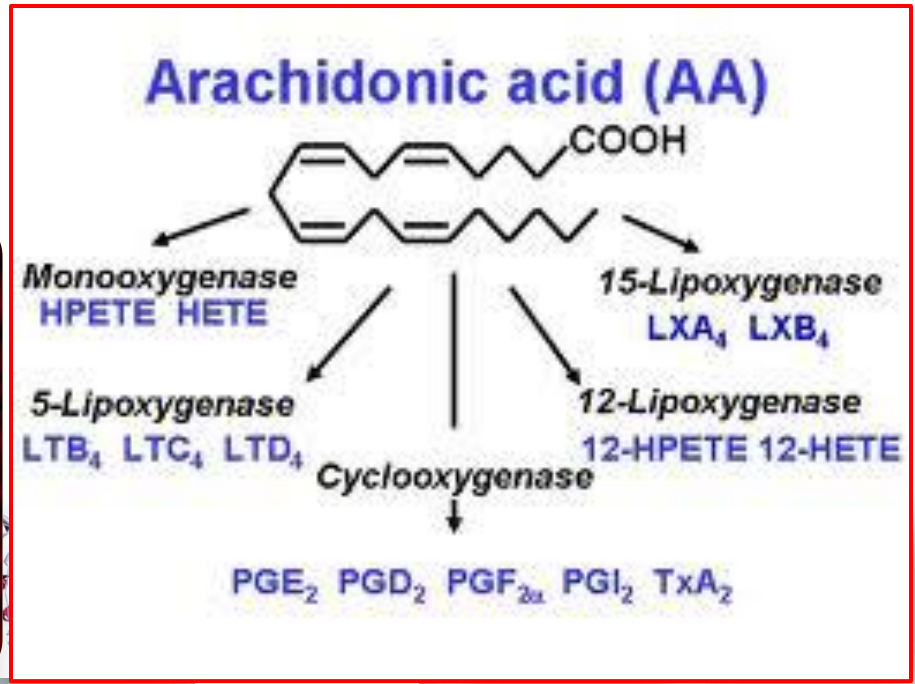


Eicosanoids:

- Derivative of 20 carbon arachidonic acid (20:4, $\Delta^{5,8,11,14}$)
- Greek 'Eikosi' means 'twenty' and as these derivatives came from a 20 carbon fatty acid so they are called 'Eicosanoids'
- They exert hormone-like activities on various tissues in which they are produced
- There are THREE major classes of eicosanoids:
  1. Prostaglandins (PG)
  2. Thromboxanes (TX)
  3. Leukotrines (LT)







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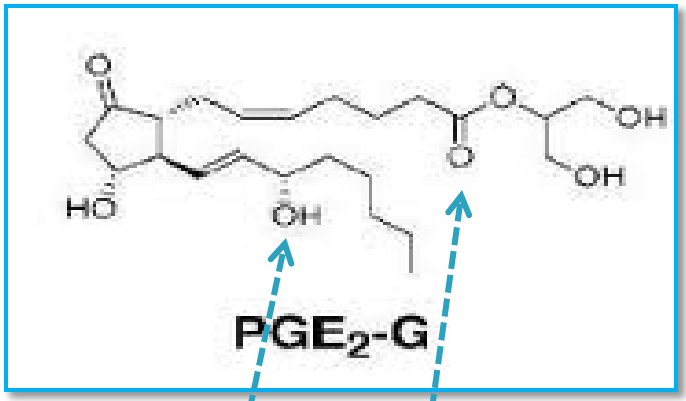
Fatty acid derivatives



1. Prostaglandins (PG):

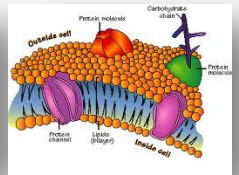
Synthesis:

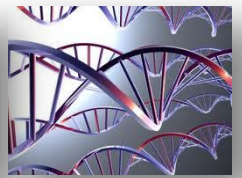
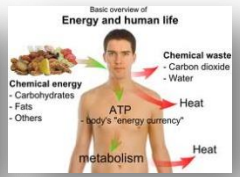
- **Synthesize in the all mammalian cells except Red Blood Cell (RBC)**
- **Prostaglandin synthesis has been recorded in crustaceans, insects, amphibians, fish, and mammals but not in prokaryotes and lower class eukaryotes such as yeast**
- **These circulating hormones are not stored (unlike insulin) but produced within 10-30 seconds after a stimuli**

Chemistry:

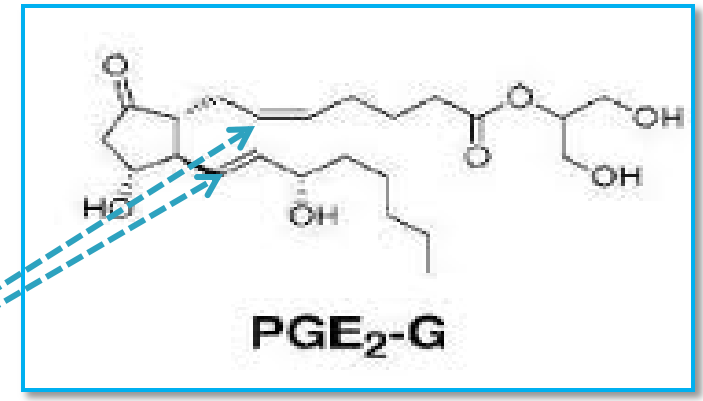
- **These hormones contain diverse groups such as keto (=C=O), carboxyl (-COOH), hydroxyl (-OH) which are found on the side chain or cyclopentane ring in the structure**





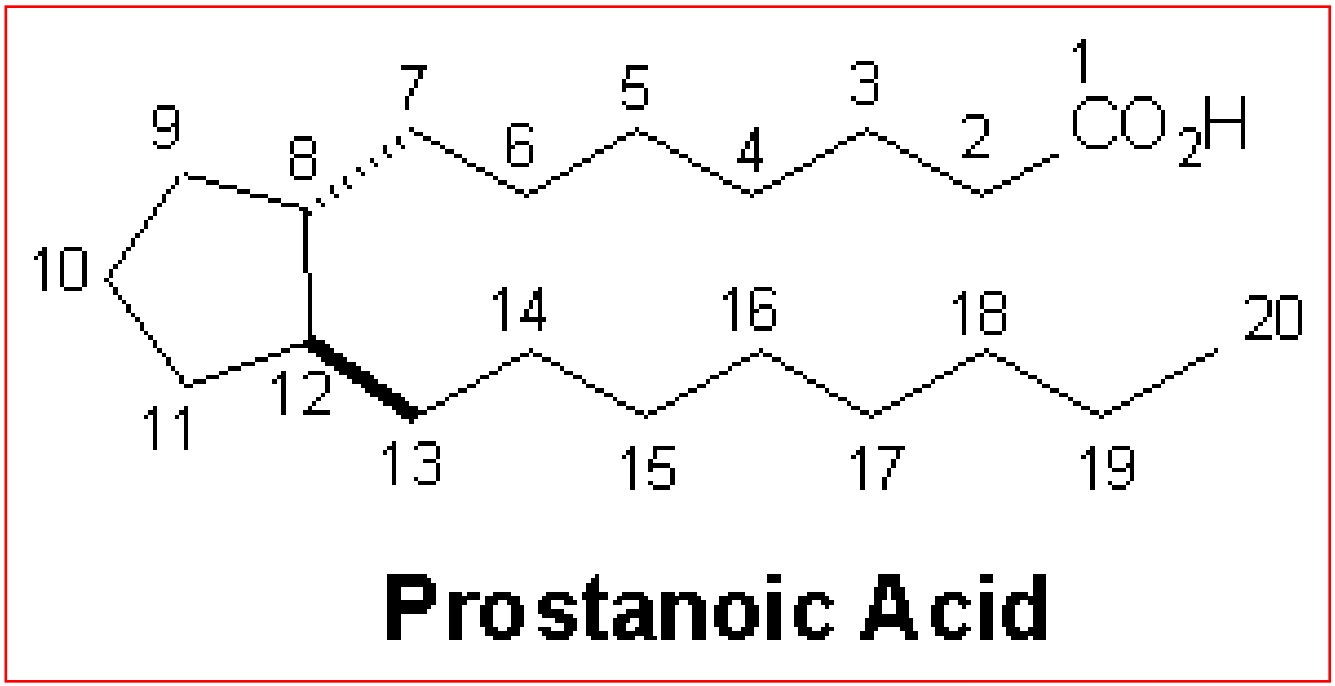



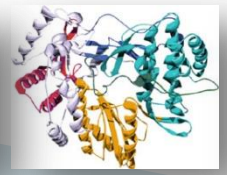
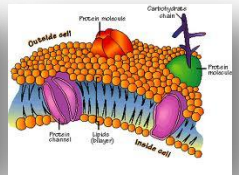
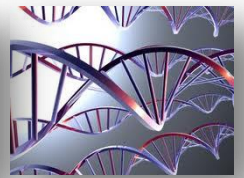
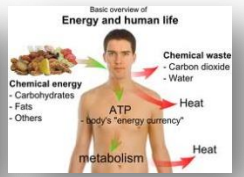
Prostaglandins (PG)



Chemistry: (contd....)

- Double bonds are in the 'TRANS' configuration
- These are also the derivatives of prostanoic acid

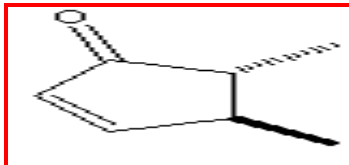


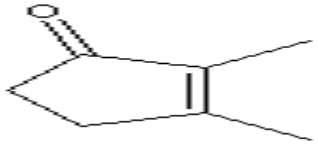






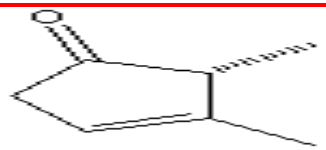
Prostaglandins (PG)

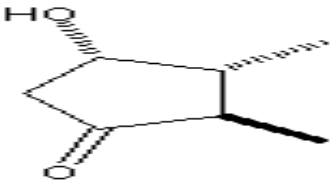
Nomenclature and classification:

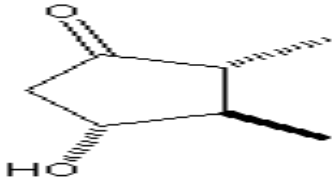
- The letter occurring after the abbreviation PG (such as PGE) indicates the nature of the oxygen containing substituents present in the cyclopentane ring
- **Based on this, prostaglandins are classified into several families as follows:**

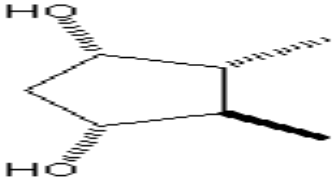

PGA

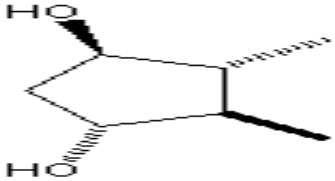

PGB

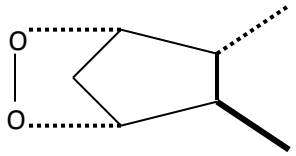

PGC


PGD


PGE


PGFα

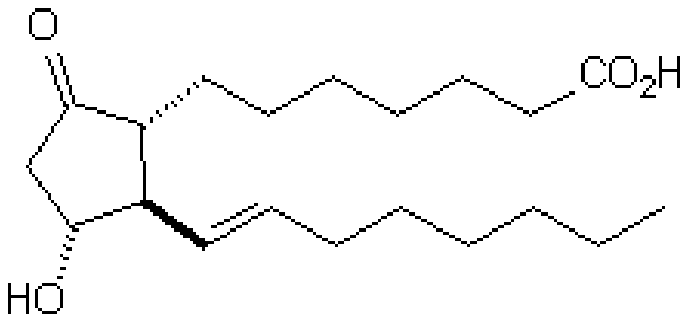

PGFβ


PGG or PGH or PGR

Prostaglandins (PG)

Nomenclature and classification: (contd….)

- **Each family further sub-divided based on the number of double bonds present in the hydrocarbon side chains. For example-**



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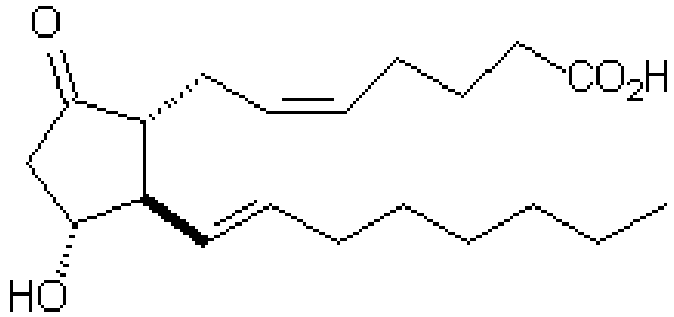

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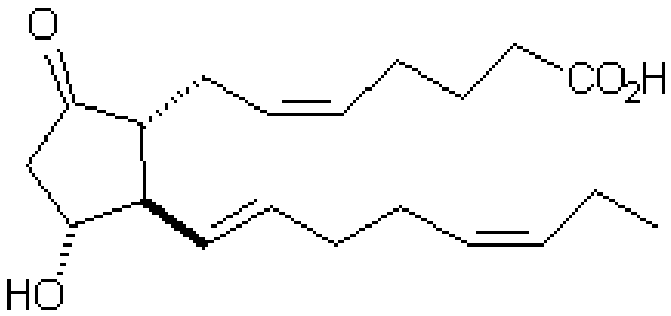


PGE_3

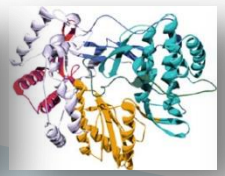
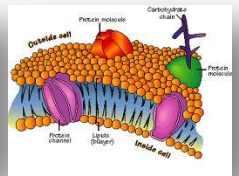
SI (study induction)Session

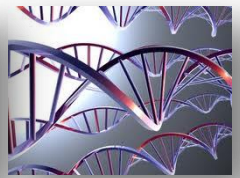
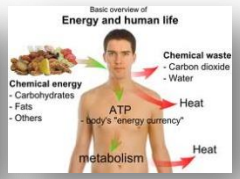
Starting date : 06 March, 2013 (Wednesday)

BIOC201
Monday 6th period L02 (Denisha) and
Friday 3rd period L08 (Chantal)

GENE240
Monday 4th period (Jenisha), Monday 5th period L08 (Kyle) and Tuesday 4th period L08 (Aerin)

MICR213
Tuesday 3rd period L03 (Shandre), Wednesday 4th period L02 (Farzana) and Wednesday 6th period E3-425 (Ruqsar).

Prostaglandins (PG)

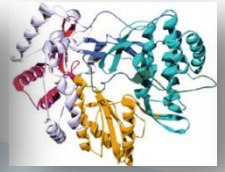
Effects:

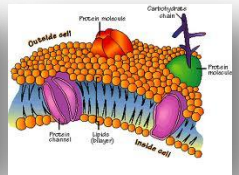
- Physiological effects of prostaglandins are confusing
- Usually they work as a natural mediator of fever, pains and inflammation such as- arthritis, skin or eyes inflammations etc.
- Release of prostaglandins in eyes after eye inflammation can increase vascular permeability and intraocular pressure

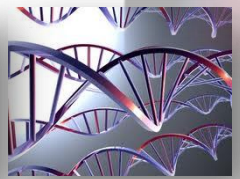
(These effects are blocked by corticosteroid or anti-inflammatory drugs which inhibit PG synthesis)

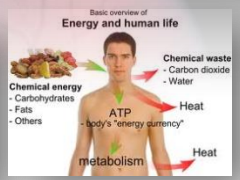
Functions:

- Water retention, ion transport and BP regulation
- Low tropical dose of some PGs to treat GLUCOMA





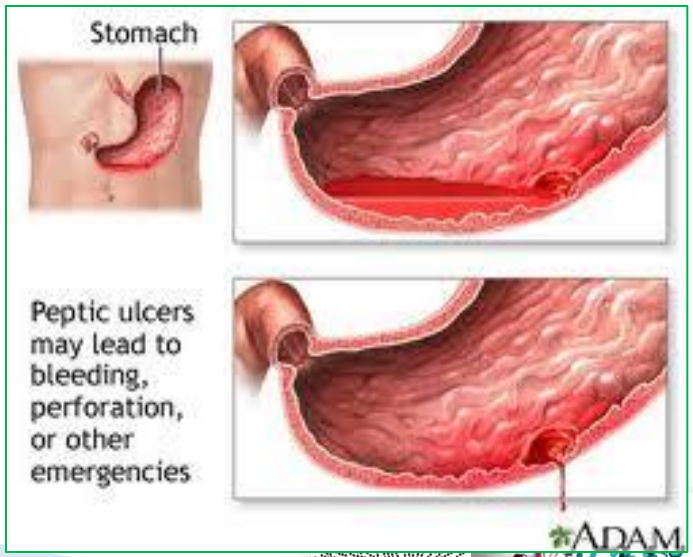


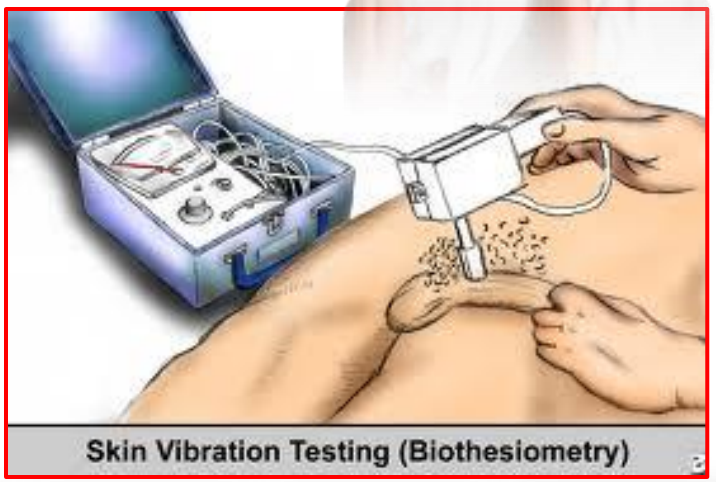


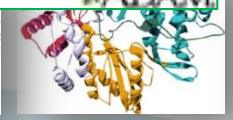
Prostaglandins (PG)

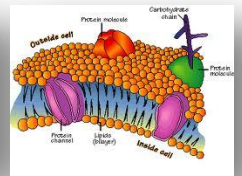
Clinical use of prostaglandins:

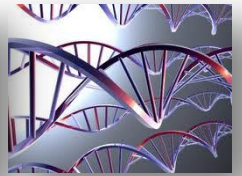
- To induce child birth or abortion (PGE_2 and PGF_2)
- To prevent and treat peptic ulcer (PGE)
- As a vasodilator during sever ischemia of limb
- To get relief from pulmonary hypertension
- To treat erectile dysfunction (ED) or penile rehabilitation after surgery (PGE_1)

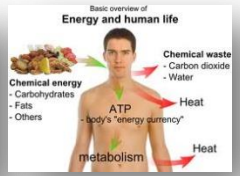












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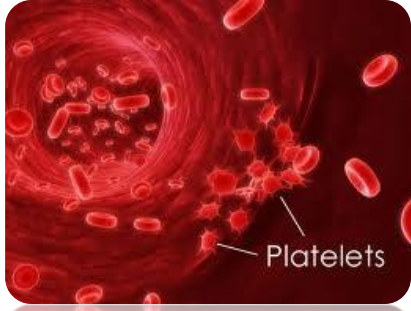
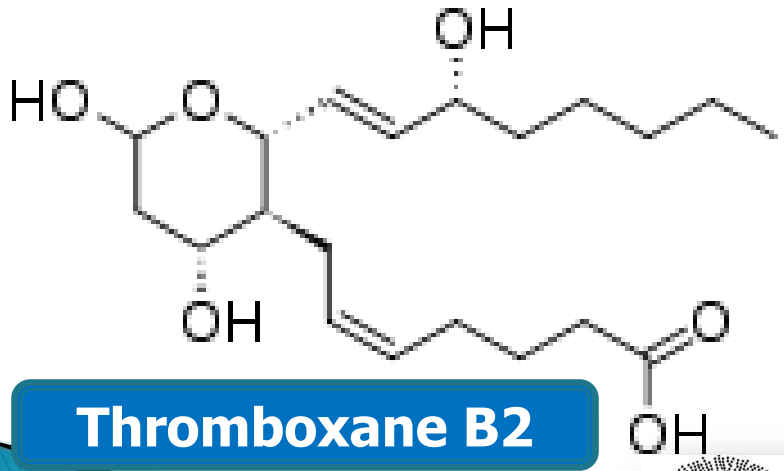
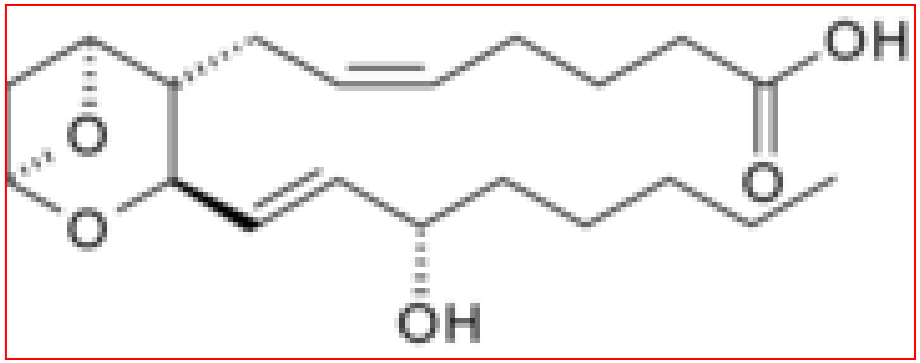
Thromboxane (TX)



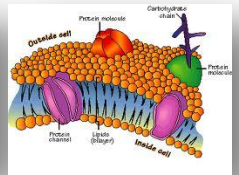
- First isolated from blood platelets and also called thrombocyte
- Name came from the term 'thrombosis' and abbreviation is TX (such as TXA_2, TXB_2)
- Has a six-membered ring containing an ether
- The letter after TX denotes the nature of oxygen containing six-membered ring and number after that denotes the number of double bonds

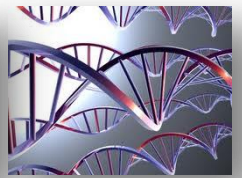


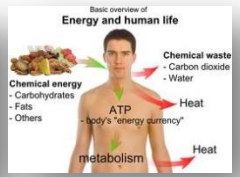
Thromboxane B2



Thromboxane A2







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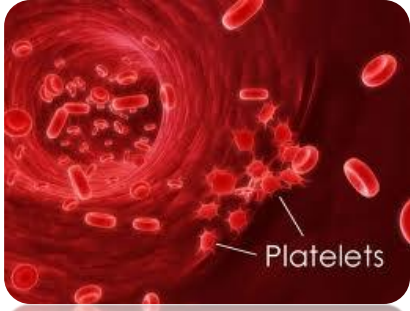
Thromboxane (TX)



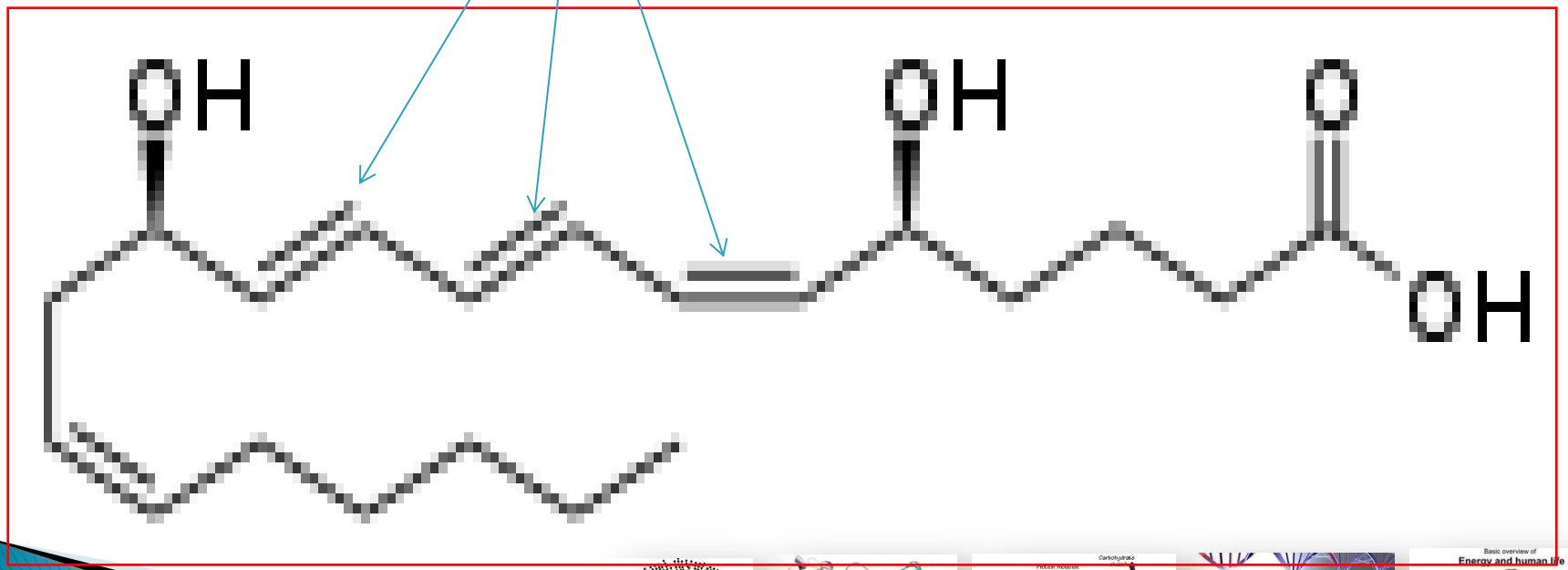
Functions:

- Produced by platelets and act in the formation of blood clots
- Reduction of blood flow to the site of blood clot
- (Aspirin or aspirin type drugs, which reduce or block the synthesis of throboxanes, are usually used to relieve from this kind of intravascular thrombosis)

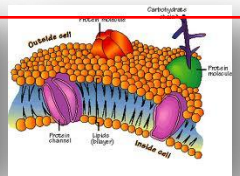
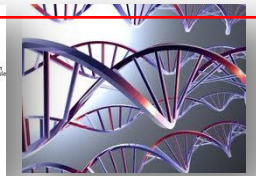
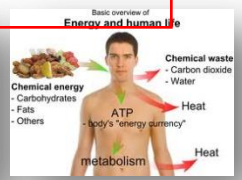
Leukotrienes (LT)

Nomenclature and Chemistry:

- **Found in the White Blood Cells (WBC) or leukocytes and contains THREE conjugated double bonds so they are called leukotrienes**
- **Derived from arachidonic acid (20:4) & synthesized by several oxidase & lipoxyginase (LOX)**



