



Lipids

Chemistry-1

By lecturer:

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M.sc in Biochemistry and Molecular Biology

Objectives:

► **By the end of this lecture, the student should be able to:**

- 1. Define lipids.**
- 2. Describes the important functions of lipids.**
- 3. Classifies lipids according to their different characteristics.**
- 4. Classification & Nomenclature of fatty acids.**

Introduction

Nutrition Facts	
Serving Size 1 cup (228g)	
Servings Per Container 2	
Amount Per Serving	
Calories 250	Calories from Fat 110
% Daily Value*	
Total Fat 12g	15%
Saturated Fat 3g	15%
Trans Fat 3g	
Cholesterol 30mg	10%
Sodium 470mg	20%
Total Carbohydrate 31g	10%
Dietary Fiber 0g	0%
Sugars 5g	
Protein 5g	

- 12g fat = 110 calories
- 31g carbohydrates = 110 calories
- 1g fat = 9 calories
- 1g carbohydrates = 3 calories



Introduction

- Lipids constitute about **13-15%** of the normal body weight
- Knowledge of lipid biochemistry is necessary in understanding many important biomedical areas, e.g., **obesity, diabetes mellitus, atherosclerosis.**
- The role of various **polyunsaturated fatty acids** in nutrition and health.

Definition

- **Lipids:** are group of heterogeneous compounds made of C, H,O, including **Fats, Oils, Steroids, Waxes & related compounds** characterized by:
- **Insoluble in water , but soluble in nonpolar solvents such as** (Ether, Benzene & Chloroform).

Properties of lipids

- **Can be liquid or solid at room temperature.**
- **Colorless, tasteless and odorless**
- **Soluble in organic solvents like alcohol and insoluble in water**
- **Solid fats have high proportions of saturated fatty acids.**
- **Liquid fats have high proportions of unsaturated fatty acids**
- **Energy rich organic molecules.**

Lipids functions

- **Energy source (fatty acid).**
- **Serves as an energy reserve**
- **Major component of cell membranes**
- **Nourishes skin & hair**
- **Thermal insulator.**

Lipids functions

- **Cushion the vital organs to protect them from trauma.**
- **Fat-soluble vitamins (vitamin A,D,E&K).**
- **Intracellular second messenger for certain hormones eg. Diacylglycerol.**
- **Surfactant in the lungs (Dipalmitoyl lecithin).**

Lipids functions

- **Electrical insulator in myelinated nerve fibre.**
- **Co-enzyme e.g., Co enzyme Q in respiratory chain.**
- **Hormones (steroid hormones).**

Lipids classification

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graph TD; A[Lipids classification] --> B[simple lipids]; A --> C[Complex lipids]; A --> D[Derived lipids]; B --> B1[1. fats]; B --> B2[2. waxes]; C --> C1[1. Phospholipids]; C --> C2[2. Glycolipids]; C --> C3[3. Sulfolipids]; C --> C4[4. Aminolipids]; C --> C5[5. lipoproteins]; D --> D1[Fatty acids]; D --> D2[Steroids & steroid hormones]; D --> D3[Ketone bodies]; D --> D4[Fat soluble vitamins]; D --> D5[cholesterol];
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simple lipids

- 1. fats**
- 2. waxes**

Complex lipids

- 1. Phospholipids**
- 2. Glycolipids**
- 3. Sulfolipids**
- 4. Aminolipids**
- 5. lipoproteins**

Derived lipids

Fatty acids
Steroids & steroid hormones
Ketone bodies
Fat soluble vitamins
cholesterol

1. Simple lipids

Esters of fatty acids with various alcohols.

