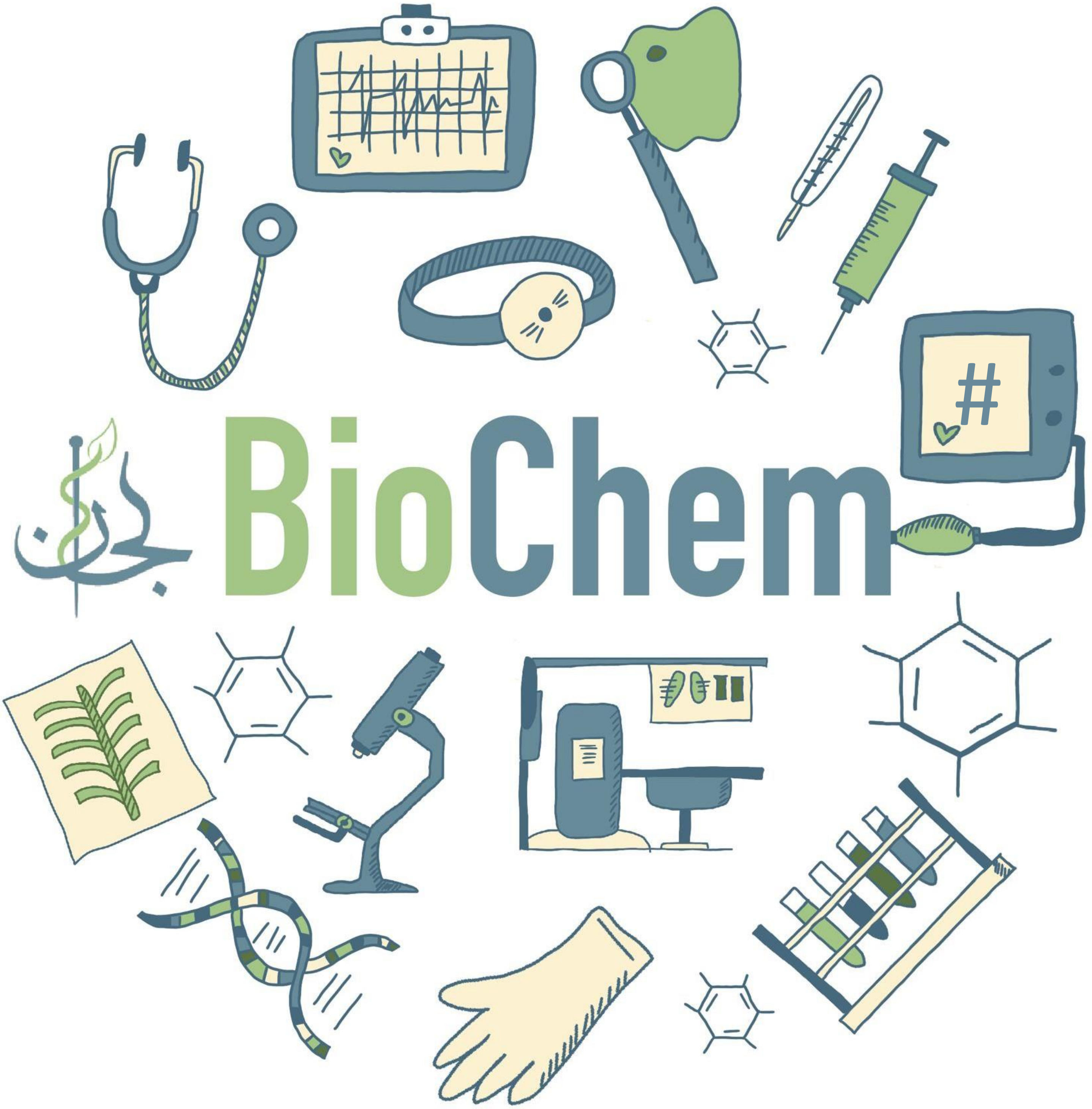

Writer: ALI ALMAHROOK & OLA NAWAFLEH

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Grammar: LANA KHABBAS

Doctor: DIALAA ABU-HASSAN

Lipids: -

- Lipids are a heterogeneous class of naturally occurring organic compounds that share some properties based on structural similarities, mainly a dominance of nonpolar groups.

  This group of molecules are highly heterogeneous because we can't find an organic chemistry group of functional group that can belong to.

- Many of them are **Amphipathic** (have both polar and non-polar side) in nature.

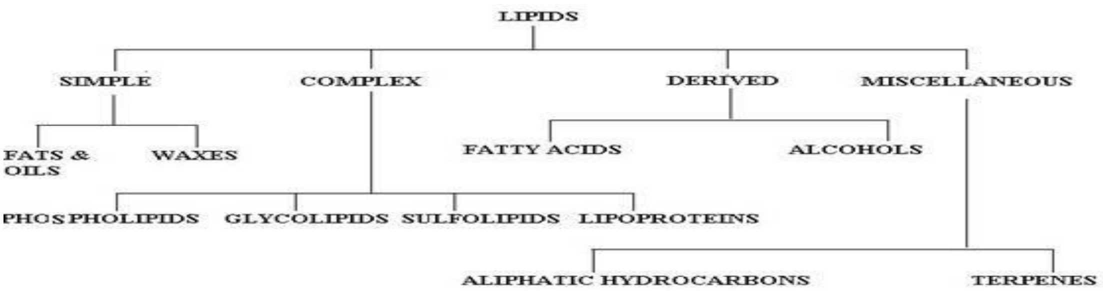
  Some of them are completely non polar

- They are insoluble in water, but soluble in fat or organic solvents (ether, chloroform, benzene, acetone).

- They are widely distributed in plants & animals

Classes: -

They are mainly classified into simple and complex Lipids.



- **simple lipids** (fats, oils, and waxes).
- **Complex lipids like membrane lipids** (glycerides , glycerophospholipids, sphingolipids, glycolipids, lipoproteins).
- **Derived lipids** (fatty acids, alcohols, eicosanoids).
- **Cyclic lipids** (steroids).

- Another don’t belong to any of these classifications like **Aliphatic hydrocarbons** and **Terpenes.**

***The classification differs between text books.**

Lipid Functions: -

The main function is storage of energy on form of lipid molecules.

Remember that the carbohydrates are the major source of energy but lipid molecules are a storage form of energy so we store energy in lipids and whenever we need it we start to burn lipids and get energy out of it.