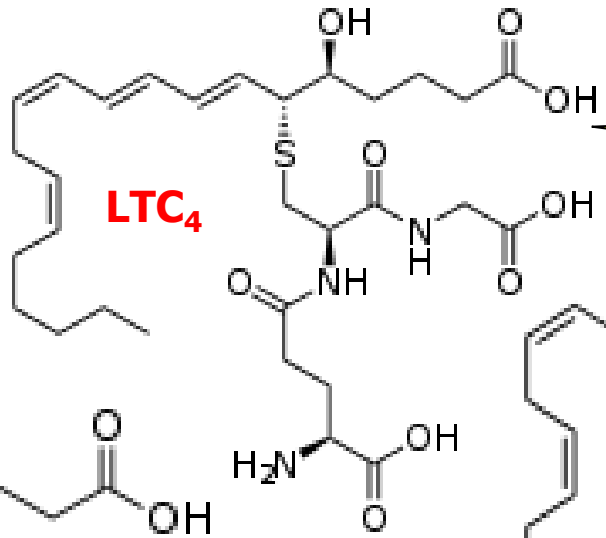


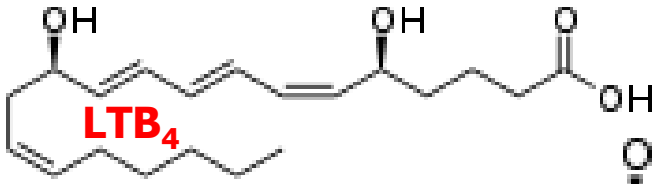




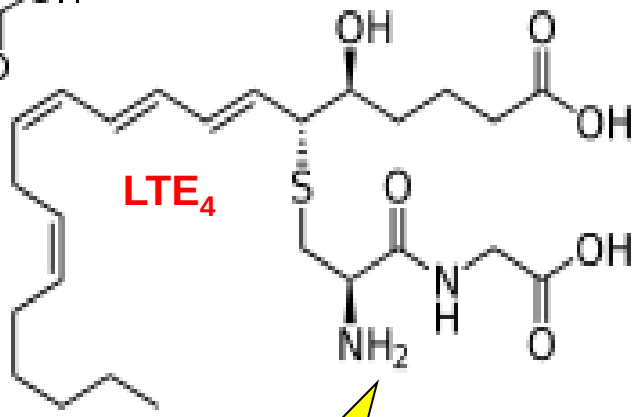
Leukotrienes (LT)

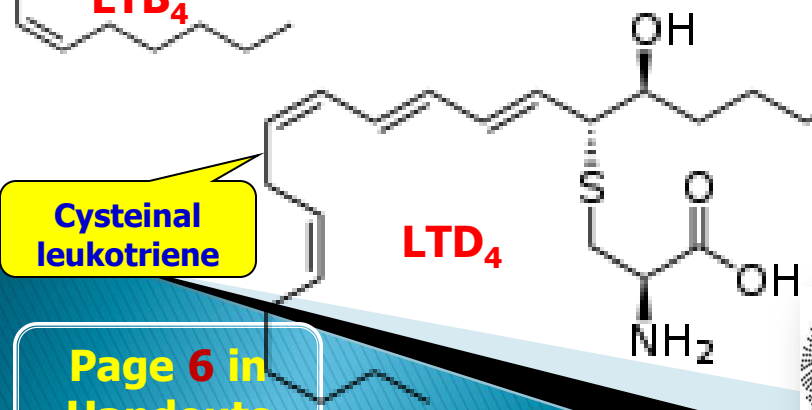
Nomenclature and Chemistry:

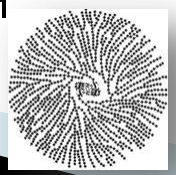
- **The abbreviated name is LT & here are many kinds of leukotrienes such as- LTA_4, LTB_4, LTC_4, LTD_4, LTE_4 and LTF_4 where letters after LT indicate the nature of O_2-containing substituents & the number thereafter indicates the number of double bonds**

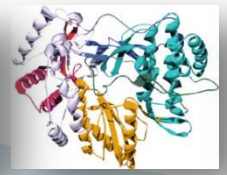


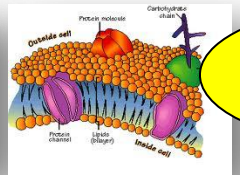


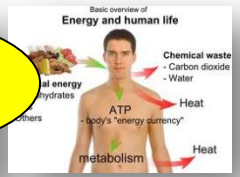












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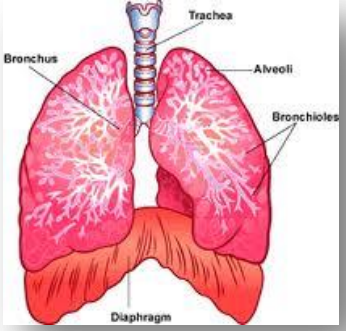
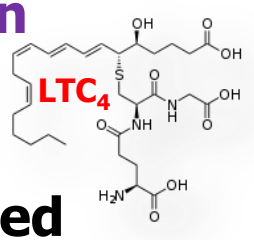
Leukotrienes (LT)



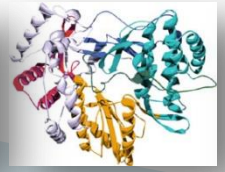
Functions:

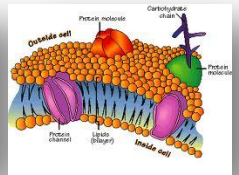
- Results in contraction of smooth muscle especially lung
- They also may have inflammatory properties involved in rheumatoid arthritis
- The strong contraction of smooth muscle of the lungs occurred due to potentially fatal allergic reactions caused by leukotrines
- This reaction is more fatal for the person who are hypersensitive to bee stings, penicillin etc.

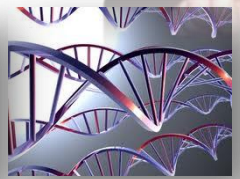


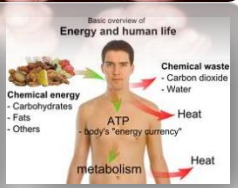
Clinical correlation:

- Asthmatic attack may results from this contraction function by the synthesis of LTC_4.
- The drug that inhibits the synthesis of LTC_4 shows promising effect for the treatment of asthma and used in the inhalers



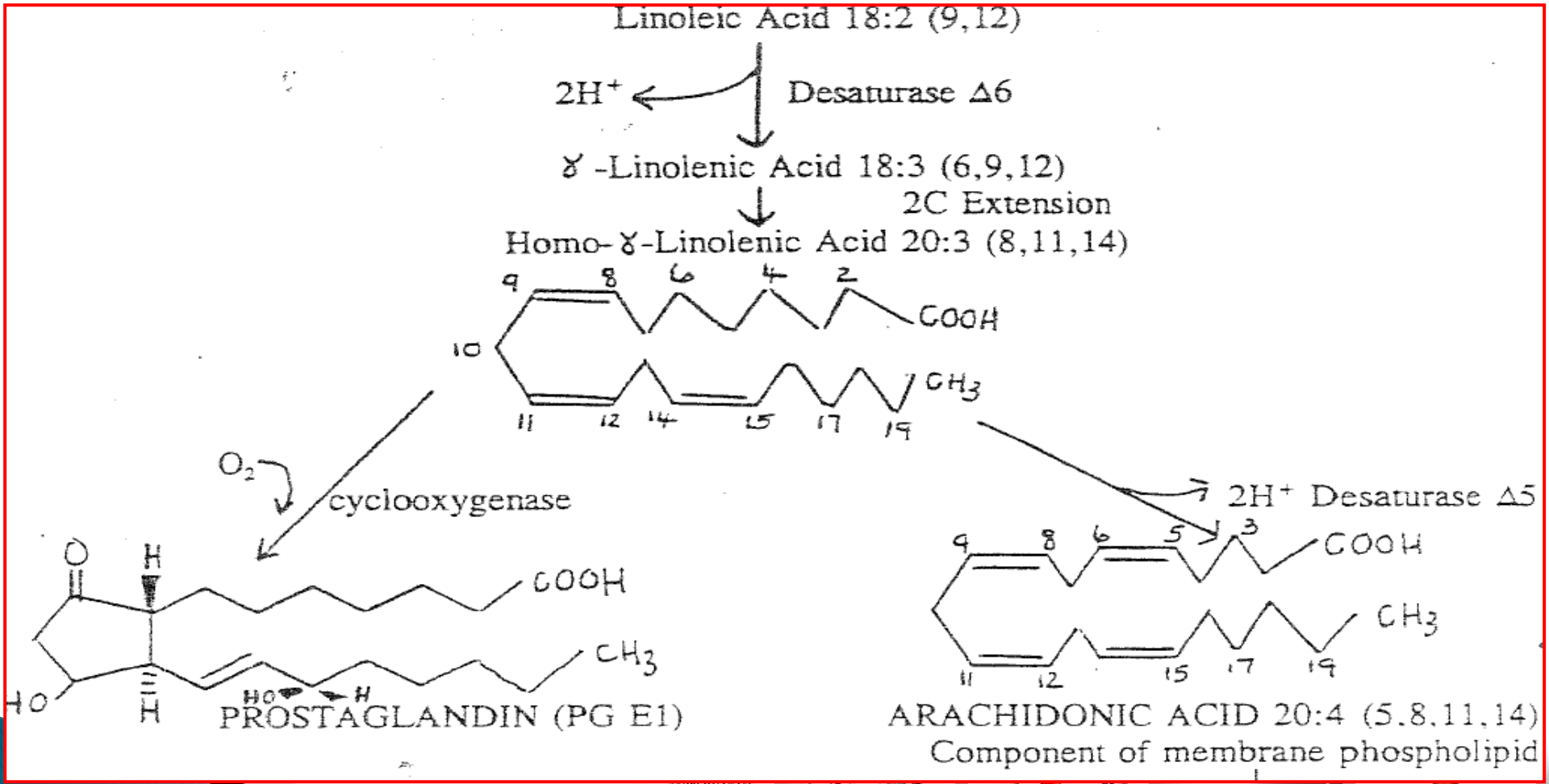






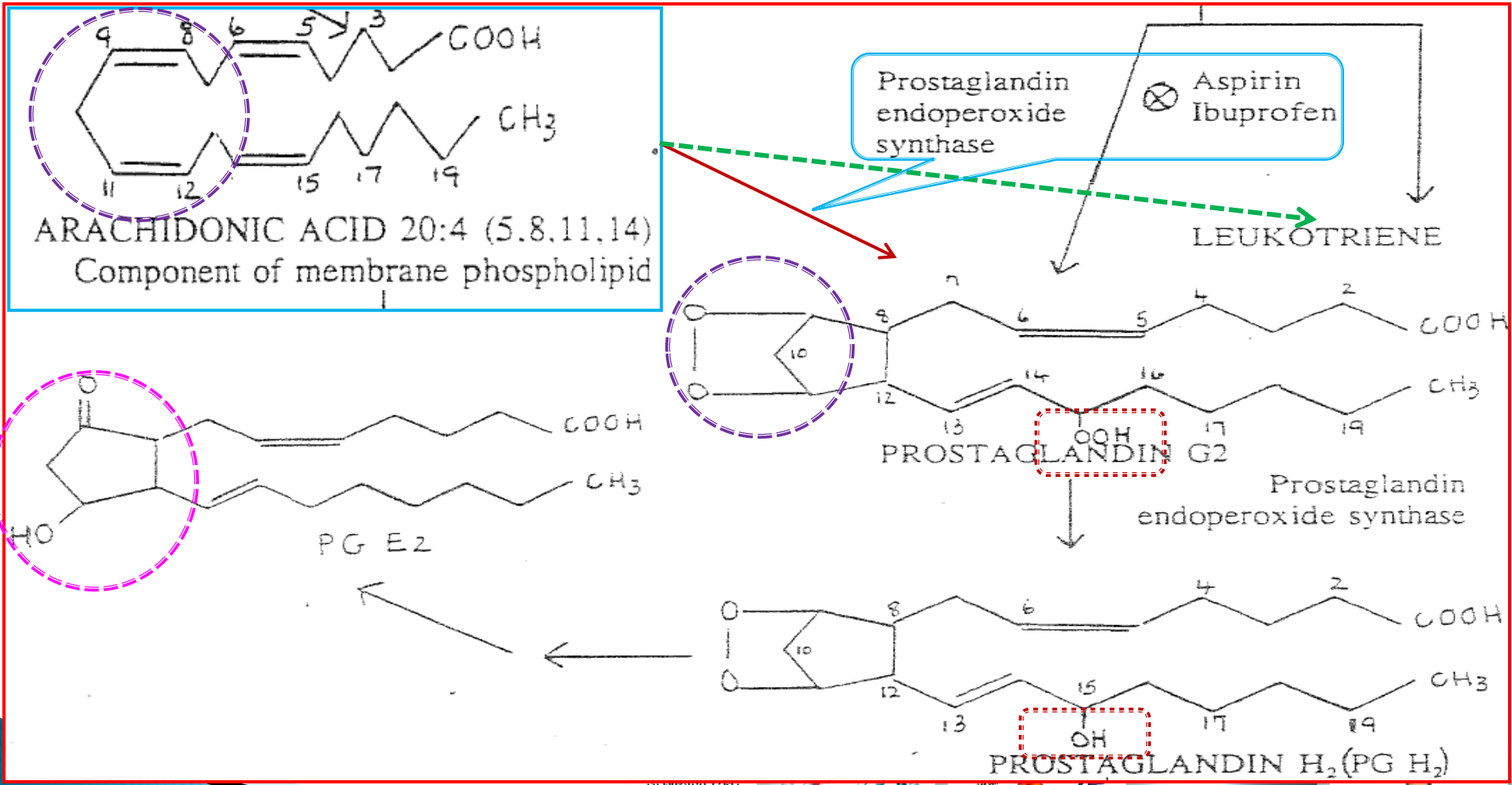
Biosynthesis of eicosanoids

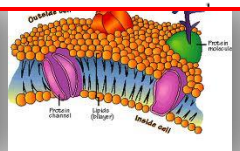
Biosynthesis of prostaglandins (PG):

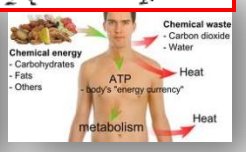


Biosynthesis of eicosanoids

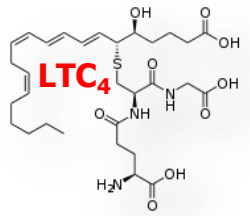
Biosynthesis of prostaglandins (PG): contd…



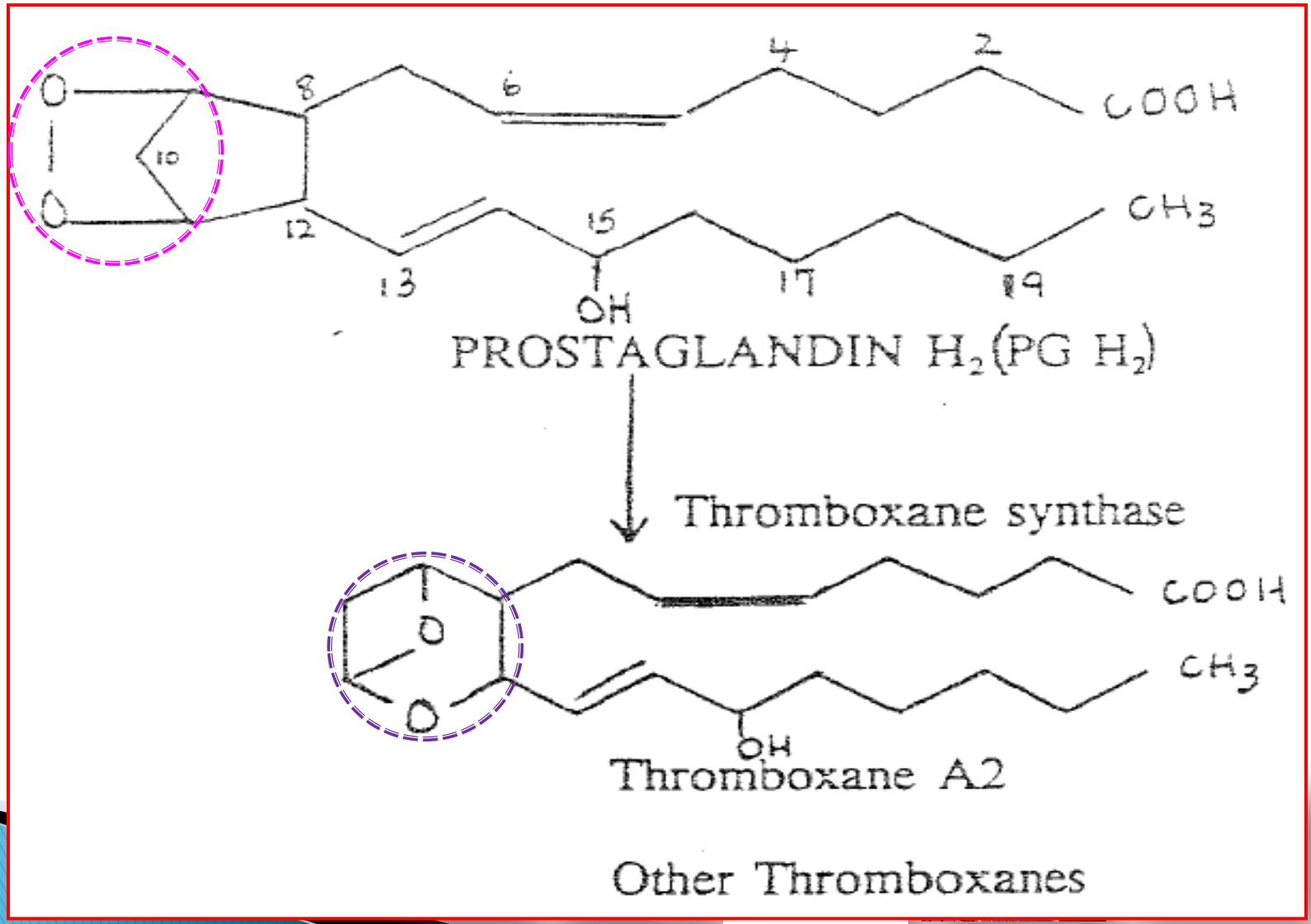




Biosynthesis of eicosanoids

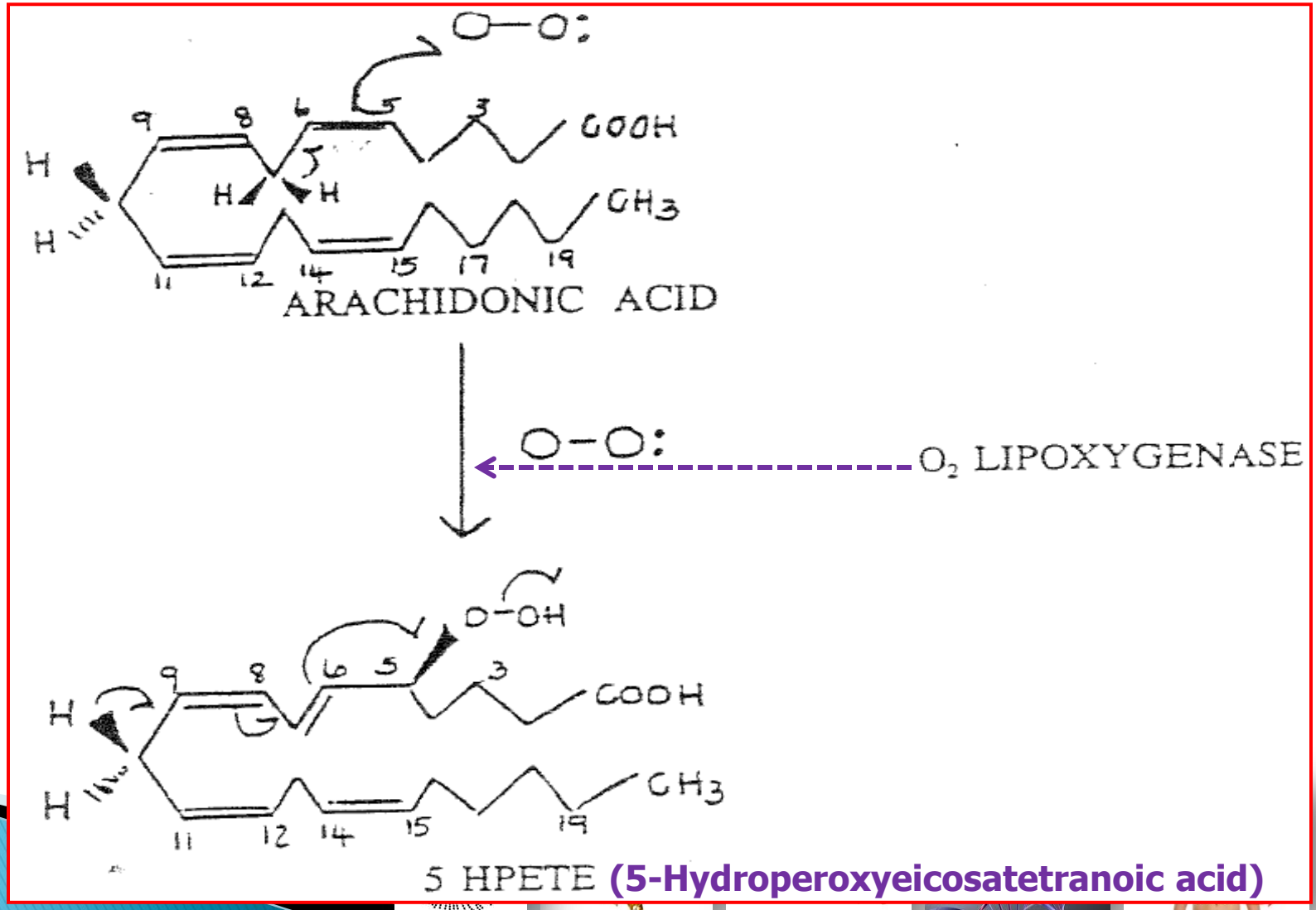


Biosynthesis of thromboxanes (TX):

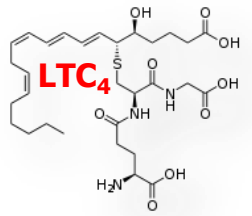


Biosynthesis of eicosanoids

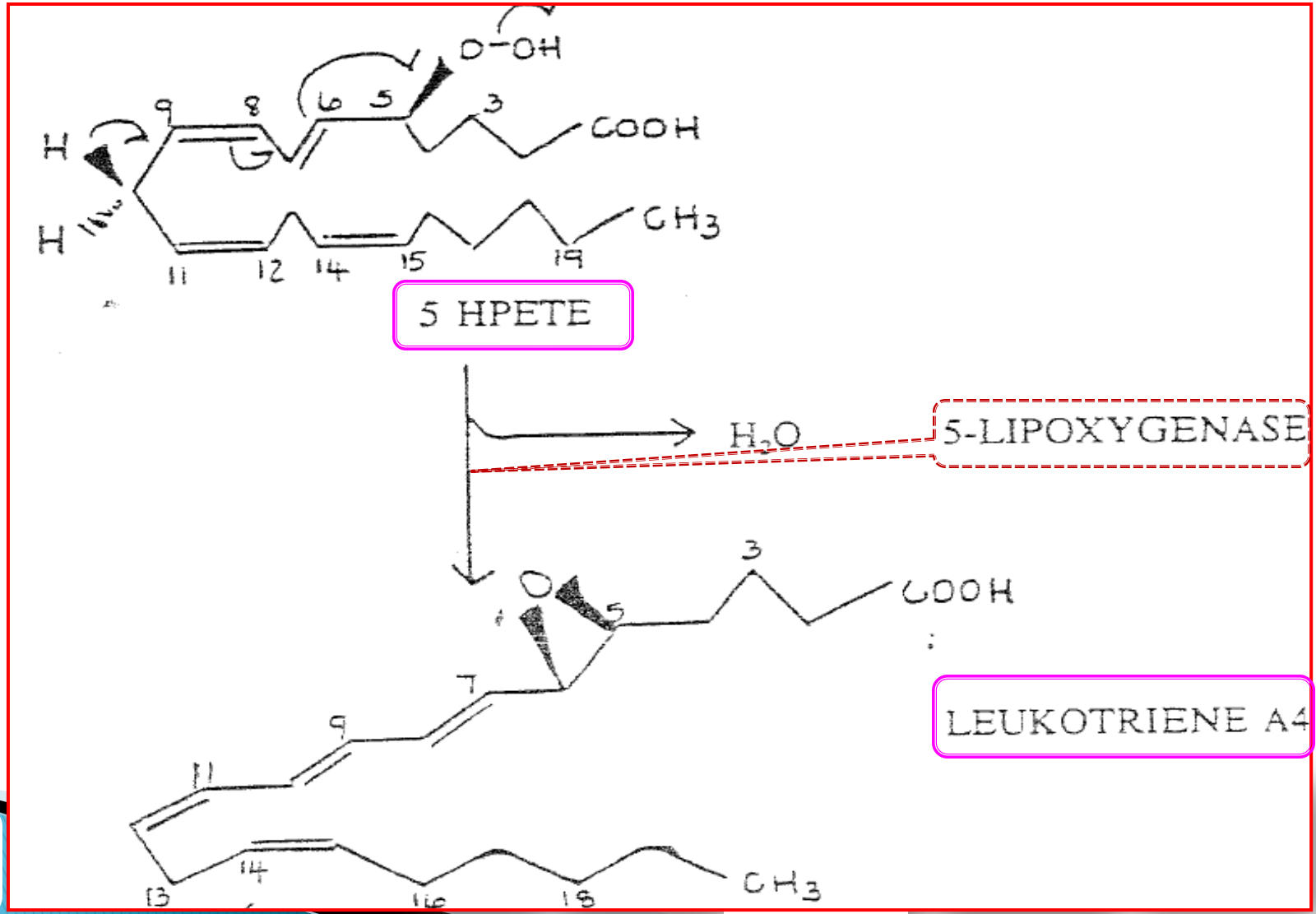
Biosynthesis of leukotrienes (LT):



