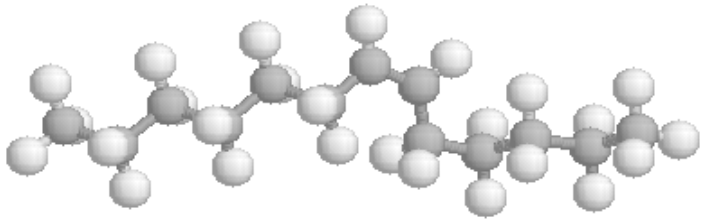
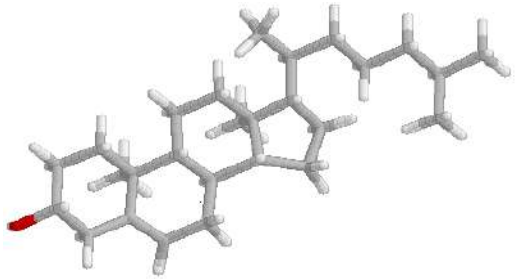




The lipid classes and fatty acids as principal components: an overview of structures, functions and the main physiological /pathological roles

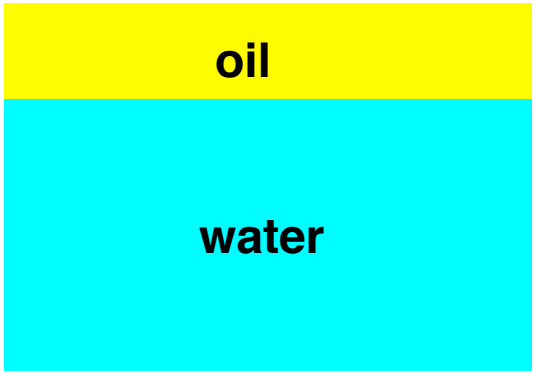
Carla Ferreri, Senior Researcher CNR, Bologna

Seminar for

Rep-eaT
Horizon 2020 MSCA-COFUND
Rep-Eat - G.A. n. 713714

Lipids: definition

Lipids are chemical structures with biological roles in living organisms that are classified together due to their water insolubility



From the Greek word LIPOS

Lipid classes

LIPIDS

FATTY ACIDS

Steroids

Lipid vitamins

Terpenes

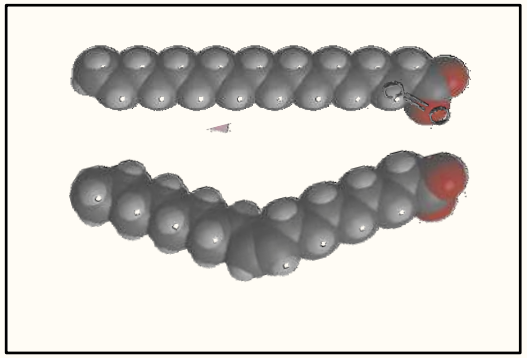
Isoprenoids

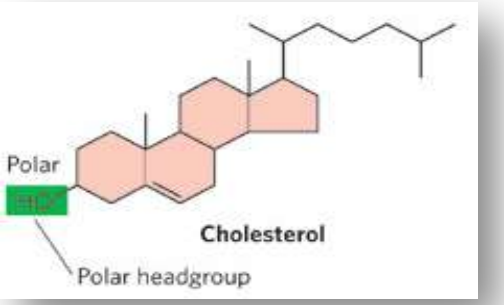
eicosanoids

triglycerides

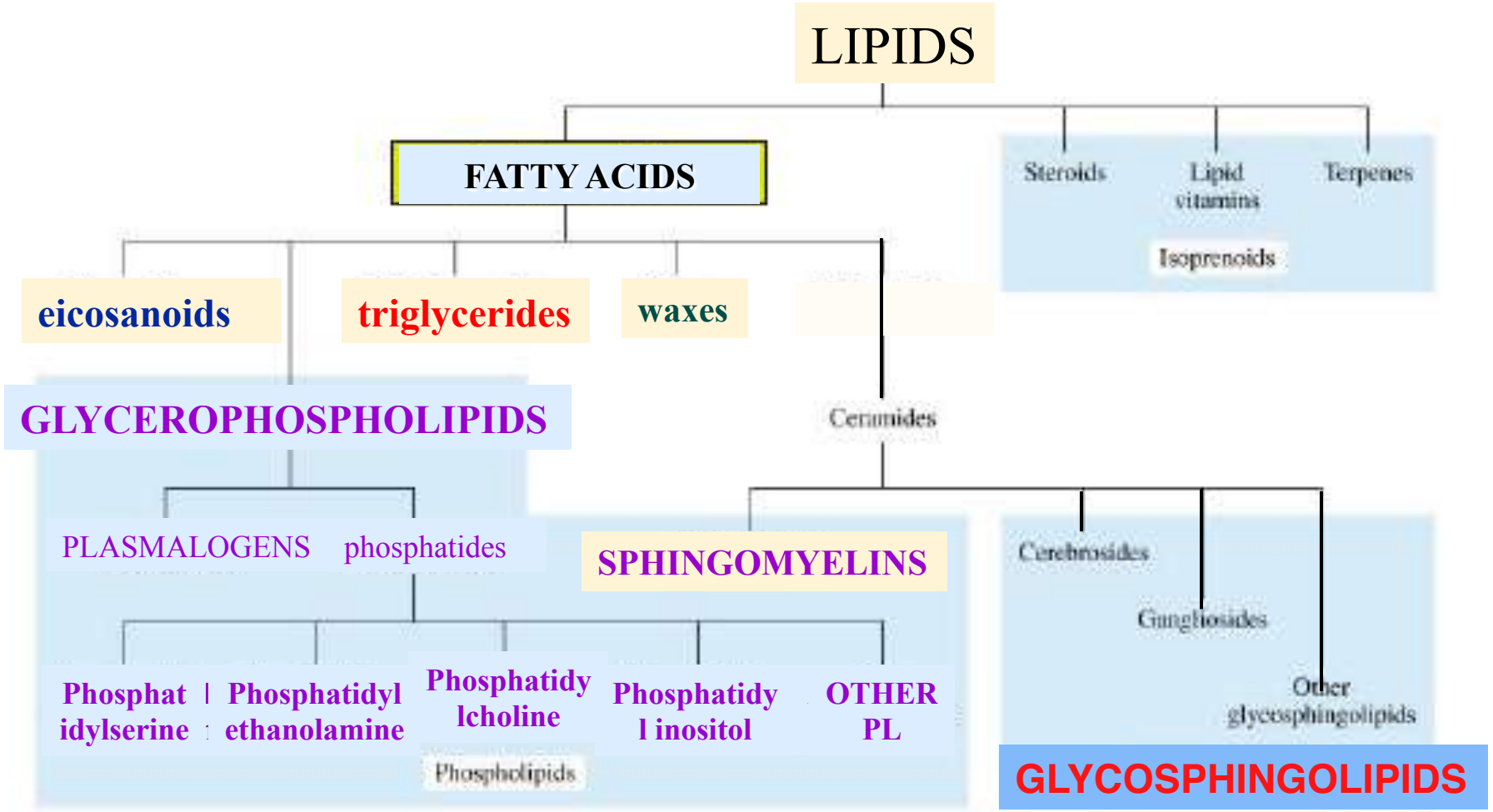
waxes

Ceramides

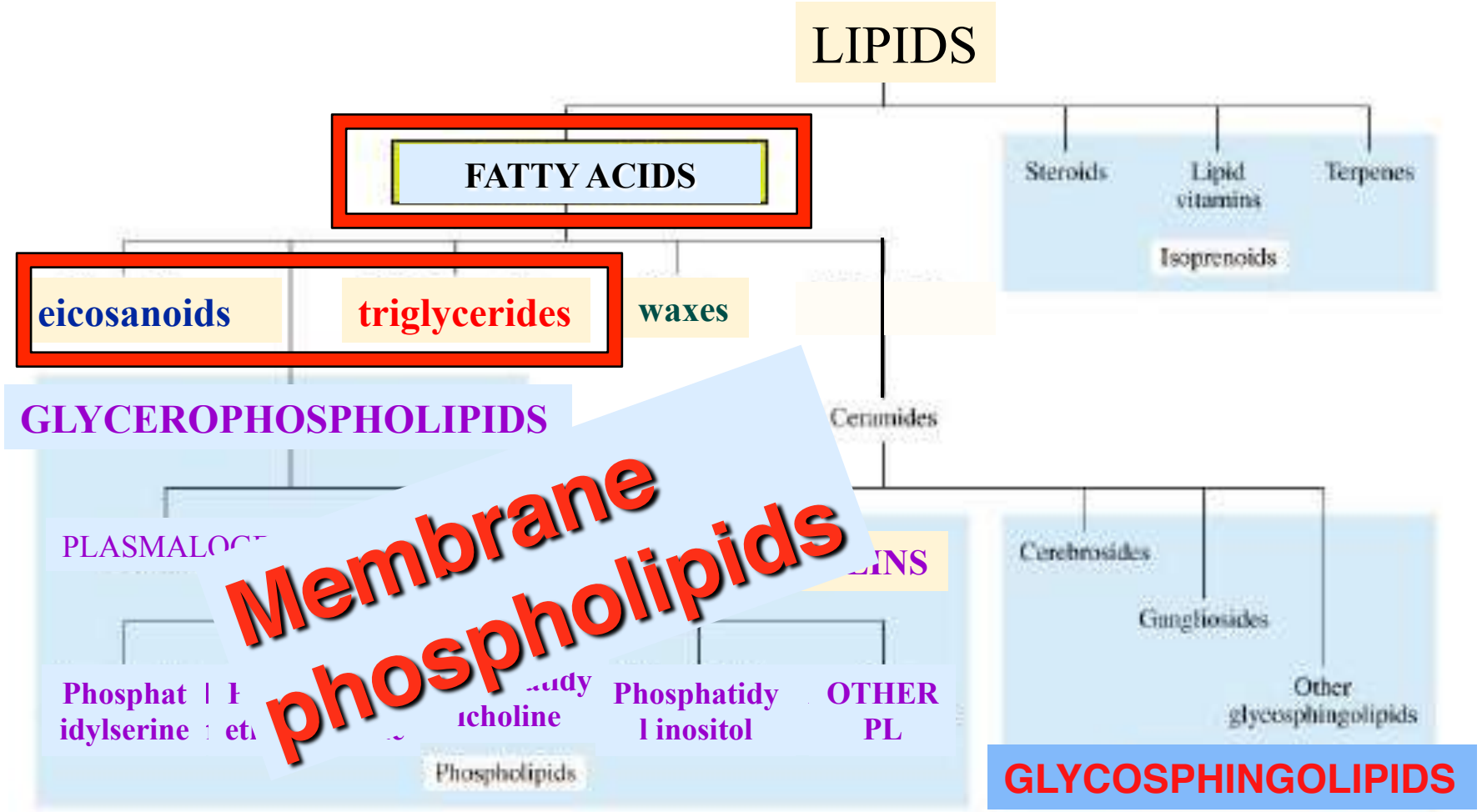




Lipid classes



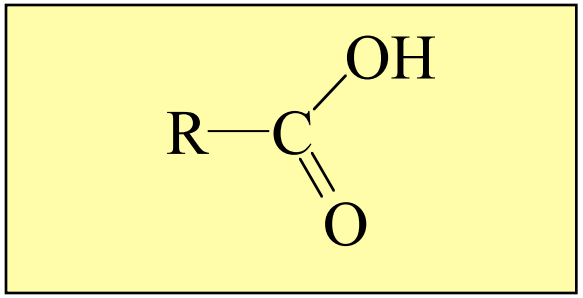
Lipid classes



Summary

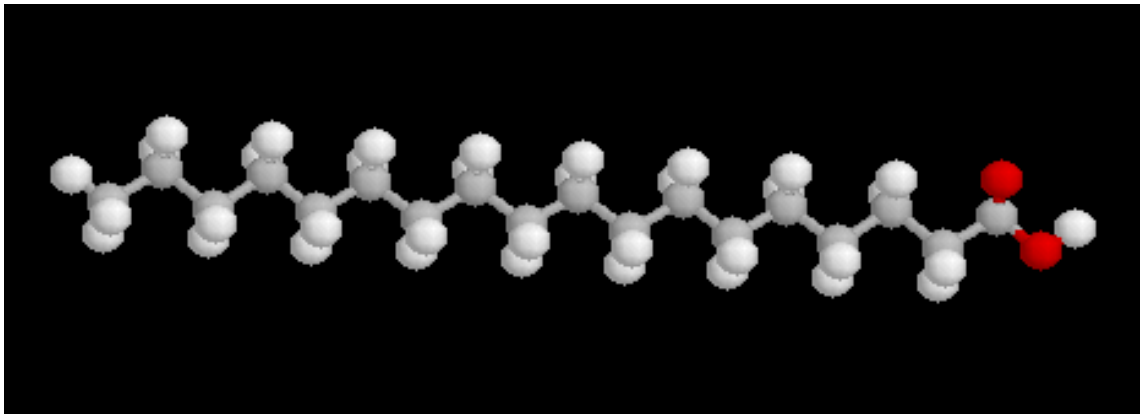
- Fatty acid structures
- From triglycerides to phospholipids: lipid metabolism for life
- Membrane formation and organization

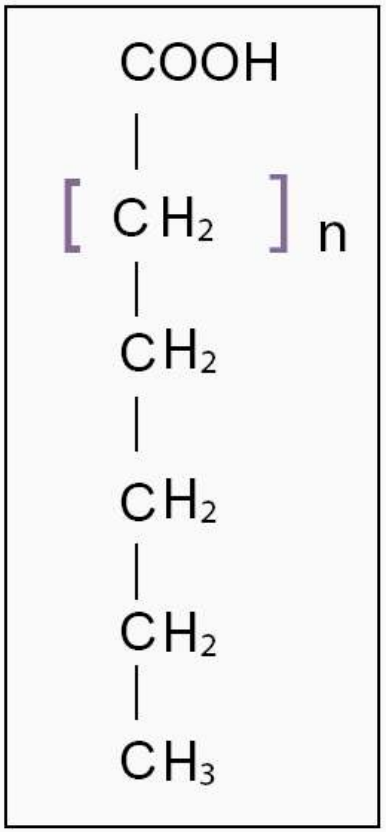
Fatty acids



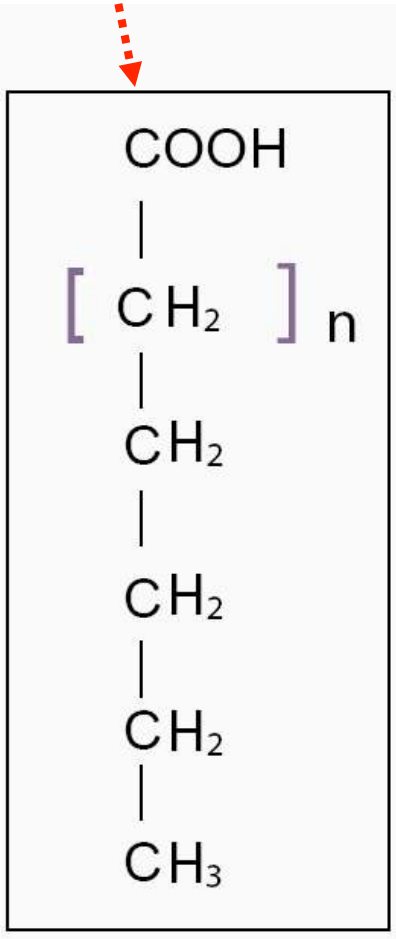
Carboxylic group (H^+)

Basic molecular structure to build up LIPIDS

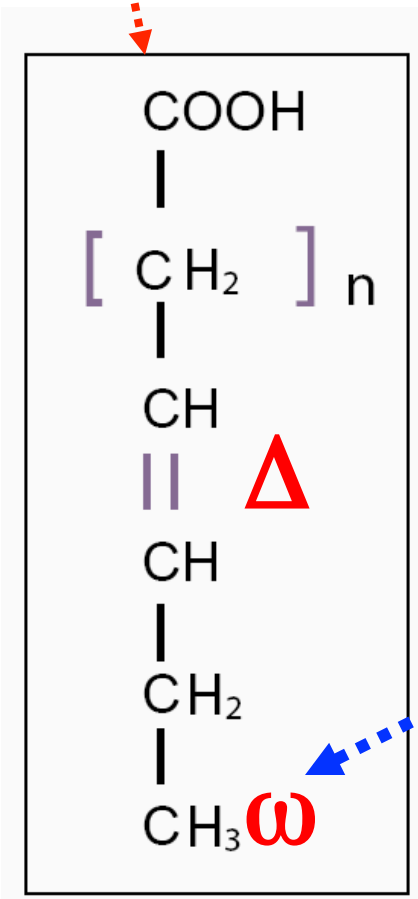




2-carbon atom structure repeated several times: EVEN number



SATURATED FATTY ACIDS SFA



UNSATURATED FATTY ACIDS UFA

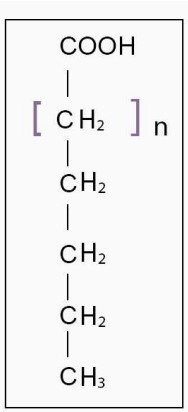
- **CARBOXYLIC GROUP – start**
- **define the position of the unsaturation Δ of the unsaturated fats**
- **METHYL GROUP - Chain end (define the position of the end - The ω of the unsaturated fats)**

Nomenclature of fatty acids

n. Of C atoms/
n. double bonds

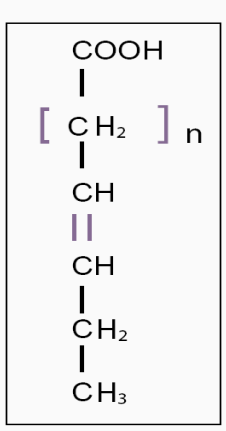
SFA

12:0
14:0
16:0
18:0
20:0

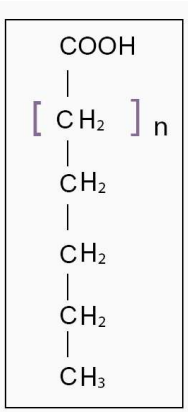
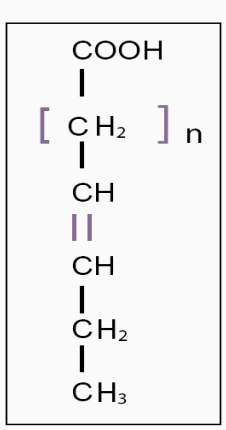


