FATTY ACIDS

Nomenclature, Characterization, Properties and Utilization

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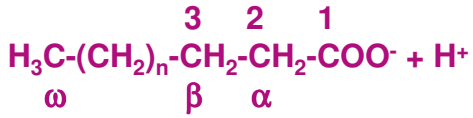
FATTY ACIDS (FAs)

- **Compounds containing a long hydrocarbon chain and a terminal carboxylic group**

(i) SATURATED
(ii) UNSATURATED (with double bonds in the hydrocarbon chain)



FATTY ACIDS (FAs)

two major physiological roles:

- **(i) building blocks of *phospholipids* and *glycolipids***
  in *biological membranes*
- **(ii) *fuel molecules***

CLASSIFICATION OF FAs

- **According to the chain length**

***- short-chain fatty acid* - SCFA**	**< 6 carbon atoms**
***- medium-chain fatty acid* - MCFA**	**6-12 carbon atoms**
***- long-chain fatty acid* - LCFA**	**14-20 carbon atoms**
***- very-long chain fatty acid* - VLCFA**	**> 20 carbon atoms**

- **According to the degree of saturation (presence or absence of double bonds)**
  - *saturated*
  - *unsaturated cis/trans isomers*

- **Branched** (unusual)
- **Hydroxylated** (unusual)

FATTY ACIDS - NOMENCLATURE

Systematic name:

SATURATED: parent hydrocarbon + *oic*
e.g. C18: Octadecan*oic acid*

UNSATURATED: with one double bond: + *enoic*
e.g. C18: Octadec*enoic* acid

with two double bonds: + *dienoic*
e.g.C18: Octadeca*dienoic* acid

with three double bonds: + *trienoic*
e.g. C18: Octadeca*trienoic* acid

FATTY ACIDS - NOMENCLATURE

Common name	Systematic name	Formula
SATURATED FAs		
C16:0 Palmitate	n-Hexadecanoate	$CH_3(CH_2)_{14}COO^-$
C18:0 Stearate	n-Octadecanoate	$CH_3(CH_2)_{16}COO^-$
UNSATURATED FAs		
C16:1(9) Palmitoleate	*cis*-9-Hexadecenoate	$CH_3(CH_2)_5CH=CH(CH_2)_7COO^-$
C18:1(9) Oleate	*cis*-9-Octadecenoate	$CH_3(CH_2)_7CH=CH(CH_2)_7COO^-$
C18:2(9,12) Linoleate	all *cis*-9,12-Octadecadienoate	$CH_3(CH_2)_4(CH=CHCH_2)_2(CH_2)_6COO^-$
C18:3(9,12,15) Linolenate	all *cis*-9,12,15-Octadecatrienoate	$CH_3CH_2(CH=CHCH_2)_3(CH_2)_6COO^-$
C20:4(5,8,11,14) Arachidonate	all *cis*-5,8,11,14-Eicosatetraenoate	$CH_3(CH_2)_4(CH=CHCH_2)_4(CH_2)_2COO^-$

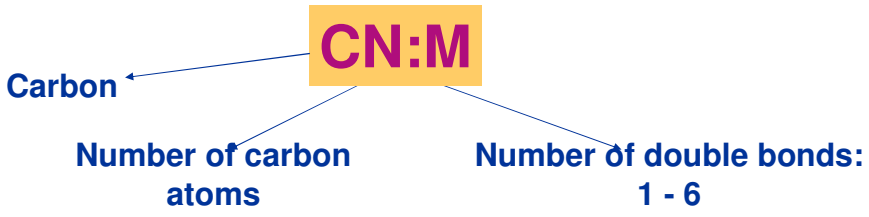
FATTY ACIDS - NOMENCLATURE

UNSATURATED

Counting from the carboxy end:	from the methyl (ω) end:
C16:1(9) Palmitoleate	16:1, *n*-7 (ω7)
C18:1(9) Oleate	18:1, *n*-9 (ω9)
C18:2(9,12) Linoleate	18:2, *n*-6 (ω6)
C18:3(9,12,15) Linolenate	18:3, *n*-3 (ω3)
C20:4(5,8,11,14) Arachidonate	20:4, *n*-6 (ω6)
C20:5(5,8,11,14,17) EPA (Eicosapentaenoic acid)	20:5, *n*-3 (ω3)
C22:6(4,7,10,13,16,19) DHA (Docosahexaenoic acid)	22:6, *n*-3 (ω3)