Biosynthesis of eicosanoids

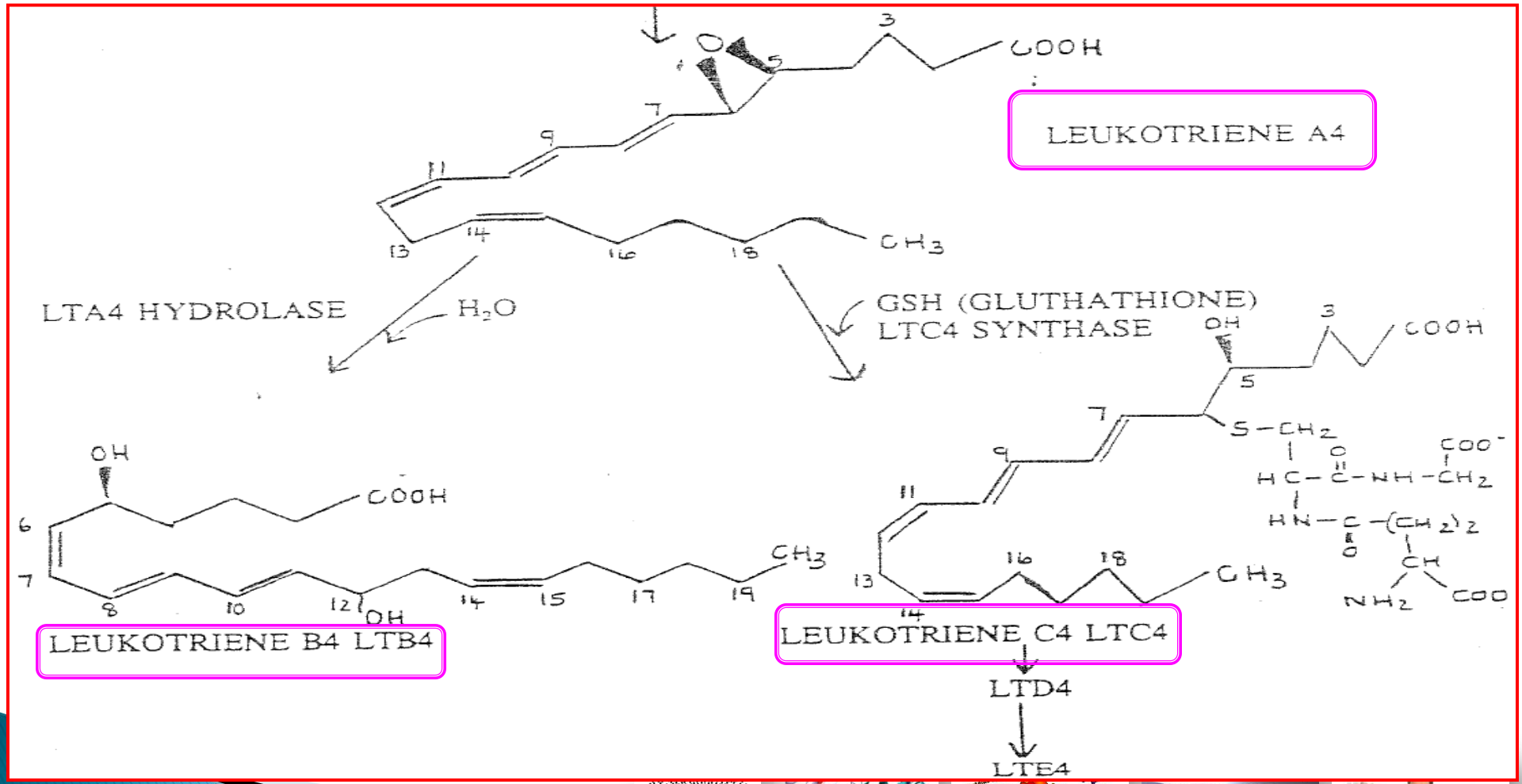


Biosynthesis of leukotrienes (LT): contd…



Biosynthesis of eicosanoids

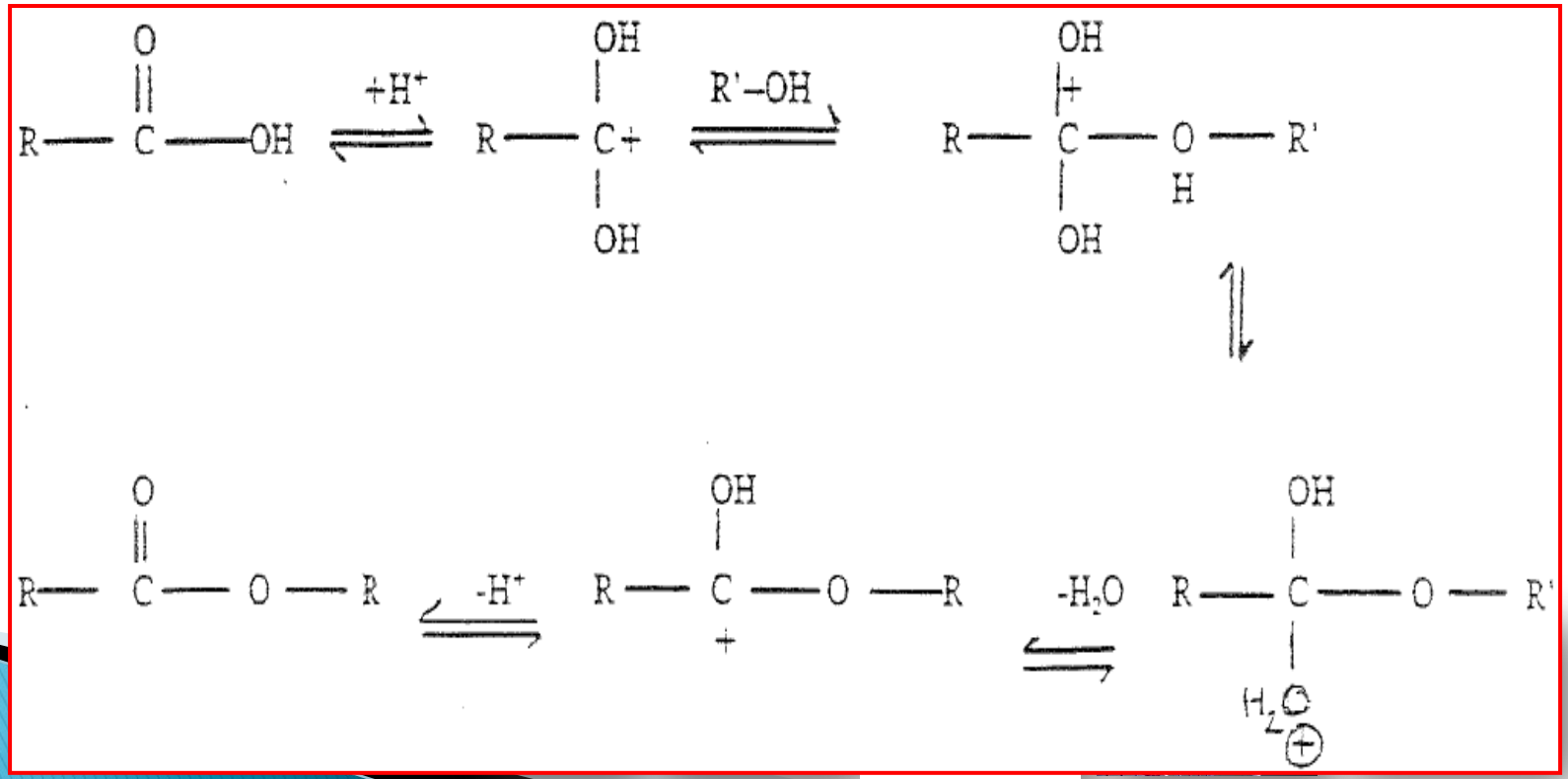
Biosynthesis of leukotrienes (LT): contd…



Reactions of fatty acids

Esterification:

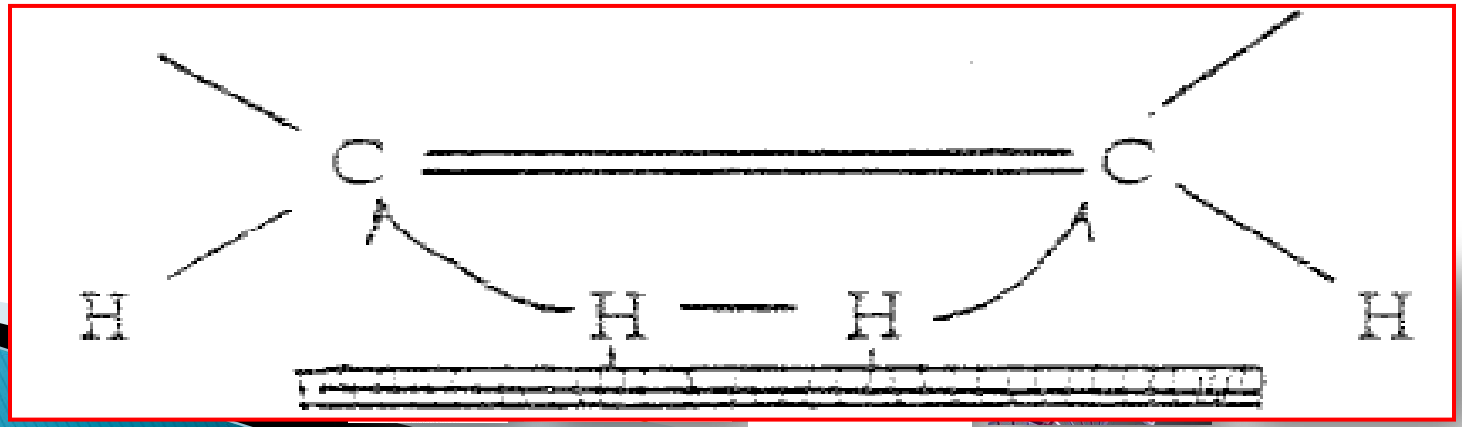
- **The most important reaction of the carboxyl group is esterification reaction**
- **In this reaction, one molecule of acid and one molecule of alcohol react reversibly to yield one molecule of water and an ester.**



Reactions of fatty acids

Hydrogenation:

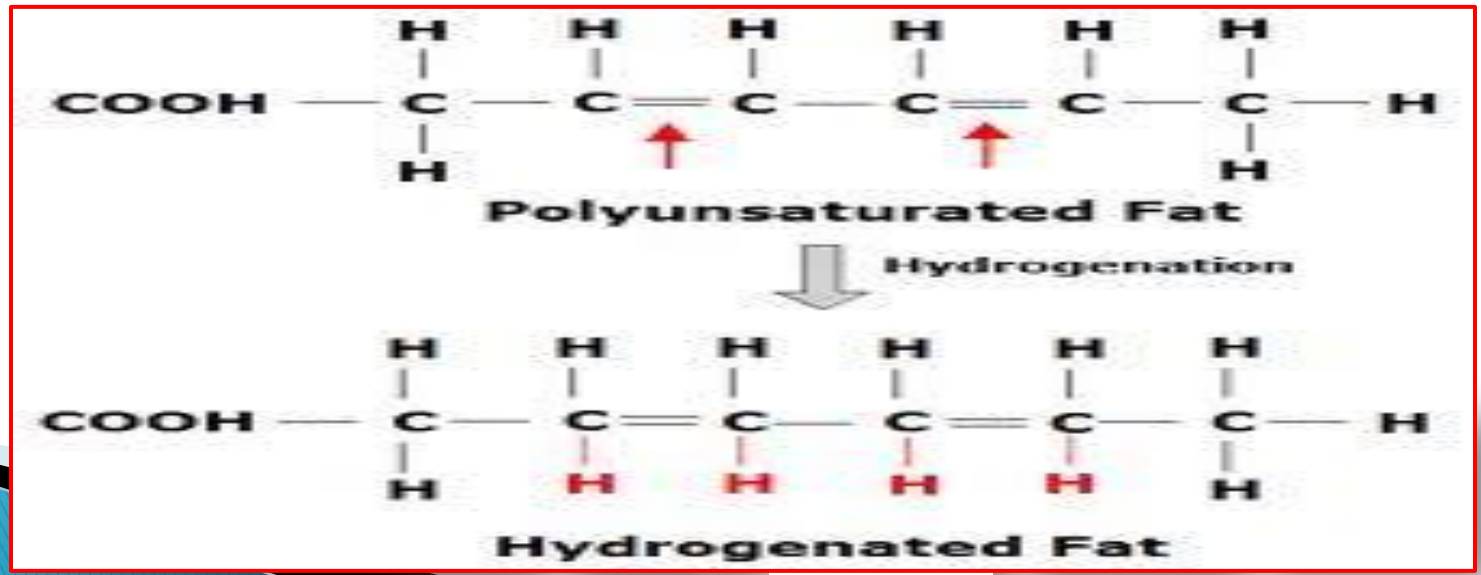
- **The H2 may be added across the double bonds on unsaturated fatty acids or their lipid parents in the presence of Ni, Pt, or Pd catalysts.**
- **The addition of H2 is *cis* since both hydrogen atoms of the hydrogen molecule attack the double bond simultaneously.**
- **This occurs because the H molecule is bound to the catalyst surface by unpaired electrons as it is the alkenes (pi bond interactions).**
- **For example – linoleic (C18:2,Δ9,12) or oleic acid (C18:1,Δ9) is converted to stearic acid by hydrogenation reaction.**



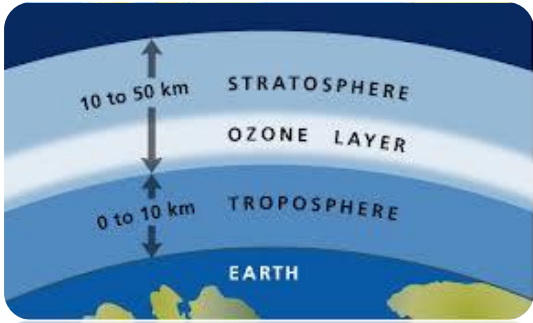
Reactions of fatty acids

Applications of hydrogenation reaction:

- **Hydrogenation is a TEST which may be used to determine unsaturation (number of double bonds) in a sample of fat.**
- **On large scale it is used in the manufacture of margarine. For example – triglyceride from plant sources (oils) are hydrogenated until they become solids at room temperature and assume the consistency of butter.**
- **For example - linoleic (C18:2,Δ9,12) or oleic acid (C18:1,Δ9) is converted to stearic acid by hydrogenation reaction.**

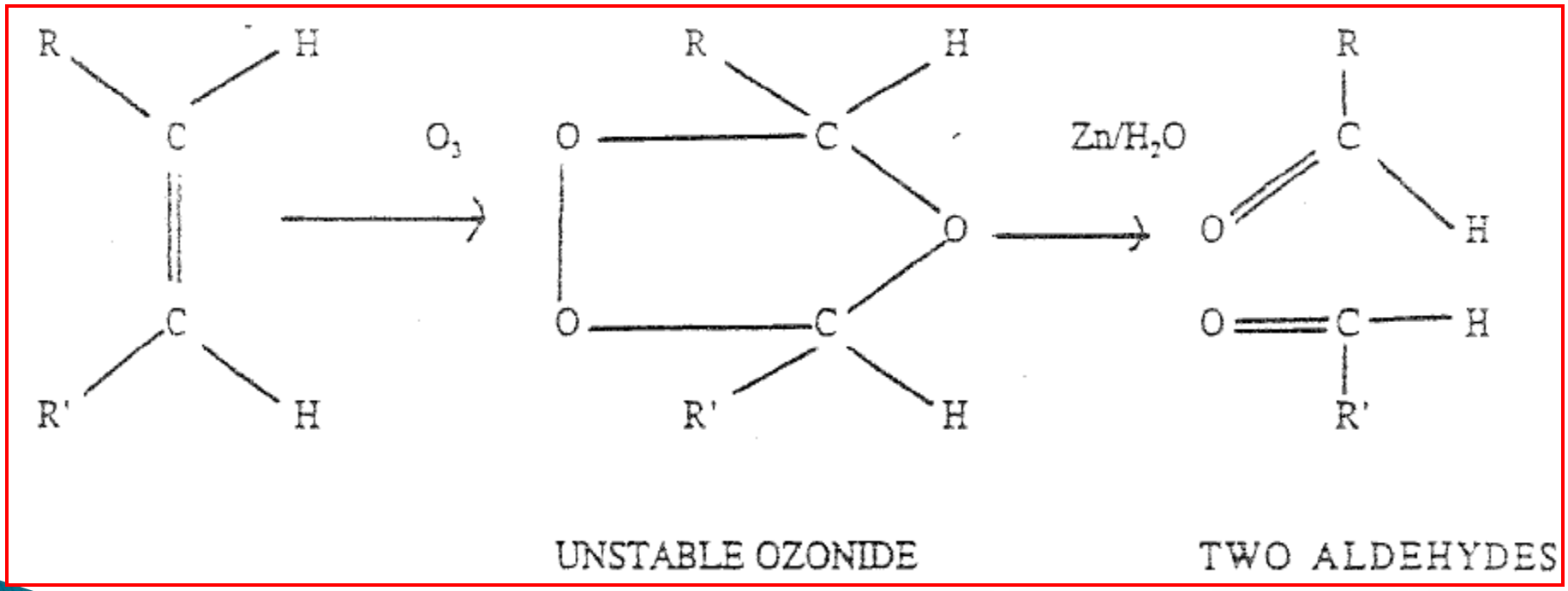


Reactions of fatty acids

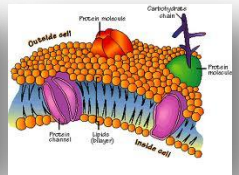
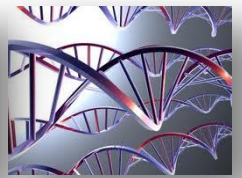
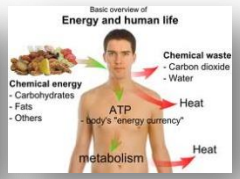


Ozonolysis:

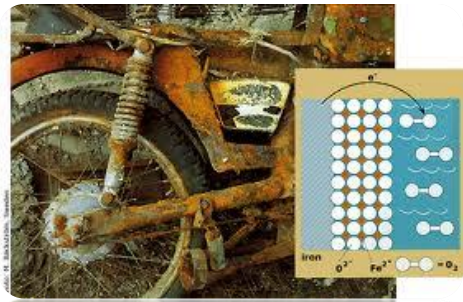
- **One of ozone (O3) can join with a double bond of an unsaturated fatty acids and initially forms an unstable ozonide with a final product of two aldehydes.**





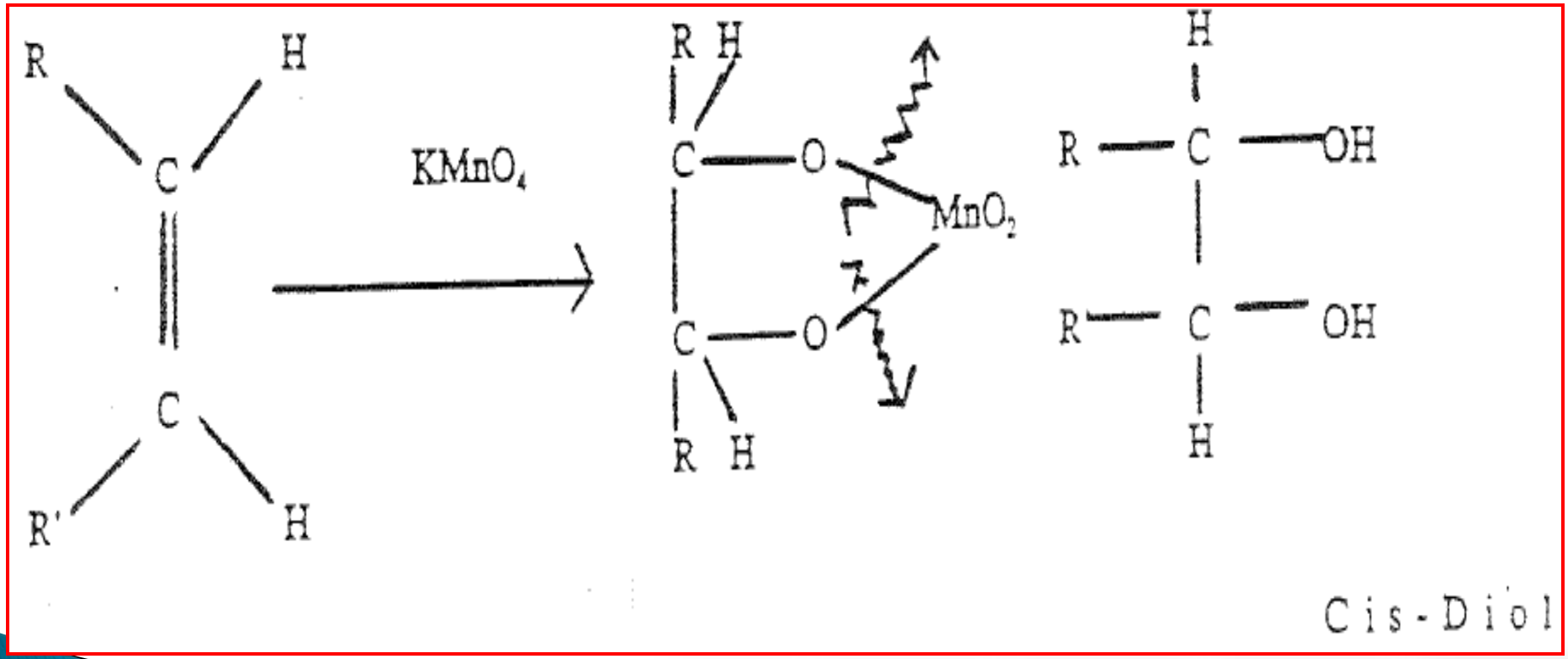




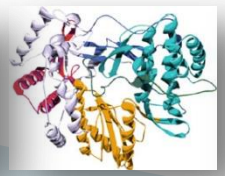
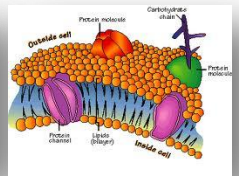
Reactions of fatty acids

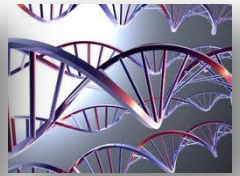
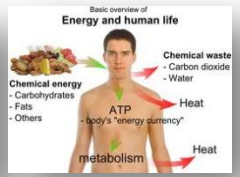


Oxidation by KMnO4 (at neutral pH):

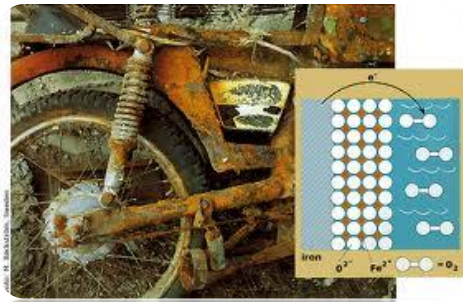
- **At neutral pH, each double bond of an unsaturated fatty acid can be oxidized by KMnO4 to form a *cis*-Diol.**



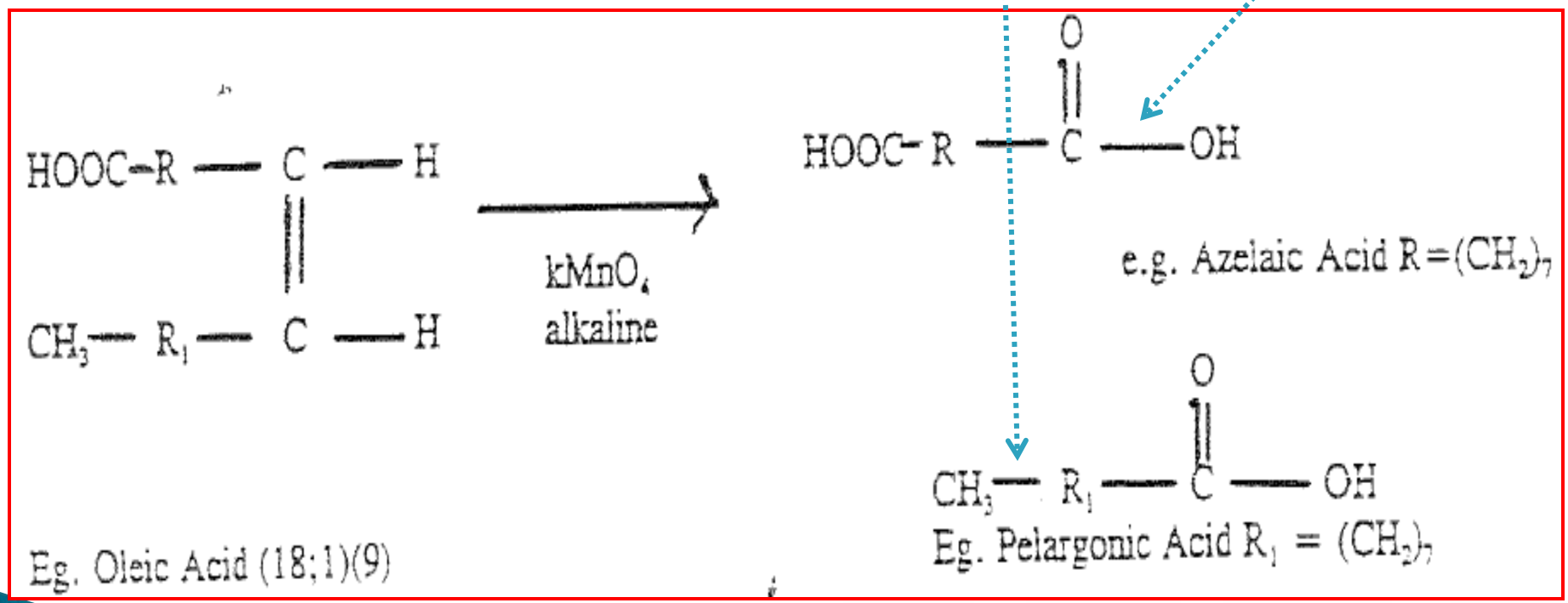



Reactions of fatty acids

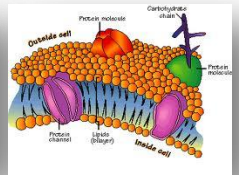
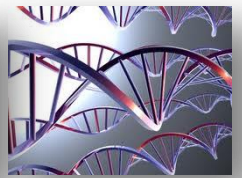
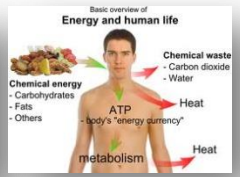


Oxidation by KMnO4 (at alkaline pH):

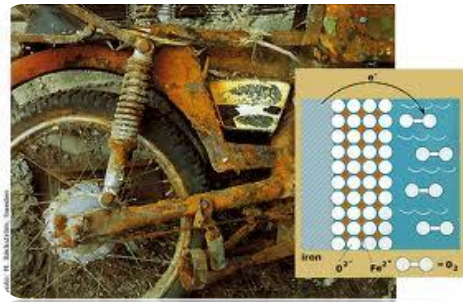
- **At alkaline pH, double bonds of an unsaturated fatty acid can be oxidized by KMnO4 to form a mono- or di-carboxylic acid.**