MUFA
PUFA

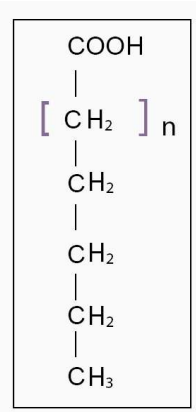
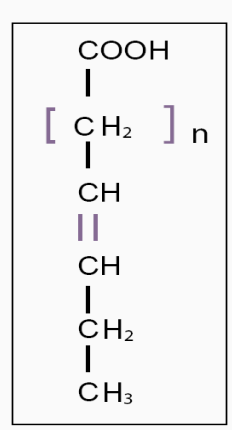
16:1
18:1
18:2
18:3
20:4



Nomenclature of fatty acids

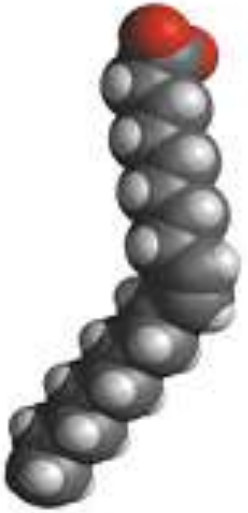
	n. Of C atoms/ n. double bonds		Common name
SFA	12:0		lauric acid
	14:0		miristic acid
	16:0		palmitic acid
	18:0		stearic acid
	20:0		arachidic acid
MUFA PUFA	16:1		palmitoleic acid
	18:1		oleic acid
	18:2		linoleic acid
	18:3		linolenic acid
	20:4		arachidonic acid

Nomenclature of fatty acids

	n. Of C atoms/ n. double bonds		Common name	melting point (°C)
SFA	12:0		lauric acid	44
	14:0		miristic acid	58
	16:0		palmitic acid	63
	18:0		stearic acid	70
	20:0		arachidic acid	77
MUFA	16:1		palmitoleic acid	32
	18:1		oleic acid	16
PUFA	18:2		linoleic acid	- 5
	18:3		linolenic acid	- 11
	20:4		arachidonic acid	- 49

Fatty acid structures

Palmitic acid 16:0



Oleic acid 18:1

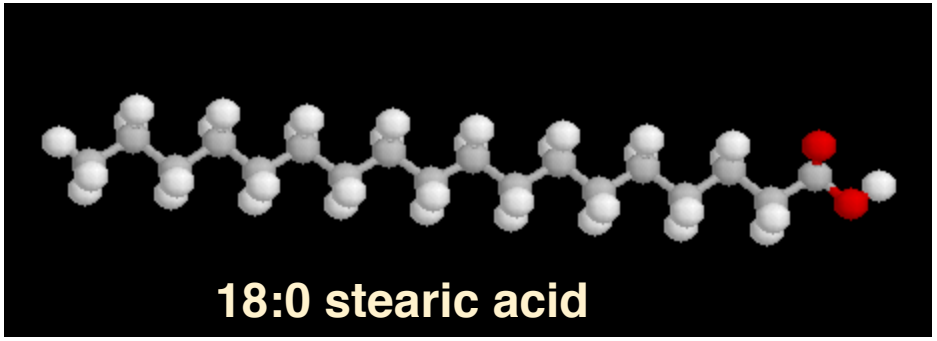
SATURATED

Effects of physical properties on biological properties

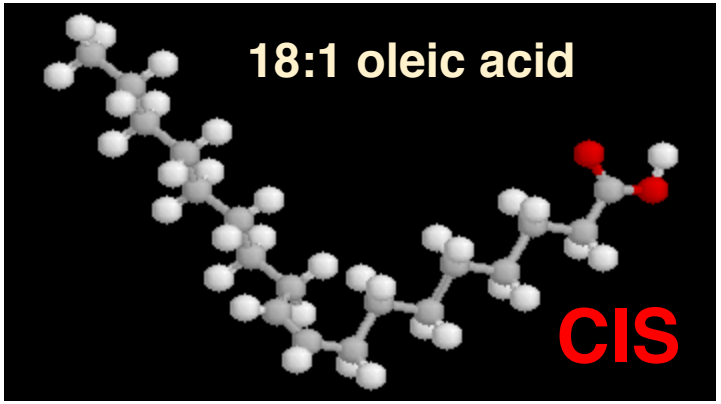
UNSATURATED

CIS

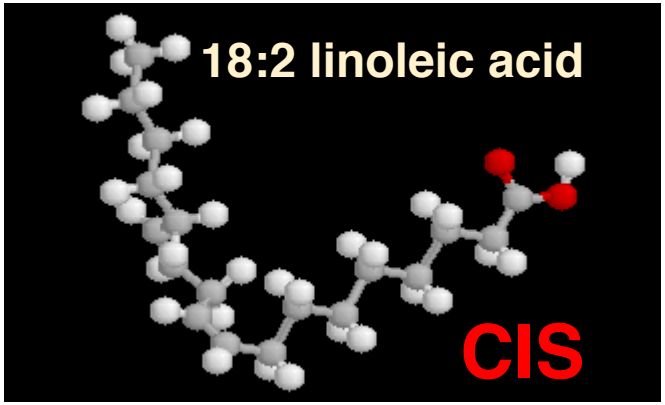
Fatty acid structures

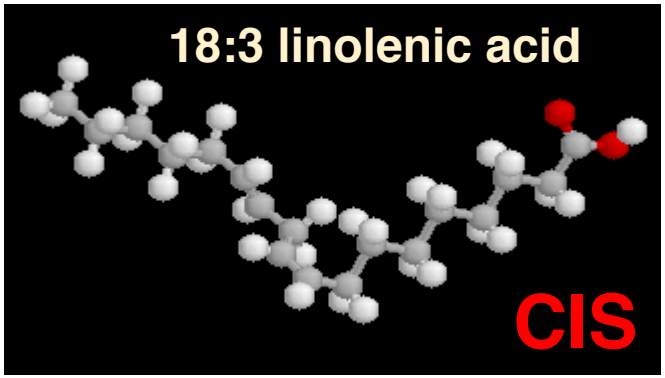


SATURATED



MONO UNSATURATED, MUFA

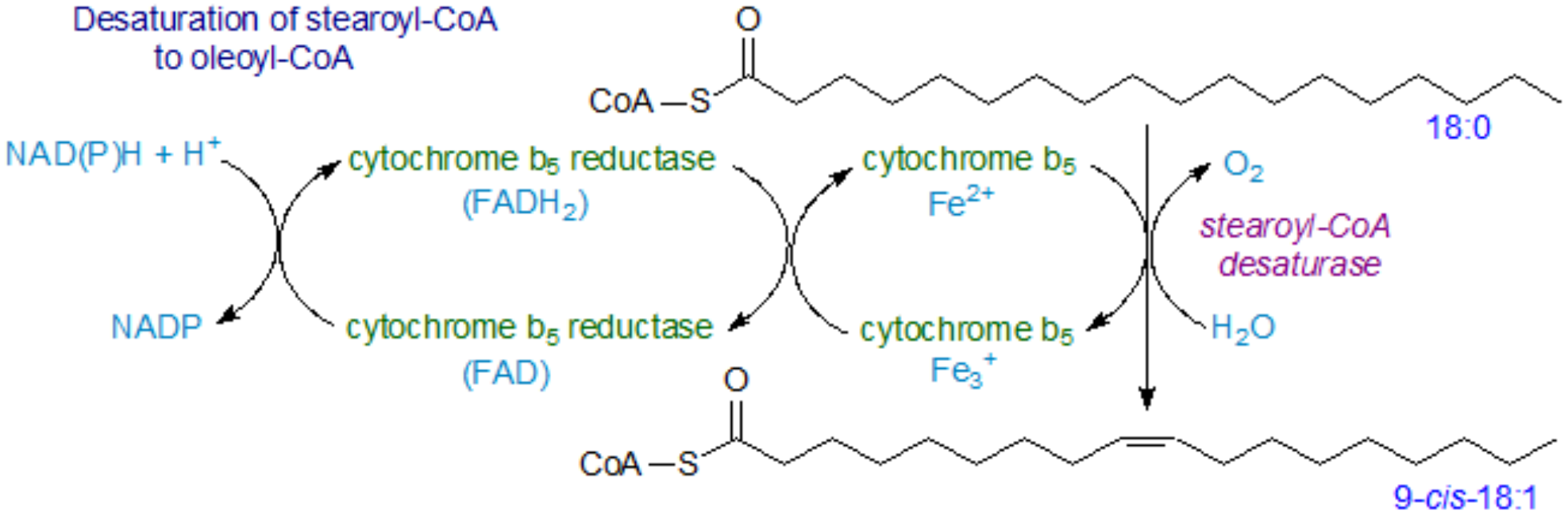


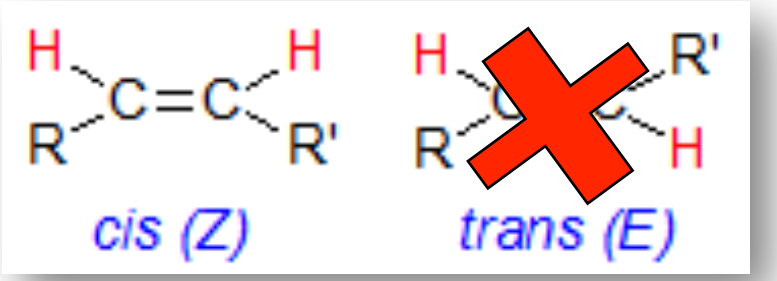


POLYUNSATURATED
PUFA

ALL NATURAL UNSATURATED FATTY ACIDS ARE CIS ISOMERS

Desaturase mechanism





- ❑ **STEREOSPECIFICITY**
- ❑ **REGIOSPECIFICITY**

http://www.lipidhome.co.uk/lipids/fa-eic/fa-mono/index.htm

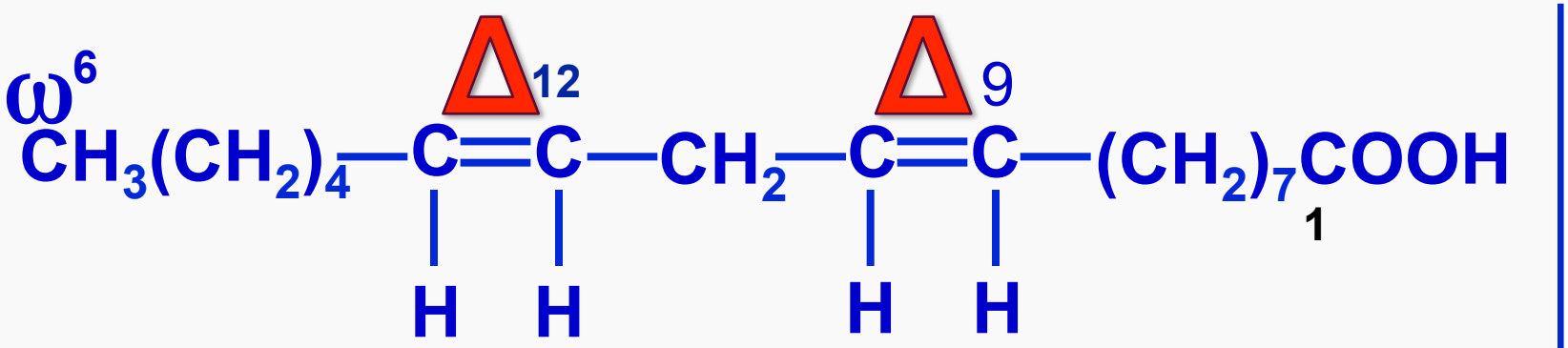
Polyunsaturated fatty acids

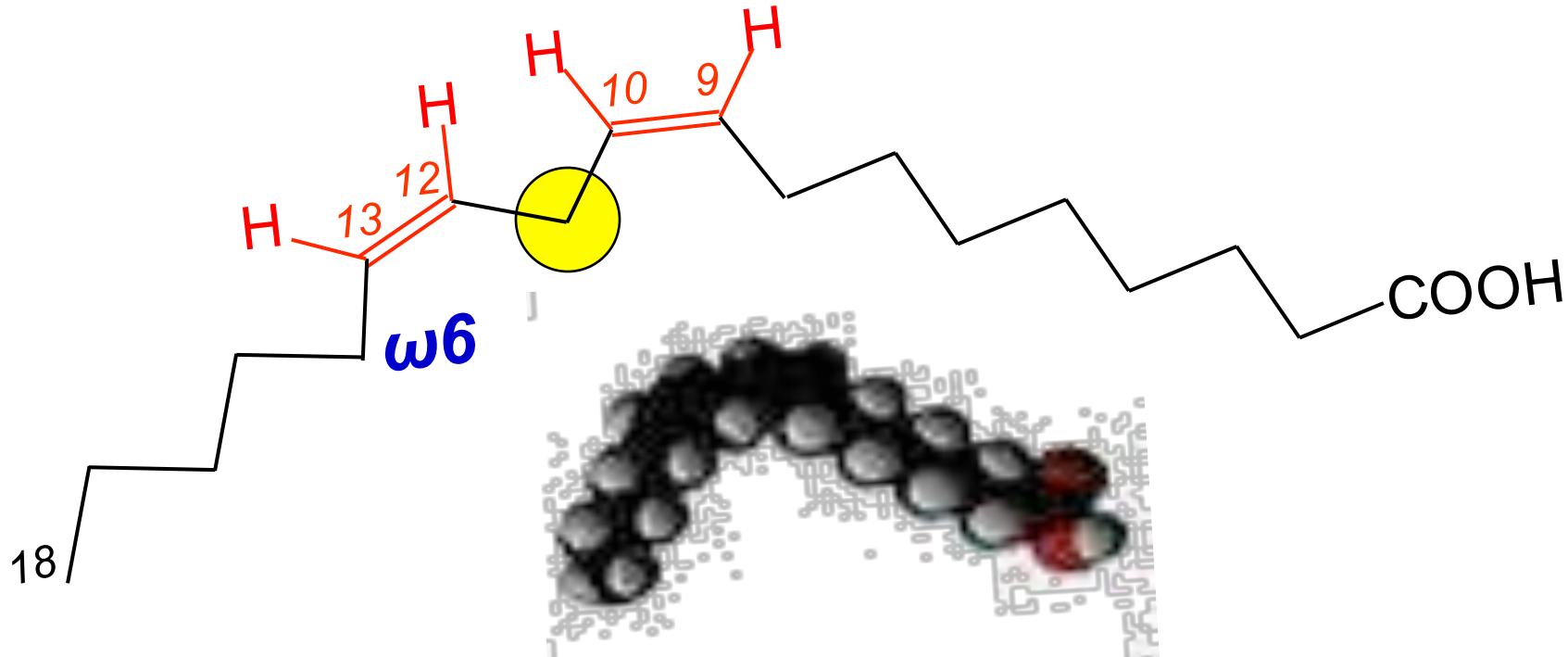
PUFA

With more than one double bond separated by one methylenic group CH_2

Linoleic acid (**18:2^{9,12} - 18:2, ω-6**)

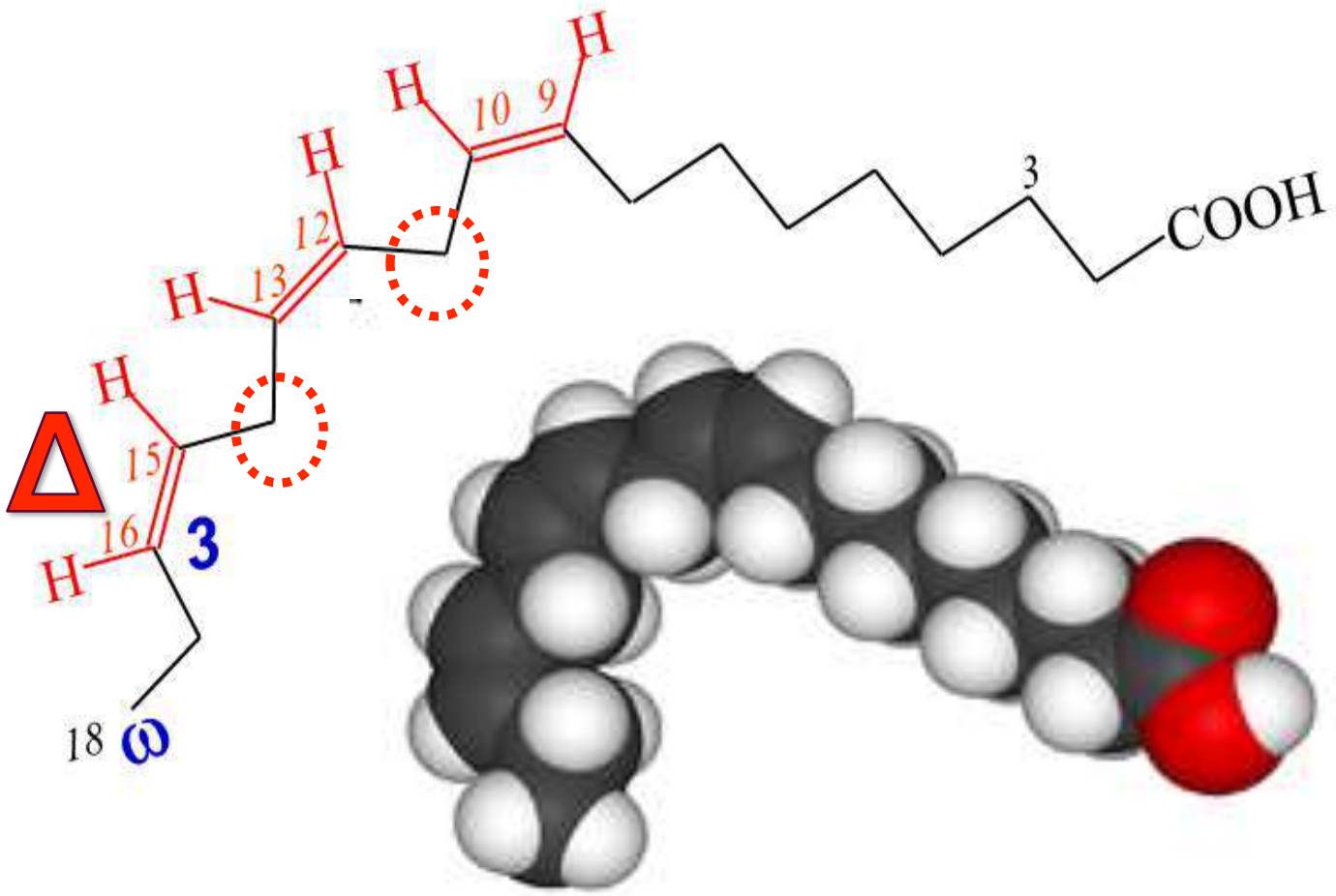
all cis-Δ9,12-octadecadienoic acid





Alpha-Linolenic acid $18:3^{9,12,15}$ - 18:3, ω-3)