Lipids are stored in Adipose tissue specifically in the form of **Triglycerol.**

- **Lipids include:**
  - Storage lipids.
  - Structural lipids in membranes.
  - Lipids as signals, cofactors & pigments.
- **They are a major source of energy:**
  - They are storable to unlimited amount (vs. carbohydrates).
  - They provide considerable amount of energy to the body (25% of body needs) & provide a high-energy value (more energy per gram vs. carbohydrates & proteins).
- **Structural components** (cell membranes,cholesterol in animal cells, sphingolipids)these components separate the cell from its environment.
- **Precursors of hormone and vitamins**(sex hormones ,vitamins A,D,E,K are lipid soluble)
- **Shock absorbers thermal insulator** (they keep our body temperture in normal range and shock absorbers specially for kidneys because they’re relatively superficial hence covered by a thick layer of lipids.

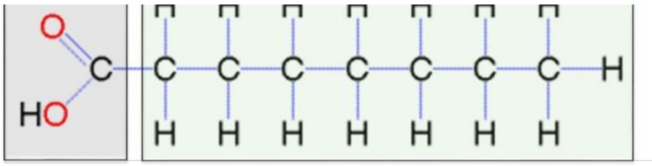
❖ Why we store energy in a form of lipids rather than carbohydrates?

➢ 1g of fat has 9 calories but 1 g of carbohaydrates or proteins has 4 calories so its much larger in terms of amount.

➢ Because lipid molecules are water insoluble so they won’t attract water molecules to the adipose tissue but if we stored energy in carbohydrates which are highly polar so they will attract the water molecules so it will enlarge our size and that what makes us huge.

Fatty acids: -

- **Aliphatic mono carboxylic acids**
- **Formula R-$(CH_2)_n$-COOH**



- **Lengths:**

  - Physiological (12-24 carbons)
  - Abundant (16 and 18 carbons)

Polar Non-polar

- **Degree of unsaturation**
- **Amphipathic molecules**

The hydrocarbon chain is connected through single or double bonds.

Its non-polar even if it has a polar group but the presence of the long hydrocarbon chain that is non polar will dominate and make the whole molecule non polar and insoluble in water.

Function of fatty acids: -

- **The fatty acids are building block of other lipids.**
- Used for **modifying proteins** such as lipoproteins
- **Important fuel molecules** they can be oxidized and broken down into acetyl coA that can enter Kreps cycle and generate energy
- **Derivatives of important cellular molecules**

Types of fatty acids: -

- **Saturated** fatty acids are those with all of C-C bonds being **single.**

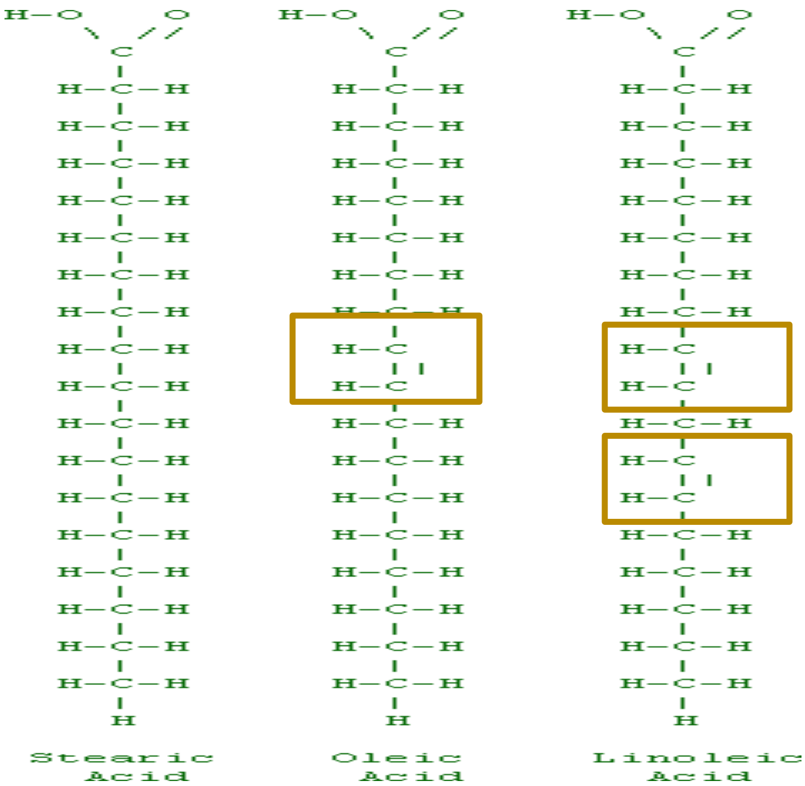
- **Unsaturated** fatty acids are those with one or more **double** bonds between carbons:

  - **Mono**unsaturated fatty acid: a fatty acid containing **one** double bond.
  - **Poly**unsaturated fatty acids contain **two** or **more** double bonds.

Stearic Acid: **Saturated**

Oleic Acid: **monounsaturated**

Linoleic Acid: **polyunsaturated**



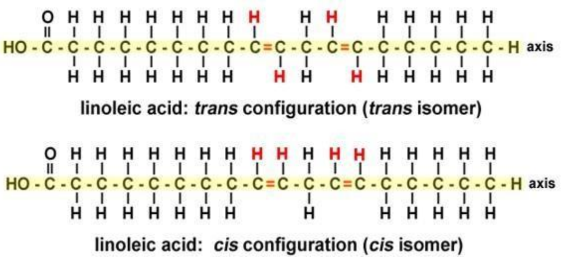
Cis Vs. Trans Bonds: -

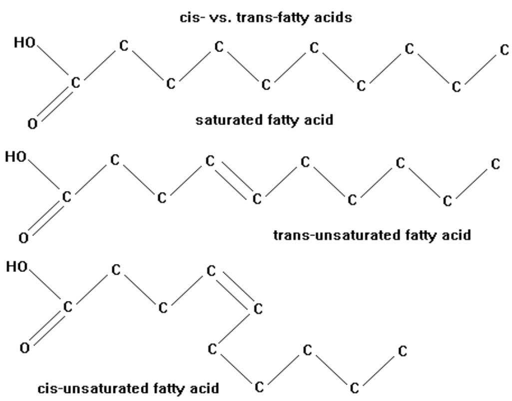
Whenever we have a double bond this will produce kinks in the structure of the fatty acid specially we have the same orientation for the atoms around the double bond.

If they are in **opposite** orientation its **trans** and because the atoms in different orientation there is no steric hindrance at all and its more favorable for the two hydrogen atoms to be in different orientation as much away as possible from each other so they we take a shape that is more similar to saturated fatty acid.

If they are in the **same** orientation its **cis** and due to the presence of the two hydrogen atoms in the same orientation that would introduce kinks in the structure to allow more space for the hydrogen atoms and avoid steric hindrance and this kink will affect the physical properties.