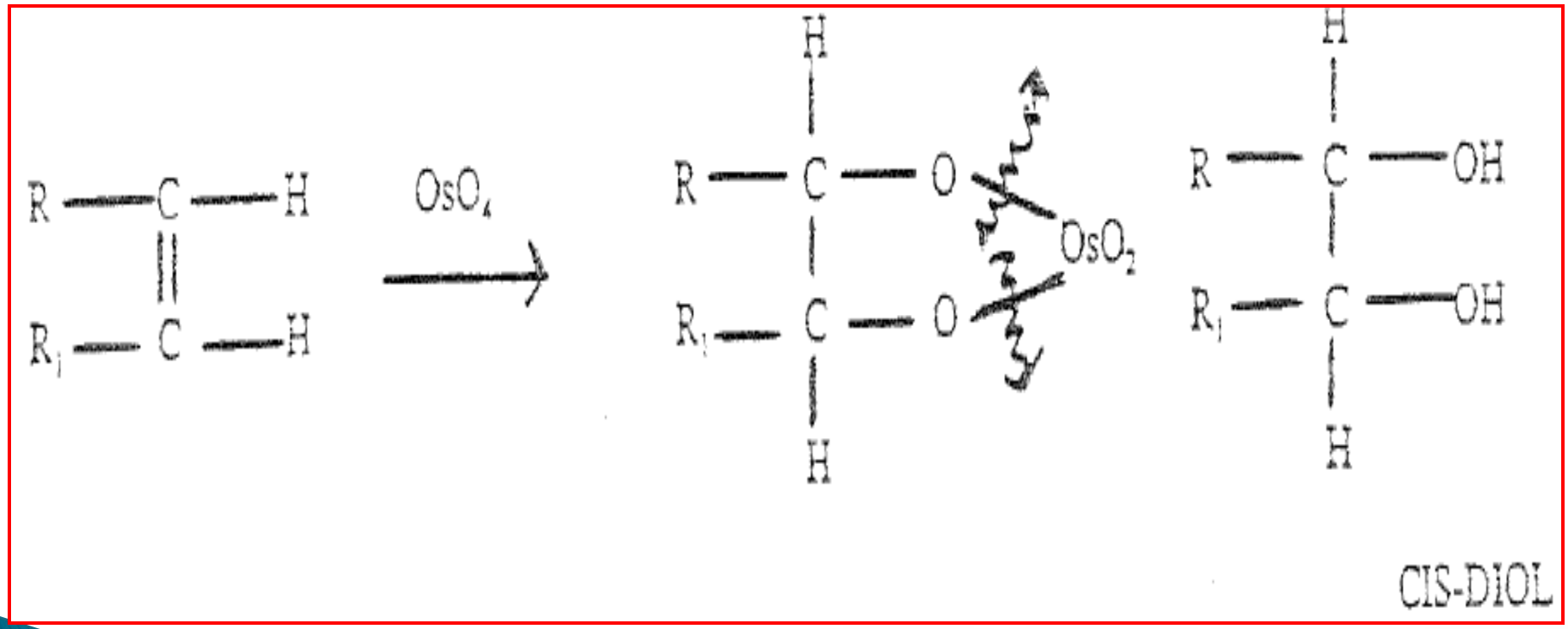




Reactions of fatty acids

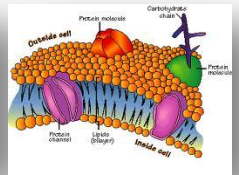
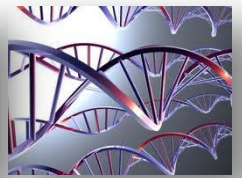
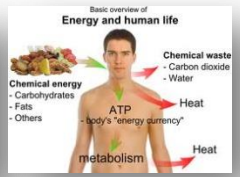


Oxidation by OsO4 (at alkaline pH):

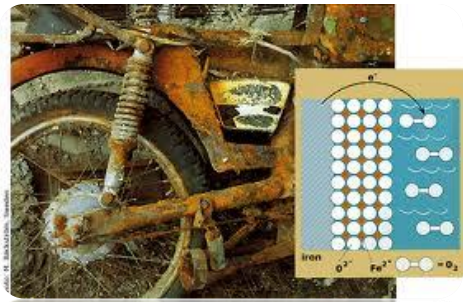
- **At alkaline pH, double bonds of an unsaturated fatty acid can be oxidized by OsO4 to form a *cis*-Diol.**





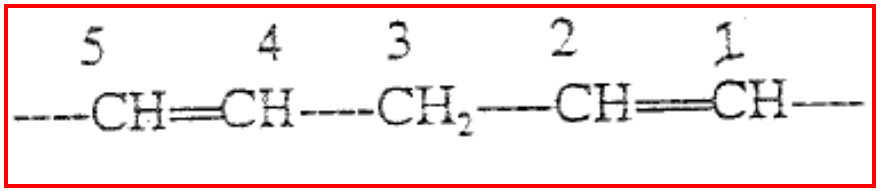




Reactions of fatty acids

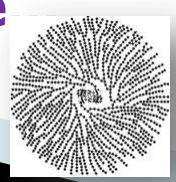


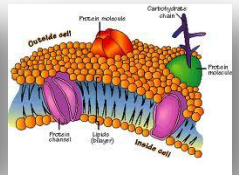
Peroxidation of unsaturated fatty acids:

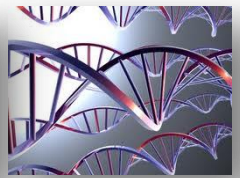
- The double bonds in polyunsaturated fatty acids are not conjugated. Successive double bonds belong to a 1,4-pentadiene system as follows.

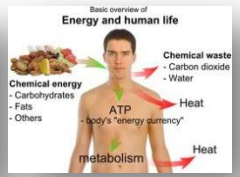


- This system shows properties which differ from those of conjugated systems where electrons are delocalized.
- The 1,4-pentadiene system is readily attacked by molecular oxygen after generation of a free radical at the methylene.
- After the addition of molecular oxygen it will be converted to a conjugated hydroperoxide which will be finally converted keto- and hydroxy-keto acids
- This kinds of conversion of fats or lipids is called the rancidation which is inversely proportional to its quality
- Reactions in next slide

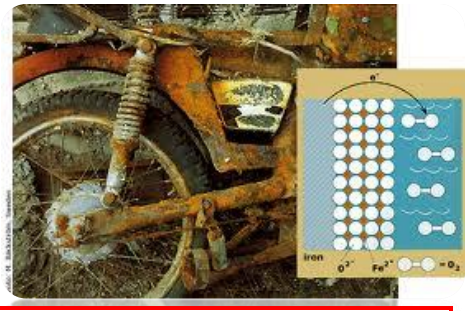




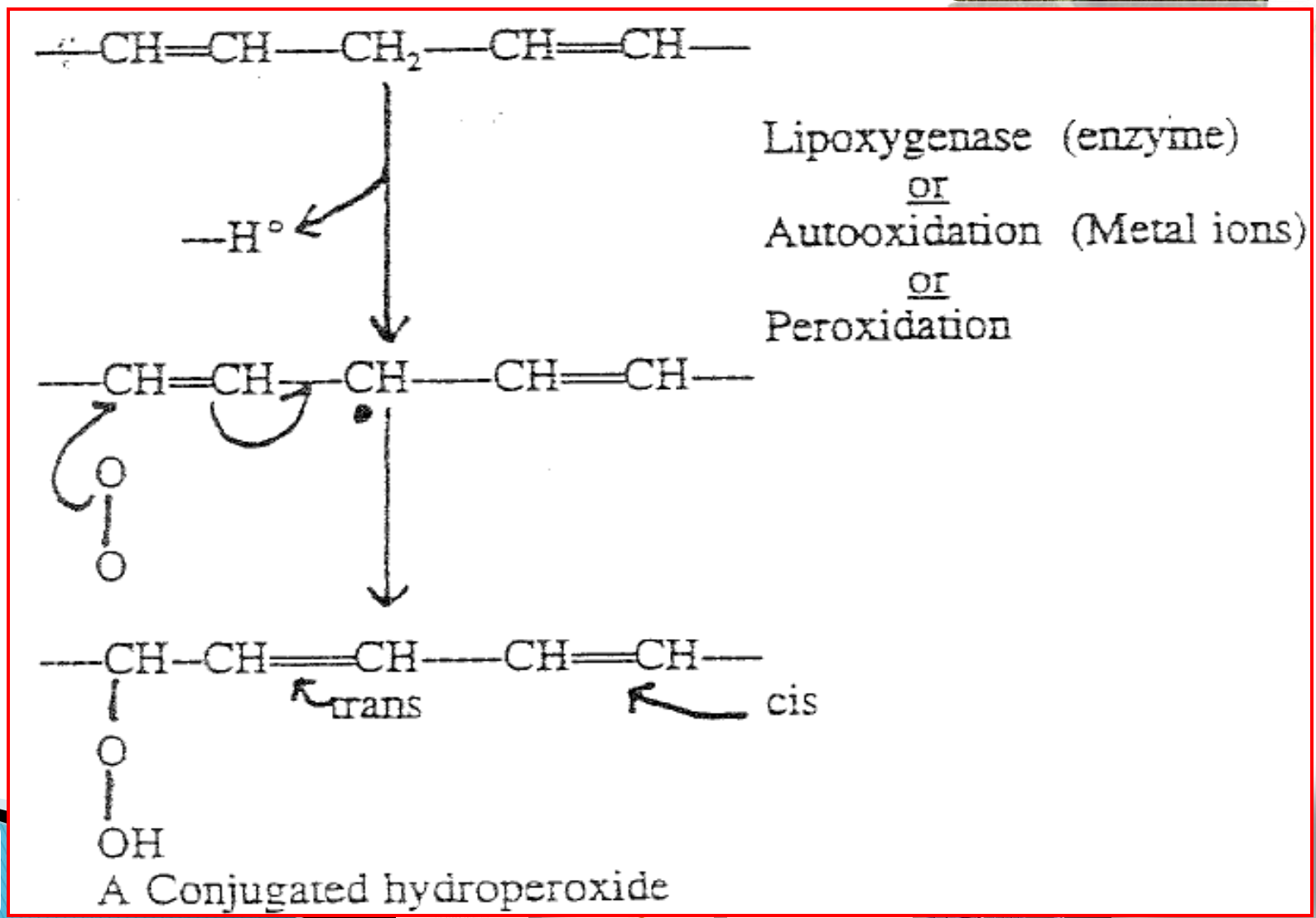




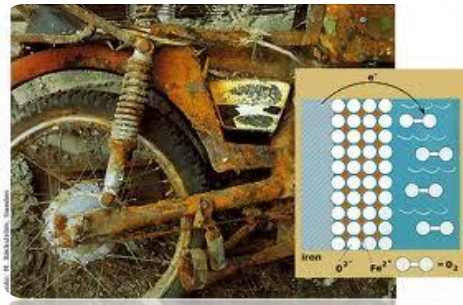
Reactions of fatty acids



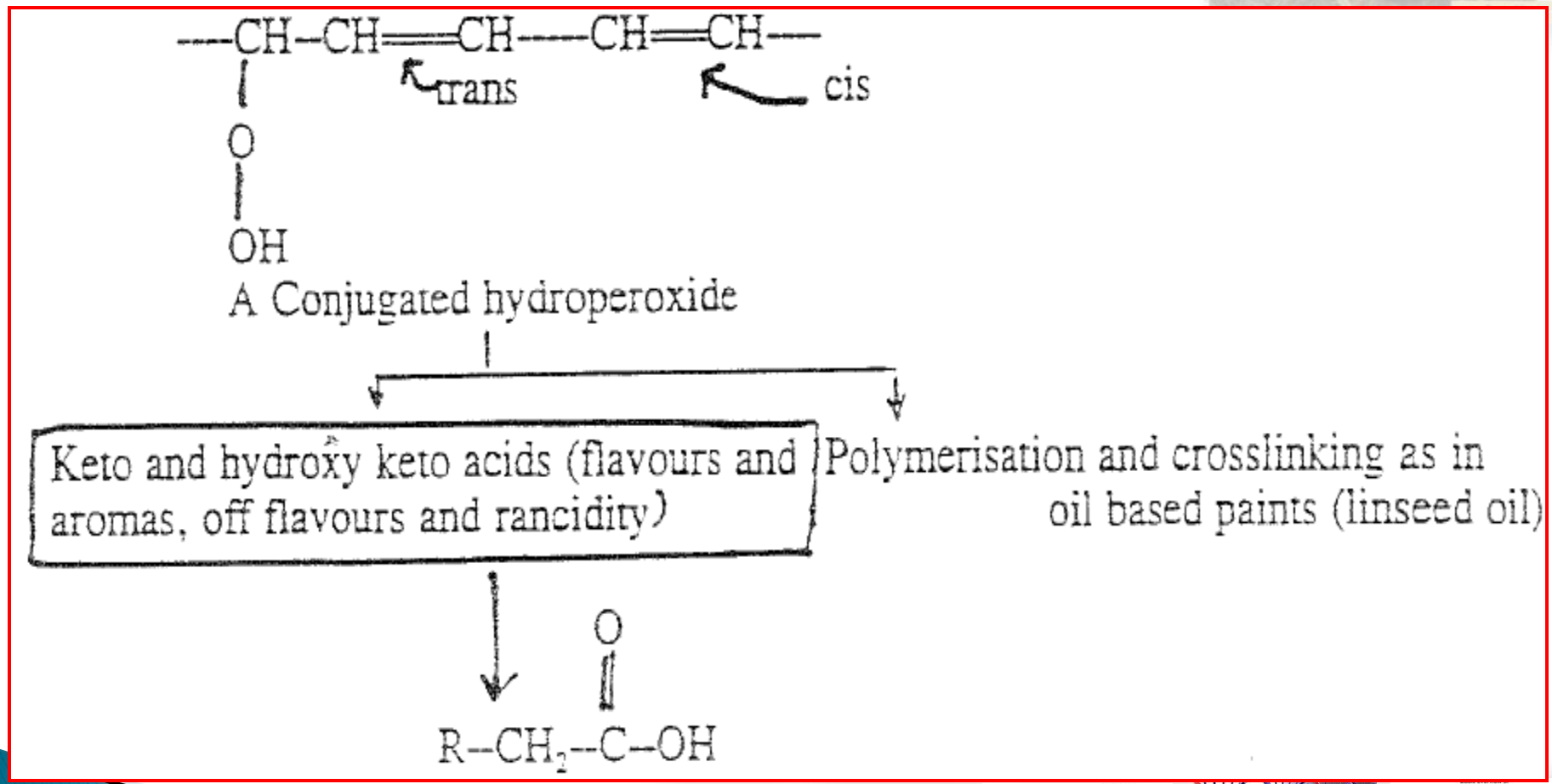
Peroxidation of unsaturated fatty acids: contd…



Reactions of fatty acids



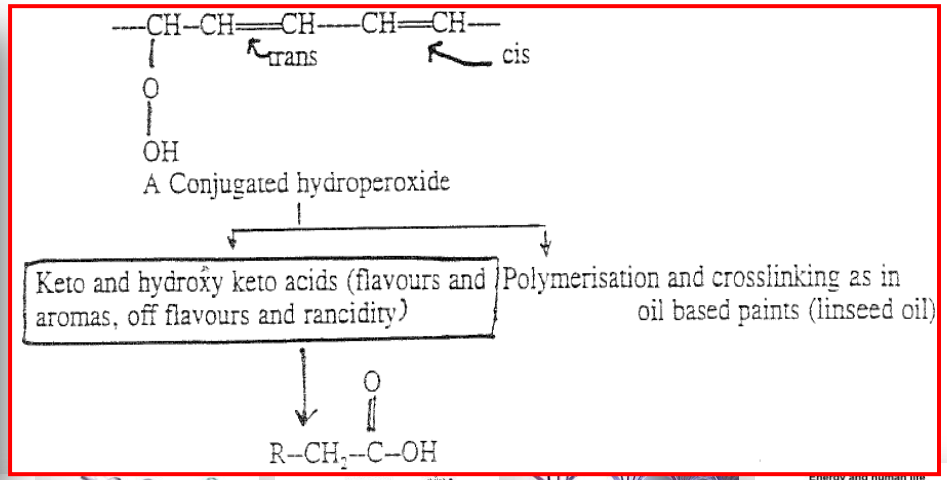
Peroxidation of unsaturated fatty acids: contd…

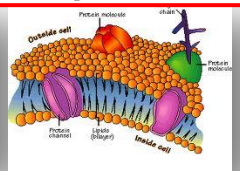


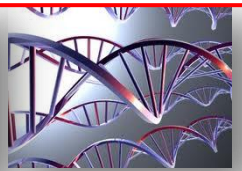
Reactions of fatty acids

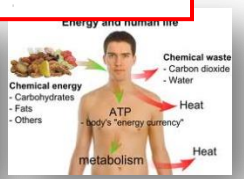
Rancidity of fats or lipids – why does it happen?

- During storage, fats can be rancid due to peroxide formation at double bonds with atmospheric oxygen or microbial hydrolysis when free fatty acids are released
- These short chain fatty acids have some unpleasant odour and taste
- The higher amount of short chain fatty acids the higher rancid the fat









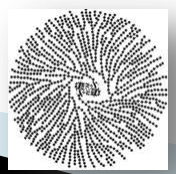
Reactions of fatty acids

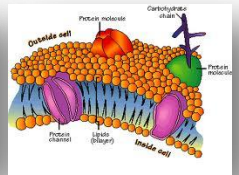
How the rancidity of fats can be determined?

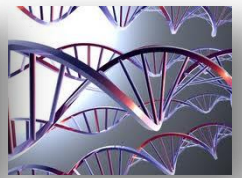
Taste or smell: From unpleasant taste of smell of fat the qualitative rancidity of fat can be determined

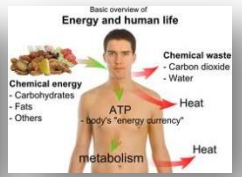
Titration reaction: By the titration of the fat with alkali such as KOH and an indicator such as phenolphthalein can quantitatively determine the level of rancidity in fat.

Acid value: The result of titration is called ACID VALUE and the higher the acid value the lower the quality of fat.





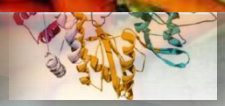


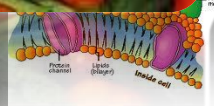


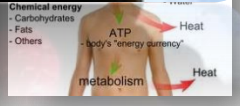
Reactions of fatty acids

How can we protect this fat oxidation?

- Fat is the major component of our cell membrane. If membrane function is defective, it causes cell death
- Anti-oxidant containing foods such as Vit-E, Vit-C, Flavonoids, Polyphenols, Carotenoids and many other phytochemicals work as anti-oxidant in our system to prevent cell death
- Several anti-oxidative compound and enzymes such as Glutathion, Super oxide dismutase, Catalase also work as auto anti-oxidants in our system







Isomerism of fatty acids

Isomerism:

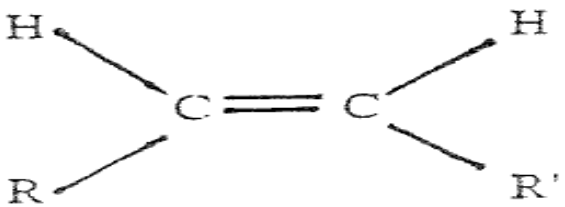
- Isomers are very common in biological system
- Isomers may have different physical and chemical properties

i) Geometrical isomerism:

- Orientation of hydrocarbon chains around the double bond
- Most of the double bonds of fatty acids are naturally in CIS configuration
- Some fatty acid derivatives are got TRANS configuration
- TRNAS isomers more stable than their CIS counterparts

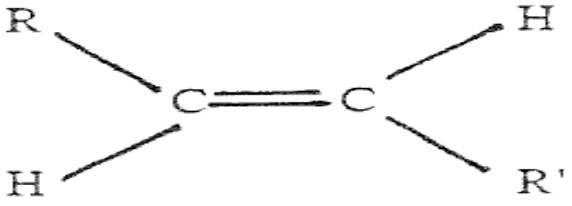
Page 12 in Handouts

Eg. Oleic acid 18:1(9)



CIS

Elaidic acid 18:1(9)t



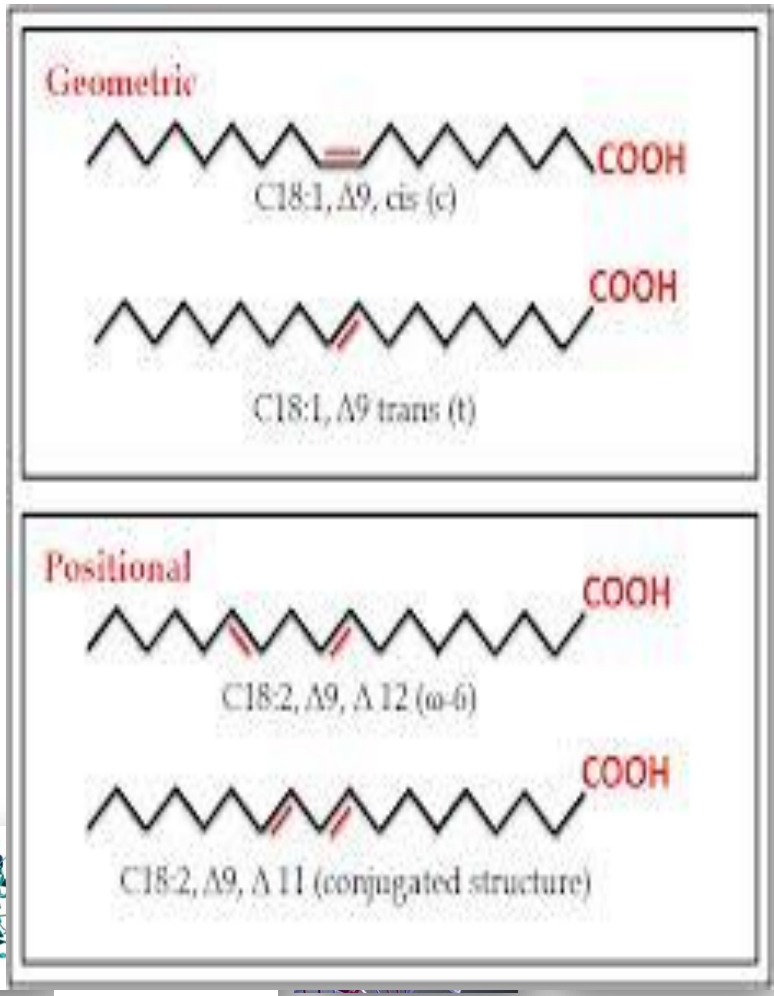
TRANS

(Less stable configuration)

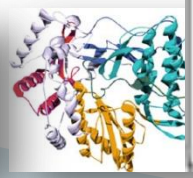
Isomerism of fatty acids

ii) Positional isomer:

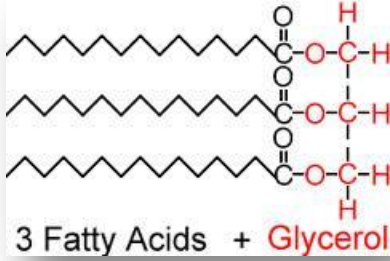
- **Number of isomers of a fatty acid depend on the position of double bond and number of carbon atom**
- **For example – one 18 carbon mono unsaturated fatty acid such as Oleic acid may have 16 positional isomer based on the position of double bond**



- **If CIS and TRANS configurations is considered for the same acid, an enormous number of isomers are possible amongst unsaturated fatty acids**



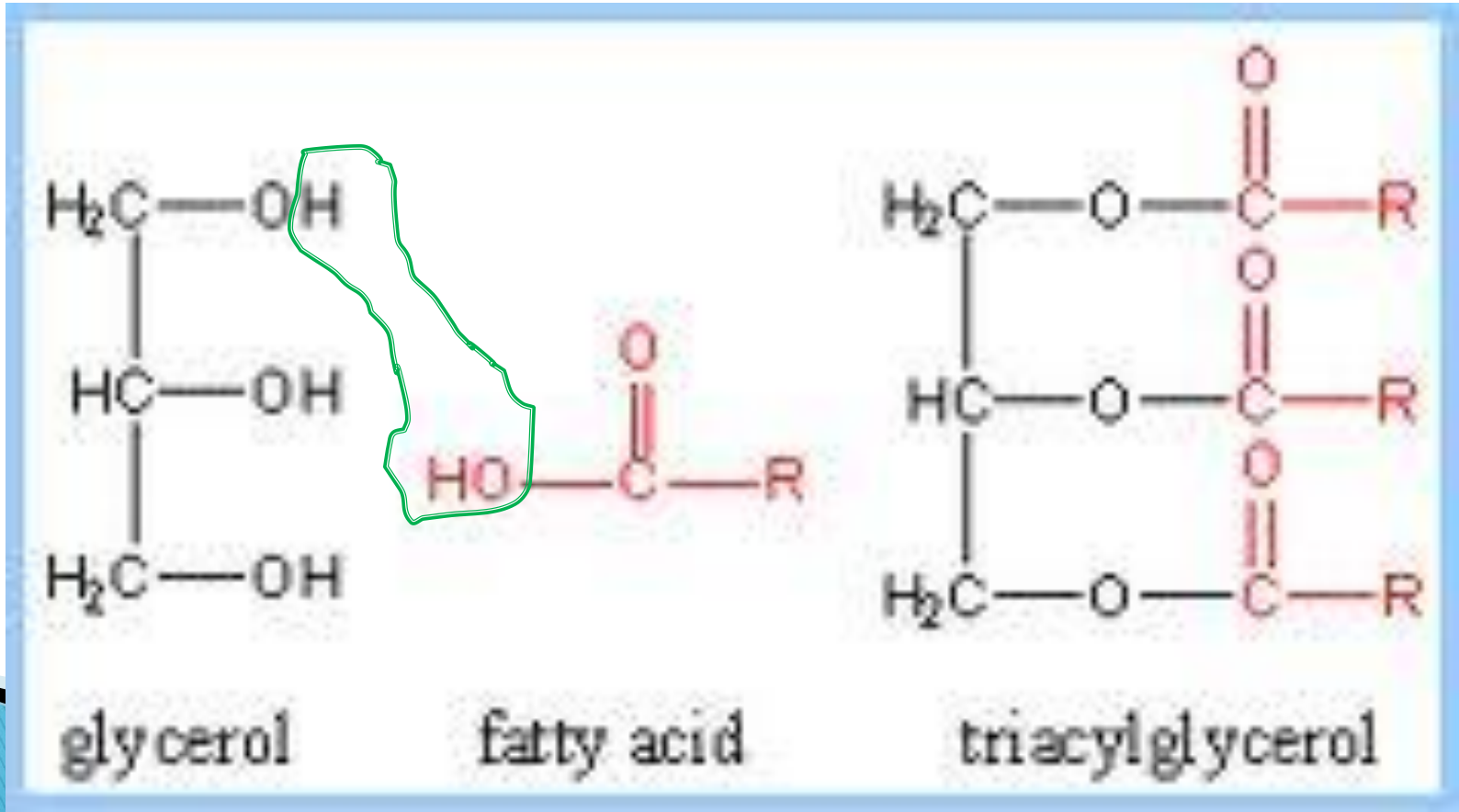
Classification of lipids?