A. Fats (acyl glycerol):

Are esters of one, two or three fatty acids with **glycerol.**

Glycerol: is a polyhydric alcohol containing 3 (-OH)

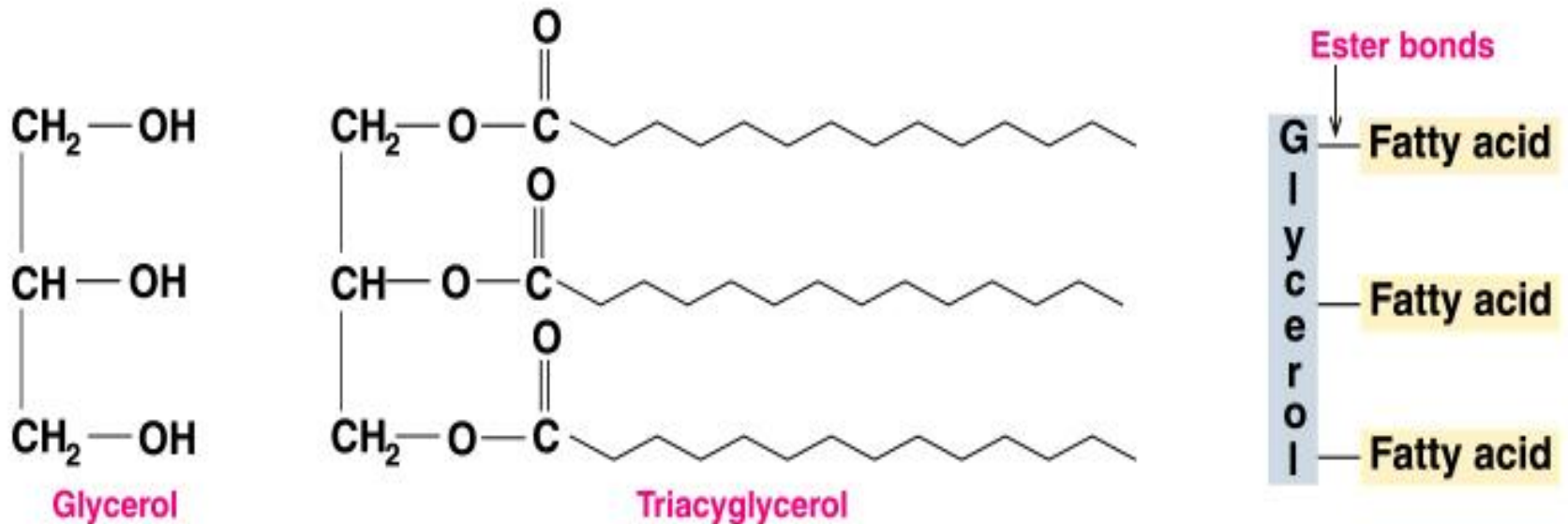
Groups, soluble in water and alcohol, insoluble in nonpolar solvents.

Triacylglycerols

- **Triacylglycerols** (triglycerides) are the most abundant *dietary lipids*, **stored** mainly in adipose tissues for **energy**.
- Body fat is an important source of energy, 1 gram fat gives 9.3 kcal.
- Human fat is liquid at room temperature and contains high contents of oleic acid.
- They are called neutral fat because they carry no charge
- Most triacylglycerols are “**mixed**.” The 3 fatty acids differ in chain length & number of double bonds.

Triacylglycerols

In a **triacylglycerol**, glycerol forms ester bonds with three fatty acids.



1. Simple lipids

B. Waxes:

Esters of fatty acids with **higher** molecular weight monohydric **alcohols**.

Higher alcohol: They contain one (-OH) group

Waxes has a protective function

Sources: Bee wax, Sebaceous secretions, Cuticles of leaves

2. Complex lipids

Esters of fatty acids containing additional group in addition to an alcohol and a fatty acid.

I. Phospholipids:

Are esters of fatty acids + alcohols containing phosphoric acid + nitrogenous base.

2. Complex lipids

II. Glycolipids (glycosphingolipids)

Fatty acid + sphingosine + carbohydrate.

III. Sulfo-lipids (lipids + sulphate group).

IV. Amino-lipids (lipids + amino group).

V. Lipoproteins (lipids + protein).

3. Precursor and derived lipids

Are derivatives of lipids obtained from hydrolysis of simple lipids and complex lipids.

Derived lipids include:

Fatty acids, steroids, ketone bodies, fat-soluble vitamins, steroid hormones & cholesterol.