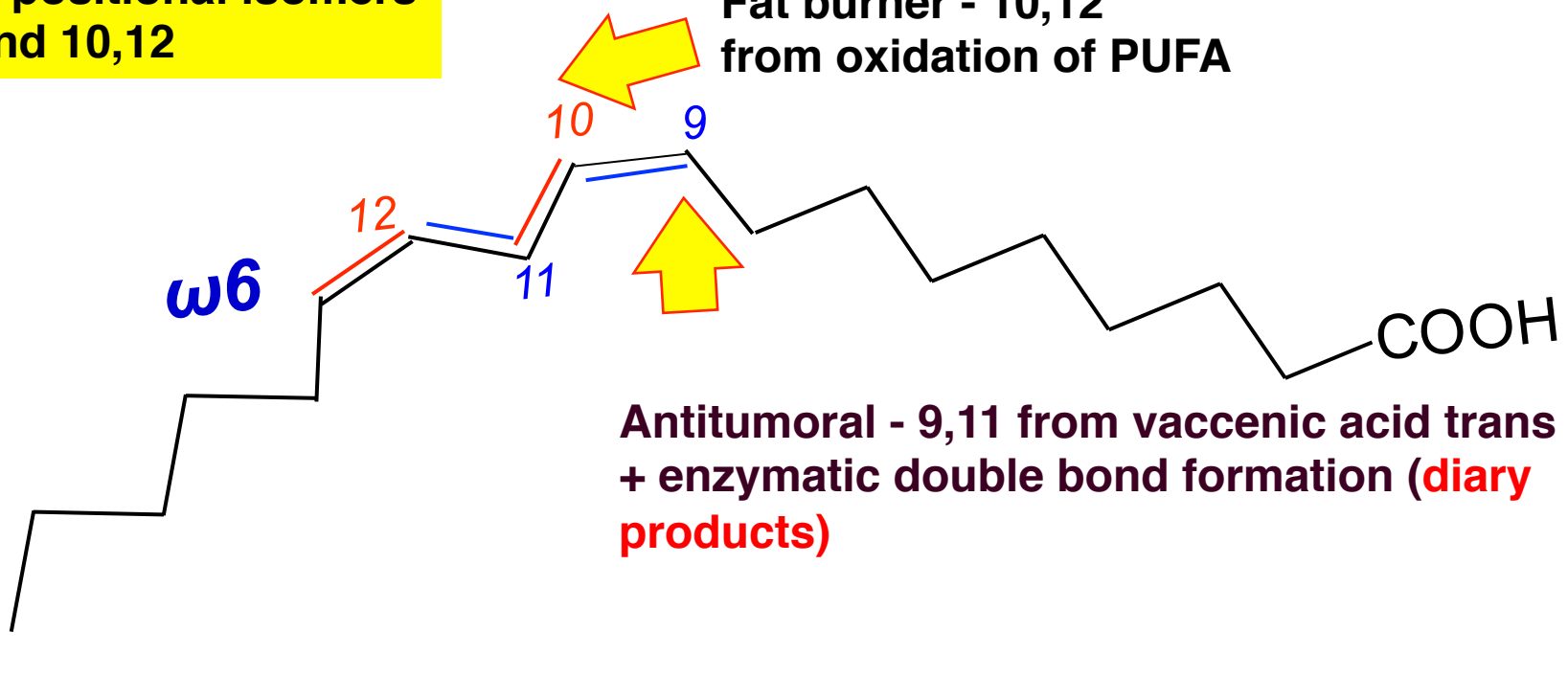
all cis-Δ9,12,15 -octadecatrienoic acid



Conjugated fatty acids
Two consecutive double bonds

Conjugated linoleic acid (**18:2^{10,12} - 18:2, ω-6**)

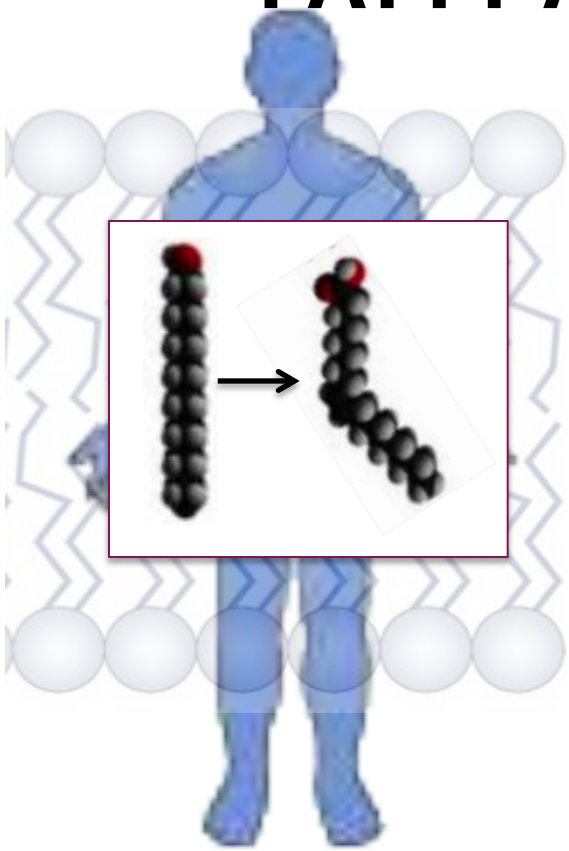
Mix of positional isomers 9,11 and 10,12



SFA-MUFA pathway

FATTY ACID Synthase ($CH_3C(O)SCoA$)

(acetylCoA)



C16:0
Palmitic acid

Elongase

(C18:0)
Stearic acid

Δ9 desaturase

(C18:1-Δ9)
Oleic acid

Δ9 desaturase

(C16:1-Δ9)
Palmitoleic acid

Elongase

(C18:1-Δ11)
Vaccenic acid

Elongase

Long chain
saturated fatty acids
20:0
22:0
24:0
26:0

Fatty acid synthase FAS

2+2+2……

BENT STRUCTURES

Elongase

Desaturase

Palmitic acid 16:0

Stearic acid 18:0

Oleic acid 18:1

Δ9 Enzyme (SCD-1)

ELONGASE adds two carbon units

DESATURASE forms CIS double bonds

regio- and stereospecific enzymes

SFA

Excess!!

- Too much from the diet
- Not good post-transformation by desaturase

DIET

SATURATED FATS
CARBOHYDRATES
(glycemic index)

BIOSYNTHESIS

Fatty acid synthase

Fundamental transformation

SFA

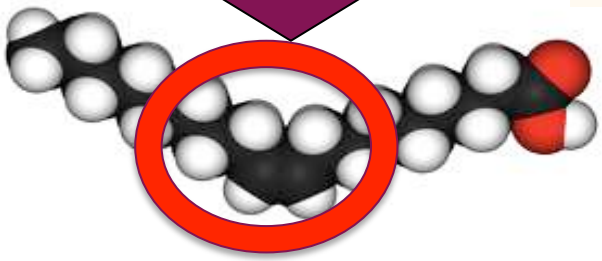
C16:0 palmitic acid mp 63 °C

C18:0 stearic acid mp 70 °C

Delta9 desaturase

DESATURASE: control mechanism for saturated fats accumulation

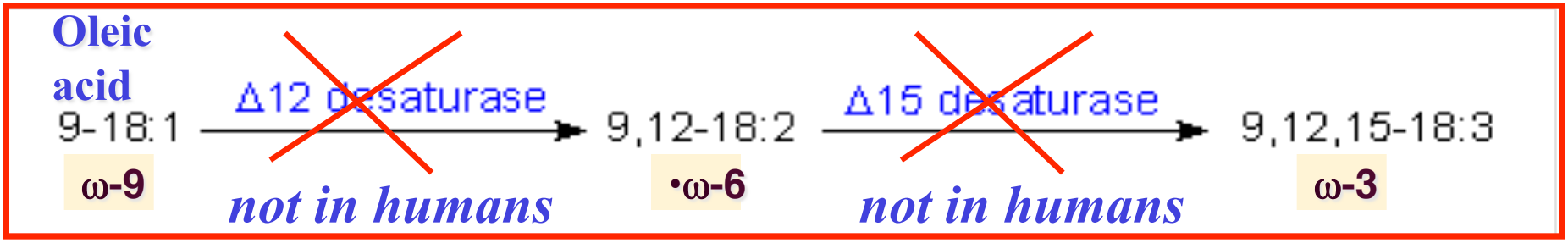
C16:1 palmitoleic acid mp 32 °C



C18:1 oleic acid mp 16 °C

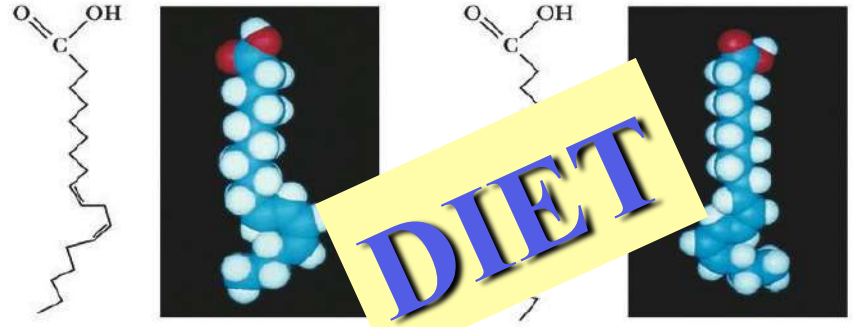
MUFA

Essential PUFA



Omega-6

ω-6
n-6



Linoleic acid

α–Linolenic acid

Omega-3

ω-3
n-3

Eczema, allergies, hair loss
arthritis, high pressure,
high cholesterol
8-12 g/d LA assumption

Omega-6

Omega-3

Allergy, Alzheimer, CV risk,
immune deficiency,
INFLAMMATION
1.1 g/d ALA
EPA-DHA (250 mg/d)

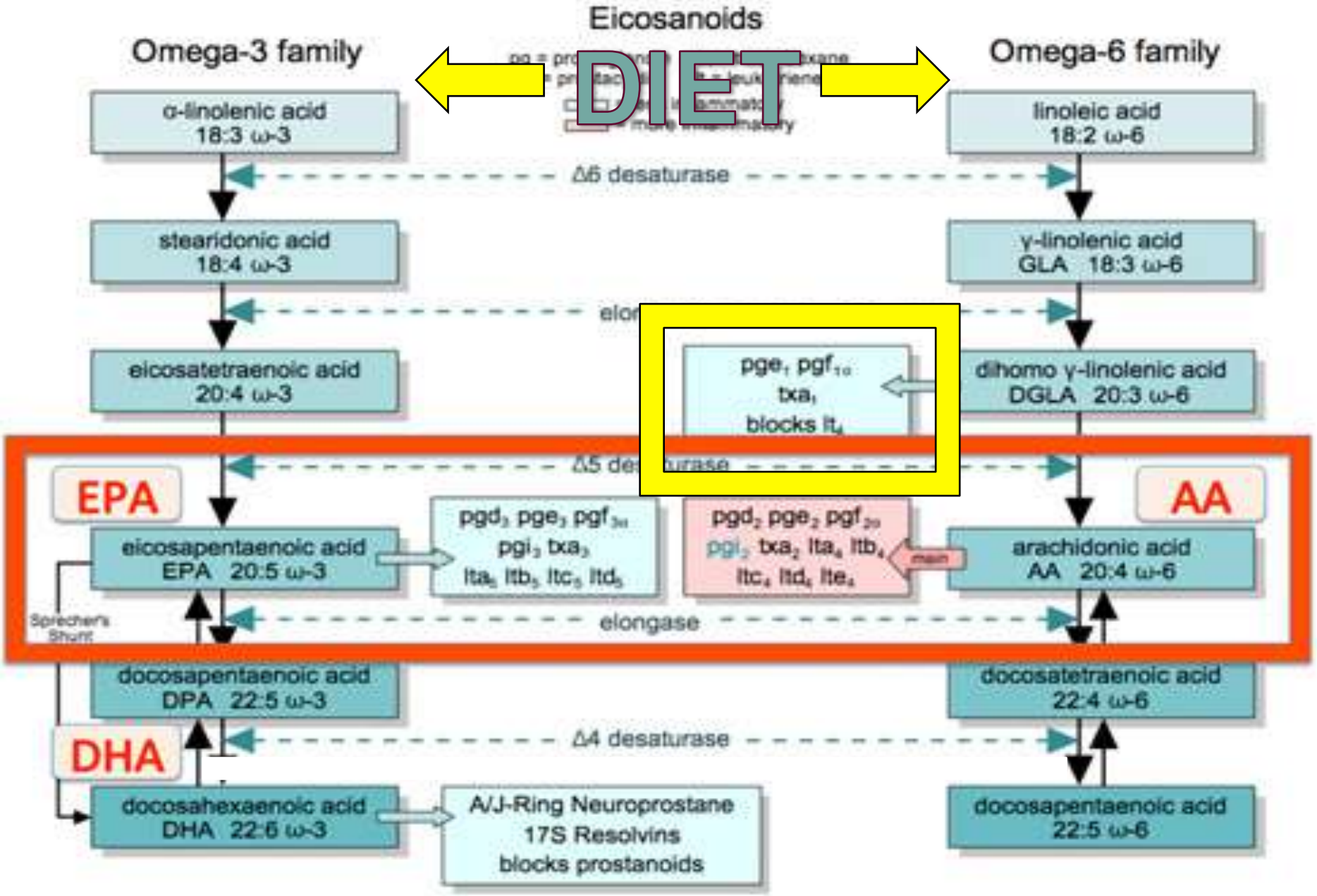
EFSA

WHO

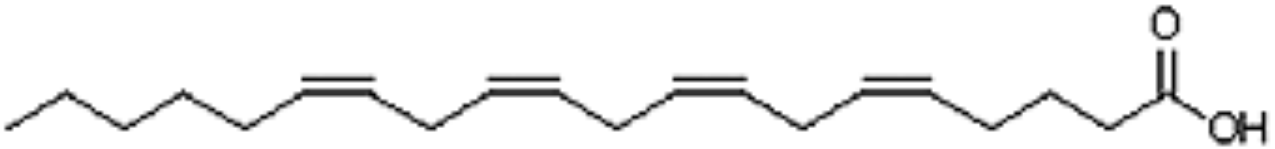
FAO

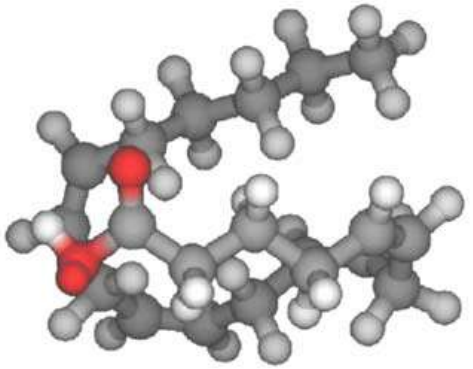
Omega-6/omega-3 nutritional ratio
4:1 – 1:1

PUFA transformations



Eicosanoids

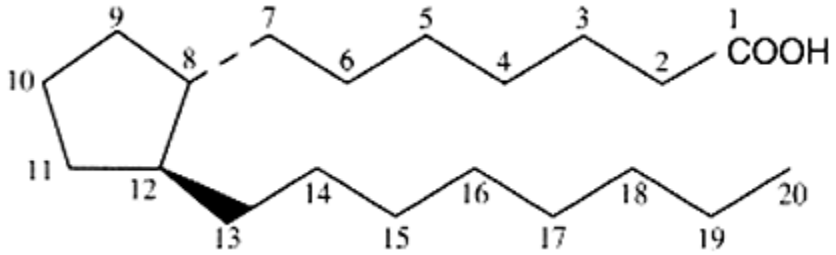




Arachidonic acid

Structures with 20 carbon atoms

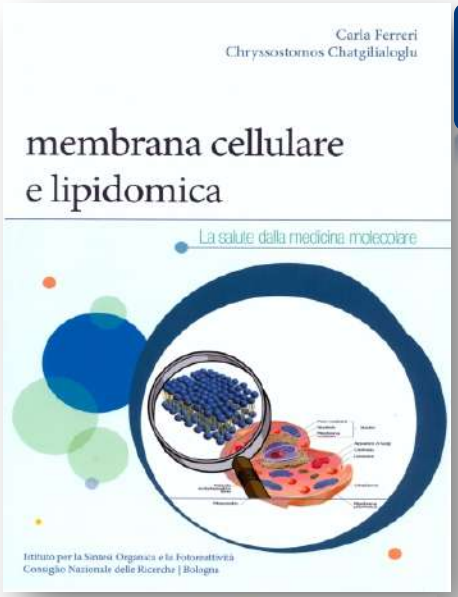
Bergstrom, Samuelsson, Vane
1982 Nobel prize