2. Neutral esters of fatty acids and glycerol (Glycerides):

Chemistry:

- **Ester of fatty acids and tri-hydric alcohols (glycerol)**
- **They form this neutral lipids by esterification reaction**



Neurtral lipids?

Nomenclature:

- **The product can be named as acylglycerol or glyceride such as monoacylglycerol or monoglyceride**
- **Mono-, di- and tri- are used based on the number of fatty acids are esterified with the tri-hydric alcohol**
- **Number of carbons, where fatty acid molecules are added into the tri-hydric alcohol, are also used before the name of these lipids such as 1-Monoacylglycerol, 2-Monoacyl glycerol, 1,3-Diacylglycerol etc.**

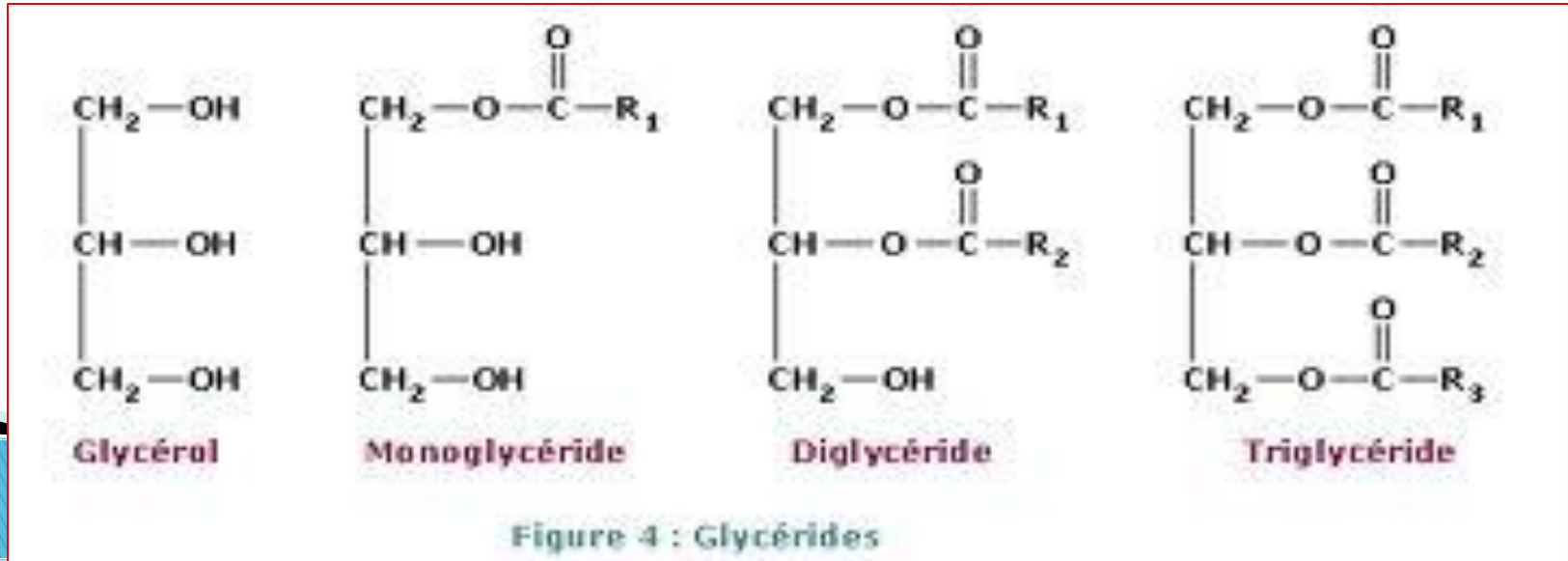


Figure 4 : Glycérides

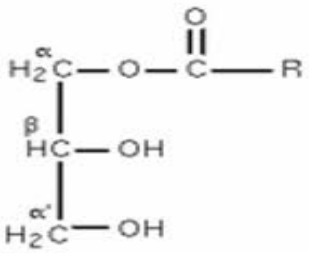
Classification of neutral lipids?

Based on the number of fatty acids esterified with the tri hydric alcohol, neutral lipids are classified into three classes:

i) Monoacylglycerol or Monoglyceride

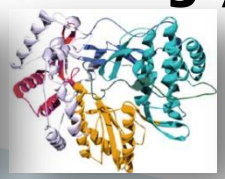
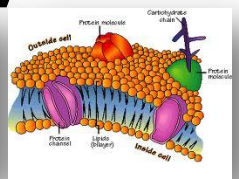
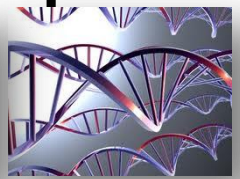
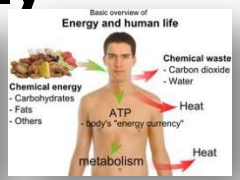
ii) Diacylglycerol or Diglyceride

iii) Triacylglycerol or Triglyceride



i) Monoacylglycerol or monoglyceride (MG):

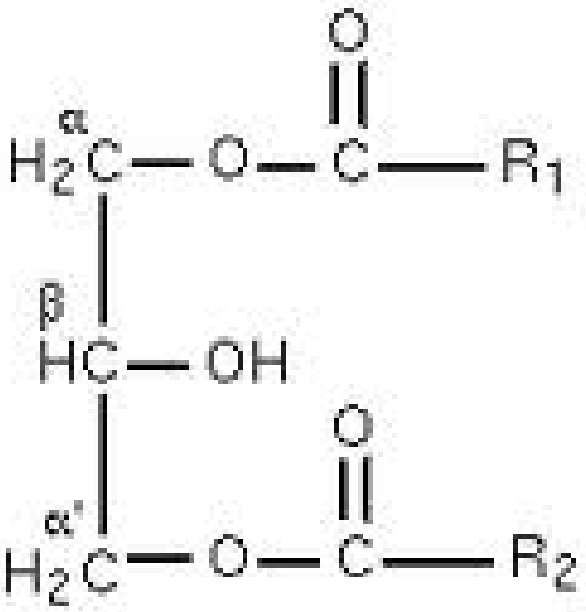
- **When only one fatty acid molecule esterified with the anyone of the carbons of tri-hydric alcohol is called monoacylglycerol or monoglyceride such as 1, 2, or 3-Monoacylglycerol or 1,2, or 3-Monoglyceride**
- **The hydroxyl (-OH) groups present in the carbon number 1, 2 and 3 are called primary, secondary and tertiary hydroxyl groups and their respective carbons are called α, β, and γ carbon**
- **So, if a fatty acid molecule esterified with the carbon-1, 2 or 3 that is also called α, β, or γ-monoglyceride respectively**

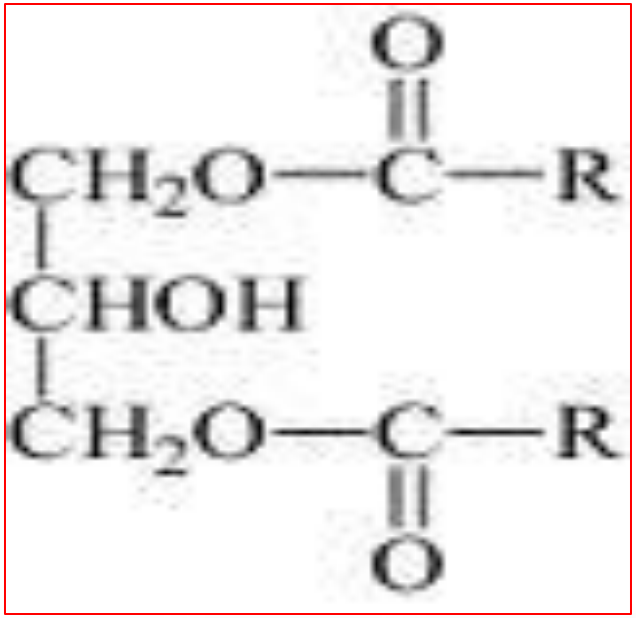






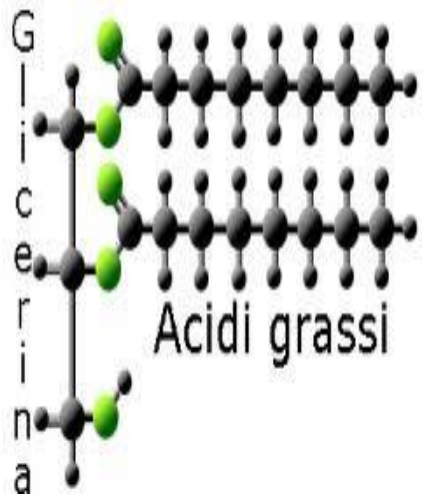
Classification of neutral lipids?

ii) Diacylglycerol (DAG) or diglyceride (DG):

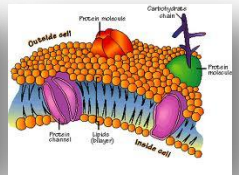
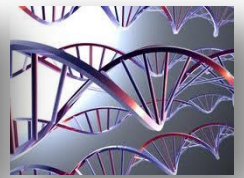
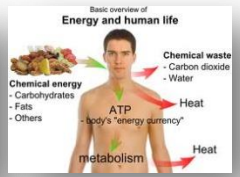
- When two fatty acid molecules are esterified with any two carbons of tri-hydric alcohol is called diacylglycerol or diglyceride such as 1,3-diacylglycerol or 1,3-diglyceride
- Two fatty acid molecules may or may not be the same







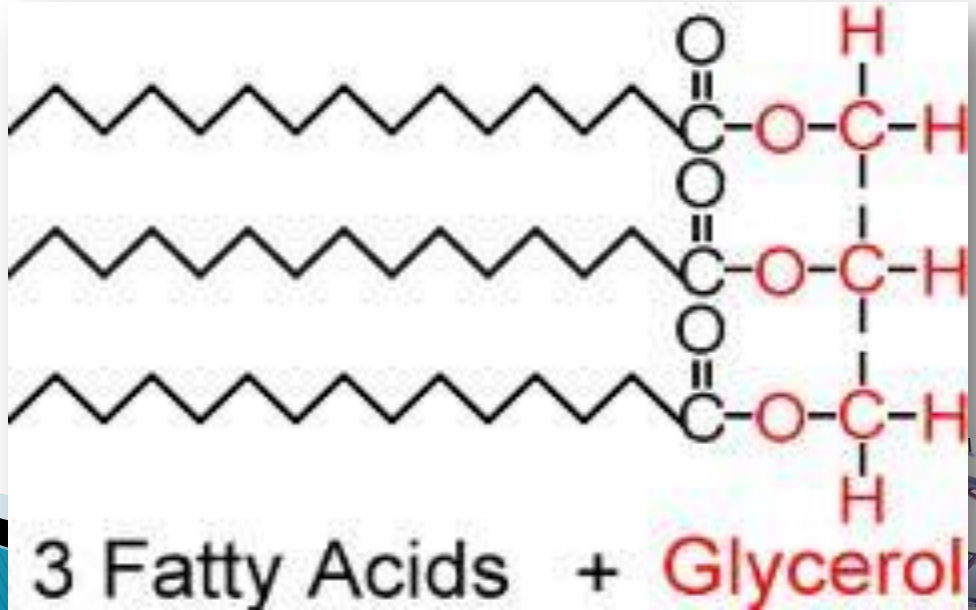


Classification of neutral lipids?

iii) Triacylglycerol (TAG) or triglyceride (TG):

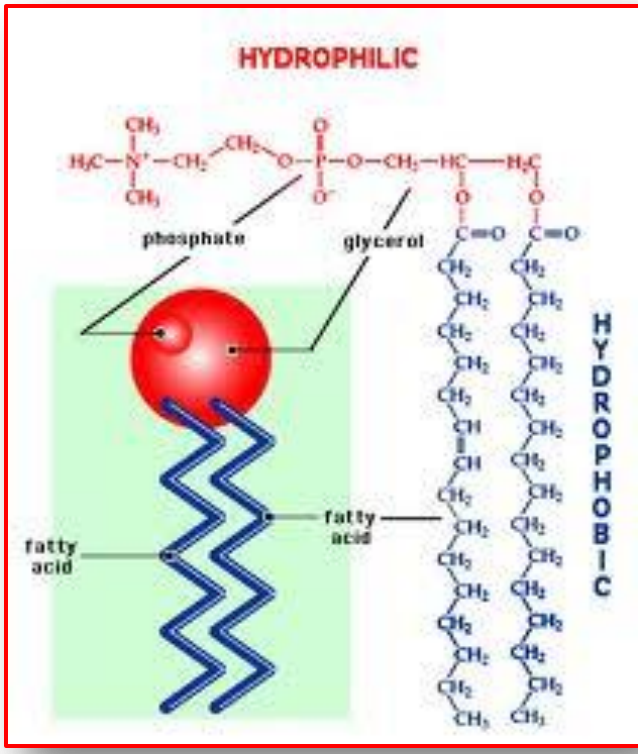
- When three different or same fatty acid molecules are esterified with a tri-hydric alcohol that is called triacylglycerol or triglyceride
- This is the most widely available neutral lipid in the animal system (95% of the total lipid in our body)
- Animal fats are mostly consist of esters of palmitic, stearic, palmitoleic and oleic acids with glycerol



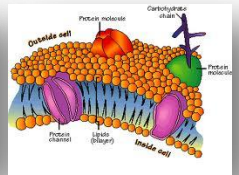
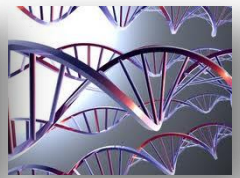
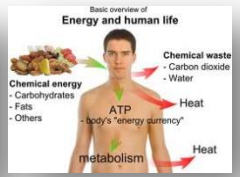
Classification of lipids?

3. Ionic esters of fatty acids and glycerol (Phospholipids):

- Phospholipids are the ionic esters of
  - glycerol
  - fatty acid
  - phosphoric acid and
  - a base
- They have a polar head and a non-polar part in their structure so they are **AMPHIPATHIC** in nature
- Generally **saturated fatty acids esterified with the carbon 1 & 2 and unsaturated fatty acids with carbon 2** of glycerol molecule
- Phosphoric acid binds with the hydroxyl group of carbon 3 and a base is linked with the phosphoric acid molecule



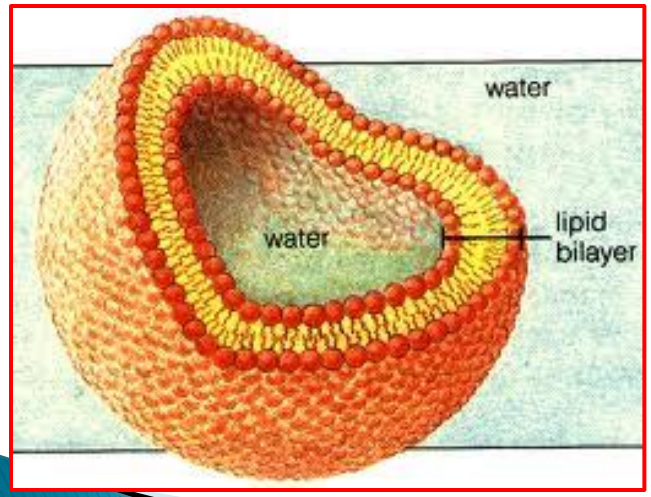


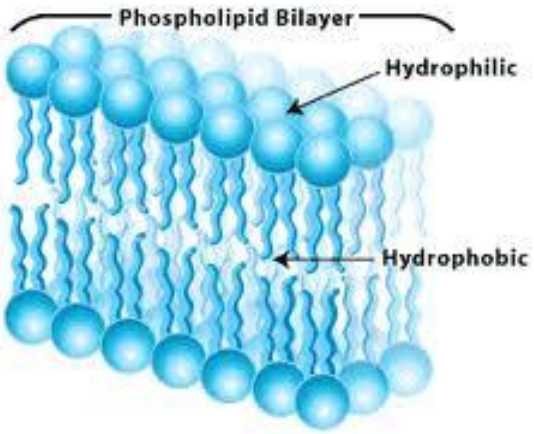




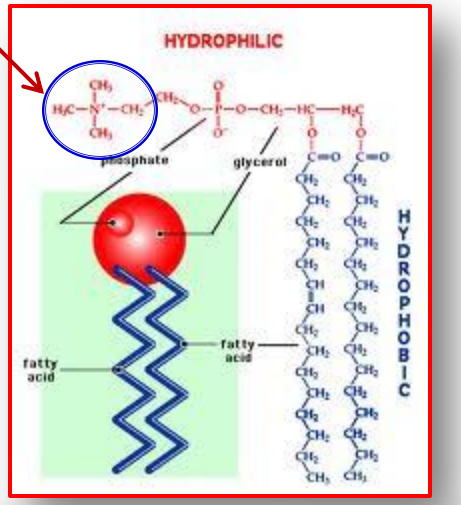
Class of Phospholipids?

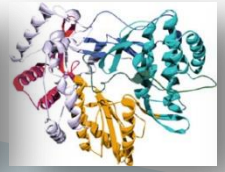
Lecithin:

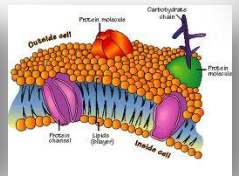
- Although triglycerides are most abundant lipids in animals and plants but they are not found in biological membranes.
- Lecithin is the most abundant lipids in biological membranes and lipoproteins of animals and plants.
- The name and function of the phospholipids are different mainly based on the types of the base.
- Example- Lecithin is called Phosphatidylcholin

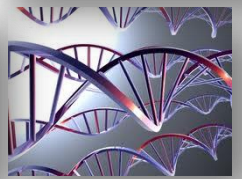


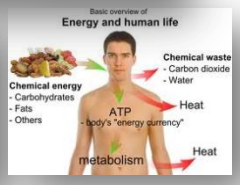




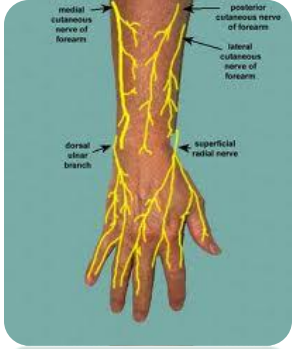






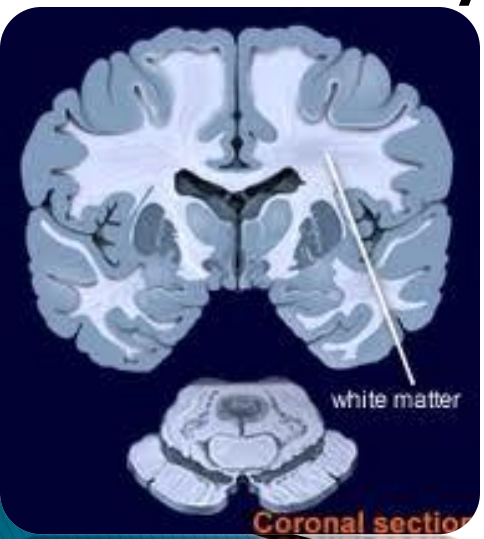


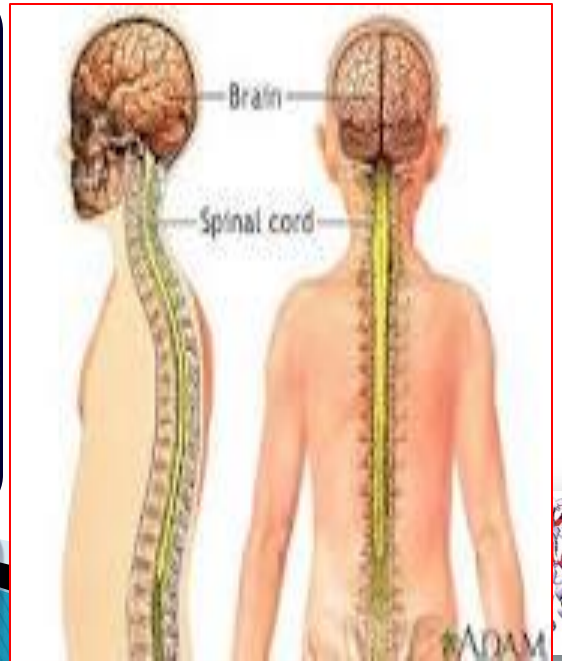
Class of Phospholipids?

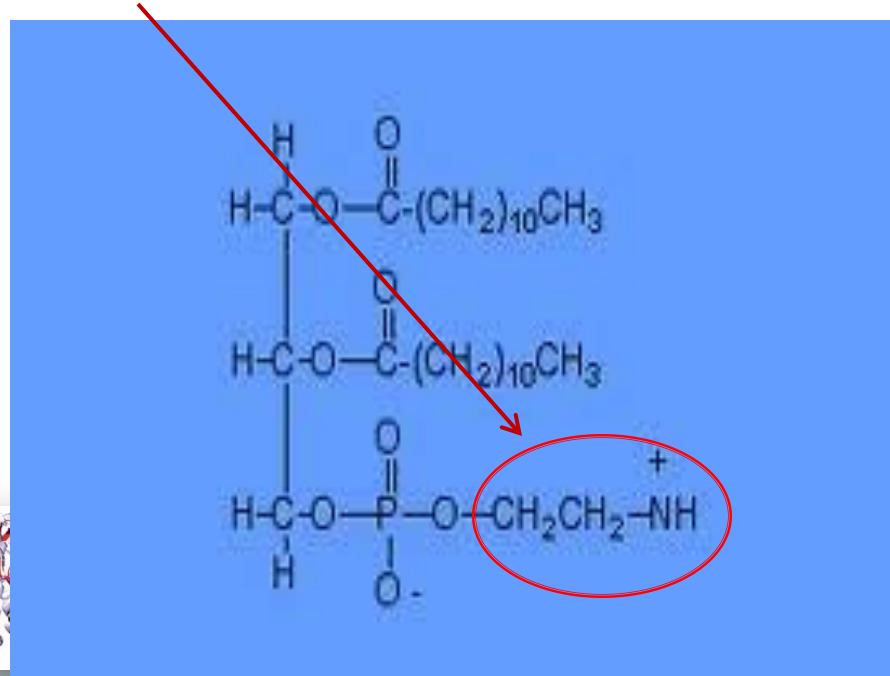


Cephalin:

- Less abundant than Lecithins in the biological system
- Present mainly in the central nervous system e.g. white matter of brain, spinal cord, neural tissues and nerves.
- Whereas lecithin is the principal phospholipid in animals, cephalin is the principal one in bacteria.
- Contains a ethanolamine base in their structure
- Chemically called phosphatidyl ethanolamine



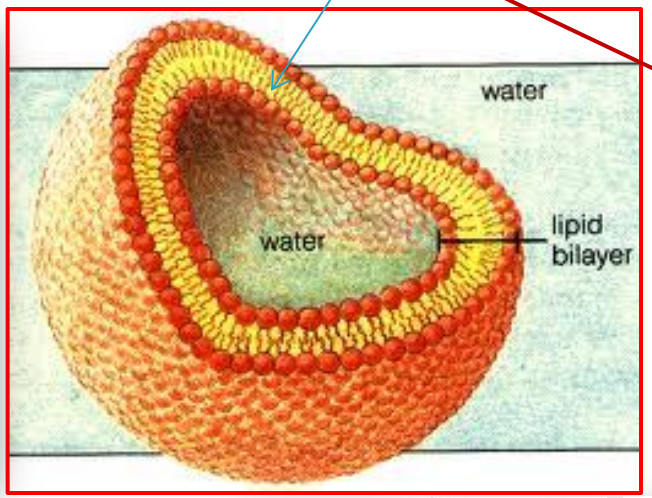


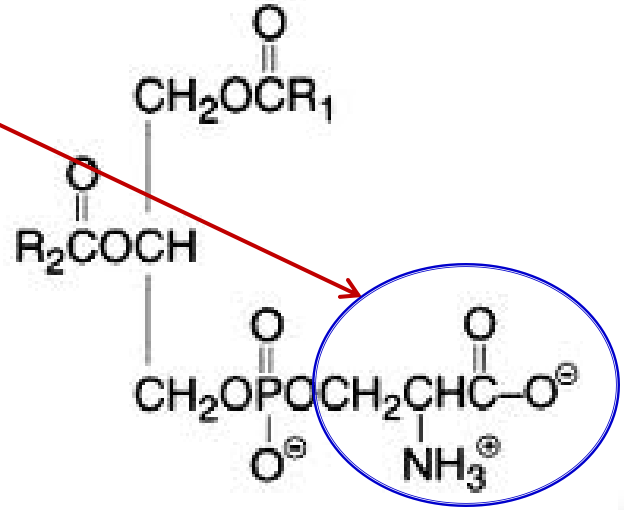


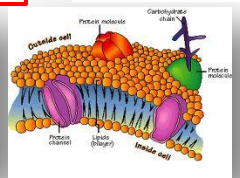
Class of phospholipids?

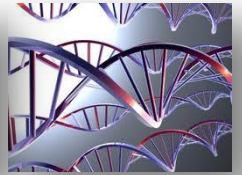
Phosphatidylserine:

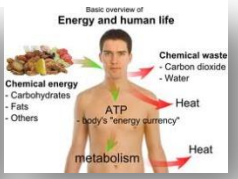
- Originally isolated from bovine brain but now-a-days isolating from soybean although they are not exactly the same
- Present in the inner side of cell membrane and beneficial to quickly recover from sports or exercise related injury
- Contains a serin amino acid as a base in their structure so they are called phosphatidyl serine











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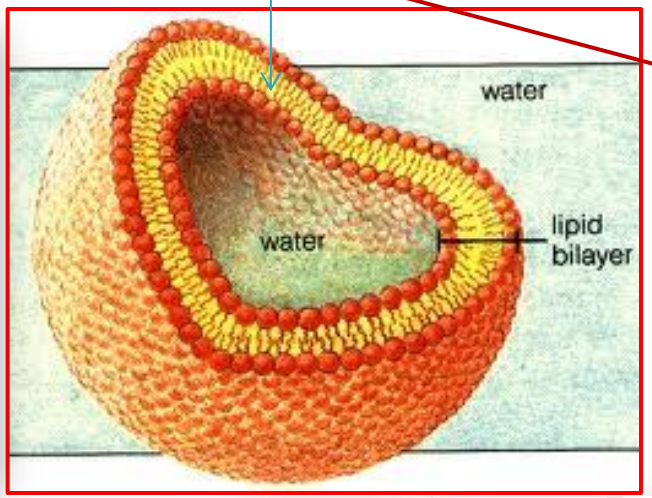
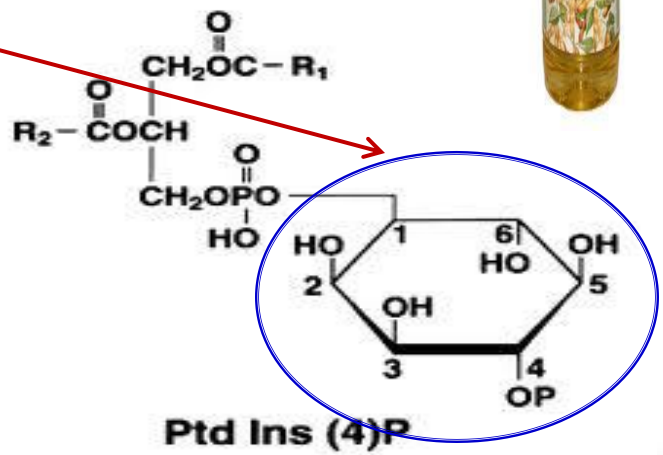
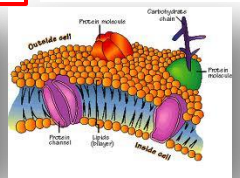
Class of phospholipids?