"Telegraphic" nomenclature of FAs (1)

SATURATED FAs:



SATURATED FAs WITH A SHORT CHAIN

- If free smell badly
- Fluid
- Present in milk fat (C4-C10)
- Easily digestible

	Common name	Systematic name	Formula
C4:0	Butyric acid	Butanoic acid	$CH_3(CH_2)_2COOH$
C6:0	Capronic acid	Hexanoic acid	$CH_3(CH_2)_4COOH$
C8:0	Caprylic acid	Octanoic acid	$CH_3(CH_2)_6COOH$
C10:0	Caprinic acid	Decanoic acid	$CH_3(CH_2)_8COOH$

SATURATED FAs WITH A LONG CHAIN

- Solid at room temperature
- Most common in animal and plant fats
- Less easily digestible

	Common name	Systematic name	Formula
C14:0	Myristic acid	Tetradecanoic acid	$CH_3(CH_2)_{12}COOH$
C16:0	Palmitic acid	Hexadecanoic acid	$CH_3(CH_2)_{14}COOH$
C18:0	Stearic acid	Octadecanoic acid	$CH_3(CH_2)_{16}COOH$
C20:0	Arachidic acid	Eicosanoic acid	$CH3(CH_2)_{18}COOH$

"Telegraphic" nomenclature of FAs (2)

UNSATURATED FAs:

position of the double bond

– *Numbering from the carboxyl end* - carboxyl C is No 1

n n-1 3 2 1

CH_3-CH_2-CH_2····· CH_2-CH_2-COOH

CN:M $\Delta^{a,b,c}$

CN:M (a,b,c)

CN:M; a,b,c

The Nos of the double-bonded carbon atoms; counting from the carboxy end

– *Numbering from the methyl end* - methyl C is marked ω or *n*

CH_3-CH_2-CH_2····· CH_2-CH_2-COOH

ω1 ω2 ω3 β α

CN:M ω a

The No of the first double-bonded carbon atom; counting from the methyl (ω, n) end

UNSATURATED FAs - classes

- With one double bond - *monounsaturated fatty acids - MUFA*
- With more than one double bond – *polyunsaturated fatty acids - PUFA*

The double bonds tend to occur at every third carbon atom toward the CH_3 terminus of the molecule (such as –CH=CH-CH_2-CH=CH-).

3 6

The double bonds are almost never conjugated. Triple bonds are rare. Two important classes of PUFA are denoted n-3 (or ω-3) and n-6 (or ω-6) fatty acids.

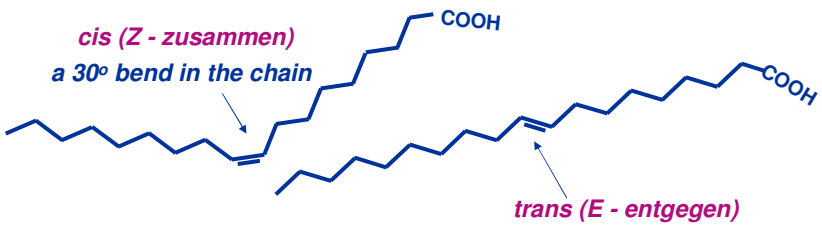
MONOUNSATURATED FAs

16:1(9) Palmitooleic a. acid	*cis*-9-Hexadecenoic
18:1(9) Oleic a.	*cis*-9-Octadecenoic acid
18:1(9) Elaidic a.	*trans*-9-Octadecenoic acid
22:1(13) Erucic a.	*cis*-13-Docosenoic acid