Fatty acids

- Are water-insoluble long chain hydrocarbons with a carboxylic acid at one end.
- $\text{CH}_3(\text{CH}_2)_n\text{COOH}$
- The fatty acid may be:
 1. Saturated (no double bonds)
 2. Unsaturated (one or more double bonds).

Saturated Fatty Acids

Are fatty acids without double bonds, their general formula is $\text{CH}_3\text{-(CH}_2\text{)}_n\text{-COOH}$ where:

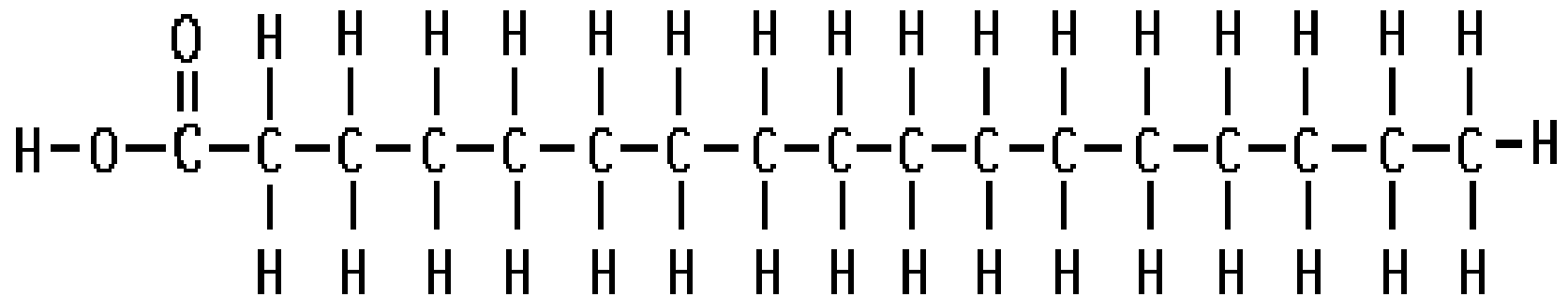
(n) = the number of methylene (CH_2) groups between the methyl and carboxylic groups.

➤ The systemic name of saturated fatty acids ends by the suffix **(-anoic)**

➤ **palmitic acid (16C) = hexadecanoic acid**

(Hexa =6, Deca =10).

Saturated Fatty Acids



Palmitic acid (C16:0)

Common saturated fatty acids

Common Name	Systematic Name	Abbreviation	Structure Hydrophobic hydrocarbon (aliphatic) tail
Capric	Decanoic	10:0	$\text{CH}_3(\text{CH}_2)_8\text{COOH}$
Lauric	Dodecanoic	12:0	$\text{CH}_3(\text{CH}_2)_{10}\text{COOH}$
Myristic	Tetradecanoic	14:0	$\text{CH}_3(\text{CH}_2)_{12}\text{COOH}$
Palmitic	Hexadecanoic	16:0	$\text{CH}_3(\text{CH}_2)_{14}\text{COOH}$
Stearic	Octadecanoic	18:0	$\text{CH}_3(\text{CH}_2)_{16}\text{COOH}$
Arachidic	Eicosanoic	20:0	$\text{CH}_3(\text{CH}_2)_{18}\text{COOH}$

Properties of Saturated Fatty Acids

- **Contain only single C–C bonds.**
- **Are closely packed.**
- **Have strong attractions between chains.**
- **Have high melting points.**
- **Long chain saturated fatty acids are solid at room temperature.**
- **Short chain fatty acids are soluble in water**
- **Long chain fatty acids are insoluble in water**

Unsaturated Fatty Acids

1. Monounsaturated

(monoethenoid, monoenoic) acids, **containing one double bond.**

2. Polyunsaturated (polyethenoid, polyenoic) acids,
containing two or more double bonds, called (Essential)

Properties of Unsaturated Fatty Acids

- ✓ Contain one or more *cis* double C=C bonds.
- ✓ Have “kinks” in the fatty acid chains.
- ✓ Do not pack closely.
- ✓ Have few attractions between chains.
- ✓ Have low melting points.
- ✓ Short chain (16-18c) and unsaturated fatty acids are liquid at room temperature.