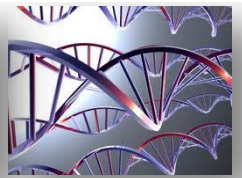
Lipositols (Phosphatidyl inositol):

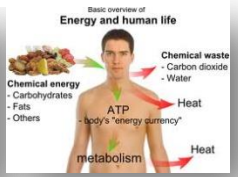
- Widely distributed in brain tissue, bacteria and soybean oil
- Present in the inner side of cell membrane
- Phosphorylated forms of phosphatidylinositol are called phosphoinositides and play important roles in lipid signaling, cell signaling and membrane trafficking.
- Contains a myo-inositol (a sugar alcohol) as a base so it is called phosphatidyl inositol



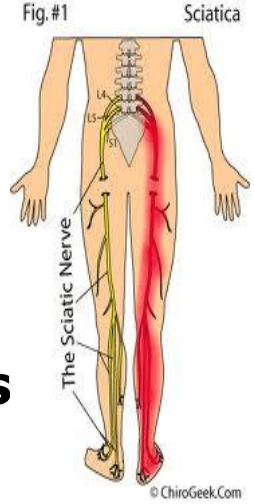






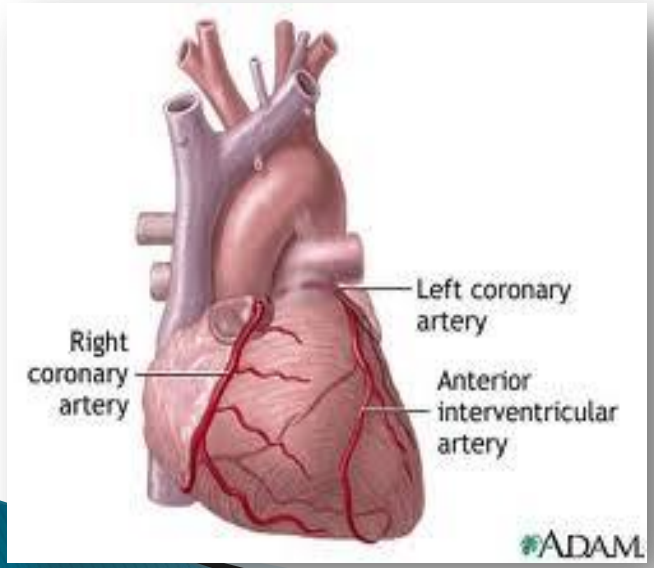


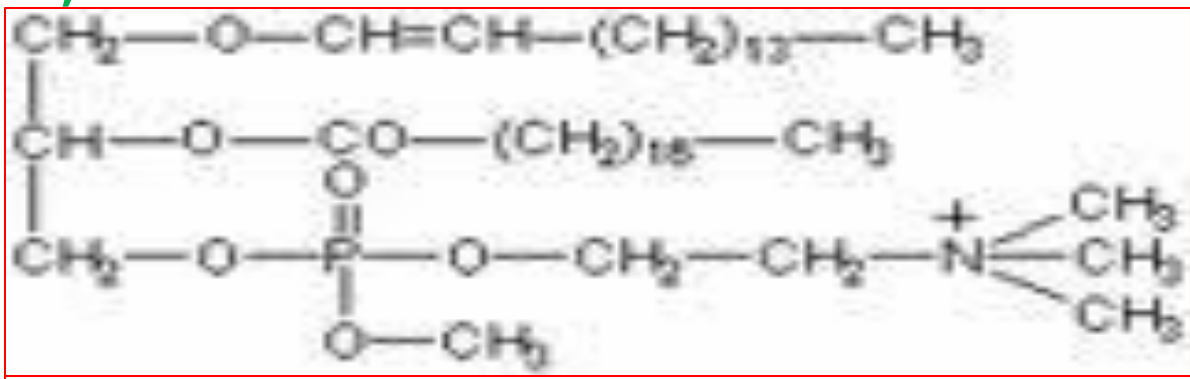
Class of phospholipids?

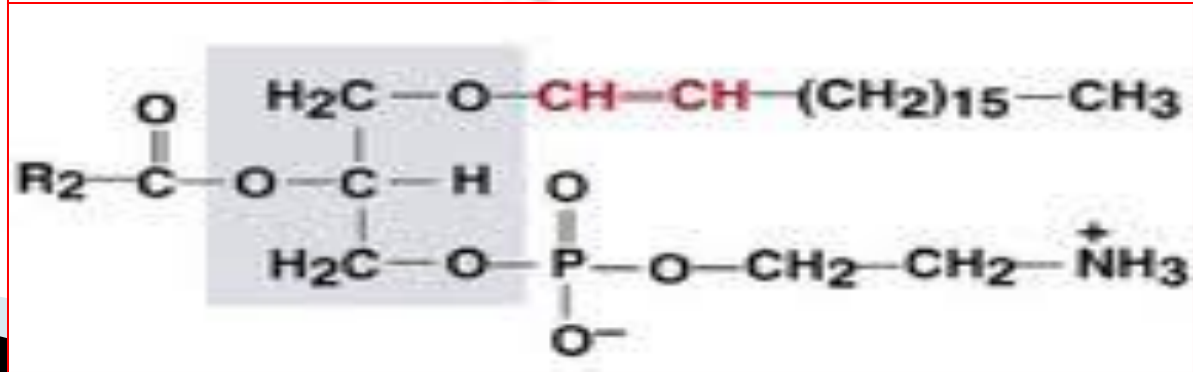


Plasmalogens:

- Present in the brain and heart tissues and in low concentration in non-animal tissues
- This is an exceptional phospholipids
- The fatty acid chain in the carbon 1 of glycerol is replaced by an α, β-unsaturated ether
- It may contain choline, ethanolamine or serine as its base







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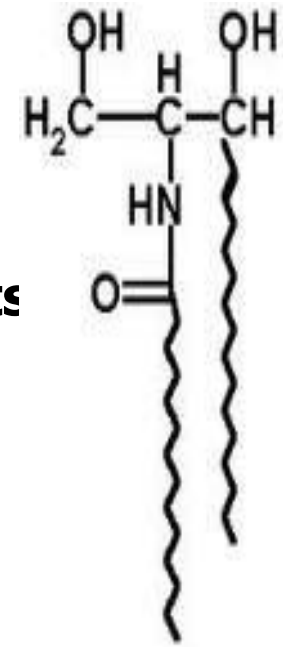
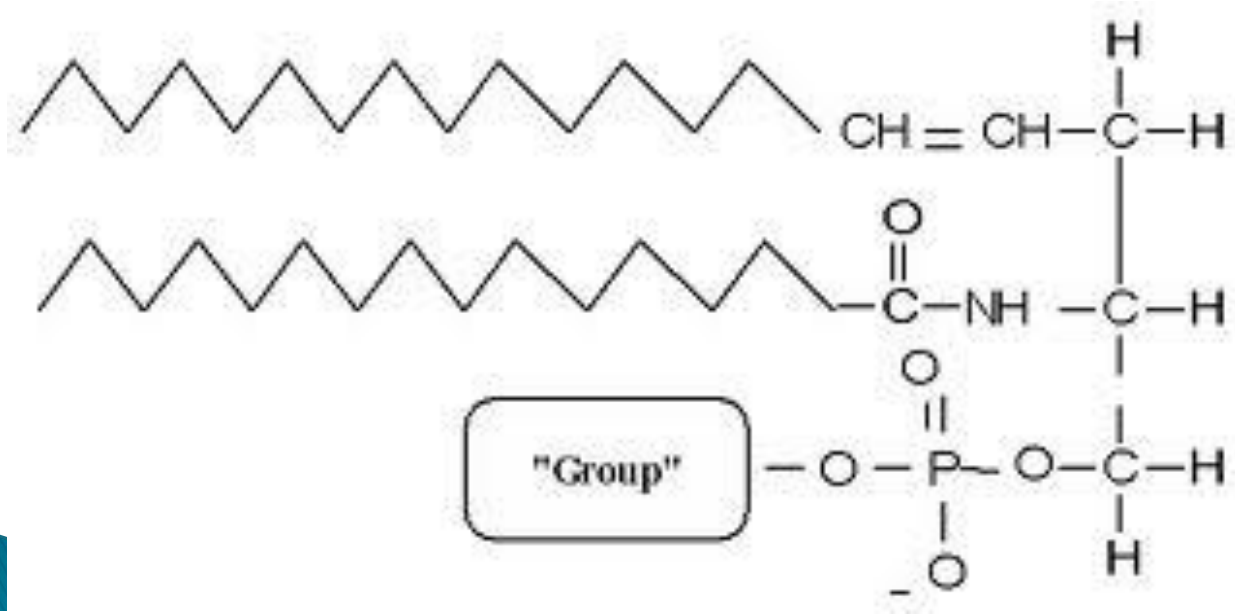
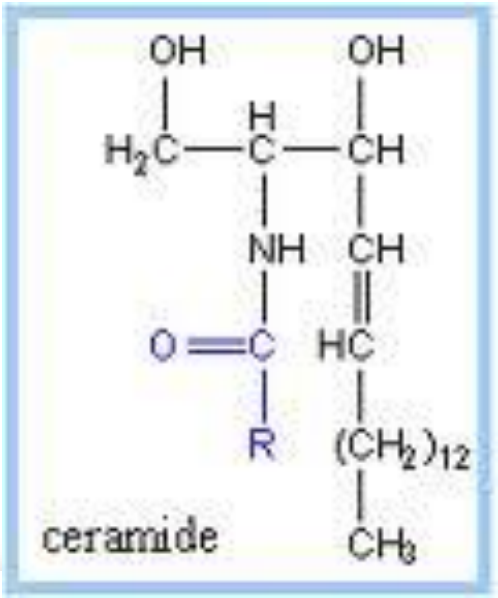
Classification of lipids?

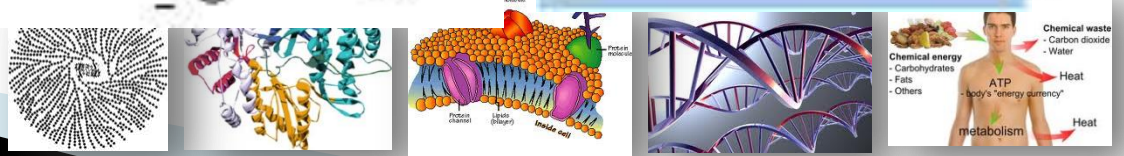


4. Lipids without glycerrol (Sphingolipids):

- **These lipids are also the major membrane components**
- **Most sphingolipids are the derivatives of C_{18} amino alcohols or sphingosine, whose double bond has the trans configuration**
- **N-Acetyl derivatives of sphingosine are known as CERAMIDE**

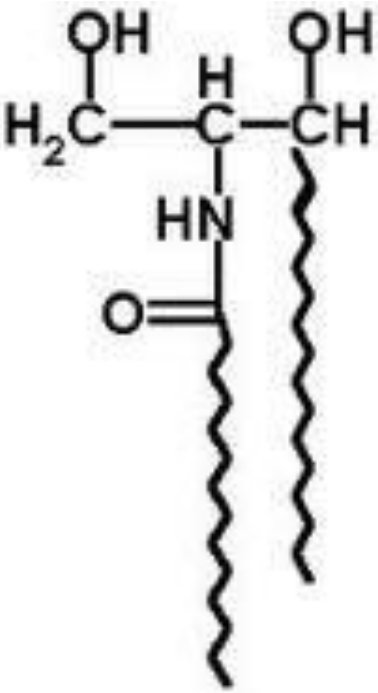


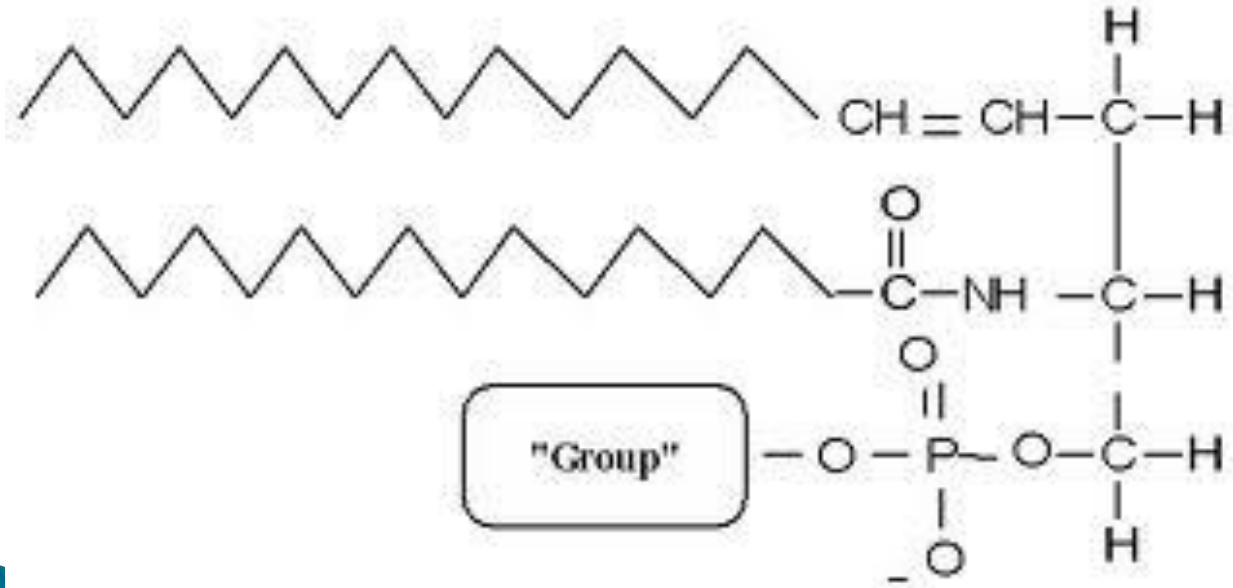


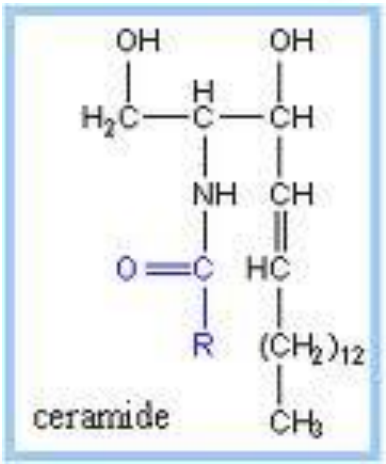


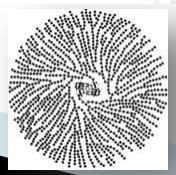
Sphingolipids?

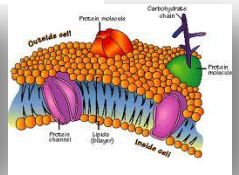
- These kinds of lipids are mainly composed of
  - A long chain fatty acid
  - A long-chain amino alcohols such as – sphingosine or one of its derivative and
  - A polar head group of a phosphate and a base

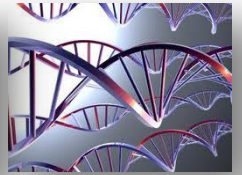


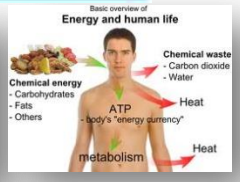




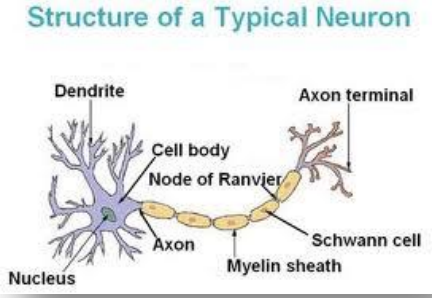






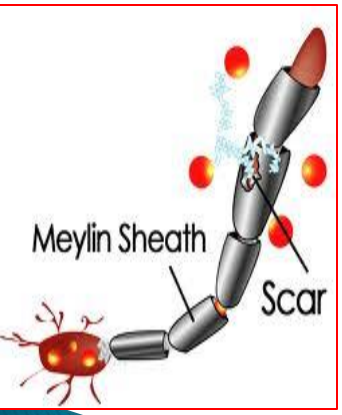


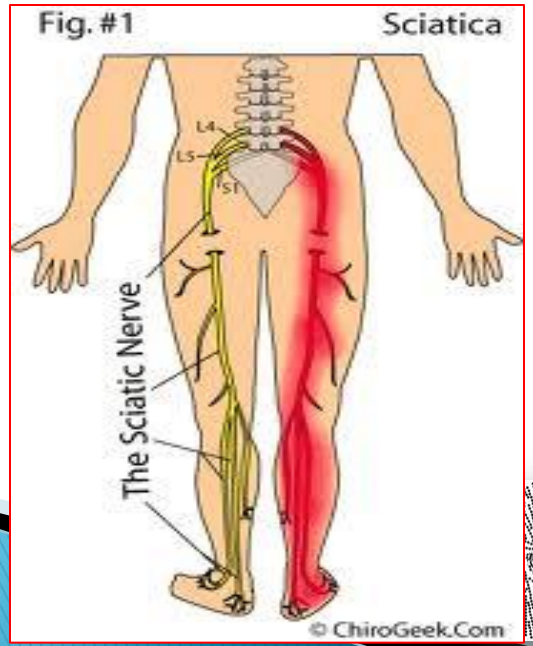
Sphingolipids?

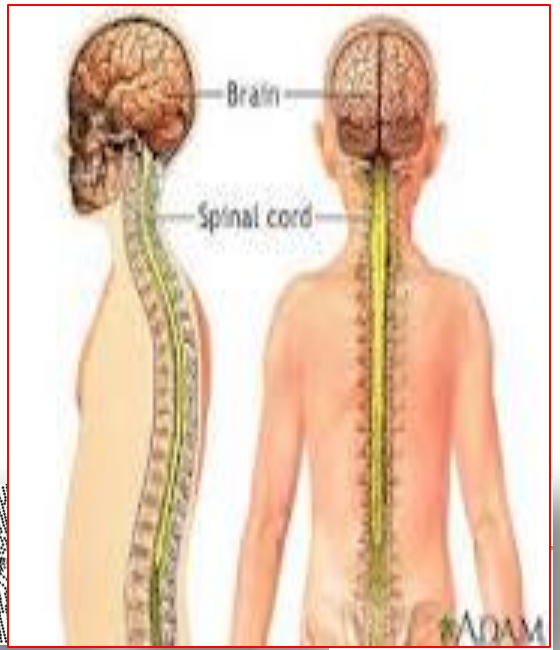


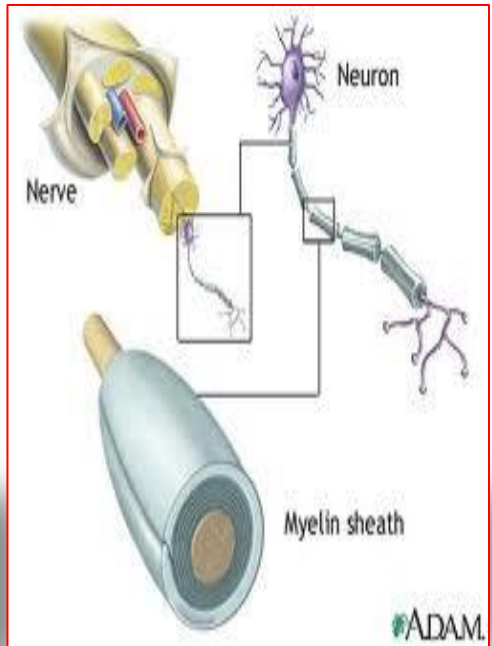
Sphingomyelin:

- It is a phosphoryl choline derivative of ceramide
- Mainly located in the nerve tissues but also found in blood (lipo-proteins)
- They are abundant in the myelin sheath, a protective multilayer for insulation of cells of central nervous system
- Also located in the nerve of the spinal cord
- They accounts for up to 25% of total lipid in human myelin









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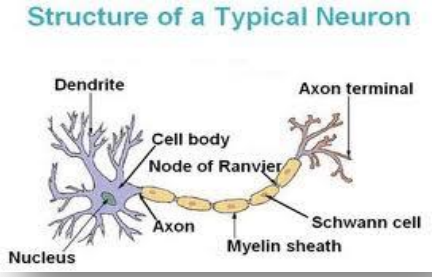
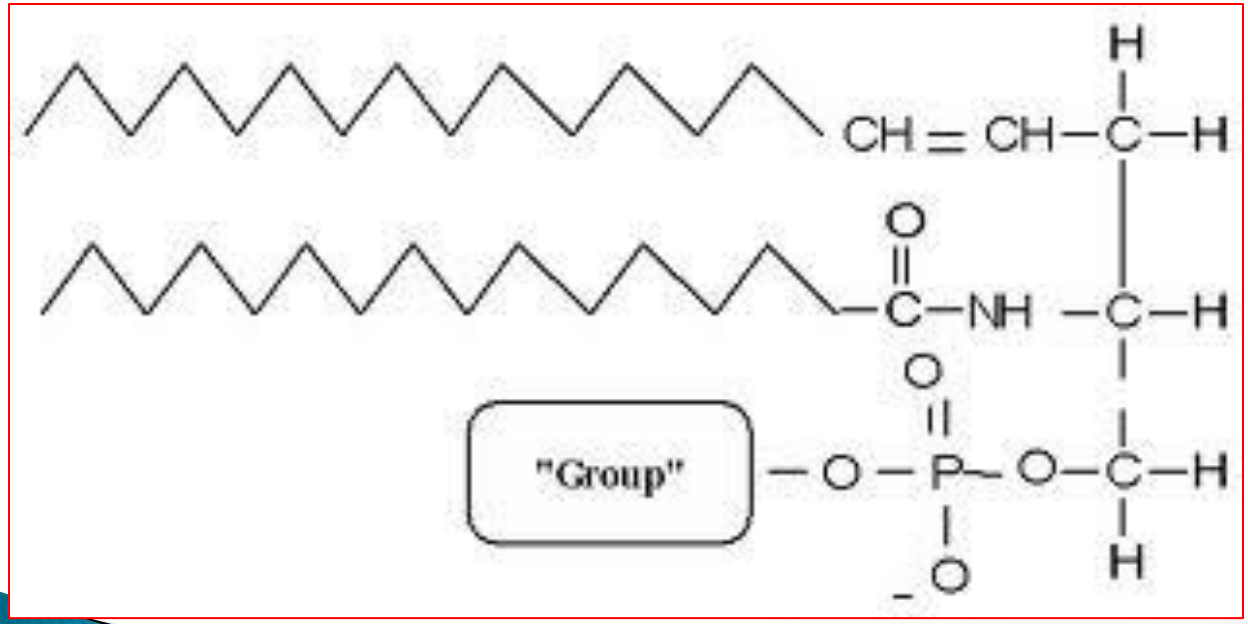
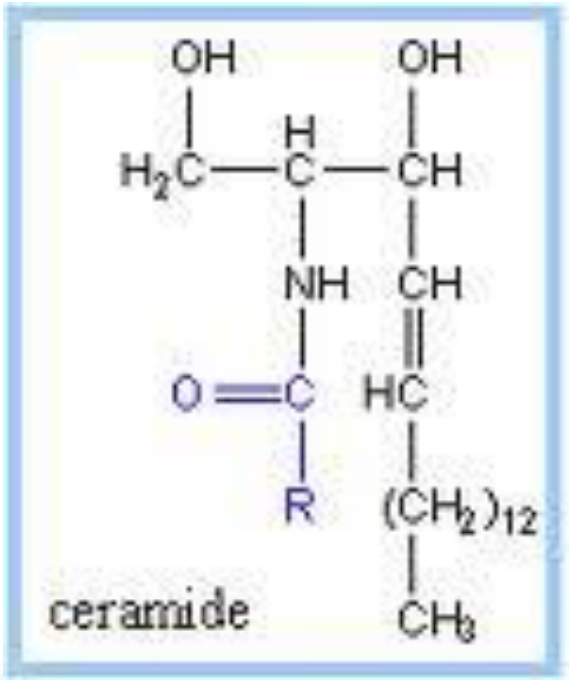
Sphingolipids?