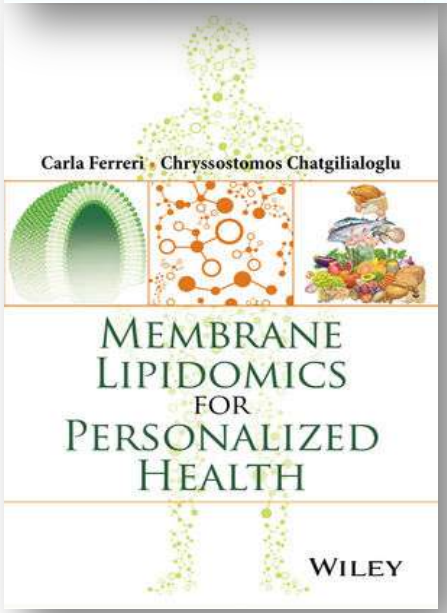


Prostanoic acid: scaffold

Prostaglandins, leukotriens, etc…

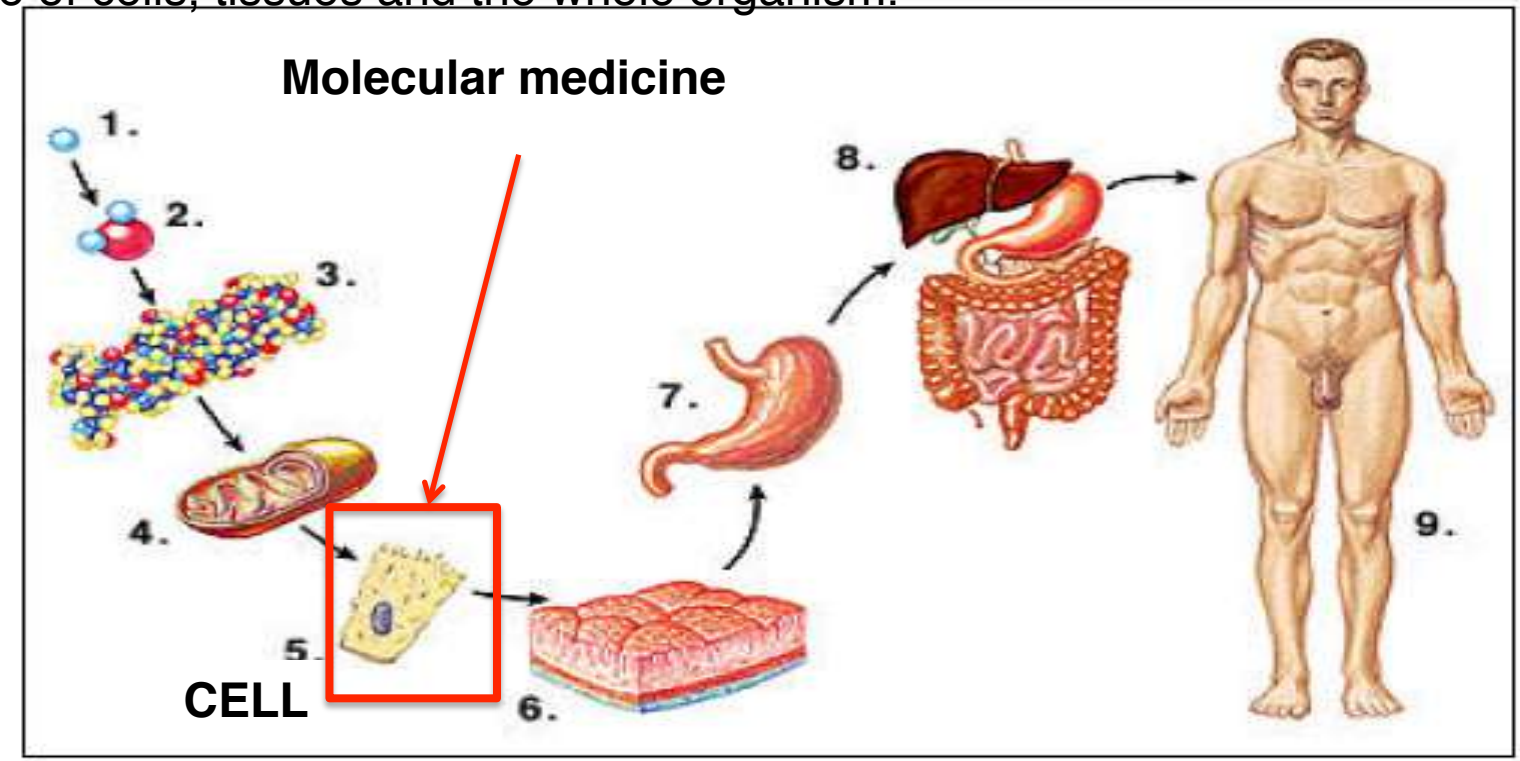
What is LIPIDOMICS



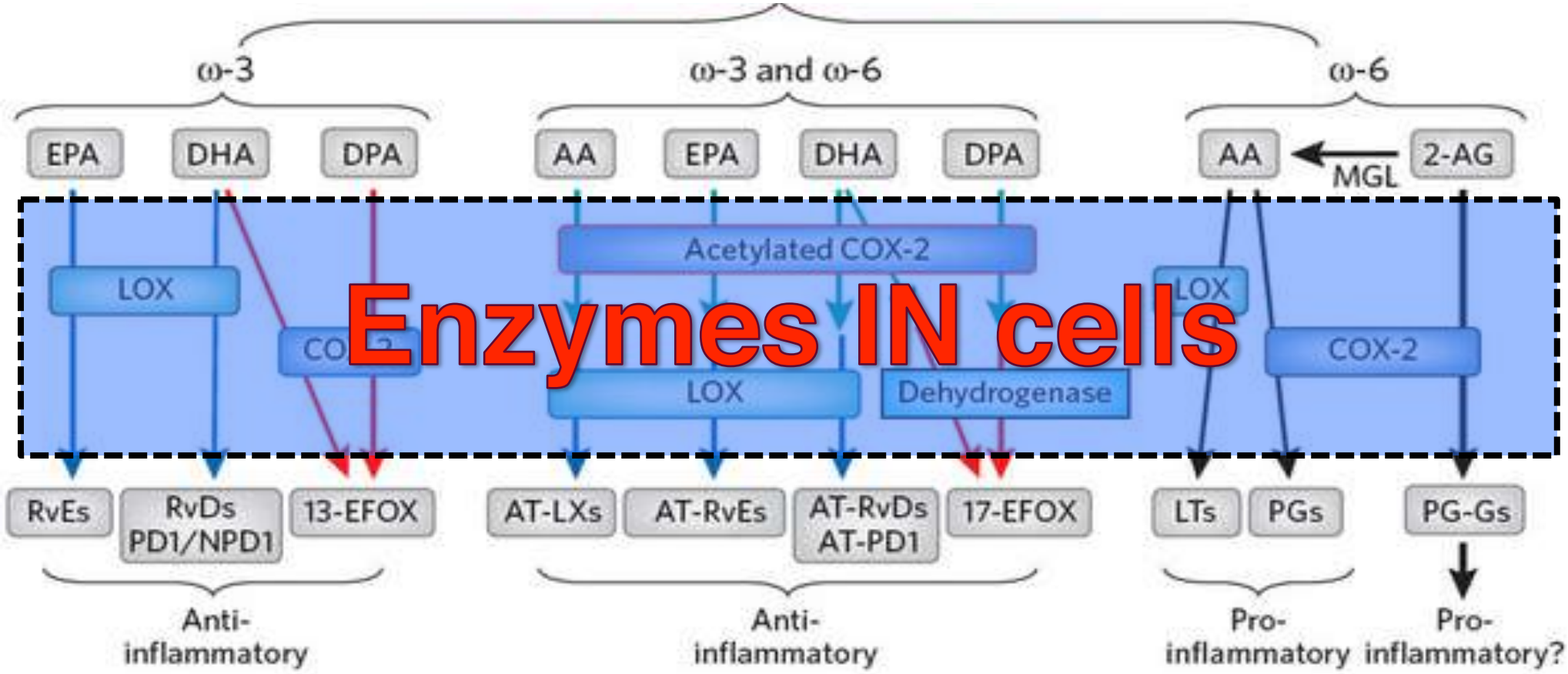


edizioni
Consiglio Nazionale delle Ricerche

Lipidomics studies LIPIDS in a DYNAMIC CONTEXT of transformations under physiological and pathological conditions, evaluating the balance between nutrition and metabolism. It is part of metabolomics when the processes belongs to metabolic pathways, whereas LIPIDOMICS of CELL MEMBRANE belongs to cell regulatory systems which decide the fate of cells, tissues and the whole organism.



From MEMBRANES: release of LIPID MEDIATORS

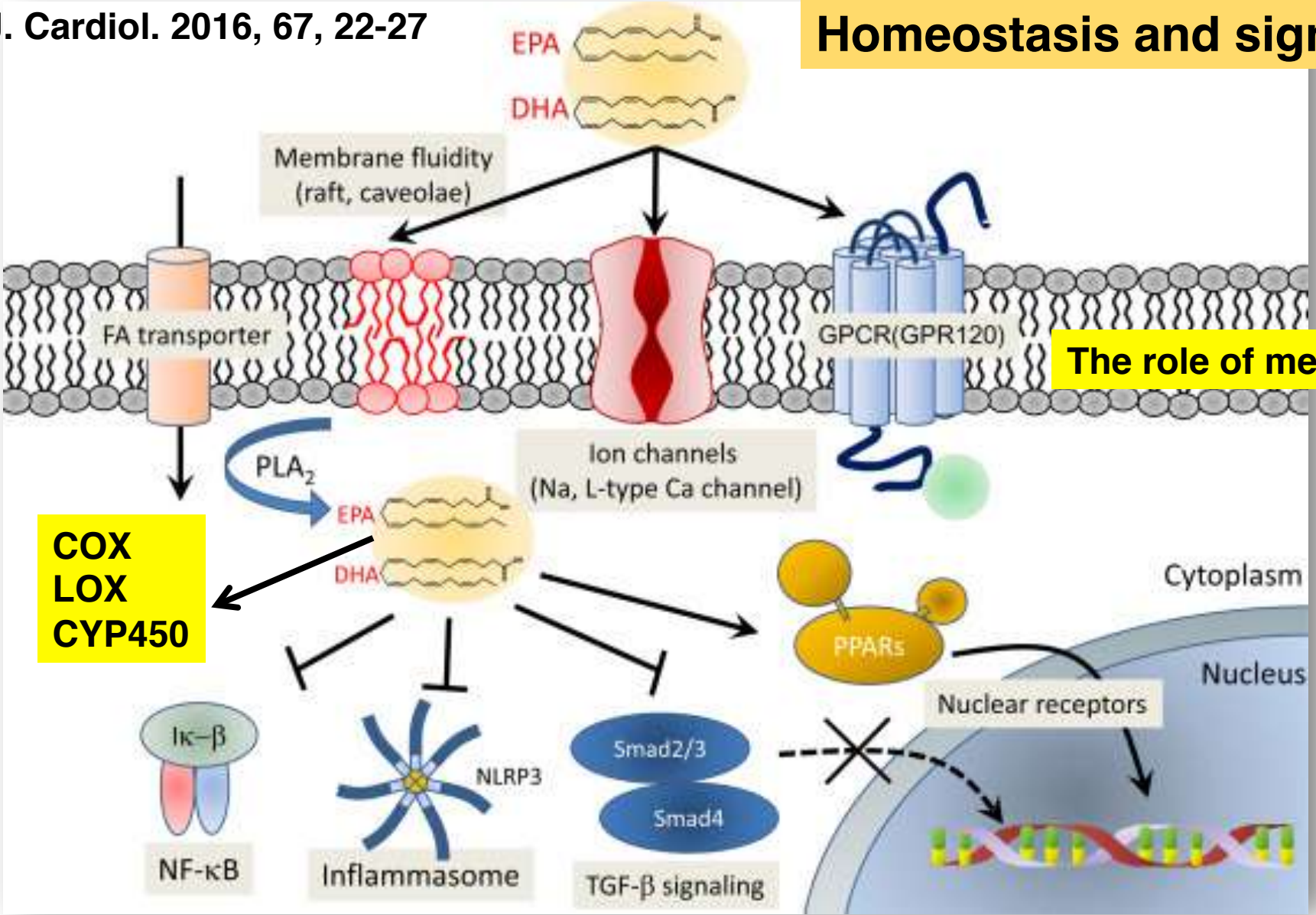


Nature Chemical Biology 6, 401–402 (2010)