NOTE: CIS isomers PREDOMINATES, TRANS are RARE





Notice:

Trans is

Similar to

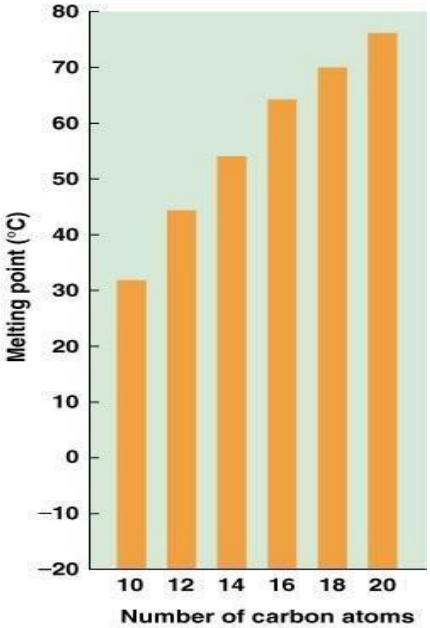
Saturated

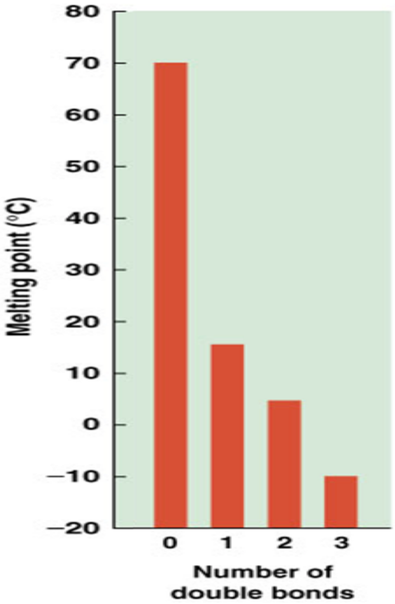
Properties of fatty acids: -

The properties of fatty acids (melting point and solubility) are

dependent on **chain length** and **degree of saturation**.

- Chain length :Whenever we have more carbons in fatty acids that makes its melting point higher because we have more non covalent and van der waals interactions so we need more energy to break it .
- Increasing in number of Carbons → increasing in melting point , but we should compare saturated with saturated or unsaturated with unsaturated.
- Degree of saturation (number of double bonds):Increasing in double bonds → decrease the melting point, because increasing the double bonds will produce kinks – in cis isomers- which will affect non covalent interactions and make it weaker so lower melting point.





Properties of saturated fatty acids

Short chain F.A.	Medium-chain F.A.	Long chain F.A.
They are liquid in nature	Solids at room temperature	Solids at room temperature
Water-soluble	Water-soluble	Water-insoluble
Volatile at RT	Non-volatile at RT	Non-volatile
Acetic, butyric, caproic FA	Caprylic & capric F.A.	Palmitic and stearic F.A

Notes on the previous slide: -

- 1-All of these fatty acids are saturated.
- 2-We have short, medium and long chains with different properties.
- 3-Water solubility might be present in the short and medium chains because the effect of the polar side will dominate.
- 4- Short chain fatty acids are volatile at Room Temperature because of the lower number of carbons, fewer non covalent bonds, and less energy needed to break the bonds and change the status of these molecules.
- 5-Acetic acid present in the vinegar.
- 6- The most common fatty acids in our body are long chain.

Naming of fatty acids: GREEK NUMBER PREFIX

Number	prefix	Number	prefix	Number	prefix
1	Mono-	5	Penta-	9	Nona-
2	Di-	6	Hexa-	10	Deca-
3	Tri-	7	Hepta-	20	Eico-
4	Tetra-	8	Octa-		

First of all we start with mentioning the number of carbons in fatty acids followed by the suffix (OIC) and we need to add to the name if it has one double bond,two,or three and apply that by naming.

Alkane to oic

Octadecane (octa=8 and deca=10) is octadecanoic acid so its 18 carbon saturated fatty acid

One double bond = octadecenoic acid E from alkene

Two double bonds = octadecadienoic acid

Three double bonds = octadecatrienoic acid

We can also write the describe the names like this: -

Designation of carbons and bonds

18:0 = a C18 fatty acid with no double bonds

stearic acid (18:0); palmitic acid (16:0)

18:2 = two double bonds (linoleic acid)

Notice that we only mention the number of double bonds but How about

Knowing their location?

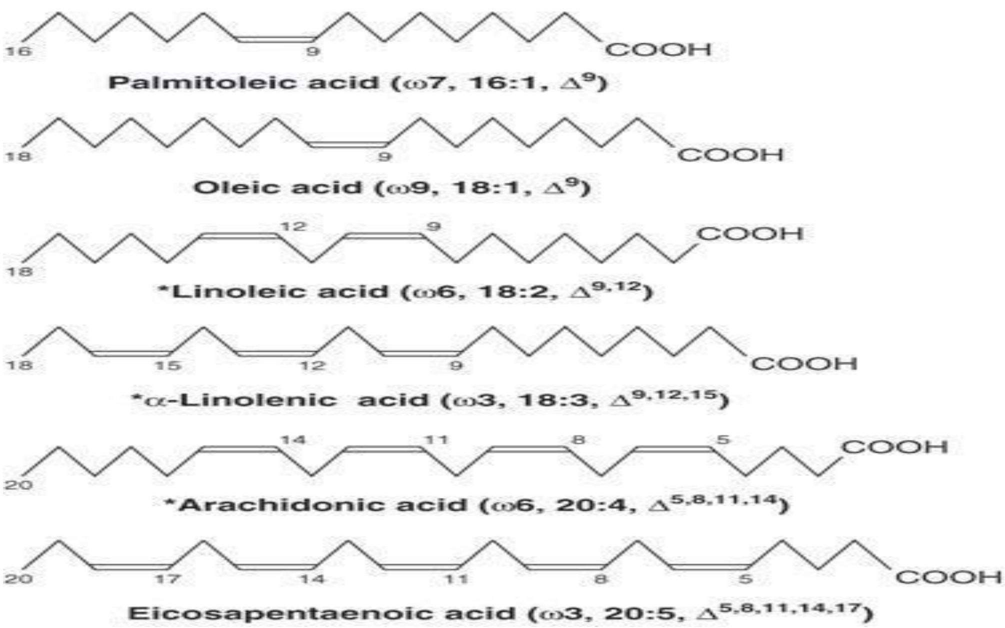
We use DELTA Δ^n: The position of a double bond

cis-Δ^9 :a cis double bond between C 9 and 10

trans-Δ^2:a trans double bond between C 2 and 3

When there is a double bond between 12&13 we will write 12 the lowest number and we should mention if it's trans or cis (mostly it will be cis if it naturally occurs as we mentioned up)

some examples: -



Palmitoleic acid has 16 carbons one double bond between carbon 9 & 10 with start counting from the carboxyl group. The name for each molecule is common name we should memorize them.