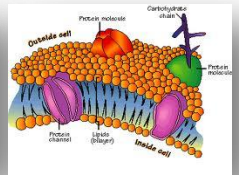


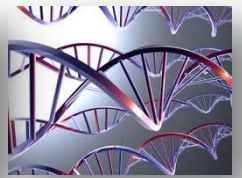
Synthesis of sphingomyelin:

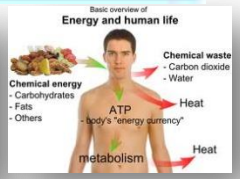
- **The fatty acid and long-chain amino alcohol (Sphingosine) together constitute a CERAMIDE**
- **Finally, a polar head group of phosphate and choline is connected to the fatty acid part of ceramide to form sphingomyelin**











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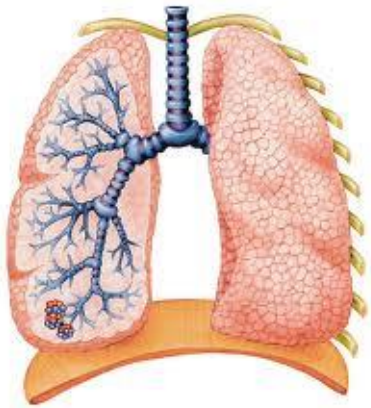
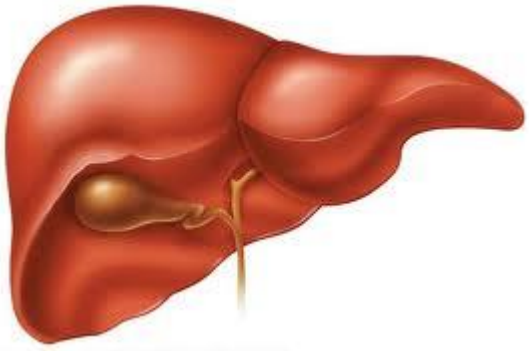
Clinical correlation - Sphingomyeline

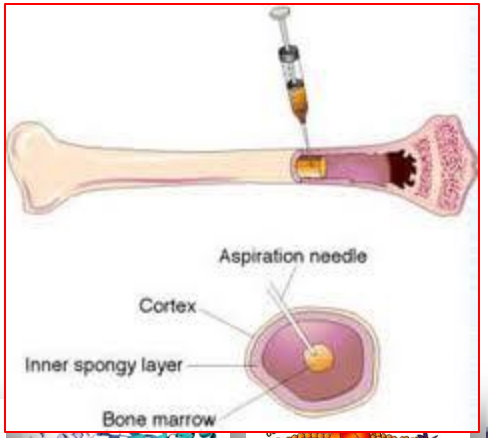
Niemann Pick Disease:

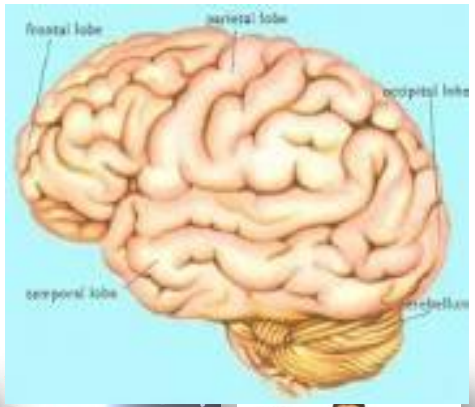
- **Sphingomyelins are hydrolyzed by an enzyme named sphingomyelinase to from a ceramide and phosphoryl choline**
- **Due to the inherited absence of this enzyme unused or extra lipids are deposited in our body what is called Niemann Pick Disease, a Lipid Storage Disease**
- **Lipid-laden cells (Foam cells) store in the lung, liver, bone marrow and brain which cause the enlargement of those organs**

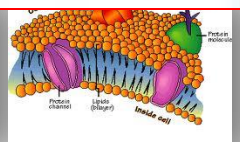
Sphingomyelin → X → Ceramide + Cholin –P

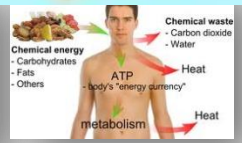












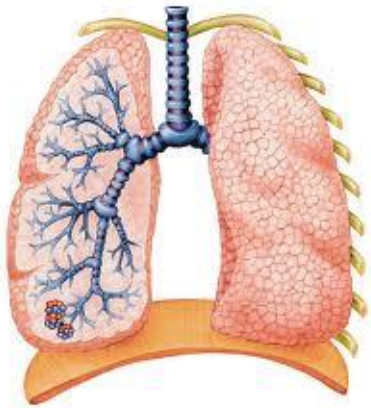
Clinical correlation - Sphingomyeline

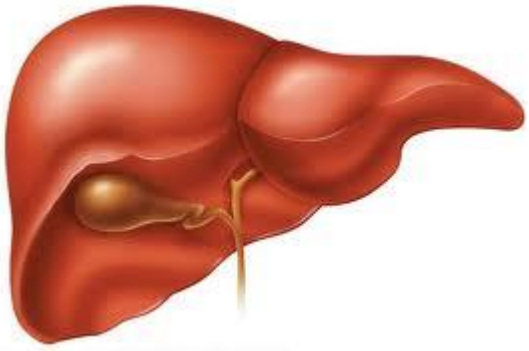
Symptoms:

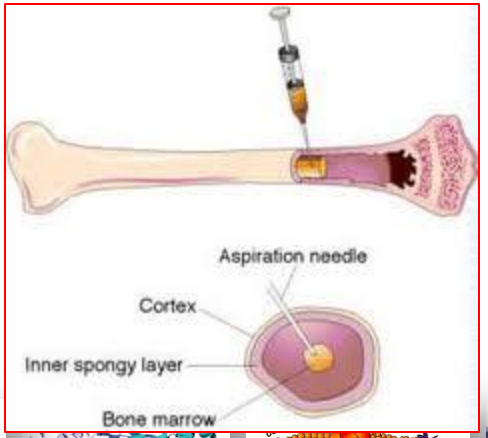
- Swelling of endothelial, mesenchymal and parenchymal cells of liver, lung, brain, bone marrow and spleen.
- Mental retardation, early death.

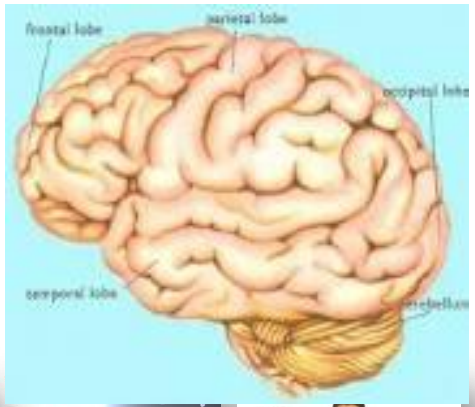
Treatments:

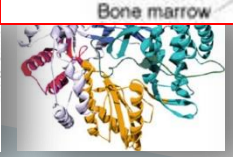
- No specific treatment. Organ transplantation, enzyme replacement and gene therapy are possible ways.

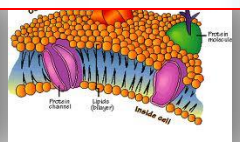


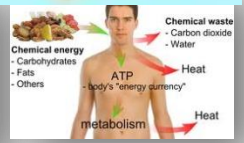








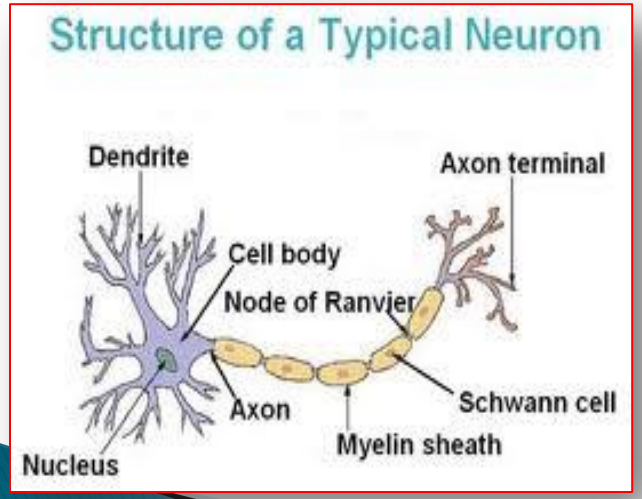


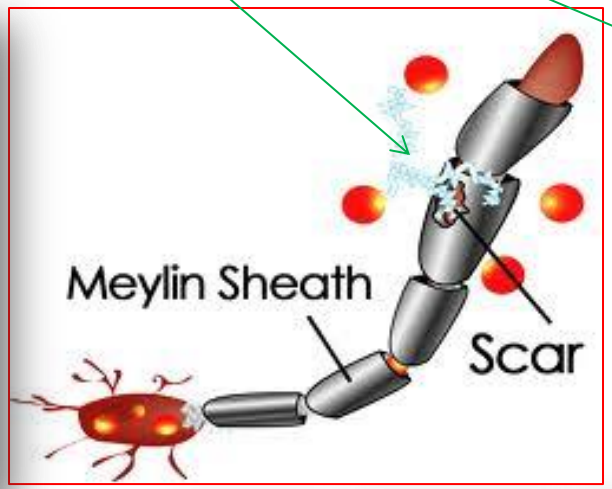


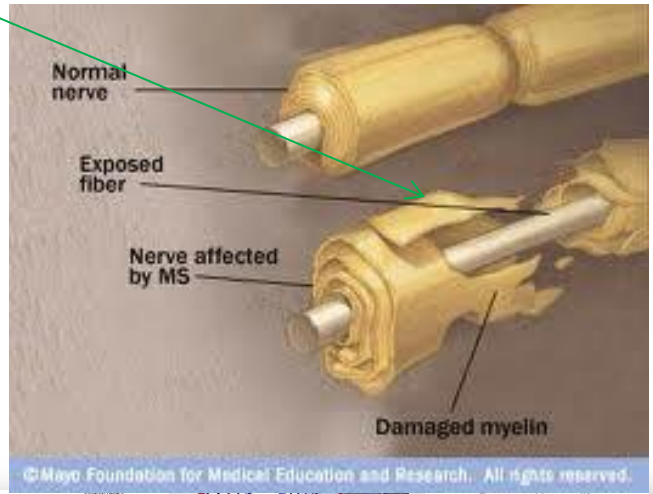
Clinical correlation - Sphingomyeline

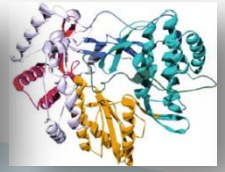
Multiple sclerosis:

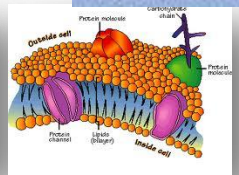
- It's an auto immune disease when immune system attacks the central nervous system and leading to plaques and lesions formation in the myelin sheath followed by demyelination
- Prevalent in young adults and more common in females
- The rate prevalence of this disease is 2-150 / 100 000 persons

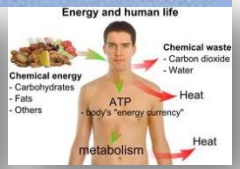








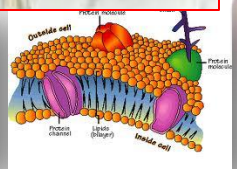


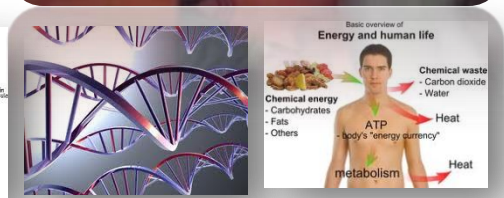


Multiple sclerosis

Symptoms:

- Fatigue, depression, cognitive impairment, unstable mood
- Lack of co-ordination, speech and vision problem
- Muscular weakness, pains, loss of sensation
- Abdominal discomfort, diarrhoea, constipation
- Irregular frequency of urination
- Involuntary movements of eye balls





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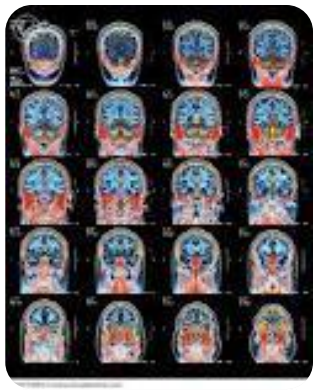
Multiple sclerosis

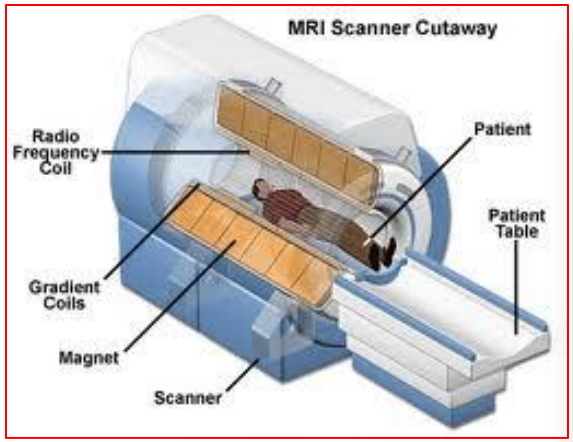
Diagnosis:

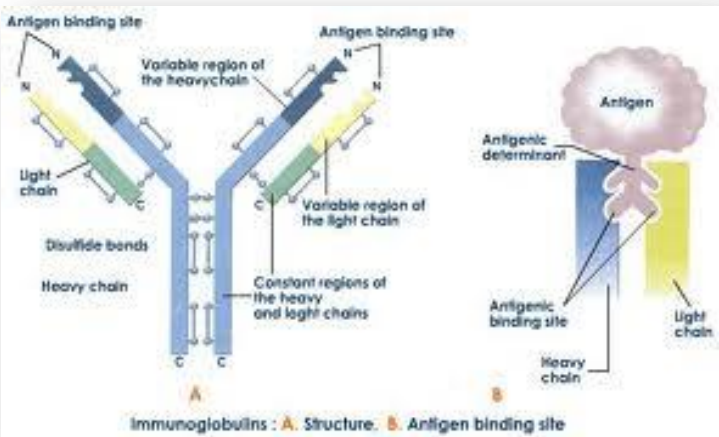
- Plaques or lesions in the white matter of the central nervous system and spinal cord can be detected by Magnetic Resonance Imaging (MRI)



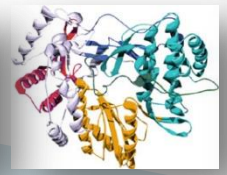
Treatments:

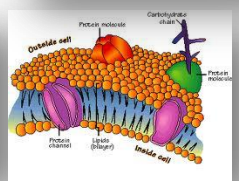
- No specific treatment is available
- Several countries started to treat with various immune suppressors such Interferon Beta 1a (IFNβ-1a) and IFNβ-1b

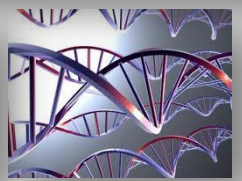


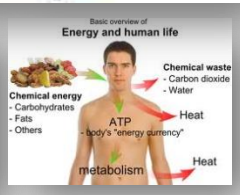


Immunoglobulins : A. Structure. B. Antigen binding site

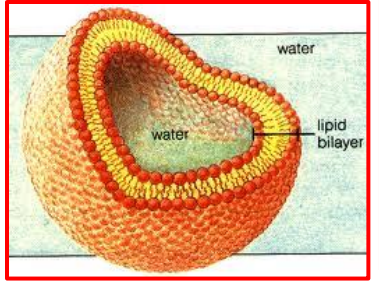


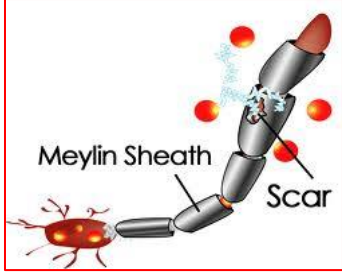






Glycolipids





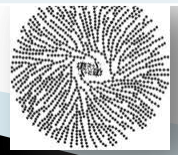
Combination of carbohydrate and lipid:

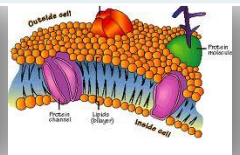
- **Normally present in the outer surface of the cell membrane**
- **They are also present in the myeline sheath of central nervous system and spinal cord**

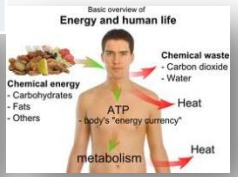
Classification:

- **Based on the chemical structure, Glycolipids are classified into two major and several sub-classes:**

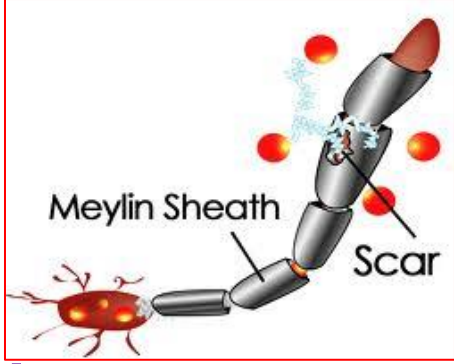
Glyceroglycolipids	Glycosphingolipids
i. Galactolipids ii. Sulfolipids	i. Cerebrosides - Glucocerebrosides - Galactocerebrosides
a. Gangliosides b. Globosides c. Sulfatides d. Glycosphosphingolipids	





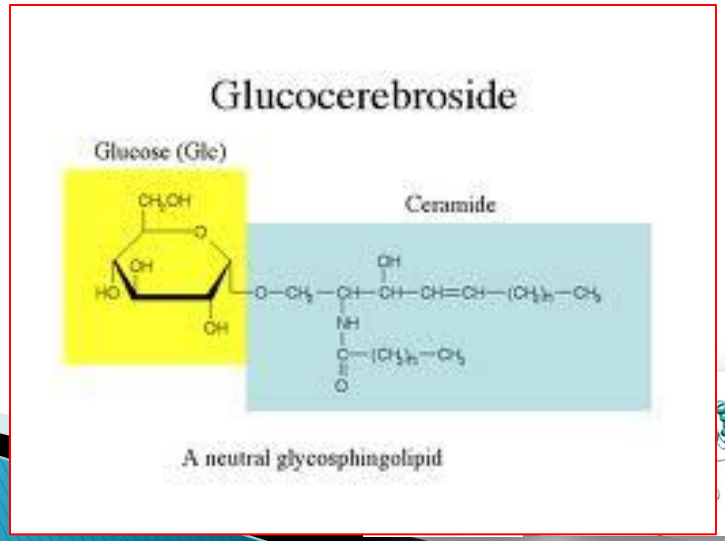


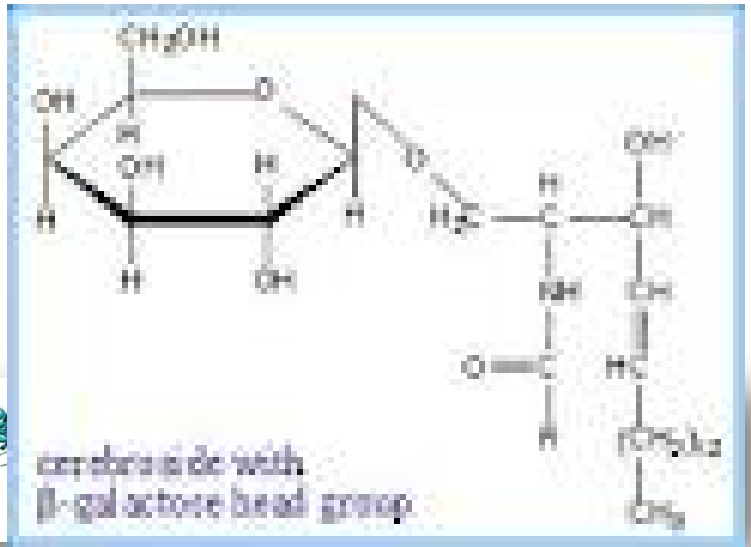
Glycolipids



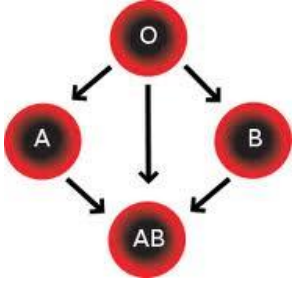
Cerebrosides:

- **Most abundant in the myelin sheath of nerves**
- **These are mainly a combination of ceramide and monosaccharides**
- **The C_1 of monosaccharide linked with the C_1 of ceramide in a β-linkage fashion**
- **Based on the type of monosaccharides attached with the ceramide, cerebrosides are classified into two sub-classes:**
  - **Glucocerebroside**
  - **Galactocerebrosides**



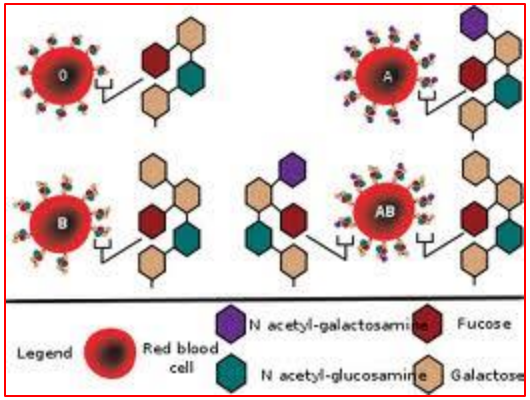


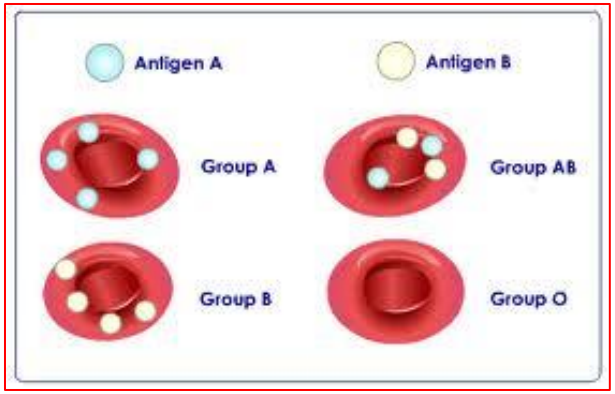
Clinical correlation



Cerebrosides:

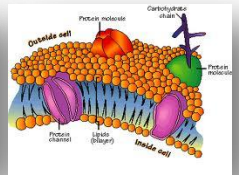
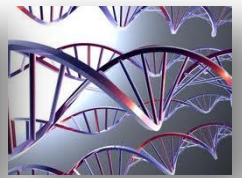
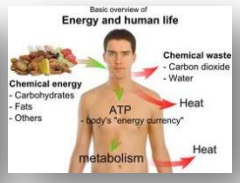
- **Further addition of monosaccharides to glucoscerebrosides converts to more complex glycosphingolipids**
- **For example, blood group antigens are oligosaccharides which protein or ceramide linked through their reducing end**
- **The different antigens have different antigenic determinants at their non-reducing end**





	Group A	Group B	Group AB	Group O
Red blood cell type	A	B	AB	O
Antibodies present	Anti-B	Anti-A	None	Anti-A and Anti-B
Antigens present	A antigen	B antigen	A and B antigens	None



Clinical correlation - cerebrosides

Antigen A:

Fuc α1,2 – Gal β1,3 – GalNAcα – Gal β1,4 – Glucose β1,1 - Ceramide

GalNAc α1,3

Antigen B:

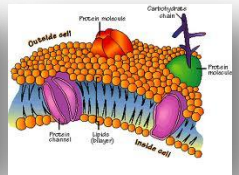
Fuc α1,2 – Gal β1,3 – GalNAcα – Gal β1,4 – Glucose β1,1 - Ceramide

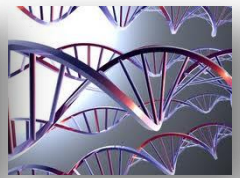
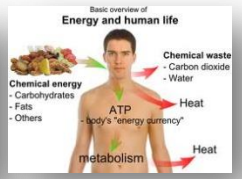
Gal α1,3

Antigen O or H:

Fuc α1,2 – Gal β1,3 – GalNAcα – Gal β1,4 – Glucose β1,1 - Ceramide





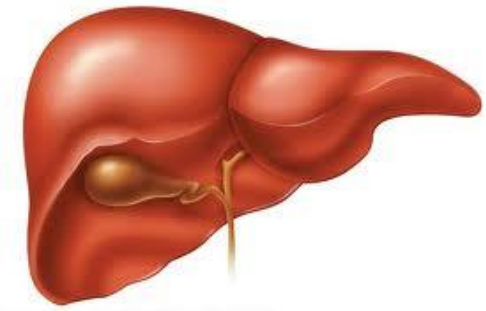
Clinical correlation - cerebrosides

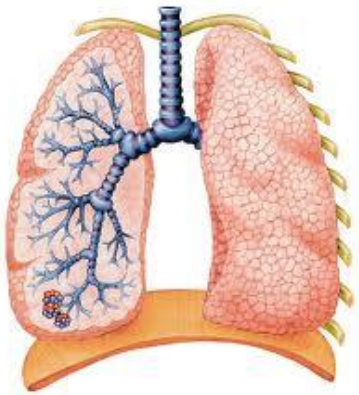
Gauchers Disease

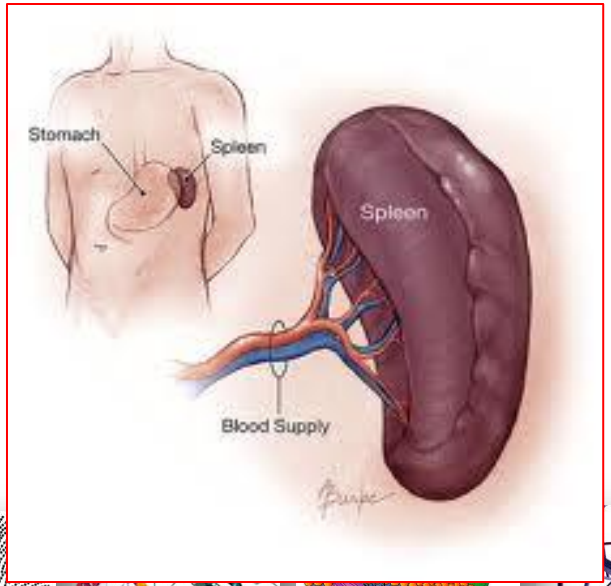
- A lipid storage disease and almost like Niemann Pick Disease
- Due to inherited deficiency of glucocerebrosidase enzyme, glucocerebroside cannot be broken to cerebroside and glucose as a results these lipids are deposited in the several organs such lung, liver, spleen, brain etc.