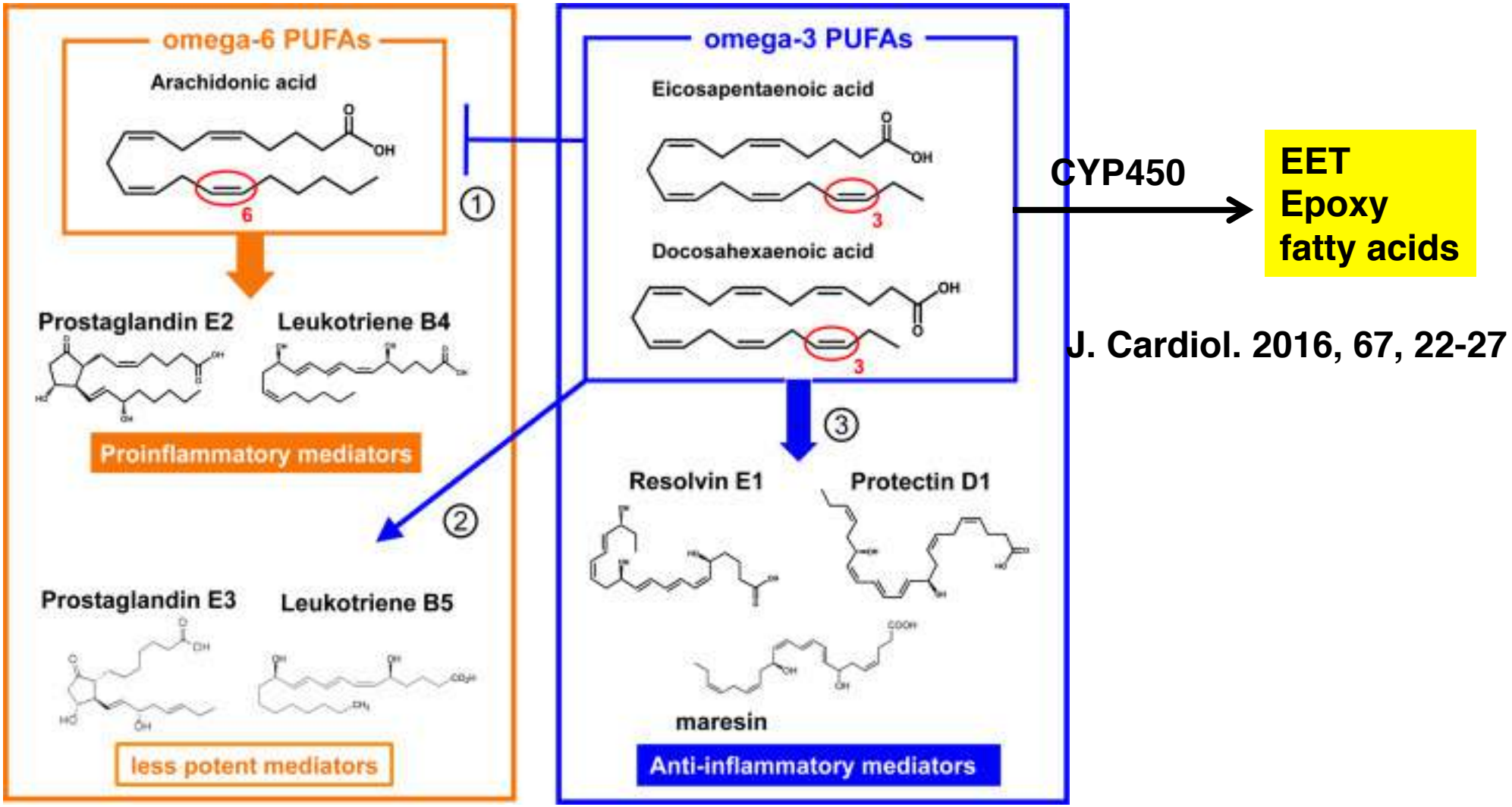
Functional & membrane lipidomics

J. Cardiol. 2016, 67, 22-27

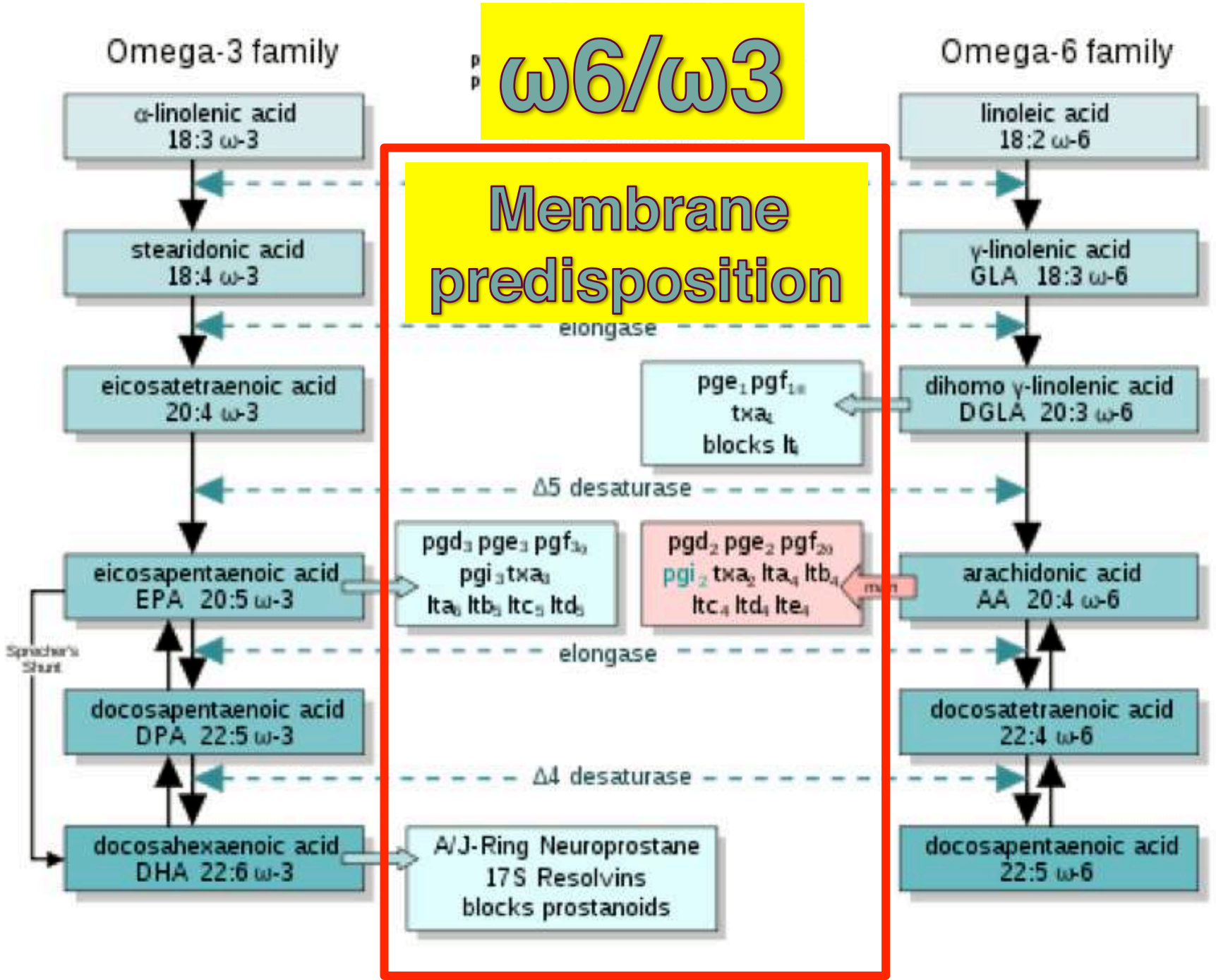
Homeostasis and signaling



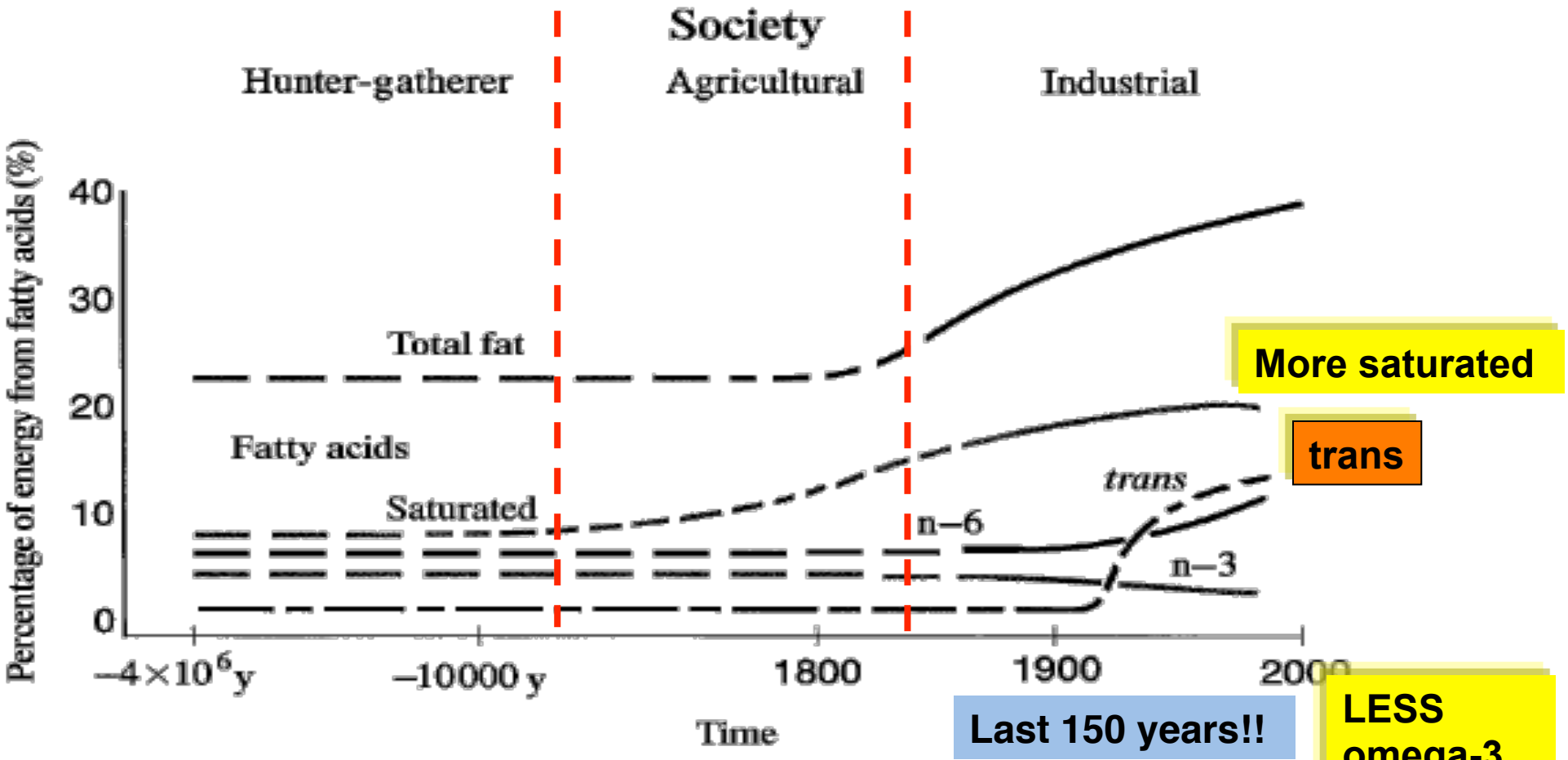
The role of membrane



J. Cardiol. 2016, 67, 22-27


ω6/ω3
Membrane predisposition
Omega-3 family
Omega-6 family
α-linolenic acid 18:3 ω-3
linoleic acid 18:2 ω-6
stearidonic acid 18:4 ω-3
γ-linolenic acid GLA 18:3 ω-6
elongase
eicosatetraenoic acid 20:4 ω-3
dihomo γ-linolenic acid DGLA 20:3 ω-6
blocks lt
Δ5 desaturase
eicosapentaenoic acid EPA 20:5 ω-3
arachidonic acid AA 20:4 ω-6
elongase
docosapentaenoic acid DPA 22:5 ω-3
docosatetraenoic acid 22:4 ω-6
Δ4 desaturase
docosahexaenoic acid DHA 22:6 ω-3
A/J-Ring Neuroprostane
17S Resolvins
blocks prostanoids
docosapentaenoic acid 22:5 ω-6

How we can influence membrane predisposition by the diet

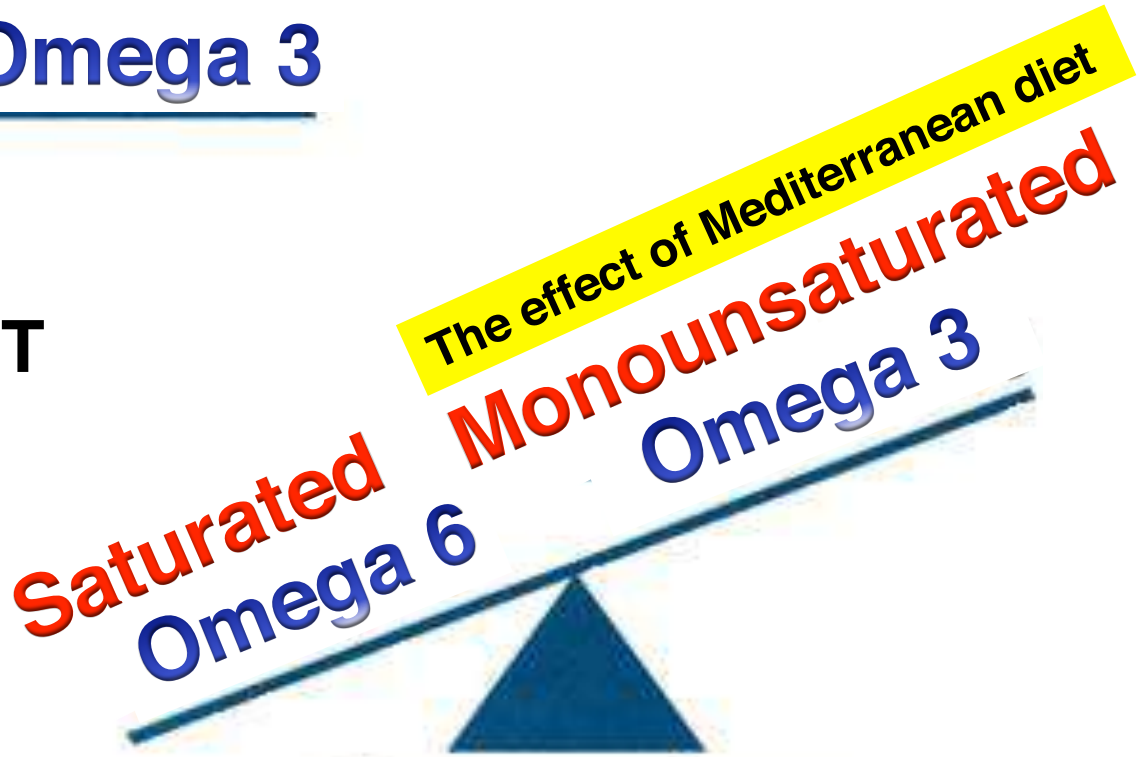


Harvard School of Public Health, Simopoulos, 2008

Unbalance

ARCAIC DIET

Time period	ω3: ω6
Paleolithic	1.3:1
Greece prior to 1960	1:1.5
Current Japan	1:5
Current India, rural	1.5-1:6
Current UK / EU	1:15
Current United States	1:17
Current India, urban	1:38-50



MODERN DIET

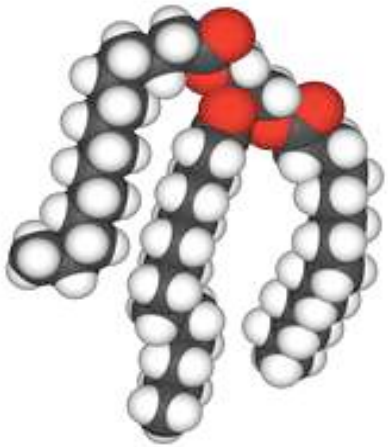
A. Simopoulos, Exp. Biol.Med. 2008, 233, 674-688

What about pets?

Summary

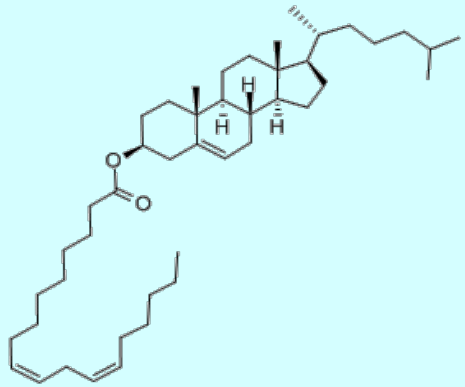
- Fatty acid structures
- From triglycerides to phospholipids: lipid metabolism for life
- Membrane formation and organization

Fatty acid-containing lipids

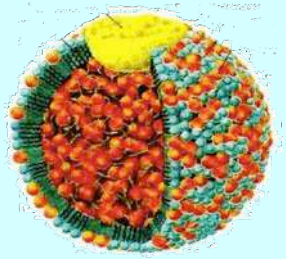


TRIGLICERIDES

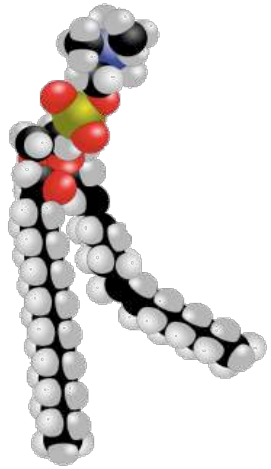
Transport and deposit



CHOLESTERYL ESTERS



LIPOPROTEINS
TG + phospholipids+
Chol.esters + cholesterol



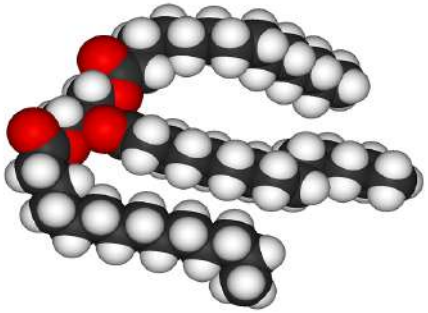
PHOSPHOLIPIDS

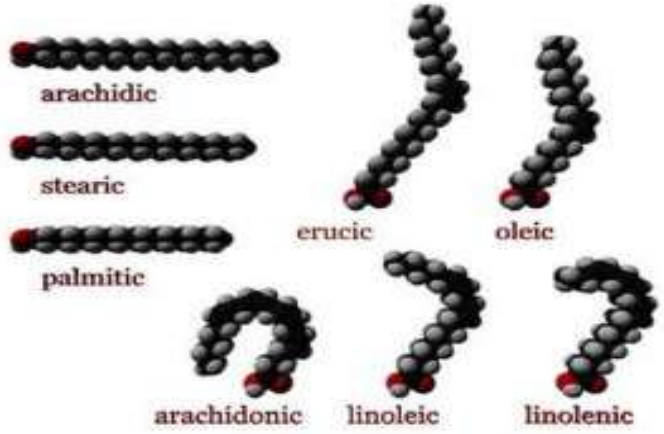
Cell membrane STRUCTURE

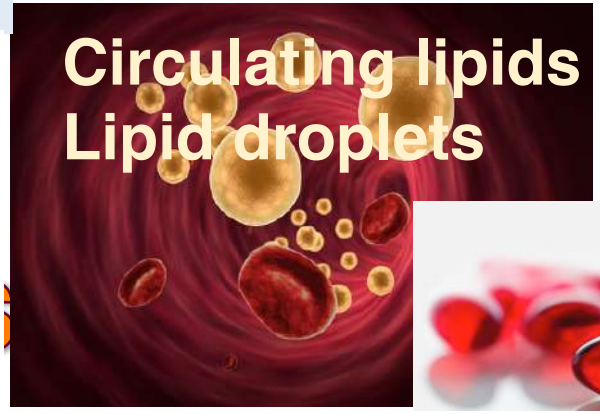
Transport and exchange

Nutrition and Metabolism

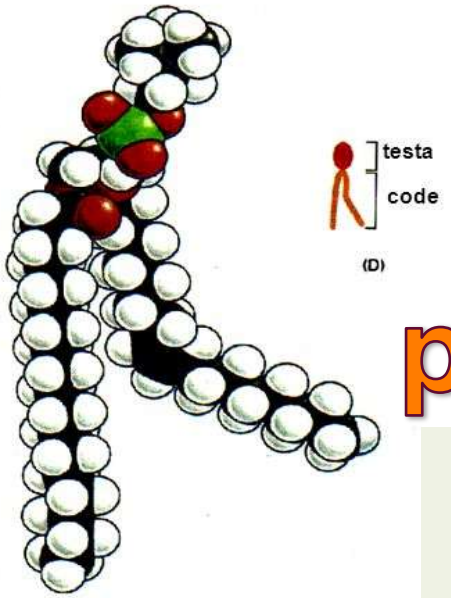
Quality of fatty acids







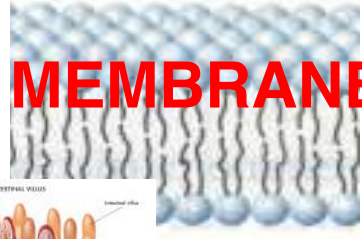
NUTRACEUTICALS

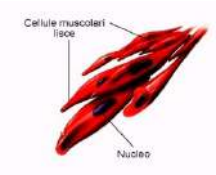


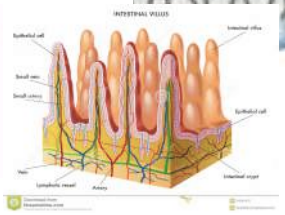
phospholipids

With saturated and unsaturated fats

Active forms



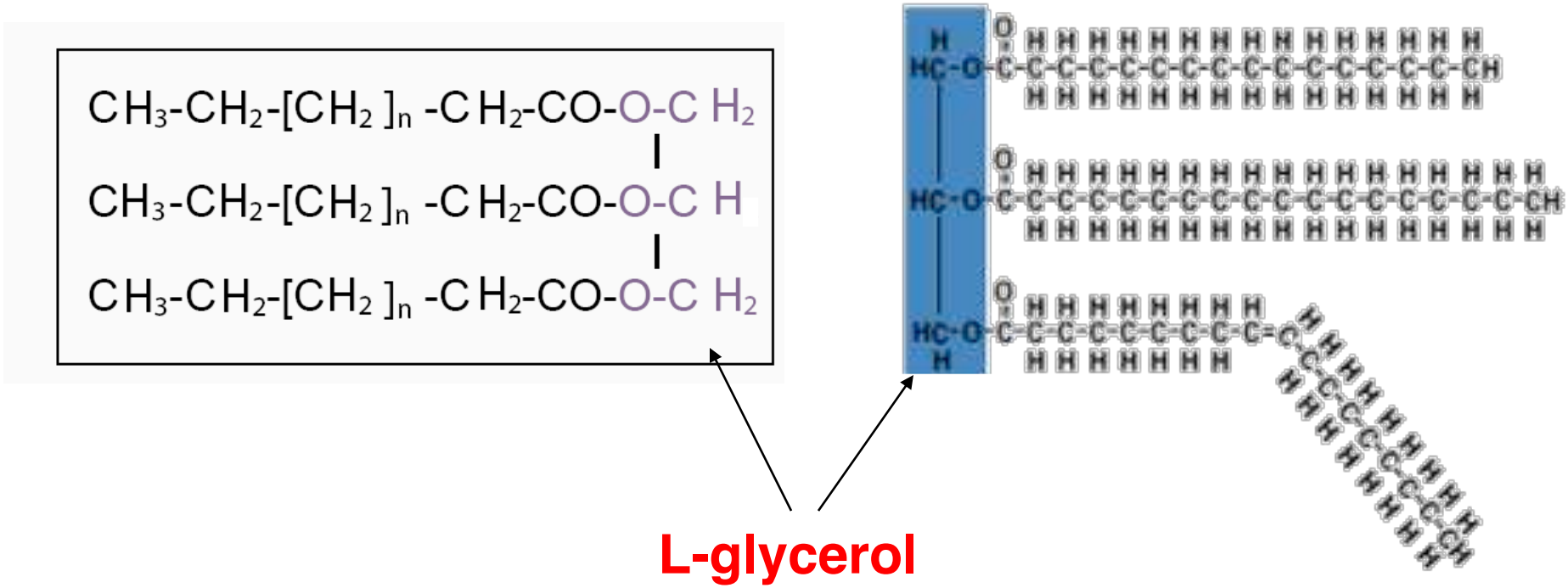




Triglycerides

Triglycerides are the main components of fats and oils and the most abundant lipids in Nature. FATS are solids/semisolds, OILS are liquids.