Common unsaturated fatty acids

Common Name	Systematic Name	Abbreviation	Structure Hydrophobic hydrocarbon (alipathic) tail
Palmitoleic	<i>cis</i> -9-Hexadecenoic	16:1cΔ9	$\text{CH}_3(\text{CH}_2)_5\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}$
Oleic	<i>cis</i> -9-Octadecenoic	18:1cΔ9	$\text{CH}_3(\text{CH}_2)_7\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}$
Linoleic	<i>Cis,cis</i> -9,12-Octadecadienoic	18:2cΔ9,12	$\text{CH}_3(\text{CH}_2)_4\text{CH}=\text{CHCH}_2\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}$
Linolenic	All- <i>cis</i> -9,12,15-Octadecatrienoic	18:3cΔ9,12,15	$\text{CH}_3\text{CH}_2\text{CH}=\text{CHCH}_2\text{CH}=\text{CHCH}_2\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}$
Arachidonic	All- <i>cis</i> -5,8,11,14-Eicosatetraenoic	20:4cΔ5,8,11,14	$\text{CH}_3(\text{CH}_2)_4\text{CH}=\text{CHCH}_2\text{CH}=\text{CHCH}_2\text{CH}=\text{CHCH}_2\text{CH}=\text{CH}(\text{CH}_2)_3\text{COOH}$

Nomenclature

- Saturated acids end in **–anoic**.

e.g. octadec**anoic** acid (Stearic)



- Unsaturated acids with double bonds end in **–enoic**.

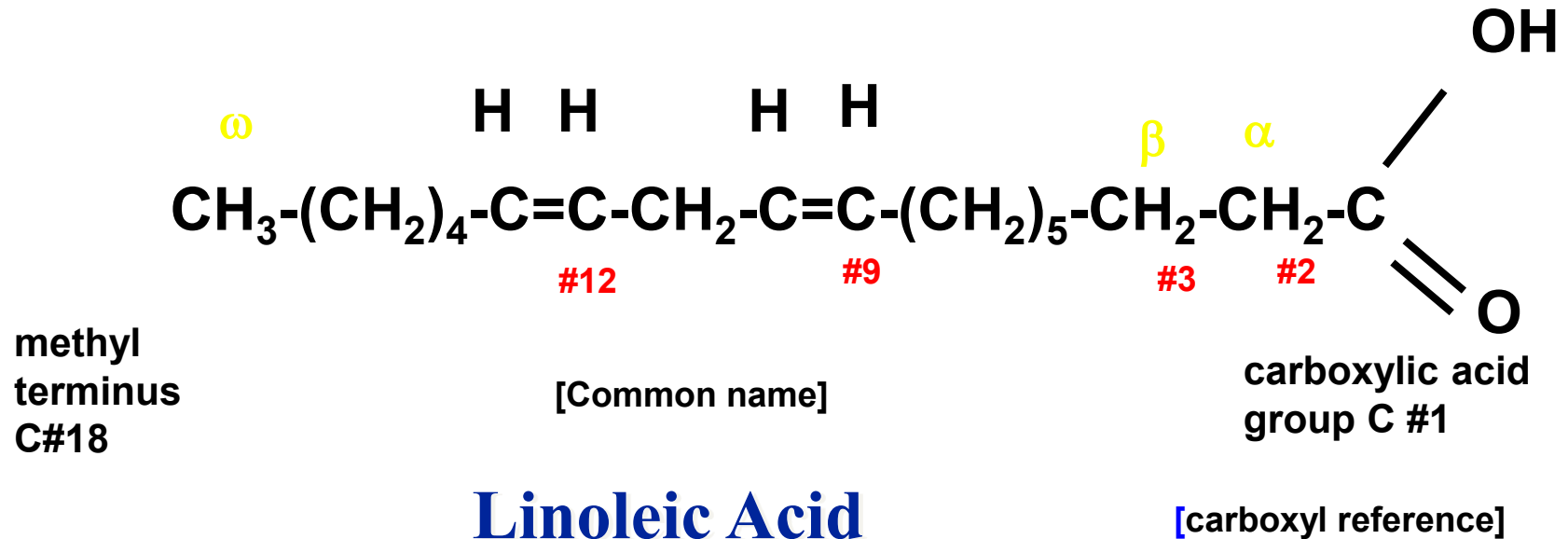
e.g. octadec**enoic** acid (oleic acid)