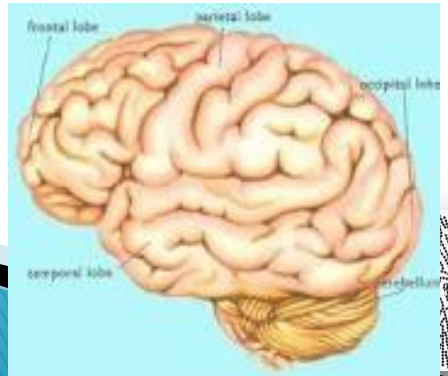
Gluco-cerebrosides

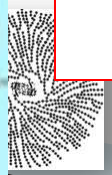
Cerebroside + Gluoose

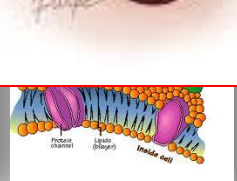


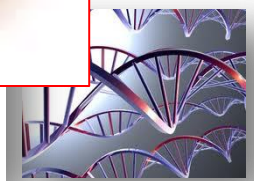


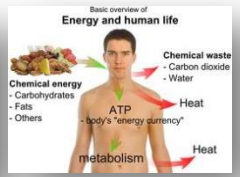












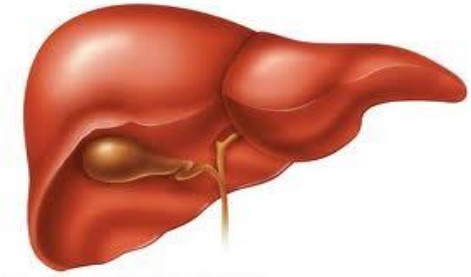
Clinical correlation - cerebrosides

Sign and symptoms:

1. Megaly: Painless hepatomegaly, spleenomegaly

2. Hypersplenism:

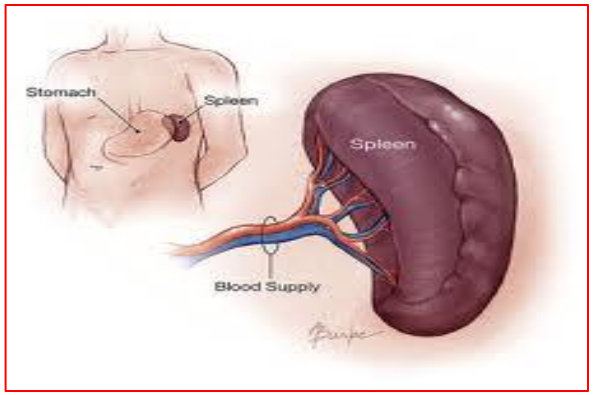
Rapid destruction of blood cells leading to anaemia, neutropenia, thrombocytopenia leading to increase risk of infection and bleeding

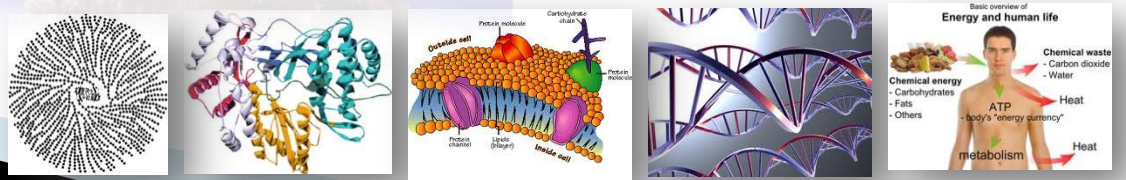


3. Liver cirrhosis, mental retardation, osteoporosis, yellowish-brown skin etc.

Treatments:

- Enzyme replacement
- Organ transplantation
- Blood transfusion
- Gene therapy
- Antibiotics

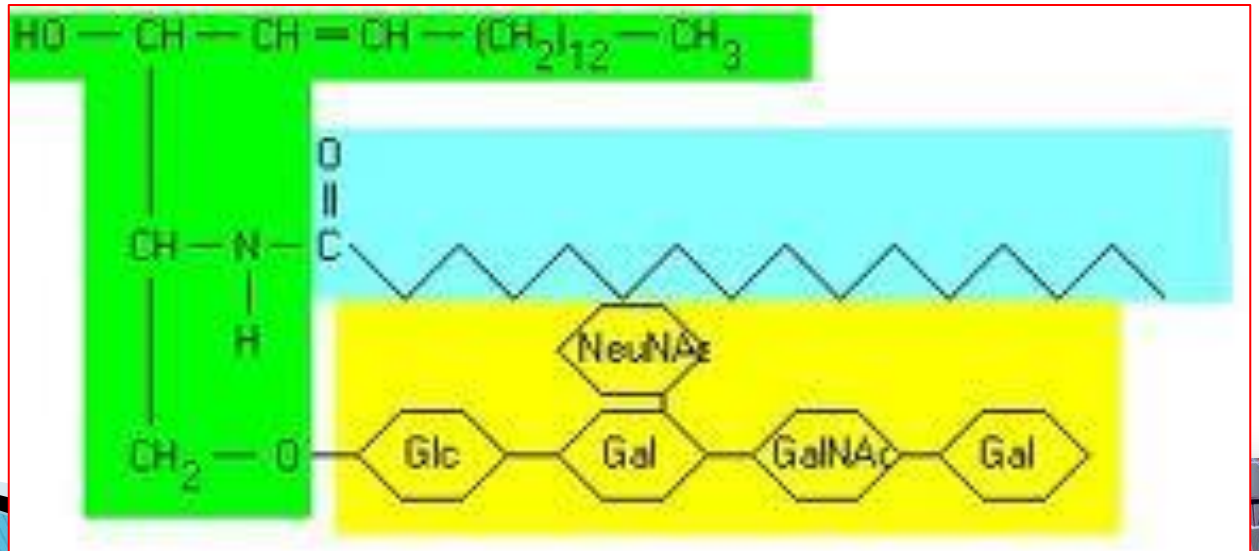


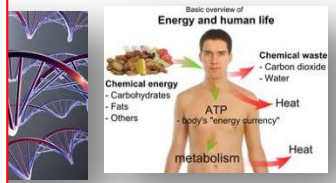


Glycolipids

Gangliosides:

- **Mainly located in the basal ganglion cells of central nervous system so they are called gangliosides**
- **Also present in the plasma membrane of the many extraneural cell types such as spleen**
- **It looks like cerebrosides but in addition to D-Glucose or D-Galactose several other carbohydrates such as NAc-Glc, NAc-Gal and N-acetyl Neuraminic Acid (NANA) are also attached**

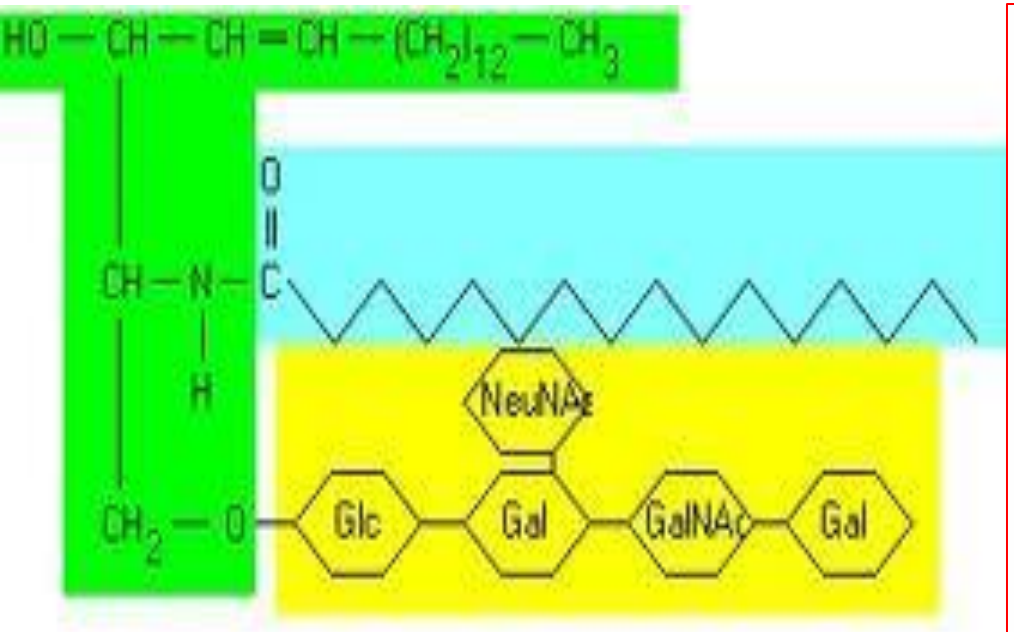


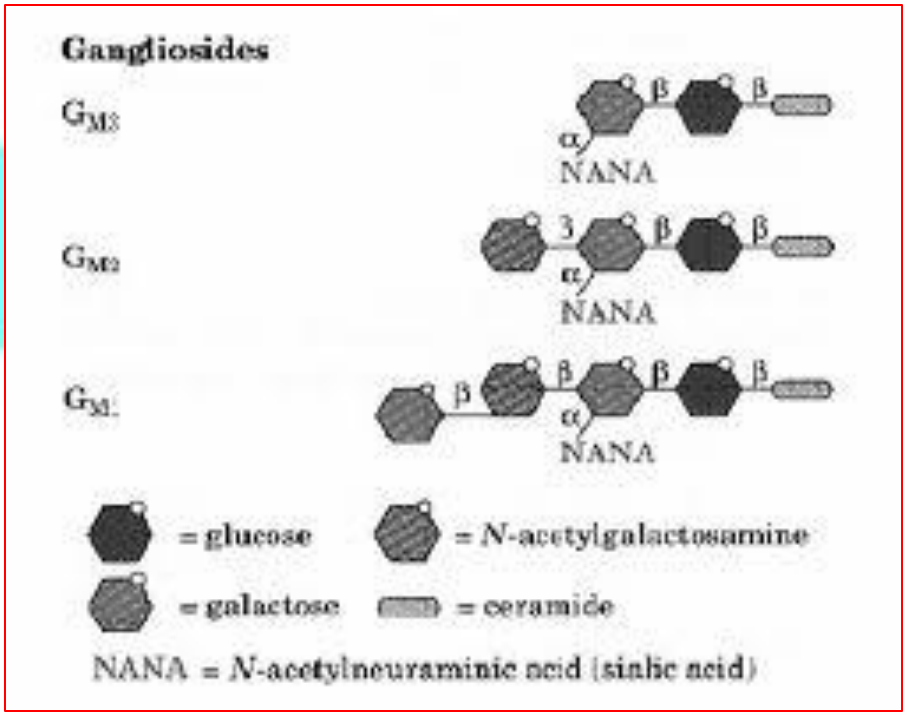


Glycolipids

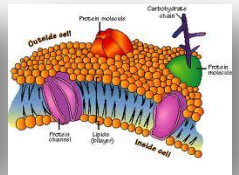
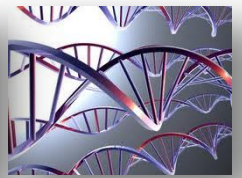
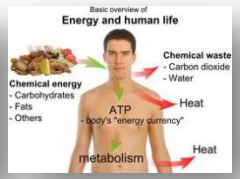
Nomenclature:

- **Name ganglioside is abbreviated to G**
- **Based on the number NANA, gangliosides are written as G_{M2}, G_{D1} etc**





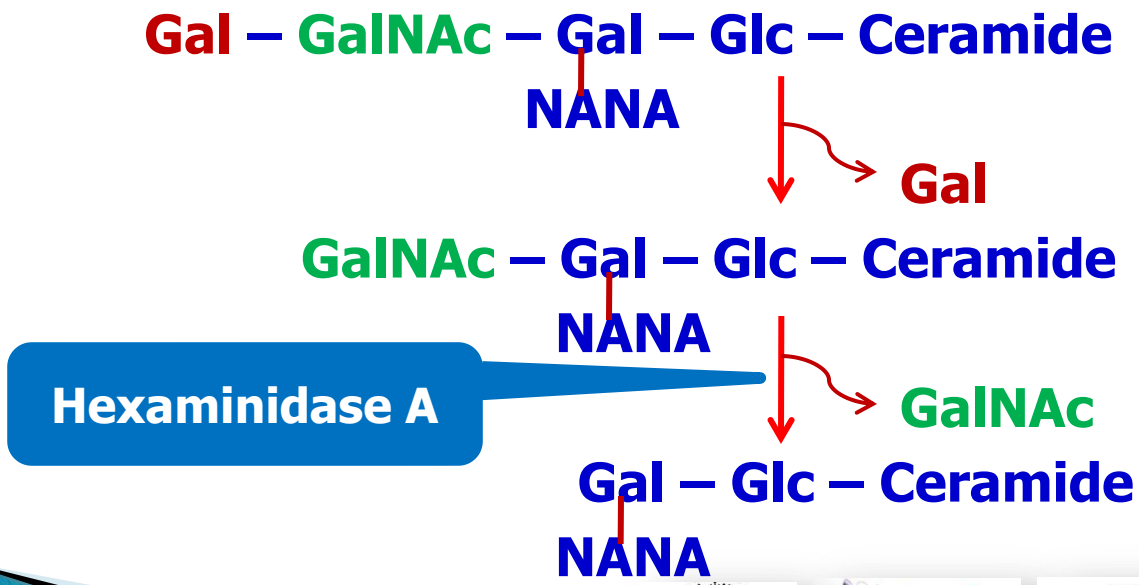


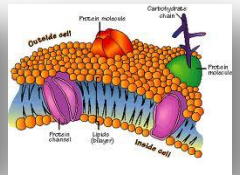
Clinical correlation - Gangliosides

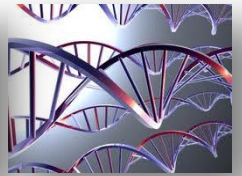
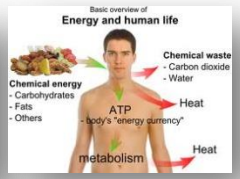
Tay Sach's Disease:

- **Inherited disorder characterized by early death (2-3 years old)**
- **This disease results from a lack of enzyme, hexaminidase A, involved in the degradation of GM2 gangliosdie or called Tay Sach's gangliosides**







Other clinical correlations

1. Induction of diarrhoea:

- **Ganglioside GM1 binds with the β-subunit of the cholera toxin then enter into the cells and**
- **A-subunit catalyses the activation of adenylate cyclase comples**
- **Finally increase intracellular cAMP levels**
- **Leads massive secretion isotonic fluids from the intestinal epithelial cells (Diarrhoea)**

2. Inhibition or protein synthesis:

- **Diphtheria toxin inhibits protein synthesis by the same mechanism**

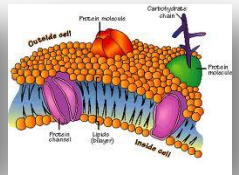
3. Influenza:

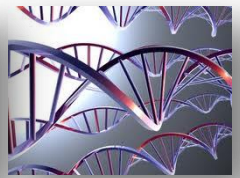
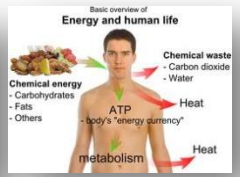
- **A specific ganglioside in the plasma membrane binds the influenza virus as a first step in the infection process**

4. Cell to cell recognition:

- **These molecules are also important for the cell to cell recognition process**





Other lipids?

Waxes:

- These are the ester of fatty acids and alcohols (not glycerol) such as – Myricyl palmitate (bee wax), triacontanyl palmitate
- Melting point of waxes is 60-100 ^{o}C what is much greater than the melting point of triglycerides (TG)

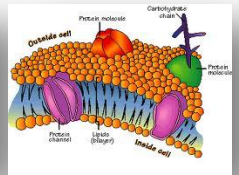
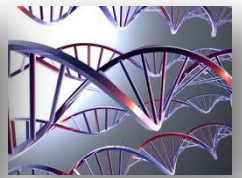
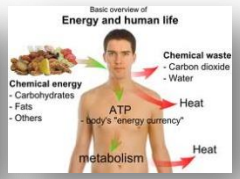
$CH_3(CH_2)_{14} - C(=O) - O - (CH_2)_{15} - CH_3$ (Myricyl palmitate/bee wax)

$CH_3(CH_2)_{14} - C(=O) - O - (CH_2)_{29} - CH_3$ (Triacontyl palmitate)

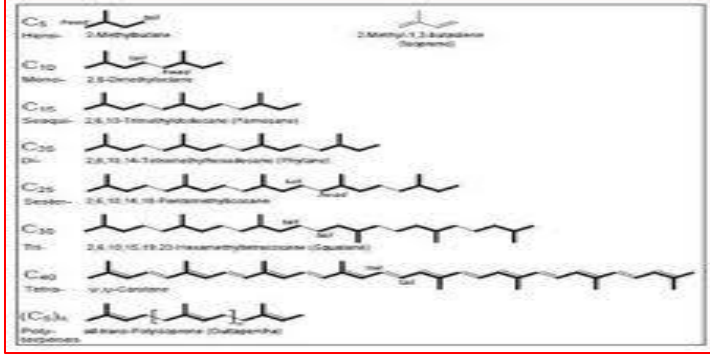
Functions / uses:

- Tropical plants got wax in their leave to avoid excessive water evaporation
- Lanolin oil (from lamb wool) and bee wax are used in the cosmetic and pharmaceutical industries to make lotions, ointments and polishes etc.



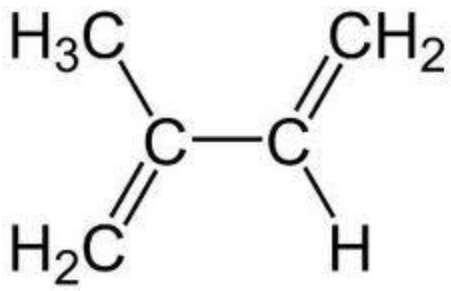




Other lipids?

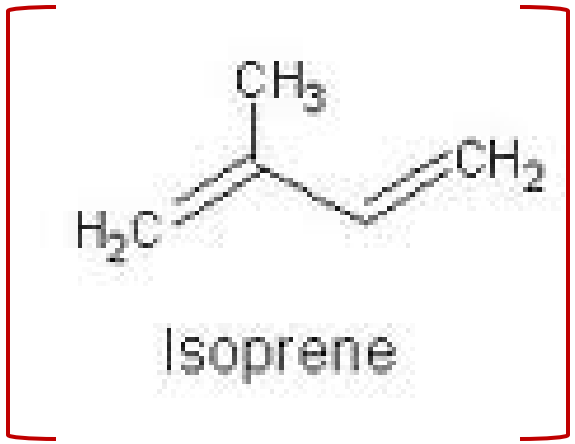


Terpenes:

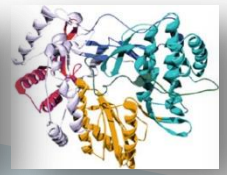
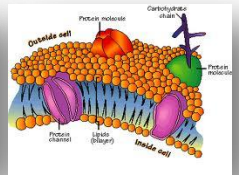
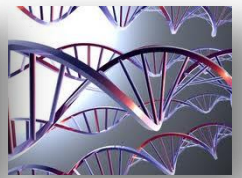
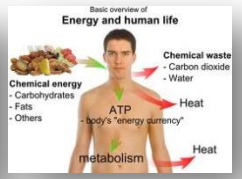
- These are the derivatives of isoprene
- Isoprene is a 5 carbon-containing hydrocarbon with two double bonds
- A several number of 5 carbon isoprenes are join together to form terpenes such as Squalene (a precursor of cholesterol)



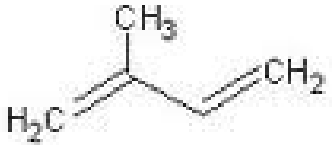
Isoprene



= Terpene

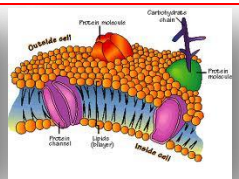
Other lipids?

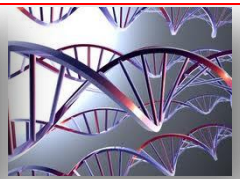
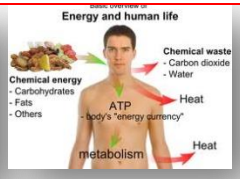


Isoprene

Terpenes:



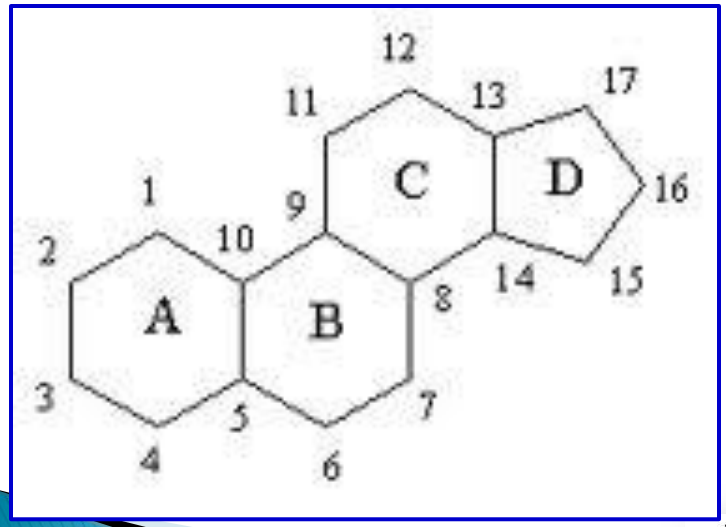


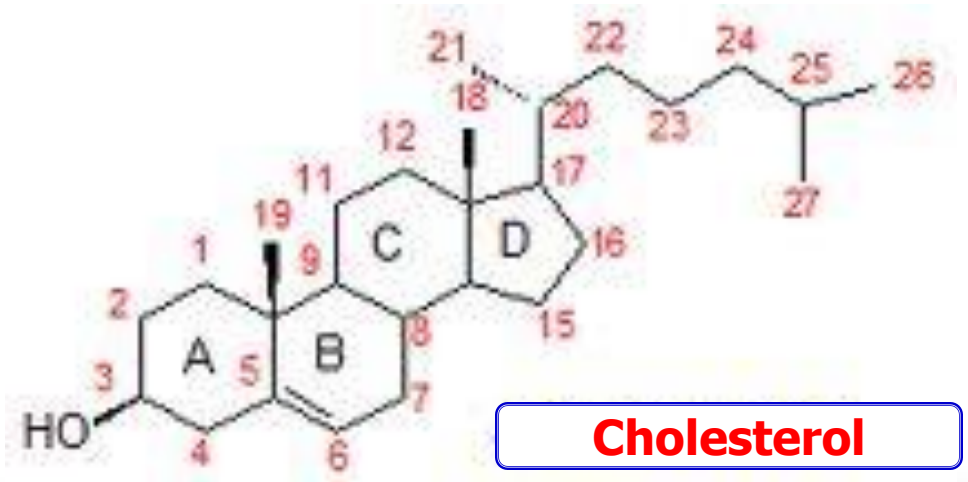



Other lipids?

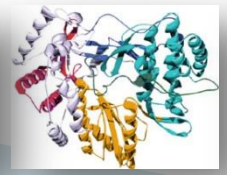
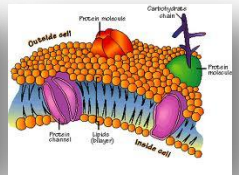
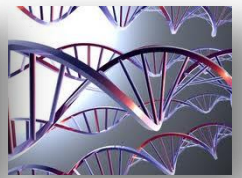
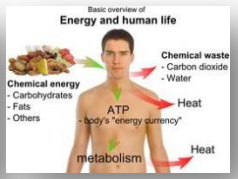
Steroids:

- These compounds are got almost a same general structure
- They contain a fused ring system of 3 six-membered rings (such as A, B, and C) and 1 five-membered ring (D) in their structures
- The precursor of this fused ring system is called – perhydrocyclopentanophenanthrene





Cholesterol

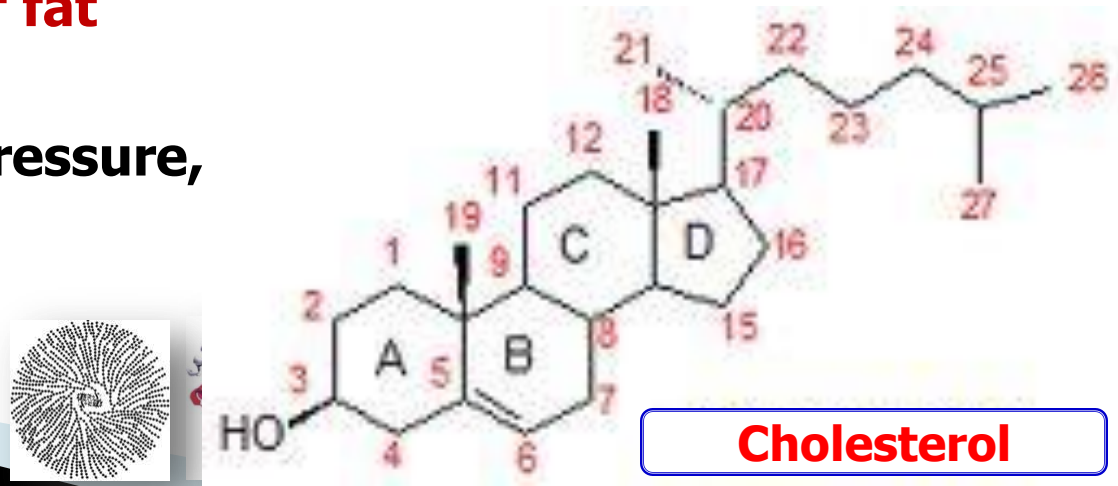
Other lipids?

Cholesterol:

- An widely known name of steroid
- It got 27 carbons in its fused ring structure with only one hydroxyl (-OH) group at C3 position
- Hence, cholesterol is highly hydrophobic in nature
- It is widespread in biological membranes

Functions:

- Important constituent of biological membranes
- It is precursor of several hormones such as sex hormones
- It is also the precursor of bile acids which play an important role in the digestion of fat in our system
- Regulates our blood pressure, pulse rate and body temperature



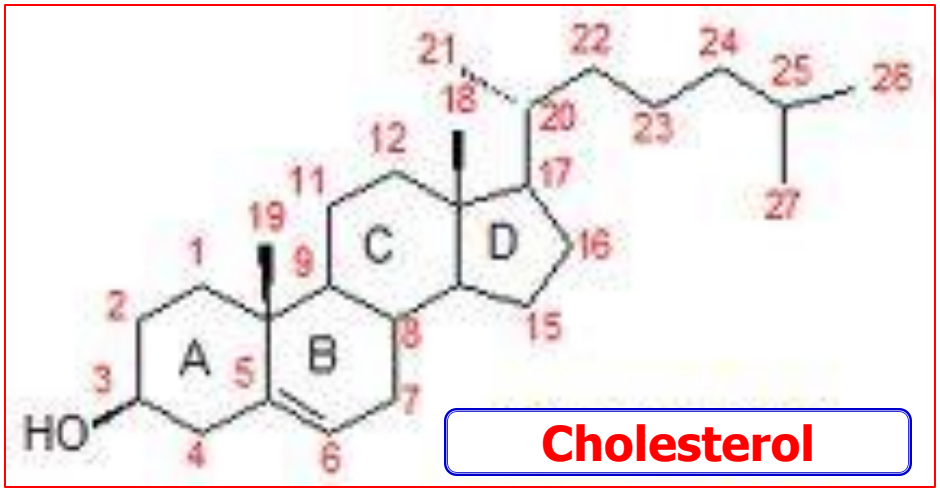
Cholesterol

Page 20 in Handouts

Other lipids?

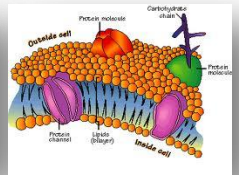
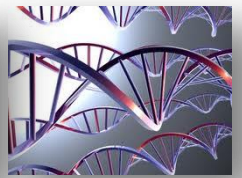
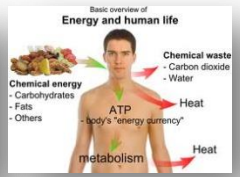
Detrimental effects of cholesterol:

- In spite of several beneficial effects cholesterol has several detrimental effects in our system, such as
- Hypercholesterimia or hyperlipidemia is a major risk factor of several diseases such as –
  - high blood pressure
  - hypertension
  - brain stroke
  - Atherosclerosis
  - heart attack and
  - other cardiovascular diseases.

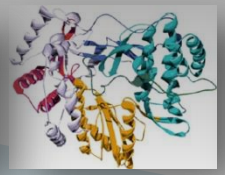


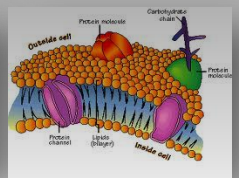
Cholesterol

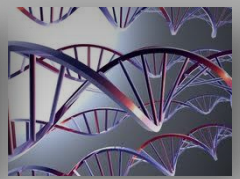


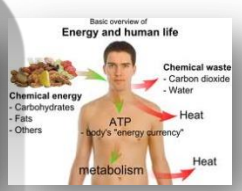




The End




Protein molecule
Carbohydrate chain
Outside cell
Protein molecule
Protein channel
Lipids (bilayer)
Inside cell




Basic overview of
Energy and human life
Chemical waste
- Carbon dioxide
- Water
Chemical energy
- Carbohydrates
- Fats
- Others
ATP
- body's "energy currency"
Heat
metabolism
Heat