THE TABLE is required with all his info

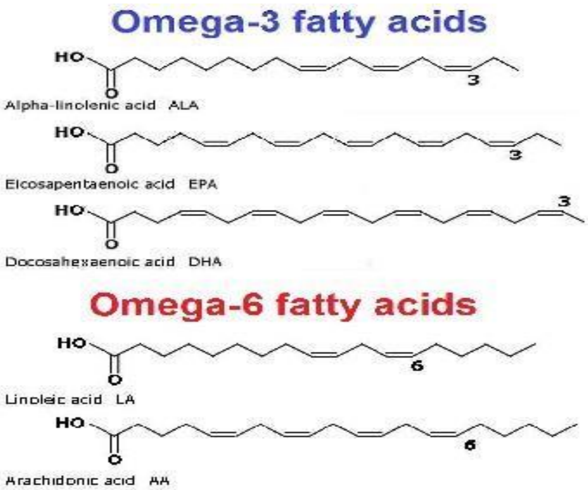
Number of carbons	Number of double bonds	Common name	Systematic name	Formula
14	0	Myristate	n-Tetradecanoate	$CH_3(CH_2)_{12}COO^-$
16	0	Palmitate	n-Hexadecanoate	$CH_3\,(CH_2)_{14}COO$-
18	0	Stearate	n-Octadecanoate	$CH_3(CH2)_{16}COO$-
18	1	Oleate	cis-Δ^9-Octadecenoate	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COO$-
18	2	Linoleate	cis,cis-Δ^9,Δ^{12}-Octadecadienoate	$CH_3(CH_2)_4CH{=}CHCH_2CH(CH_2)_7COOH$
18	3	Linolenate	all-cis-Δ^9,Δ^{12},Δ^{15}-Octadecatrienoate	$CH_3CH_2(CH{=}CHCH_2)_3(CH_2)_6COOH$
20	4	Arachidonate	all-cis-Δ^5,Δ^8,Δ^{11},Δ^{14}-Eicosatetraenoate	$CH_3(CH_2)_4\,(CH{=}CHCH_2)_4(CH_2)_2\,COOH$

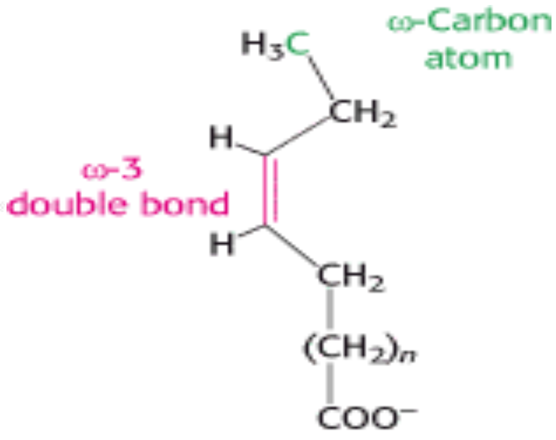
Another way of naming (Omega)

(ω)-C: distal methyl C as #1

In this system we count the carbons from the end of the molecule not from the carboxyl group and we take the first double bond that we see and naming them like that (ω 3 , ω 5 ,etc.)

Notice that if there are more than one double bond we take only the first one we face.





An ω-3 fatty acid

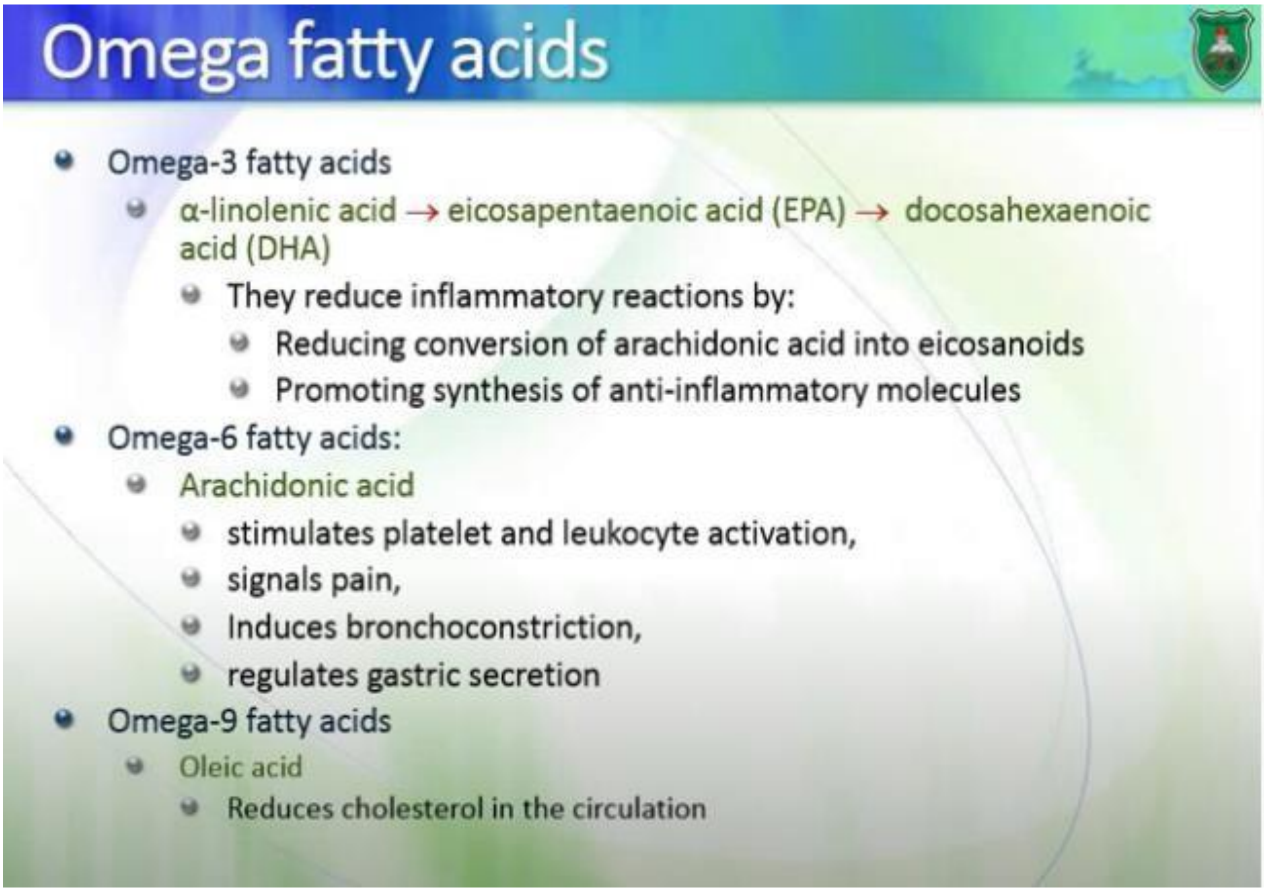
- **Linoleic acid: precursor of arachidonates**
- **Linolenic acid: precursor of EPA and DHA**