3 fatty acid units (hydrophobic) of different composition



Oil compositions

	SATURATED		MUFA	Omega-6	Omega-3
%	16:0	18:0	18:1	18:2n6	18:3n3
Olive	12	2	72	11	1
Palm	42	4	43	8	0
Linseed	**12**	1	**15**	**17**	**55** ALA
Sunflower	6	6	33	LA 53	0
Salmon*	19	4	23	1	**20-35%**

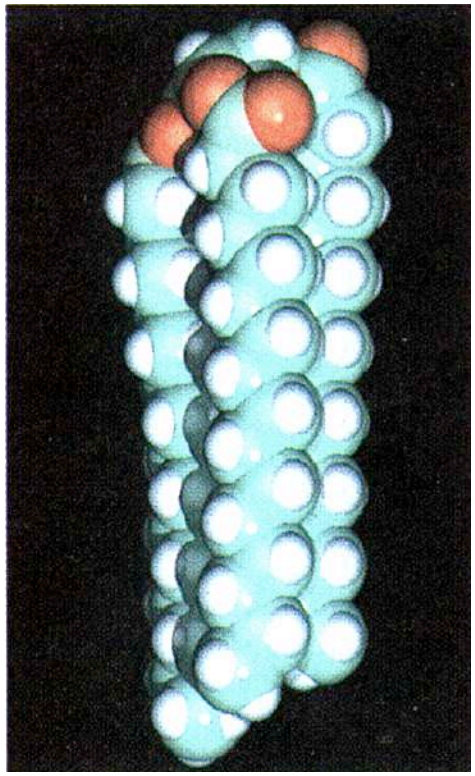
EPA + DHA

Quality of the oils for essential fat intakes

Physical status= molecular status

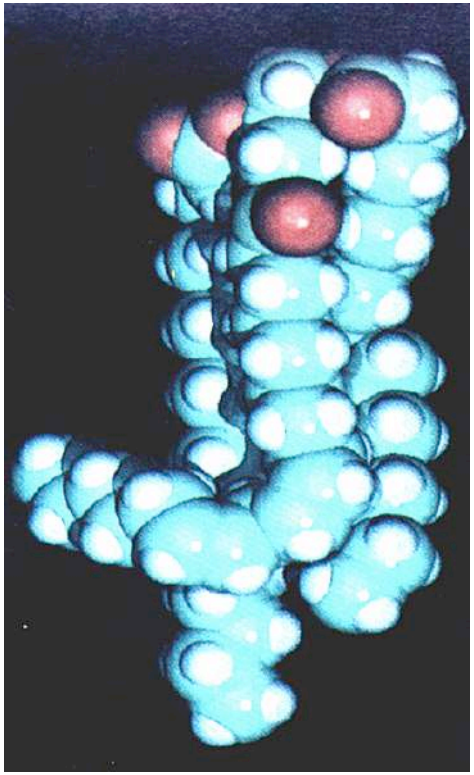
Saturated triglycerides

SOLID



Unsaturated triglycerides

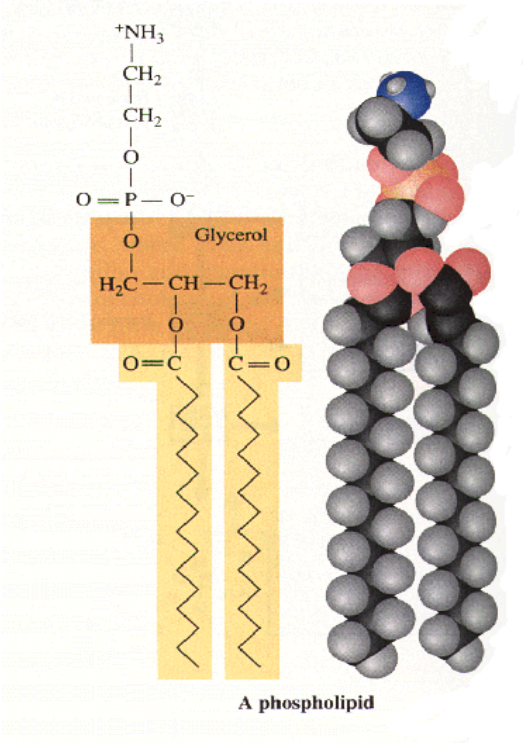
LIQUID



FLUIDITY

For the unsaturation

- **Lecithins are rich of phospholipids**
  - **Used as emulsifying agents**
  - **Contains several types of fatty acids ready to be incorporated in the body (not hydrolysed by lipases)\ the most used are not rich in omega-3**



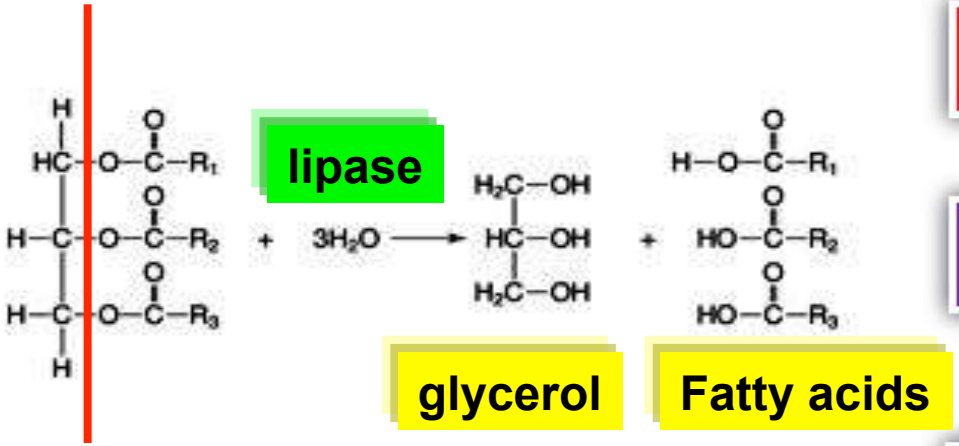
A phospholipid

SOY LECITHIN	
Palmitic	14.5%
Stearic	3.8%
Oleic	11.9%
Vaccenic	1.3%
Linoleic	63.5%
γ-Linolenic	6.3%

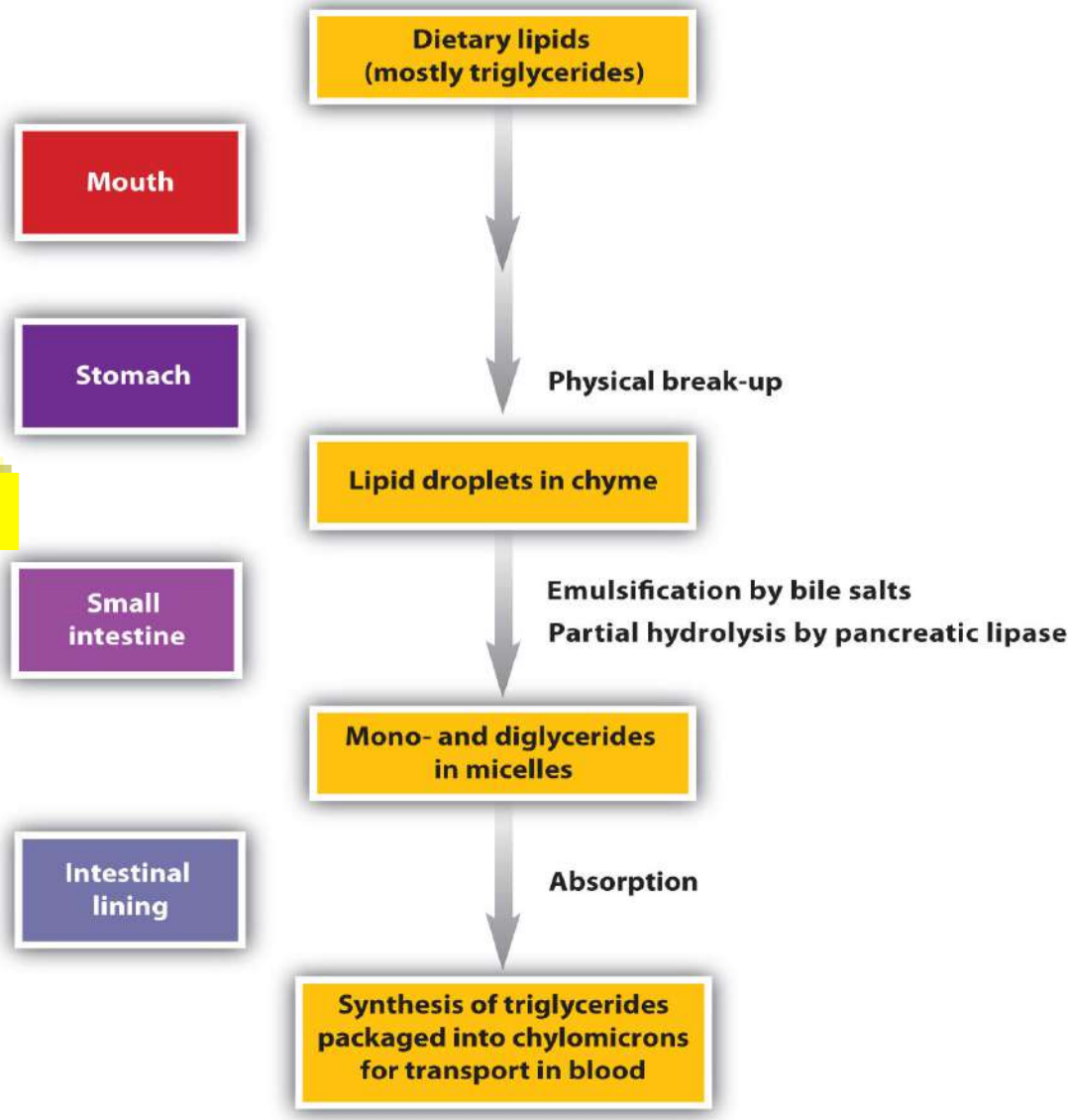
EGG LECITHINS	
Palmitic	32.0%
Stearic	14.1%
Oleic	27.0%
Vaccenic	1.2%
Linoleic	20.0%
Arachidonic	4.8%

Use of triglycerides

triglycerides

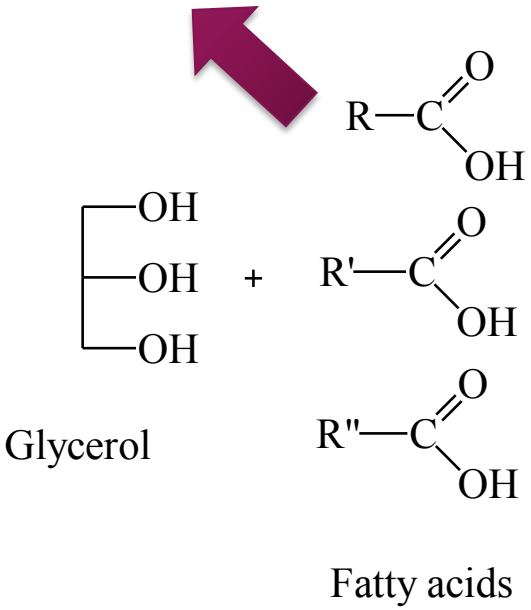


Attention to the fatty acid's quality and quantity that enters the body through food

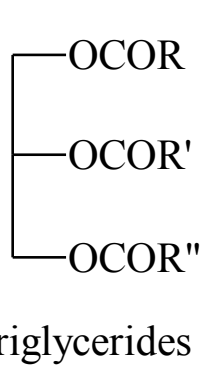


All fatty acid-cont. lipids

- degradation (acetyl groups)
- building block for lipids

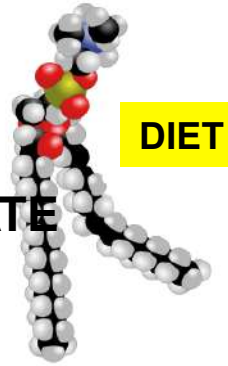


Lipase enzymes



DIGLYCERIDES

CHOLINE + PHOSPHATE

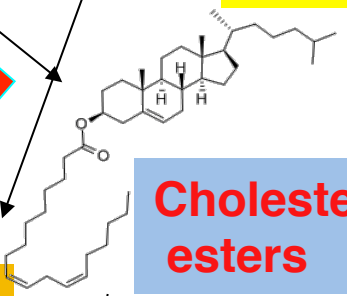


DIET

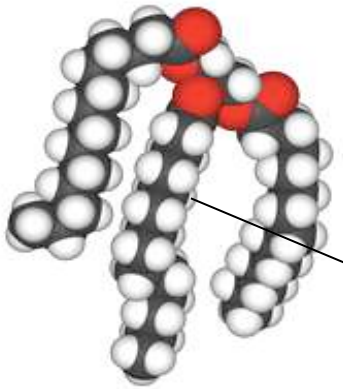
Phospholipids PC, PS, PE

+ cholesterol

DIET



Cholesteryl esters



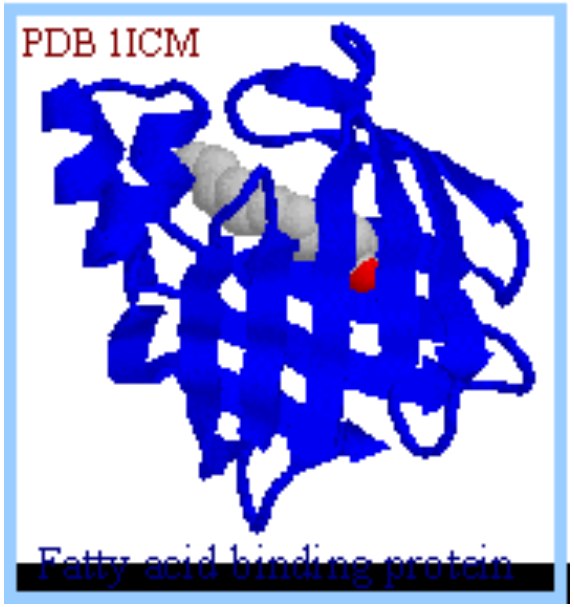
DIET

assembly

LIPOPROTEINS

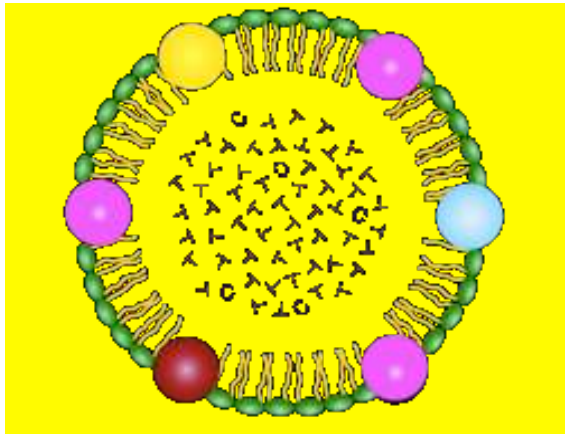
Biosynthesis

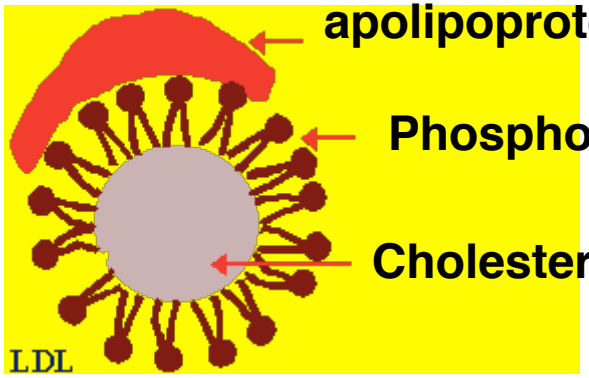
Lipid transport in blood



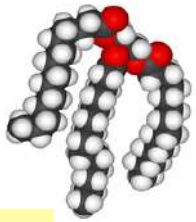
Albumin complex with fatty acids (protection from oxidations)

LIPOPROTEINS: accurate choice of fatty acid types; preference for UNSATURATED lipids. Regulation of fatty acid availability. **BBA Biomembranes 2017**

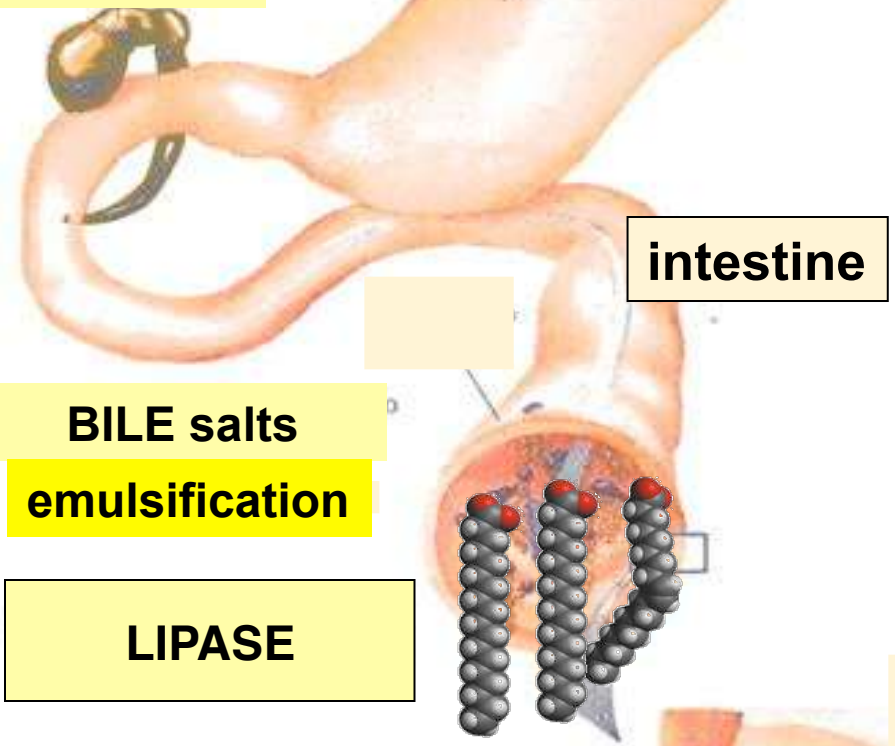




Fats from the diet



Gall bladder



intestine

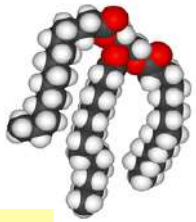
BILE salts

emulsification

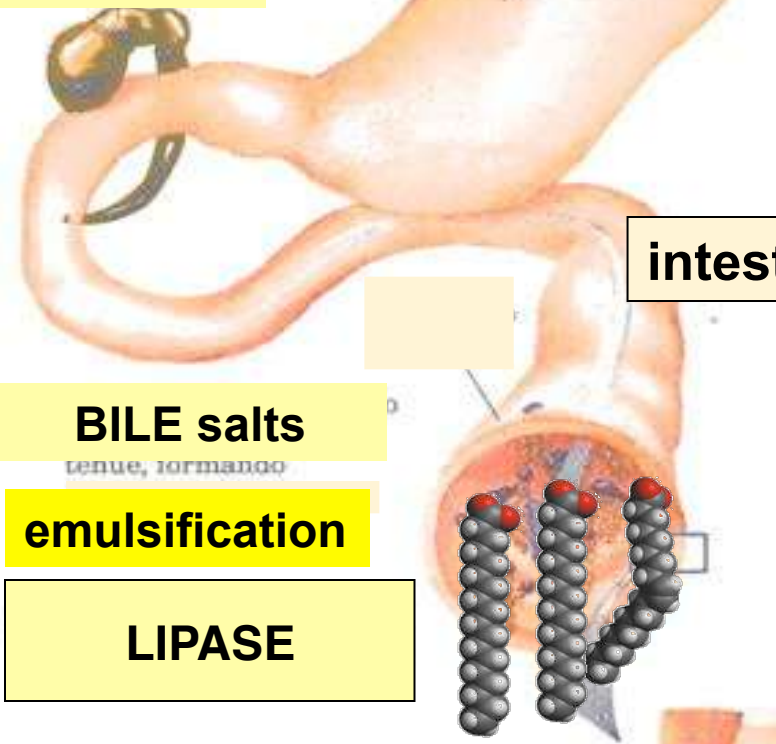
LIPASE

Formation of chilomicrons for fat absorption and entering in the blood circulation