UNSATURATED FAs:

isomerism of the double bond

- *cis*-configuration – a 30° bend in the hydrocarbon chain (*„L" shaped)*
  - *natural occurance*
  - *the melting point is lower than that of saturated FAs*
- *trans*-configuration – straight chain (similar as in the saturated FAs)



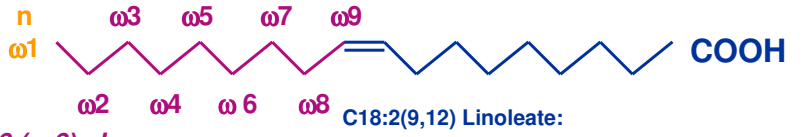
cis-UNSATURATED FAs:

position of the first double bond from the methyl (ω) end:

C18:1(9) Oleate:

ω9 (n-9) class

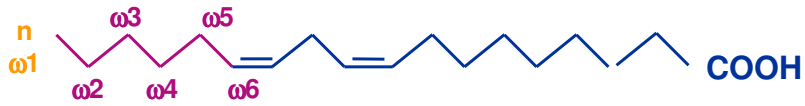
The first double-bonded carbon atom is carbon atom 9



C18:2(9,12) Linoleate:

ω6 (n-6) class

The first double-bonded carbon atom is carbon atom 6



C18:2(12,15):

ω3 (n-3) class

The first double-bonded carbon atom is carbon atom 3

FATTY ACIDS

- Over half of the fatty acid residues of plant and animal lipids are unsaturated and are often polyunsaturated.
- Bacterial fatty acid residues are rarely polyunsaturated but are commonly branched, hydroxylated, or contain cyclopropane rings.
- Unusual fatty acids also occur as components of the oils and waxes (esters of FAs and long chain alcohols) produced by certain plants.

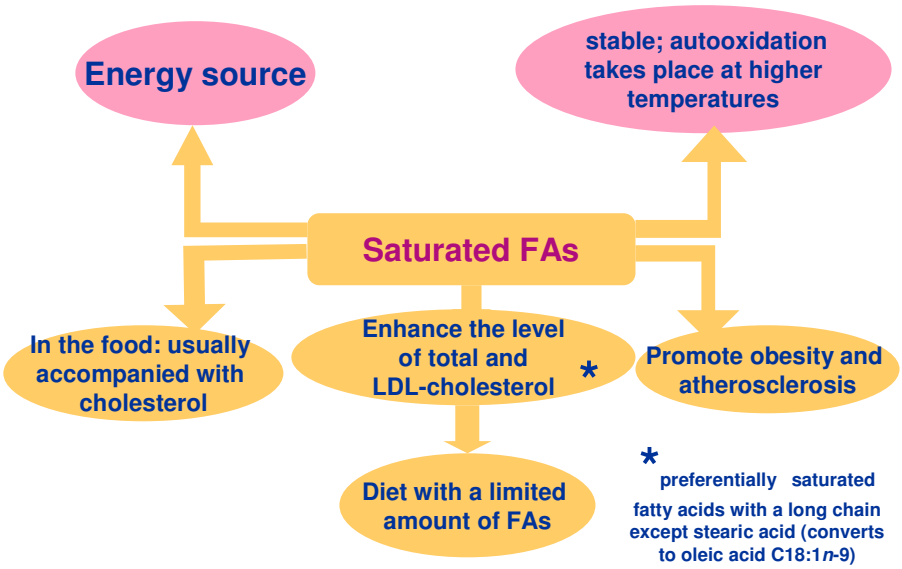
FATTY ACIDS

- more than 100 different FAs in nature
- most FAs have an *even* number of carbon atoms (mainly due to the mechanism of biosynthesis-the concatenation of C_2 units)
- mainly present in the form of *esters* (not free)
- in higher plants and animals, the predominant FA residues are those of the *C16 and C18 species* (palmitic, oleic, linoleic, and stearic acids).
- FAs with less than 14 and more than 20 carbon atoms are uncommon

FATTY ACIDS

EFFECTS

SATURATED FAs



UNSATURATED FAs

- ***Mainly in plant fats***

90 % ⟷ 10 %
(rape-seed oil) (coco-nut oil)

- ***Less in animal fats except for fish oils***

  – ***Fish oils contain* ω-3 FAs** (mostly originating from microalgae in the sea plankton) with 4-6 double bonds e.g.