***The first 4 are required**

Numerical Symbol	Common Name and Structure	Comments
$18{:}1^{\Delta 9}$	Oleic acid 	Omega-9 monounsaturated
$18{:}2^{\Delta 9,12}$	Linoleic acid 	Omega-6 polyunsaturated
$18{:}3^{\Delta 9,12,15}$	α-Linolenic acid (ALA) 	Omega-3 polyunsaturated
$20{:}4^{\Delta 5,8,11,14}$	Arachidonic acid 	Omega-6 polyunsaturated
$20{:}5^{\Delta 5,8,11,14,17}$	Eicosapentaenoic acid (EPA) 	Omega-3 polyunsaturated (fish oils)
$22{:}6^{\Delta 4,7,10,13,16,19}$	Docosahexaenoic acid (DHA) 	Omega-3 polyunsaturated (fish oils)

Omega naming system can be considered as a classification because they can might be more than one fatty acid Omega 3, Omega 6, etc.

***The acids that have the same Omega have a shared properties and functions.**



Linolenic acid produce→EPA produce DHA

They reduce inflammatory reactions, inflammation happens as a response of many changes that happen to our cells and body without any bacteria or viruses and its normal

Inflammation produces redness of the area, swelling. Pain and edema.So

Omega 3 is important for inflammation and for brain tissue

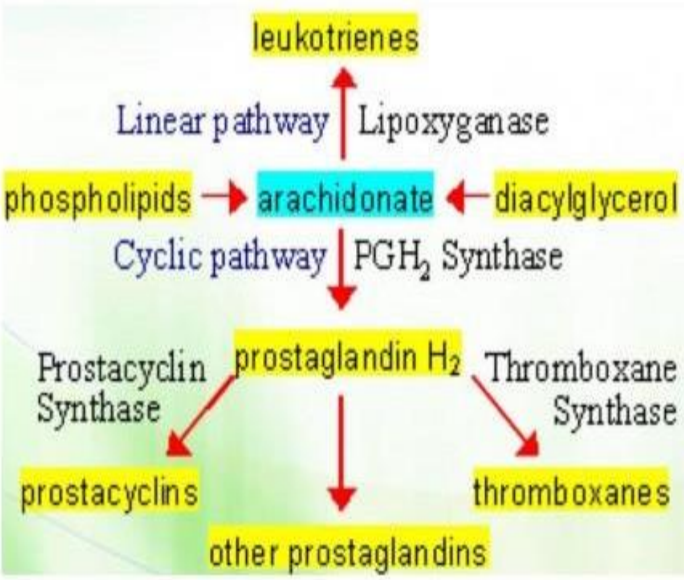
Also Arachidonic Acid which is Omega 6 is involved in inflammatory reactions

Derived Acids

Eicosanoids

These are molecules or inflammatory mediators that are derived or synthesized from arachidonic acid a (polyunsaturated fatty acid)

all cis-Δ^5, Δ^8, Δ^11, Δ^14 -eicosatetraenoate , CH3 (CH2)4 (CH=CHCH2)4 (CH2)2COO- the most important one in our bodies .



Synthesized from arachidonic acid are other molecules such as Prostaglandins , Leukotrienes, Thromboxane, Prostacyclin. (these are all eicosanoidsderived from arachidonic acid).

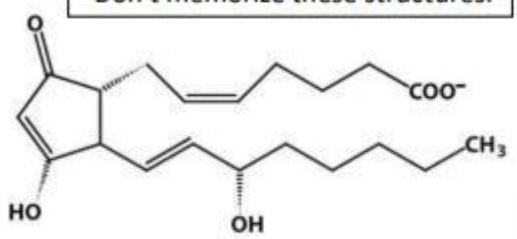
These eicosanoids are important because they're signaling molecules therefore affect the cell's function

Prostaglandins :

First found in the prostate gland but then discovered that it's synthesized by other .cells

1)Inhibition of platelet aggregation
2)blood clotting

Don't memorize these structures.



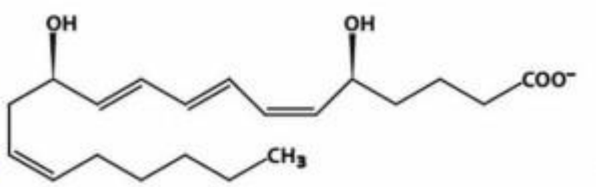
Prostaglandin E_2

(A DESCRIPTION OF THE STRUCTURE YOU DO NOT HAVE TO MEMORIZE IT)

* they have three double bonds as you can see in here (it differs from one molecule to another) , they have this cyclic structure with five members ring and their structure where hydrocarbon chains interacted with each other and formed these double bonds it has some other side chains that come out like OH but these ones differ between one type and the other . they (TYPES OF PROSTAGLANDIN) only share the presence of this five membered ring in addition to the 20 carbon *

Leukotrienes:

First discovered in leukocytes (a type of immune cells). It contains 4 **double** bonds, 3 of these double bonds are conjugated, that's why it's called leuko**trienes**.



Leukotriene B_4

* Constriction of smooth muscles

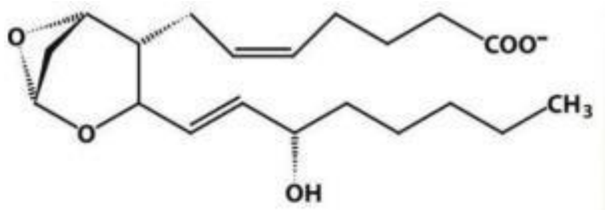
* Asthma: blood vessels are constricted so blood flow is slow, and one can't take enough oxygen. It's caused by over synthesis of leukotrienes.

Thromboxane:

Thrombo-: Blood clot.