Fats from the diet

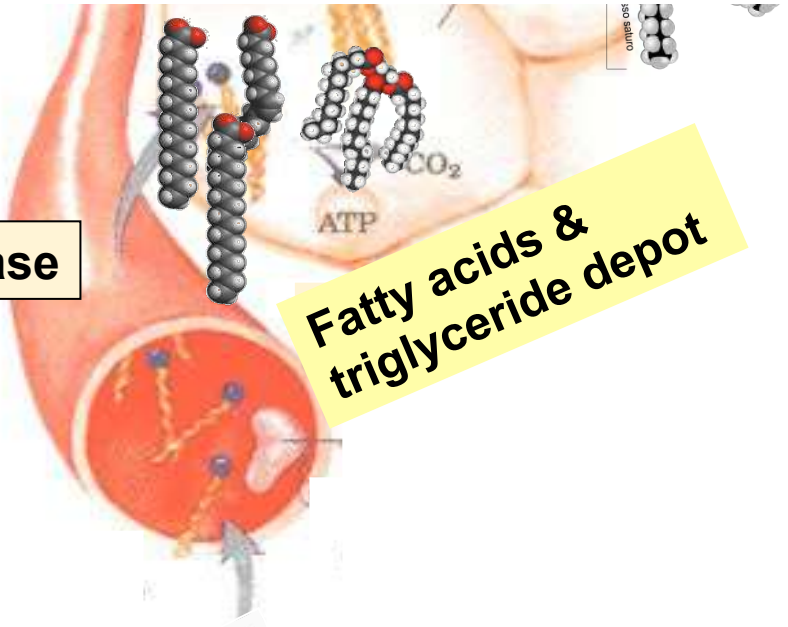


Gall bladder



intestine

vase

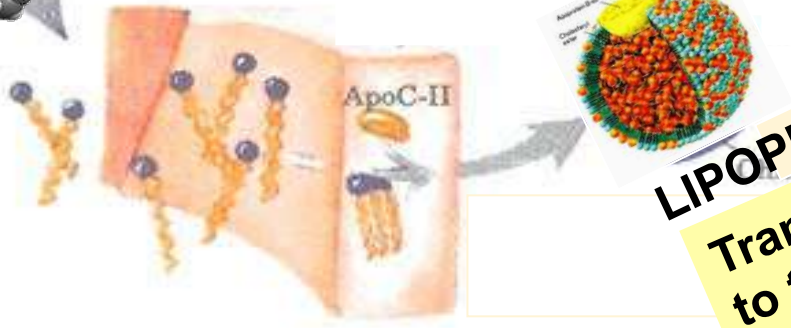


Fatty acids & triglyceride depot

BILE salts

emulsification

LIPASE

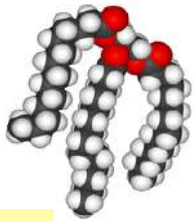


LIPOPROTEINS

Transport and release to tissues

Formation of chilomicrons for fat absorption and entering in the blood circulation

Fats from the diet



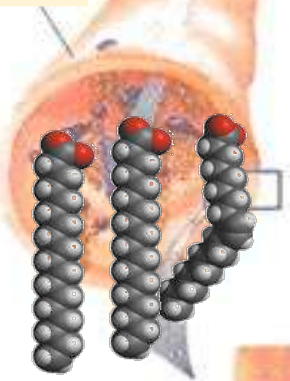
Gall bladder

BILE salts

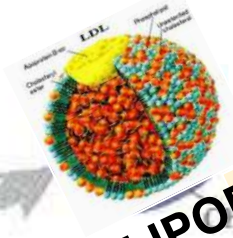
emulsification

LIPASE

intestine



Formation of chilomicrons for fat absorption and entering in the blood circulation



LIPOPROTEINS

Transport and release to tissues

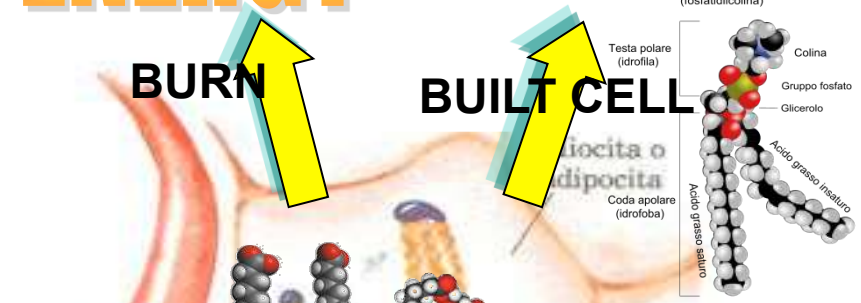
vase

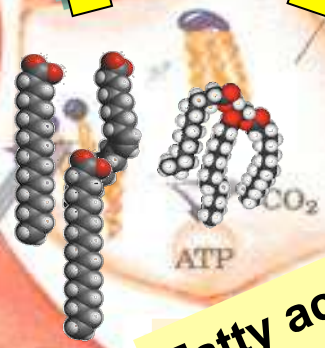
ENERGY

BURN

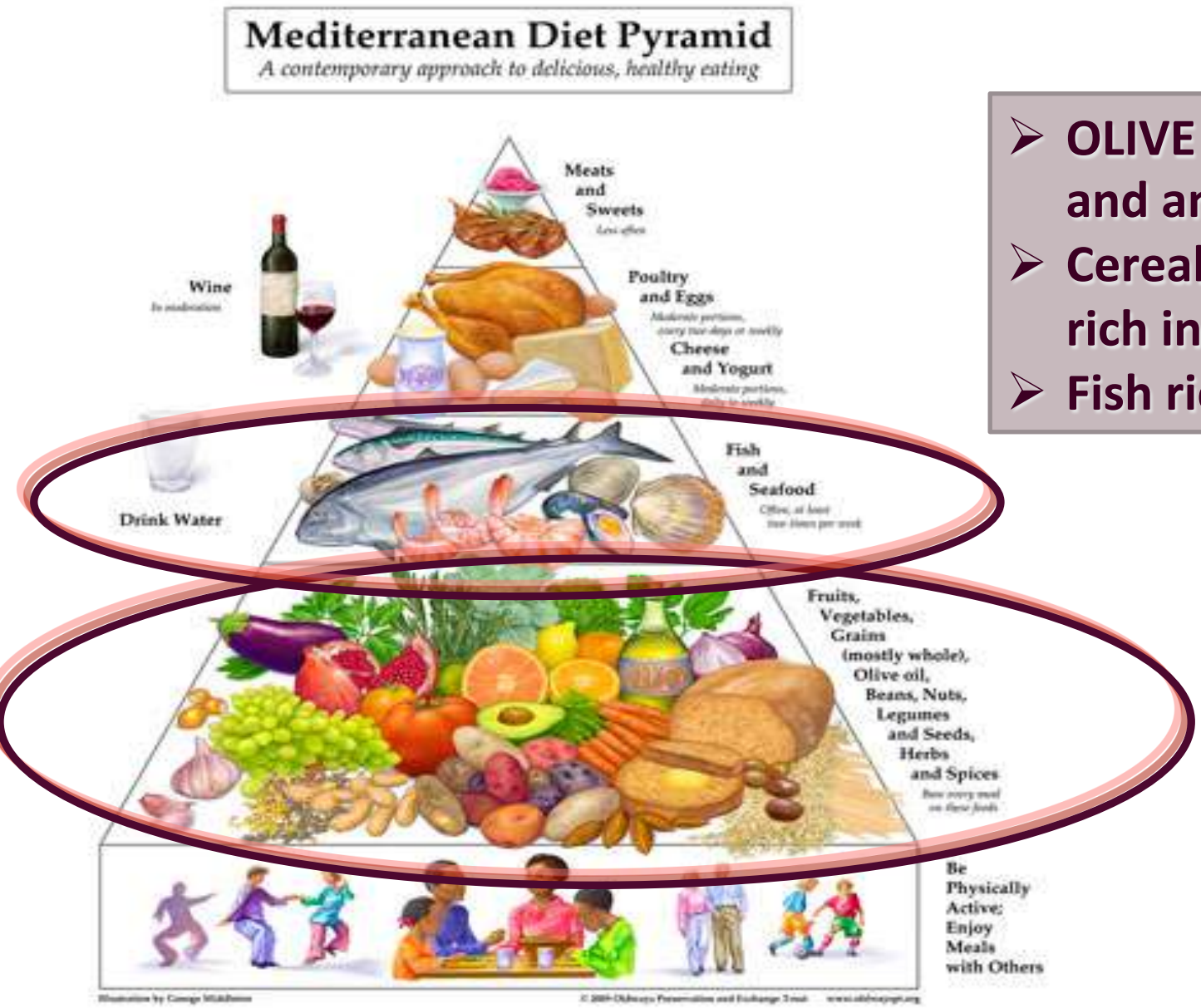
membrane

BUILT CELL



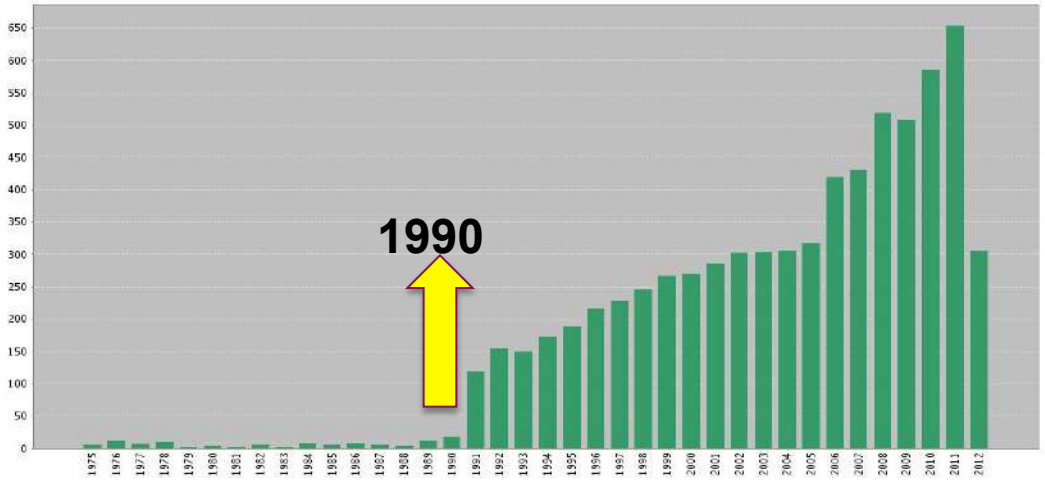


Fatty acids & triglyceride depot



- **OLIVE OIL : rich in MUFA and antioxidants**
- **Cereals and whole grains rich in omega-6 & omega-3**
- **Fish rich in omega-3**

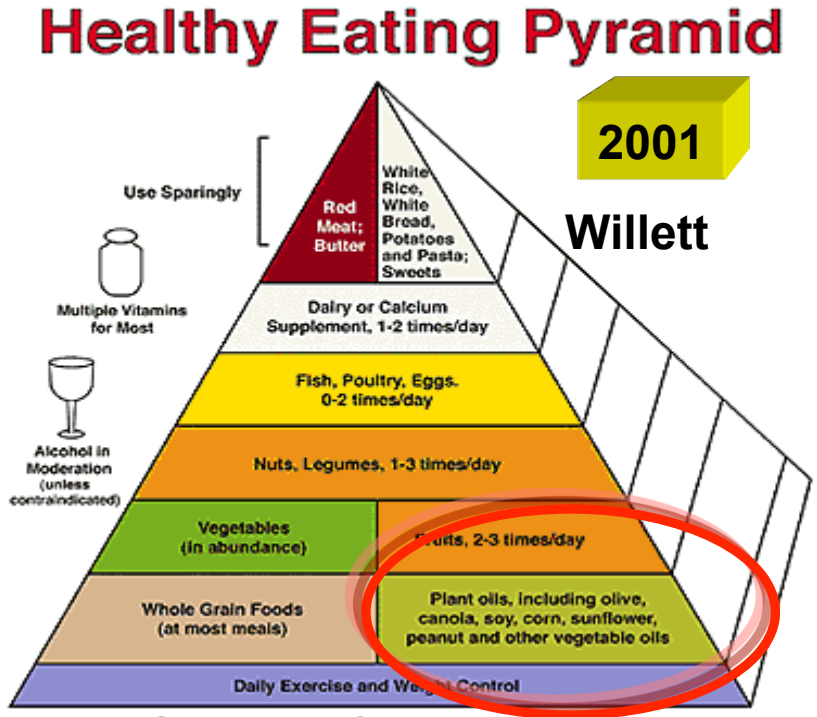
REVISION of the FOOD PYRAMIDS



CHAPTER 26

Omega 3 Fatty Acids and Bioactive Foods: From Biotechnology to Health Promotion

C. Ferreri
Consiglio Nazionale delle Ricerche, Bologna, Italy



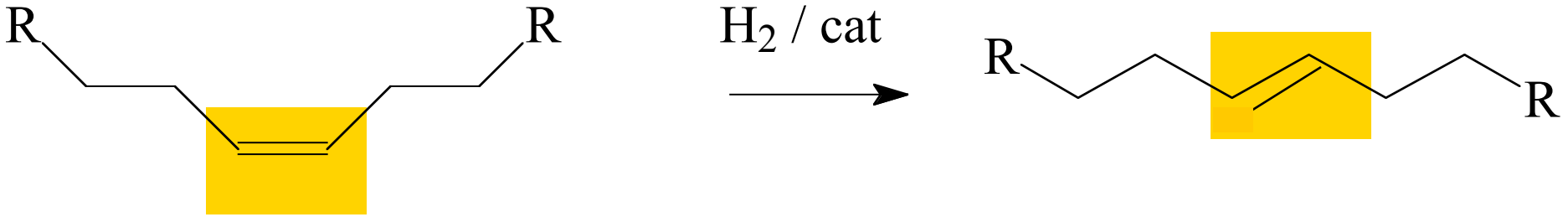
Harvard School of Public Health

Alteration of the double bonds

EXOGENOUS INTAKE of TRANS FATTY ACIDS

DETECTION OF TRANS FATTY ACIDS IN OMEGA-3 SUPPLEMENTS

(Chem. Res. Toxicol. 2018) due to the DEODORIZATION PROCESS for FISH OILS



CIS **TRANS**

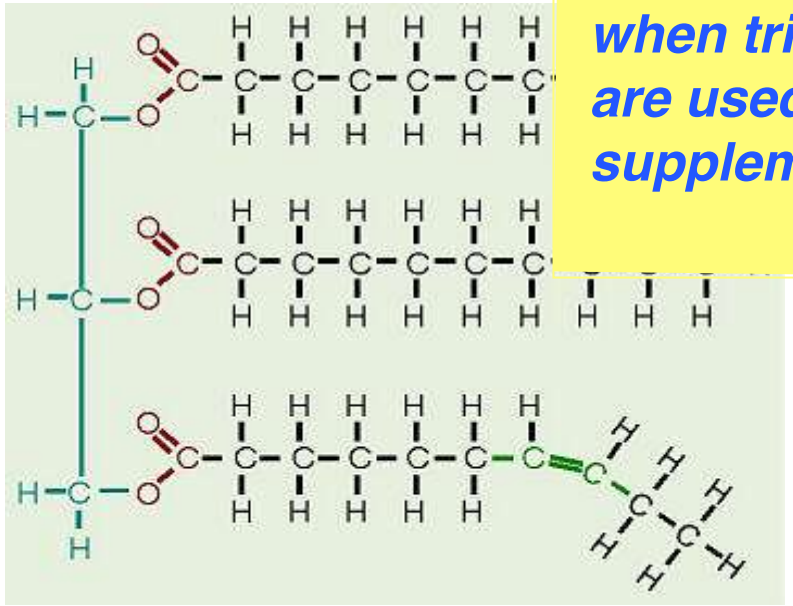
Summary

- Fatty acid structures
- From triglycerides to phospholipids: lipid metabolism for life
- Membrane formation and organization

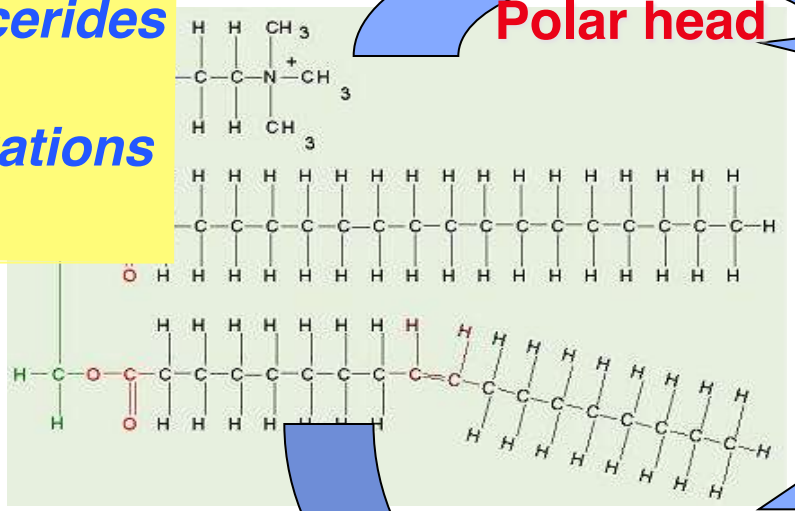
https://www.youtube.com/watch?v=LKN5sq5dtW4