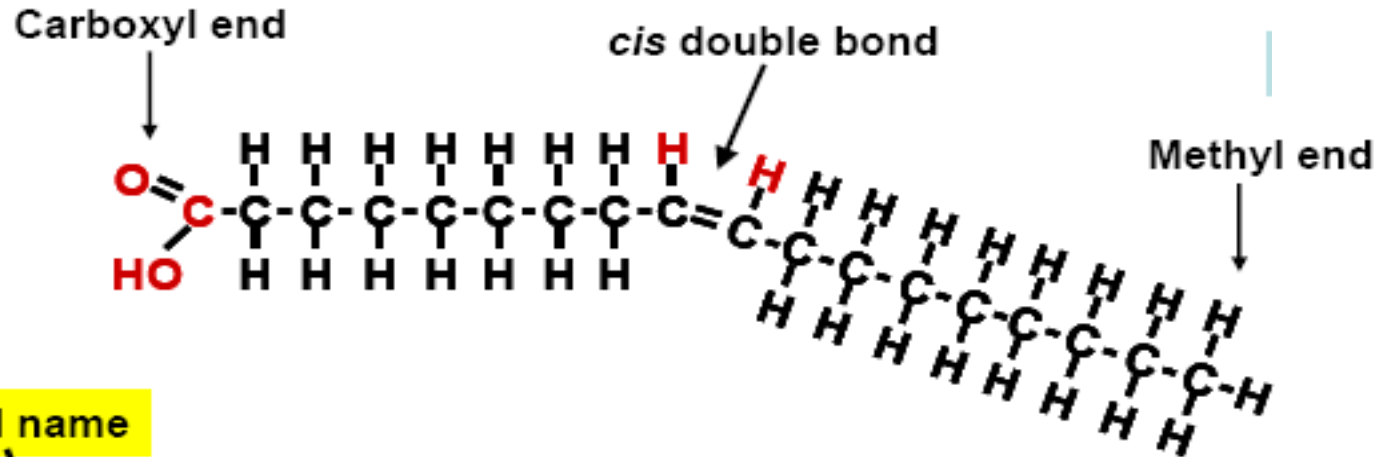
Numbering of carbon atoms

1. Counting start from **carboxylic $-(\text{COOH})$ group** as number 1 and the carbons adjacent to it as 2,3,4 respectively.
2. Counting from carbon adjacent to **carboxyl carbon** numbered as (α , β , γ , δ ,...).
3. Counting from last methyl carbon **terminal** (CH_3) which is called **omega-1carbon (ω -1)**, ω -2, ω -3, ω -4.....