* **Constriction of smooth muscles**

* **Induces platelet aggregation** ↑



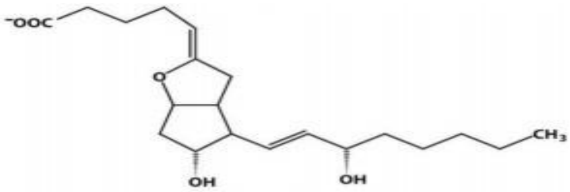
Thromboxane A_2 (TXA_2)

2 cyclic ethers

Prostacyclin:

* **An inhibitor of platelet aggregation** ↓

* **A vasodilator**



Prostacyclin (PGI_2)

[(Notice that different eicosanoids have different functions, the same eicosanoid (prostaglandins for example) also can have two opposite functions. That's because:

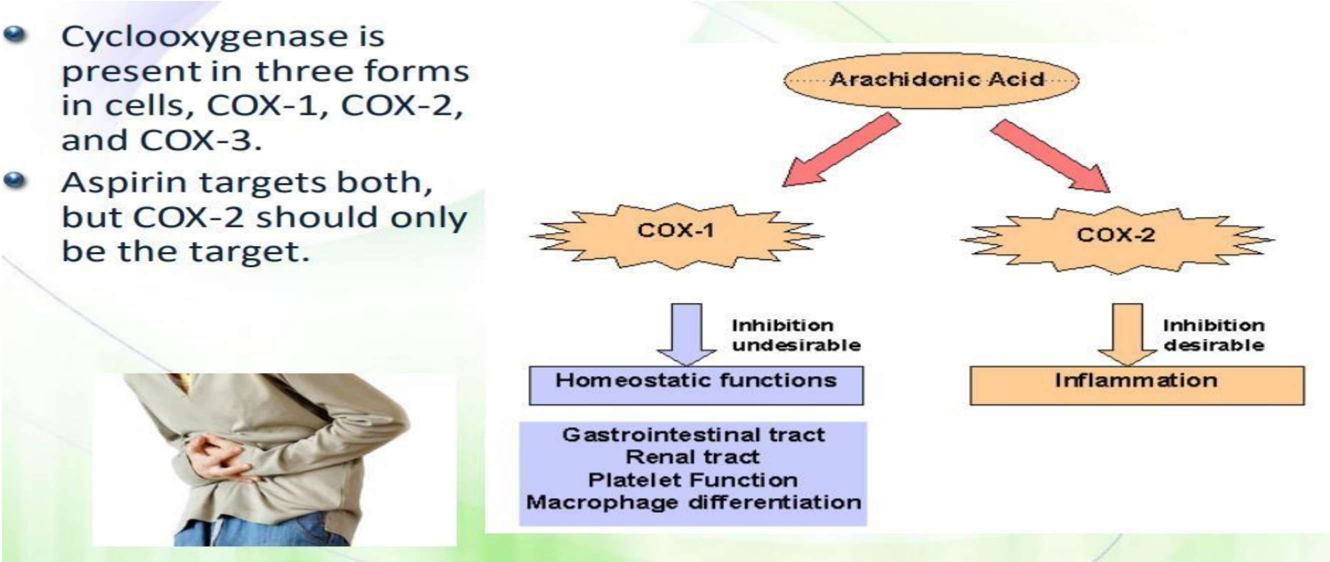
1) there are different types of prostaglandins

2) it also depends on the amount of prostaglandins secreted and where they're being secreted. -> we're talking about homeostasis (keeping a balance)

Arachidonic Acid can be converted into other compounds (such as prostaglandins and leukotrienes) by metabolism by an enzyme known as cyclooxygenases (COX). Cyclooxygenase is present in three forms in different tissues, COX1, COX2 and COX3.
There are two major pathways arachidonic acid can take depending on which enzyme is used;

1 st pathway: arachidonic acid is converted into thromboxane by COX1, which in turn induces platelet aggregation.

2 nd pathway: arachidonic acid is converted into prostaglandins by COX2, they can cause pain, fever and inflammation making the environment unhospitable for any pathogen invading the body, prostaglandins also inhibit platelet aggregation.



Cyclooxygenases Inhibitors

1) **ASPIRIN**: **a drug that is widely used for reducing body temperature and preventing inflammation process. As a side result it also inhibits platelet aggregation as well as blood clotting, so it reduces heart disease.**

Mechanism **:by inhibiting the enzymes (cyclooxygenase) that convert arachidonic acid to these molecules cyclooxygenase one converts arachidonic acid to thromboxaneand cyclooxygenase 2 converts it to prostaglandins so by inhibiting these two enzymes you reduce inflammation, reduce fever and you can inhibit platelet aggregation and reducing heart attacks .**

2) **CELEBREX: A new generation drug, but is prescribed with a strong warning of side effects on the label. what is special about it is that CELBREX is a selective-inhibitor of COX2 so that it doesn't affect aggregation and clotting of blood. Celebrex isn't recommended for people who have heart problems as it increases heart rate leading to fatal results.**

Complex lipids

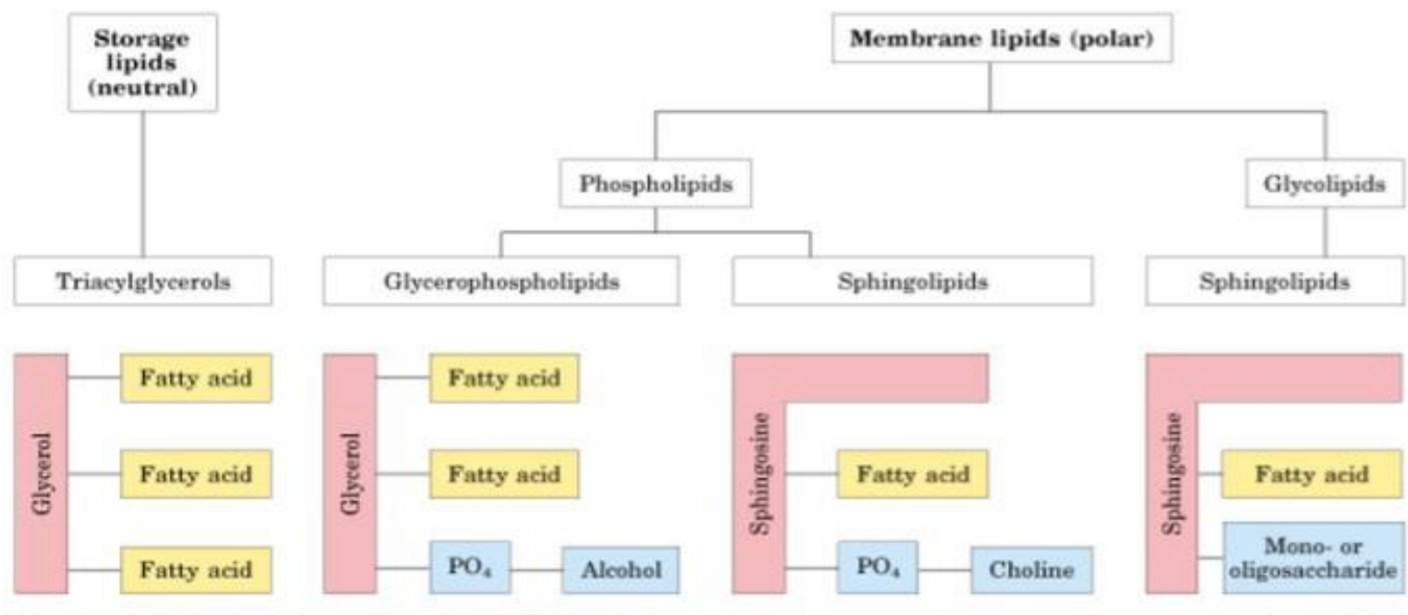
Another classification for complex lipids:

- **Triacylglycerols**
- **Glycerophospholipids**
- **Sphingolipids; that could either be Sphingophospholipids or Glycolipids.**

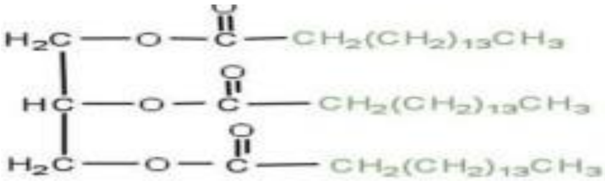
Triacylglycerols they have a backbone known as glycerol you have three fatty acids attached to it,then we have phospholipids we have two types : we have glycerol phospholipids because their backbone is glycerol and two fatty acids +(phosphate group and whatever groups attached to it), and then we have sphingolipid and the backbone is not glycerol instead it is a sphingosine and there is a fatty acid attached to it and a (phosphate+ choline) that's why it's called phospholipid,,you have another type of sphingolipids that has a backboneof sphingosine except that it doesn't have a phosphate instead it has a sugar attached to it.

- **Triacylglycerol (Triglyceride) In glycerol there are 3 hydroxyl groups each can be substituted/replaced with a fatty acid chain. So, we can get monoacylglycerol, diacylglycerol and triacylglycerol.**

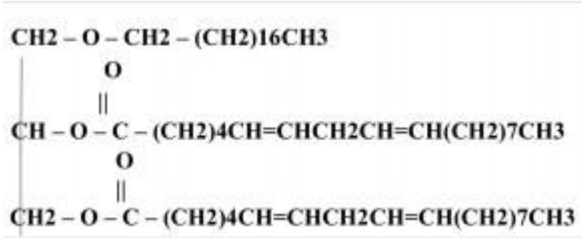
- **In our bodies, we store fat in the form of triacylglycerol. the fatty acid chains substituted for hydroxyl groups can be similar or different, they also can be saturated or not.**



simple triacylglycerol → 3 similar fatty acids



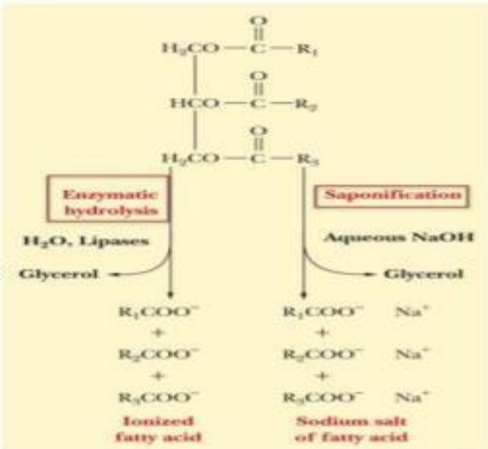
mixed triacylglycerol → 3 different fatty acids



Solid vs liquid fats: **depends mainly on the saturation of the fatty acid chains from which triacylglycerol is formed, since double bonds cause kinks in the structure of fatty acids. This is the primary reason for the different melting points of fats and oils.**

- **So you can say that the fluidity of fat is inversely proportional to the saturation at the same temperature *It is worth mentioning that vegetable oils consist almost entirely of unsaturated fatty acids, whereas animal fats contain a much larger percentage of saturated fatty acids.**

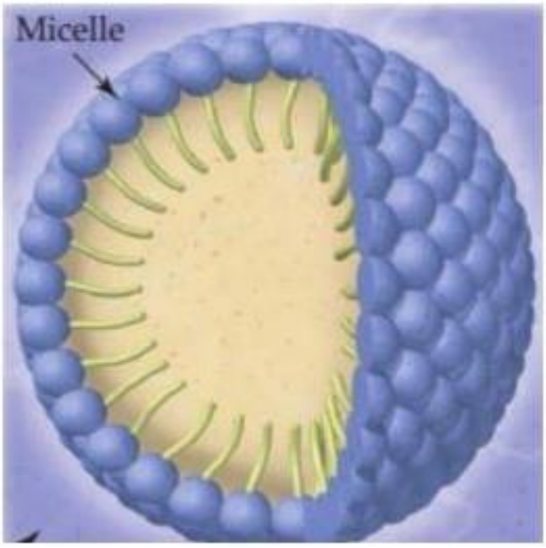
- **Saponification (hydrolysis)**:
since lipids have ester linkages, they can be cleaved back into a salt of fatty acid and an alcohol (glycerol) by reacting with water and a base (such as an aqueous solution of NaOH). It can be also cleaved in our bodies by certain enzymes (lipase of pancreas).



Hydrogenation:

In a hydrogenation reaction, two hydrogen atoms are added across C-C double bond, resulting in a hydrogen-saturated bond. So, chemists invented a method of converting unsaturated fat into a more solid form by partially hydrogenating it, but it was found that Partial hydrogenation converts some, but not all, double bonds into single bonds generating (**trans fats**). So, we will still have double bonds but in the trans form.

how does soap work?

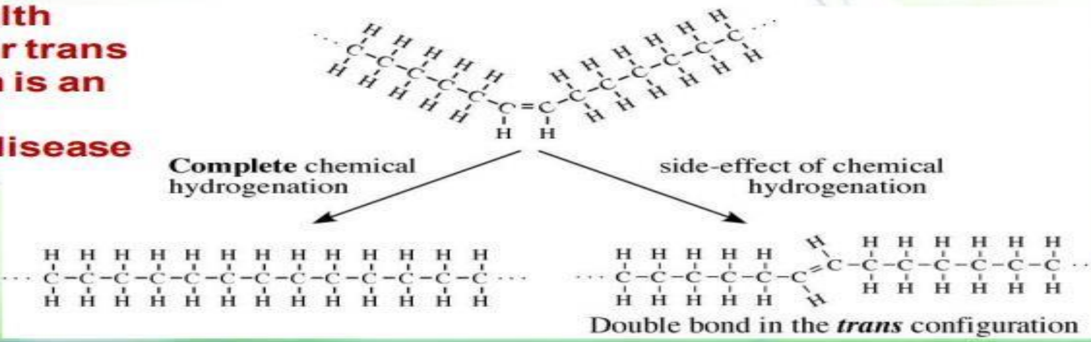


- When mixed with water, the hydrophobic hydrocarbon tails cluster together and orient inward to create a nonpolar microenvironment and the hydrophilic ionic heads interact with water.
- The resulting spherical clusters are called **Micelles**.
- Grease and dirt are trapped inside micelles and the complex can be rinsed away.