C20:5 (5,8,11,14,17) = Eicosapentaenoic acid, EPA

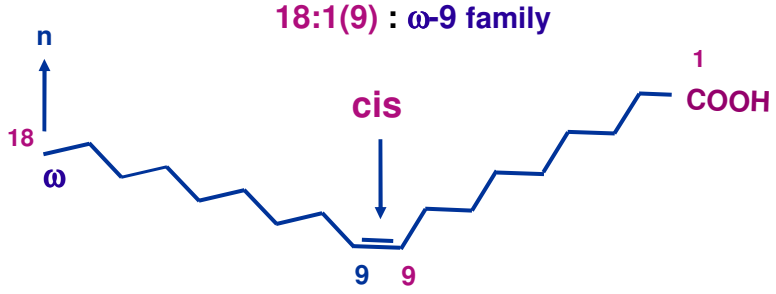
C22:6 (4,7,10,13,16,19) = Docosahexaenoic acid, DHA
(Cervonic acid)

Oleic acid

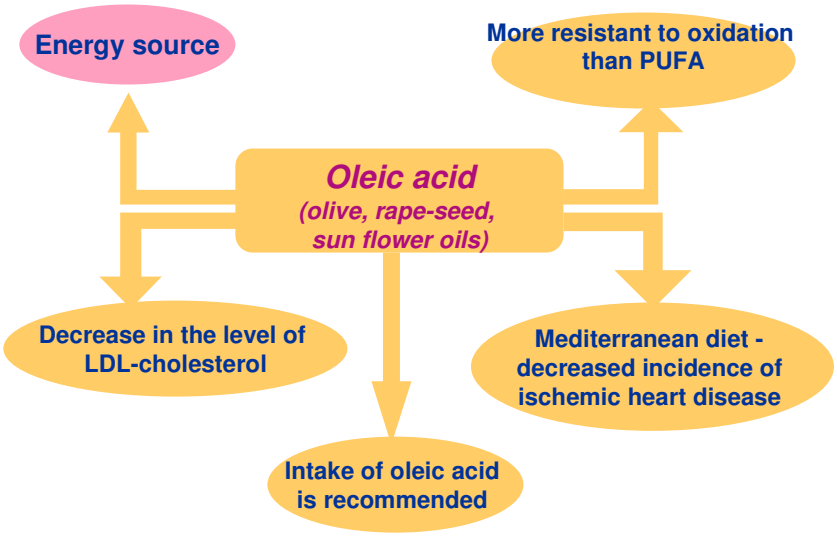
MONOUNSATURATED FA

cis-9-Octadecenoic acid

18:1(9) : ω-9 family



Oleic acid (ω-9)



POLYUNSATURATED FAs: ω-*6* FAMILY

Linoleic acid — ***cis,cis*-9,12- Octadecadienoic acid**
C18:2 (9,12) ω-*6,9*
essential FA

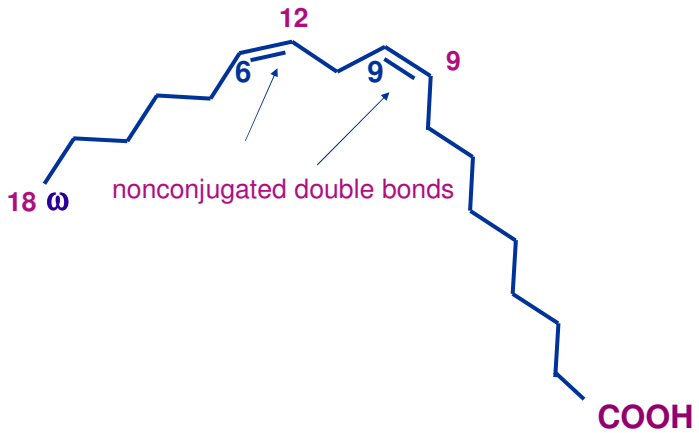
γ-Linolenic acid — **all *cis*-6,9,12-Octadecatrienoic acid**
C18:3 (6,9,12) ω-*6,9,12*