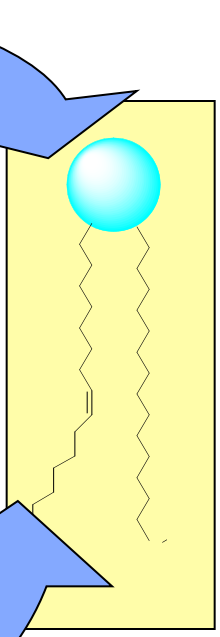
Phospholipid biosynthesis

Glycerides → phospholipids



Crucial step also when triglycerides are used in supplementations

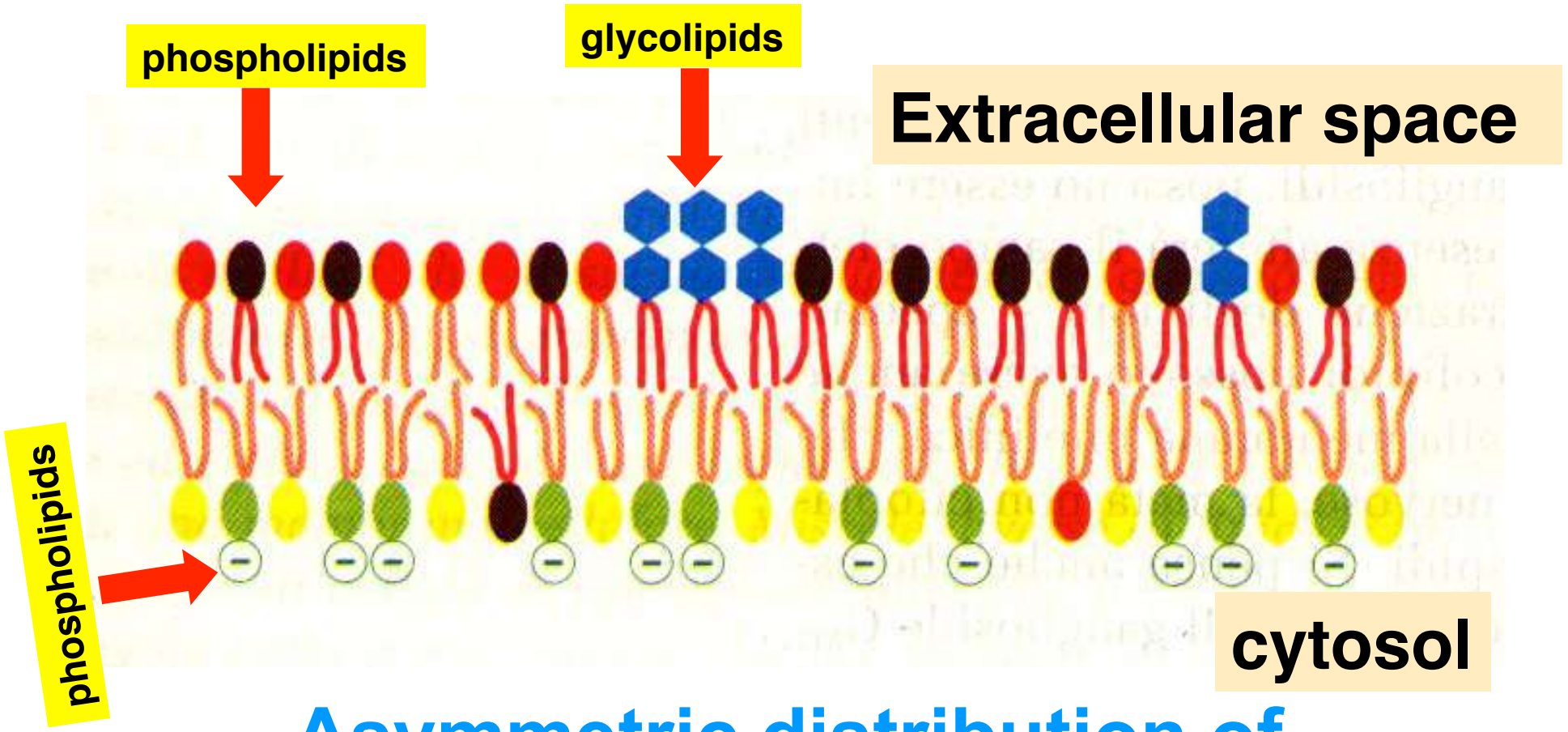




Polar head

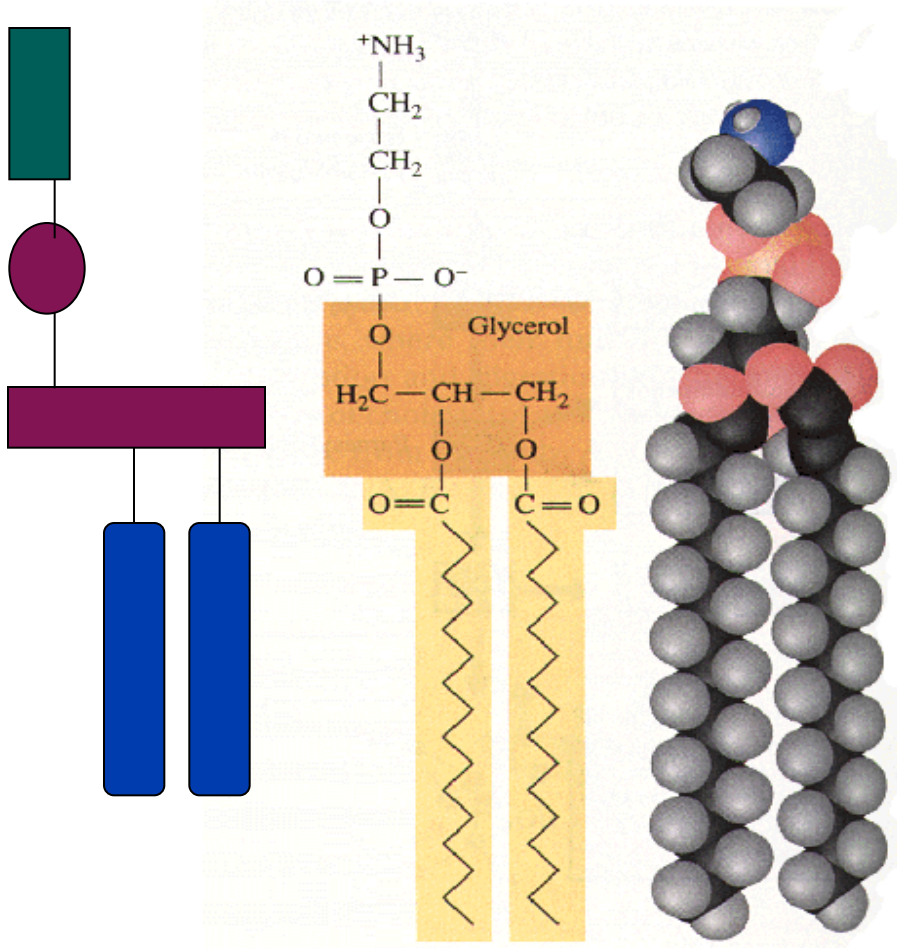
Hydrophobic tails

Molecular organization



Asymmetric distribution of phospholipids

Amphipatic structure



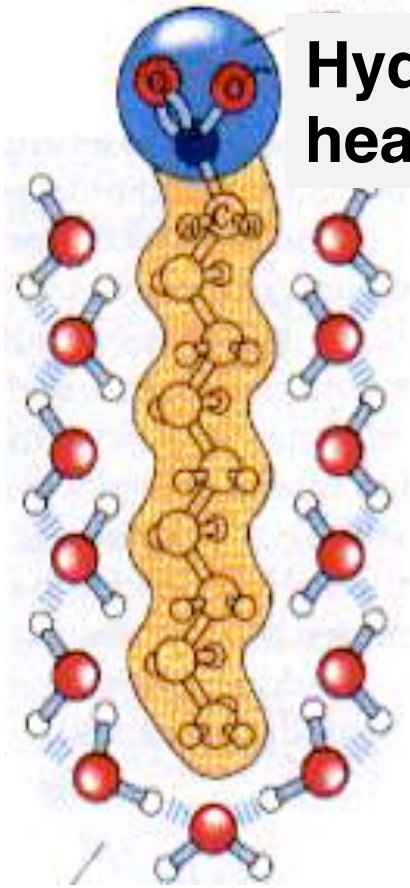
Polar head

Apolar tails
Fatty acids

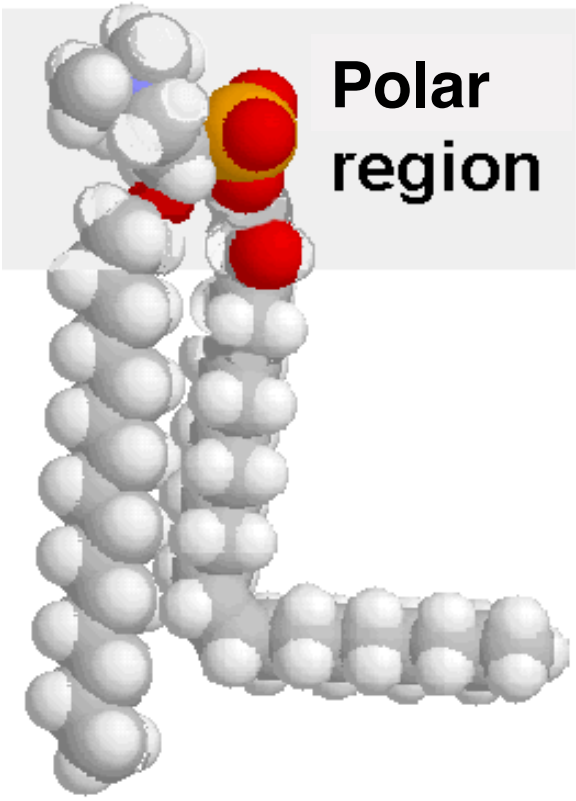
Glycerophospholipids

Lipid aggregation

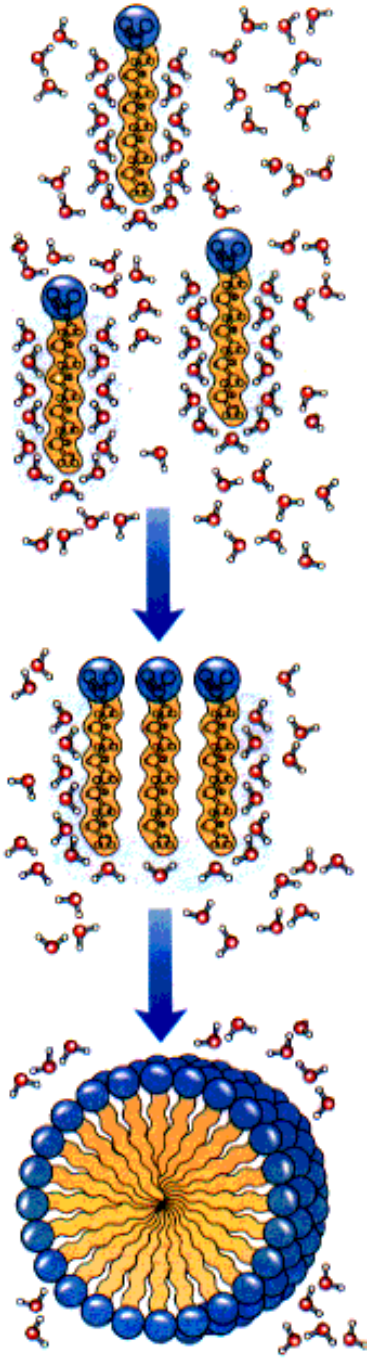
Fatty acids



phospholipids

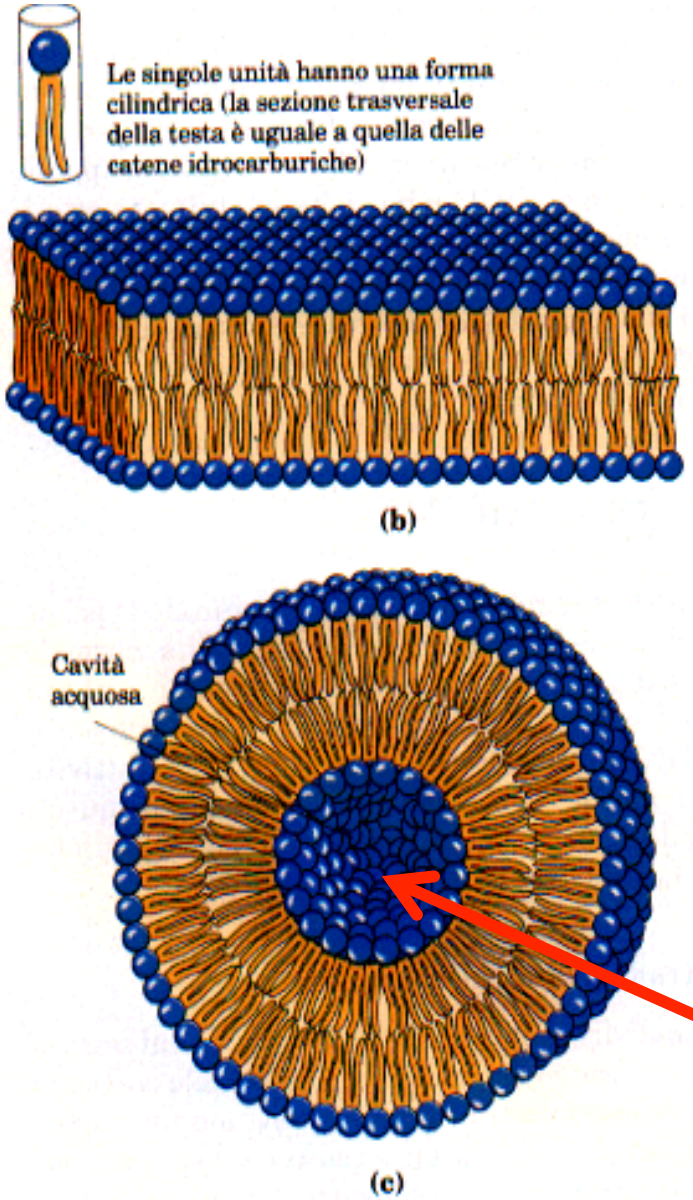


CONICAL SHAPE



Fatty acid aggregation

MICELLES

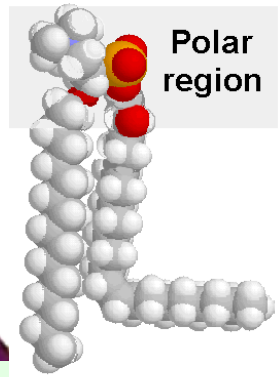


Phospholipid aggregation

Double layer LIPOSOME (vesicles)

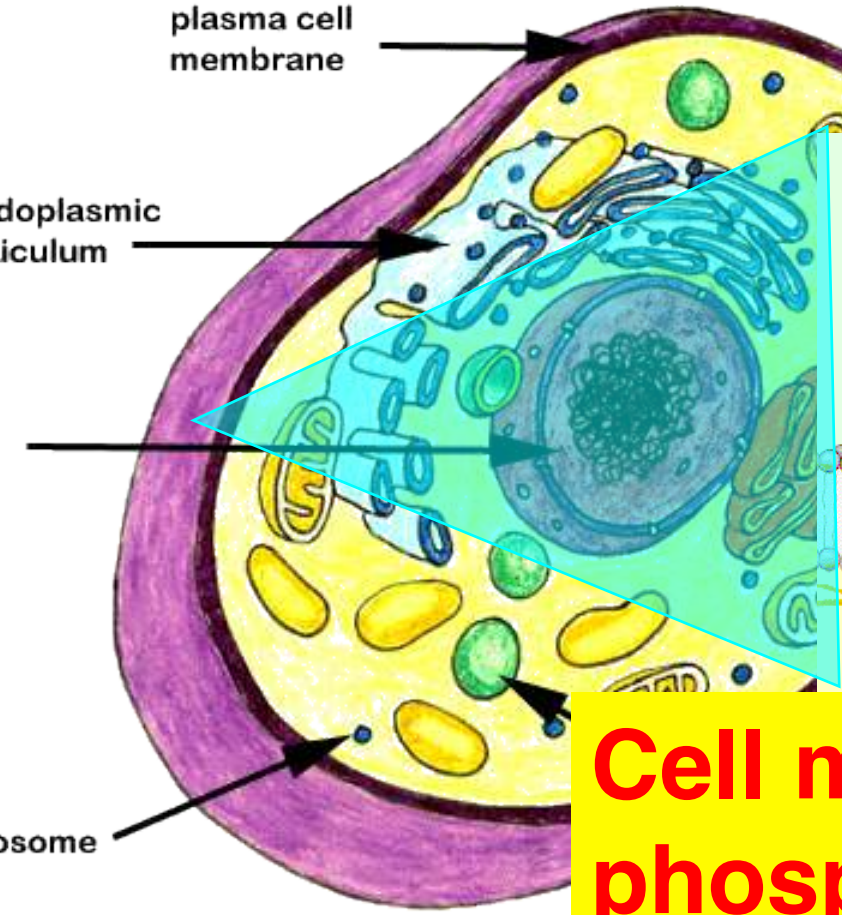
Internal aqueous compartment

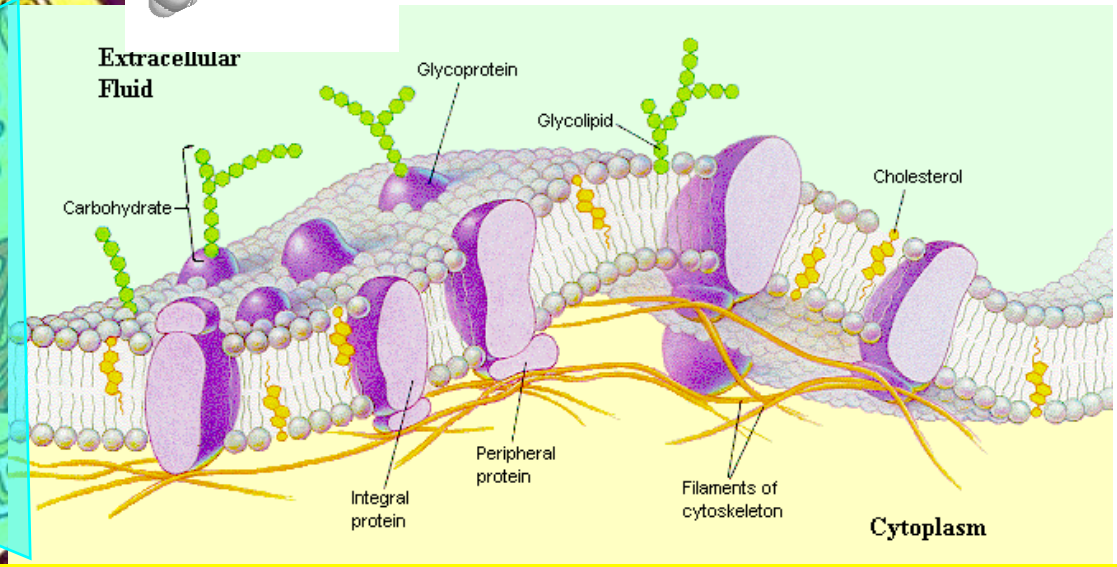
The formation of the protocell



Saturated and unsaturated lipids

- Cis and trans MUFA for bacteria
- Cis MUFA and PUFA for higher organisms





Cell membranes
phosphoLIPIDS + PROTEINS