*Basically, soap causes emulsification of oily material.

- Although the animal fat is unhealthy, it has better cooking properties and better taste.
- Therefore, chemists invented a method of converting unsaturated oil into solid form by partially hydrogenating it.
- Partial hydrogenation converts some, but not all, double bonds into single bonds generating (trans fats).

The primary health risk identified for trans fat consumption is an elevated risk of coronary heart disease (CHD).



* The primary health risk identified for trans-fat consumption is an elevated risk of coronary heart disease (CHD) and heart attacks as it accumulates in our circulation without being digested because the double bonds aren't recognized by our body enzymes. *The main reason behind using trans-fat is that it gives a longer shelf life and it tastes way better. * In margarine, only about two-thirds of the double bonds present in the starting vegetable oil is hydrogenated, so that the margarine remains soft in the refrigerator and will melt on warm toast.

Waxes :

- They are molecules that results from the Reaction between a fatty acid (C14~C36) by its carboxylic head with a monohydric alcohol (C16~C30) by Esterification reaction forming an Ester bond [EX: Palmitoyl alcohol]
- *Monohydric means that the molecule contains only a one hydroxyl group
  - So, the ester bond connects 2 long hydrocarbon chains
  - They have zero nutritional value as we cannot digest them
  - They are highly insoluble in water, negative to acroline test which tests for the presence of glycerin and fats
  - They aren't easily hydrolyzed (fats), indigestible by lipases(((also very resistant to rancidity(HYDROLYSIS OR OXIDATION OF FATS AND OILS)))
  - They have a long half-life, used to prevent loss of water in leaves, wetting of feathers and fast deterioration of fruits (e.x apples)

Examples: Beeswax, Jojoba wax and Camauba wax

Type	Structural Formula	Source	Uses
Beeswax	$CH_3(CH_2)_{14}-\overset{O}{\overset{\|\|}{C}}-O-(CH_2)_{29}CH_3$	Honeycomb	Candles, shoe polish, wax paper
Carnauba wax	$CH_3(CH_2)_{24}-\overset{O}{\overset{\|\|}{C}}-O-(CH_2)_{29}CH_3$	Brazilian palm tree	Waxes for furniture, cars, floors, shoes
Jojoba wax	$CH_3(CH_2)_{18}-\overset{O}{\overset{\|\|}{C}}-O-(CH_2)_{19}CH_3$	Jojoba	Candles, soaps, cosmetics

QUESTIONS

1) Which of the following statements concerning fatty acids is correct?

A) One is the precursor of prostaglandins.

B) Phosphatidic acid is a common one.

C) They all contain one or more double bonds.

D) They are a constituent of sterols.

E) They are strongly hydrophilic

Answer : a

2) Which of the following molecules or substances contain, or are derived from, fatty acids?

A) Beeswax

B) Prostaglandins

C) Sphingolipids

D)Triacylglycerols

E) All of the above contain or are derived from fatty acid

Answer : e

3) An example of a glycerophospholipid that is involved in cell signaling is

A) arachidonic acid.

B) ceramide.

C) phosphatidylinositol.

D) testosterone.

E) vitamin A(retinol) **Answer : c**

4) Which of the following structures is a 20:2 (Δ4,9) fatty acid?

a) CH3(CH2)9CH = CH(CH2)3CH = CH(CH2)2COOH

b) CH3(CH2)2CH = CH(CH2)3CH = CH(CH2)9COOH

c) CH3(CH2)10CH = CH(CH2)3CH = CHCH2COOH

d) CH3CH2CH = CH(CH2)3CH = CH(CH2)10COOH

Answer :A

5) Which is a property of eicosanoids?

a) All eicosanoids contain three conjugated double bonds.

b) All eicosanoids contain arachidonic acid and sphingosine.

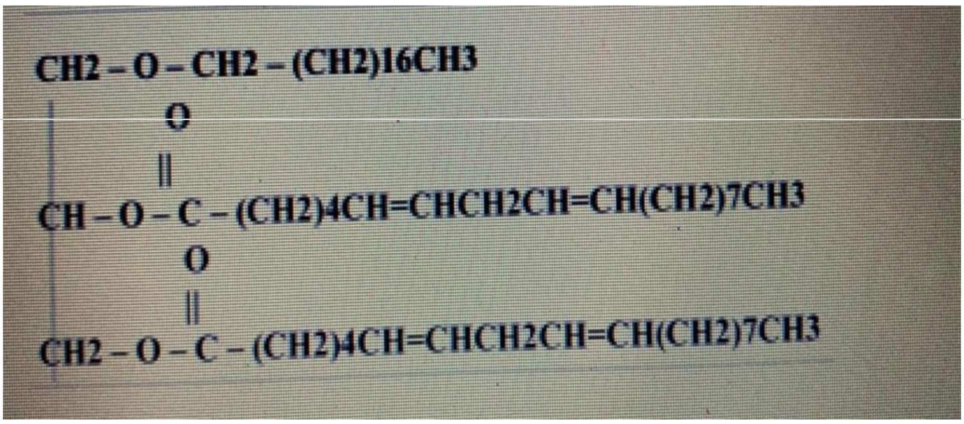
c) Prostaglandins and leukotrienes both contain a ring structure.

d) Thromboxanes and prostaglandins both contain a carboxyl group

Answer : D

6) What is the proper designation for the unsaturated fatty acids in this lipid?

a) 18:2 (Δ9,12)



b) 18:2 (Δ6,9)

c) 17:2 (Δ9,12)

d) 17:2 (Δ5,8)

Answer :B

8) Omega -6 fatty acids are derivatives of :

a) Linolenic acid
b) Stearate
c) Arachidonate
d) Linoleic acid
e) Palmitate

Answer: D

9) an Omega 9 fatty can do the following:

a) it can treat asthma
b) it reduces inflammation
c) it relieves gastric pain caused by aspirin
d) it reduces cholesterol
e) it blocks formation of eicosanoid

Answer : d

ALLAH M3KM