Arachidonic acid — **all-*cis*-5,8,11,14-Eicosatetraenoic acid**
C20:4 (5,8,11,14) ω-*6,9,12,15*
(Eicosanoids)

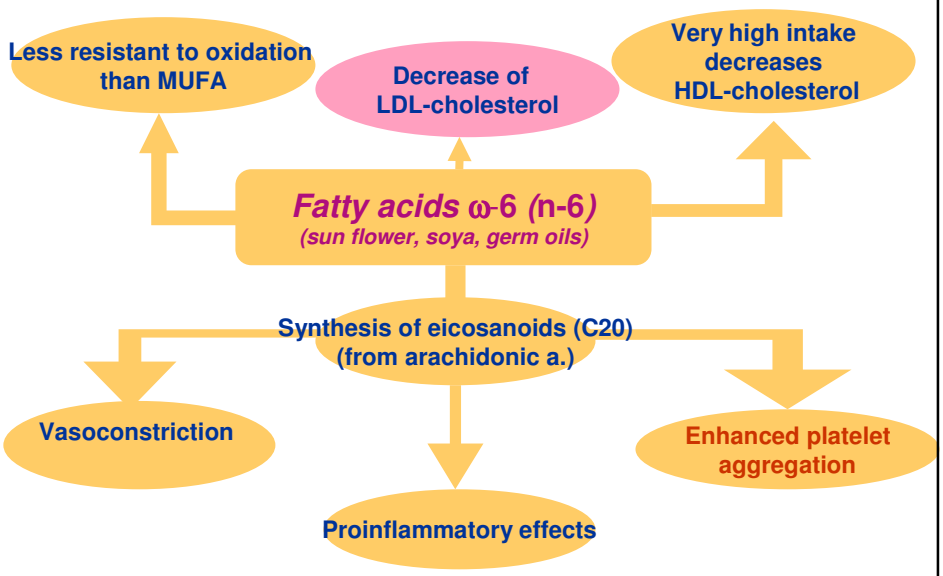
Linoleic acid (ω-*6* family)

essential FA
arachidonic acid precursor

18:2 (9,12) ω-6, 9



POLYUNSATURATED FAs: ω-6 (n-6)



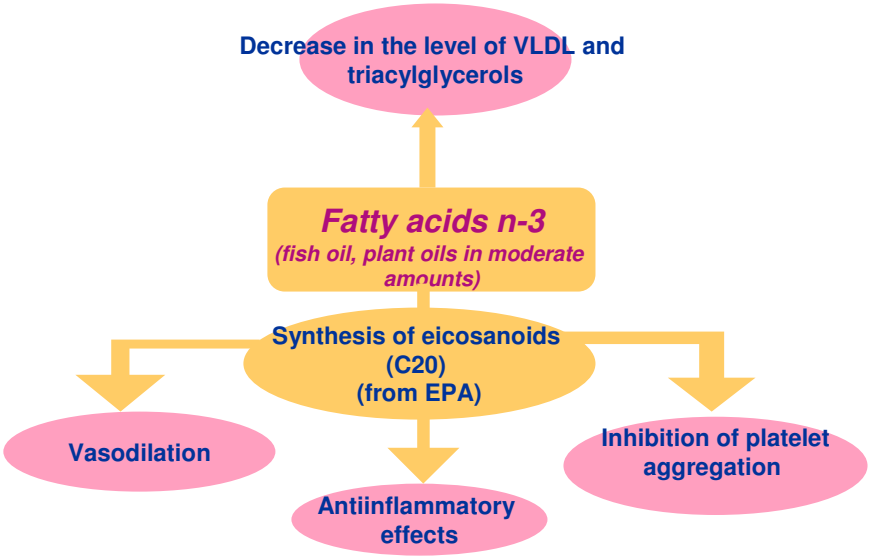
CLA - conjugated linoleic acids

- **Isomers of linoleic acid** – double bonds are conjugated
  - C18:2 CLA most frequent configuration: cis-9, trans-11, and trans-10, cis-12
- Origins of CLA
  - *in vivo* – in the intestine of cattle (isomerase of linoleic a.)
  - (not in humans)
  - *in vitro* – thermal processing of dairy products
- Effects on laboratory animals
  - antioxidative
  - anticancerogenic
  - antiatherogenic
  - antidiabetic
  - weight loss
  - immunomodulatory

POLYUNSATURATED FAs: ω-3 (n-3) Class

		mp
α-Linolenic acid *essential FA*	all cis-9,12,15 - Octadecatrienoic a. 18:3 (9,12,15) ω-3 (6,9) 18:3 n-3, 18:3 ω-3	-17°C
EPA	all cis-5,8,11,14,17- Eicosapentaenoic a. 20:5 (5,8,11,14,17) ω-3,6,9,12,15 20:5 n-3, 20:5 ω-3	-54°C
DHA	all cis-4,7,10,13,16,19 - Docosahexaenoic a. 22:6 (4,7,10,13,16,19) ω-3,6,9,12,15,18 22:6 n-3, 22:6 ω-3	

POLYUNSATURATED FAs: ω-3 (n-3)



UNSATURATED FAs – *trans* isomers

At least one double bond is in *trans* configuration
The configuration is similar to that of saturated FAs

cis
a bend in the hydrocarbon chain

trans
straight hydrocarbon chain

Saturated FA
Straight hydrocarbon chain

ORIGINS OF *TRANS* UNSATURATED FAs

in nature
- milk, dairy products and other animal fats (2-7%) – produced by microorganisms in the stomach of cattle
- in some plants (pomegranate)

artificially – industrial processing of plant oils
- during the process of artificial hydrogenation of unsaturated FAs in food industry (originally as much as 40 %; more advanced technologies: the yield of *trans* FAs is low)
- long term fat frying

The *trans* unsaturated FAs can be deposited in the human adipose tissue.

EFFECTS OF *TRANS* UNSATURATED FAs

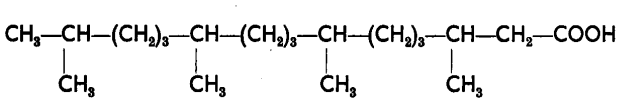
- **Increased intake** ⟶

INCREASED LEVEL OF LDL CHOLESTEROL

INCREASED RISK OF ATHEROSCLEROSIS

BRANCHED FAs

- ***Of plant origin, not synthesized in mammalian organisms***
- ***Phytanic acid*** **(in cow milk) – oxidation product of phytol**
  (part of chlorophyl)



3,7,11,15 Tetramethylhexadecanoic acid

- **In sebaceous glands**
- **Failure to degrade phytanic acid - *Refsum disease:***
- **deposits of the phytanic acid can be found in the nervous system *–neurological disorders of cerebellum, periferal nerves, eyes***
- **Prevention: phytanic acid-free food**

HYDROXYDERIVATIVES OF FAs

- *Components of sphingolipids in animals* - typically OH groups attached to C_2
  - In the CNS – C24:0 Cerebronic a. (2-hydroxytetracosanoic a.)

    $CH_3\text{-}(CH_2)_{21}\text{-}CH(OH)\text{-}COOH$
- *Ricin oil* – C18:1 Ricinoleic a. (12-hydroxy-9-Octadecenoic a.)
  - $CH_3\text{-}(CH_2)_5\text{-}CH(OH)\text{-}CH_2\text{-}CH{=}CH\text{-}(CH_2)_7\text{-}COOH$
- *Precursors of leukotrienes*
  - hydroxy(OH) and hydroperoxy(OOH) derivatives of C20 PUFAs