FA Nomenclature



FA Nomenclature



Trivial name

Oleic acid 18:1 Δ^9

Number of
Carbon atoms

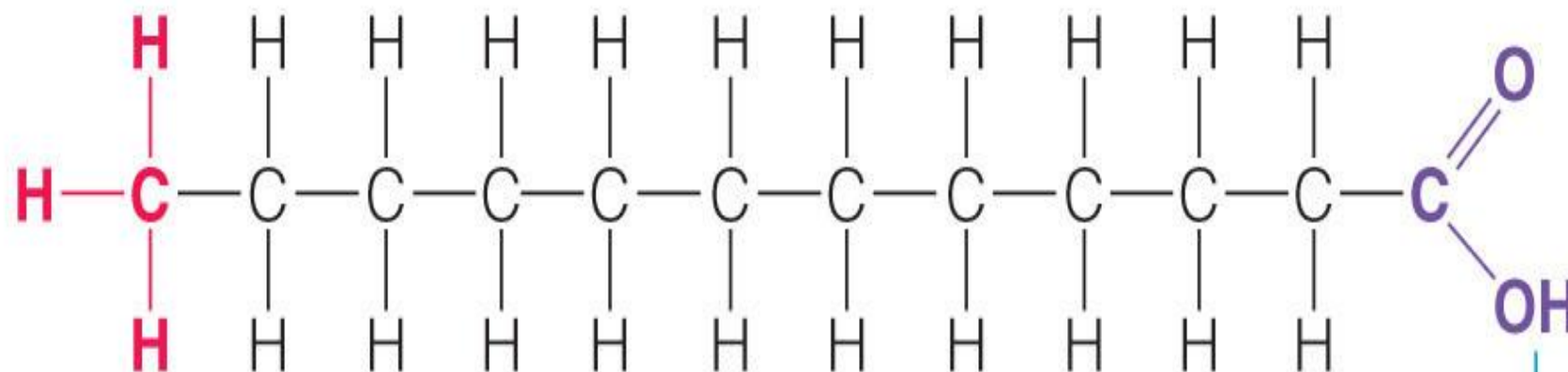
Number of
Double bonds

Double bond position (counting
from **carboxyl** end)
cis configuration unless indicated

Lauric acid (12:0)

Carboxylic acid
or alpha (α) end

Methyl or omega (ω) end



Fatty acid backbone

Methyl end is
often written
as —CH_3 .

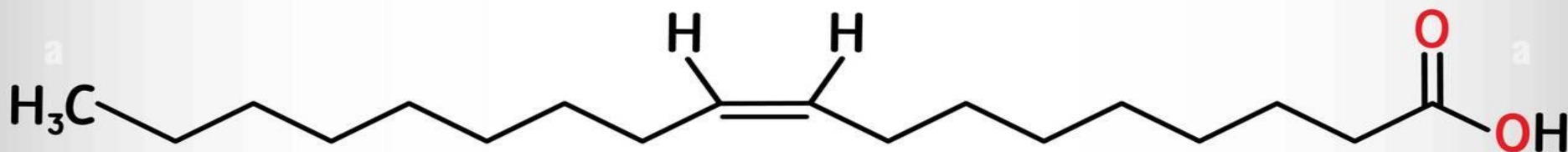
Carboxylic acid
end often written
as —COOH .

Geometric isomerism

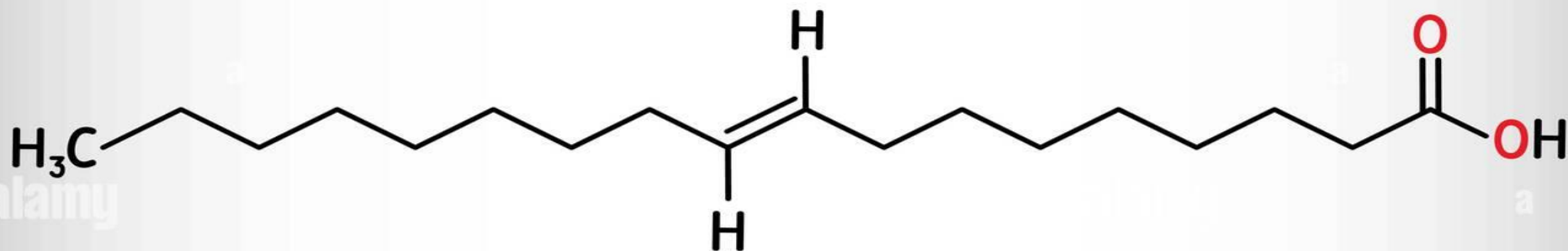
- Occurs in unsaturated fatty acids, depending on the **orientation of atoms or groups** around the axes of **double bonds**, which do not allow rotation.
- If the acyl chains are on the **same side of the bond**, it is ***cis-***, as in oleic acid
- If on **opposite sides**, it is ***trans-***, as in elaidic acid, the *trans* isomer of oleic acid

Geometric isomerism

cis (Oleic acid)

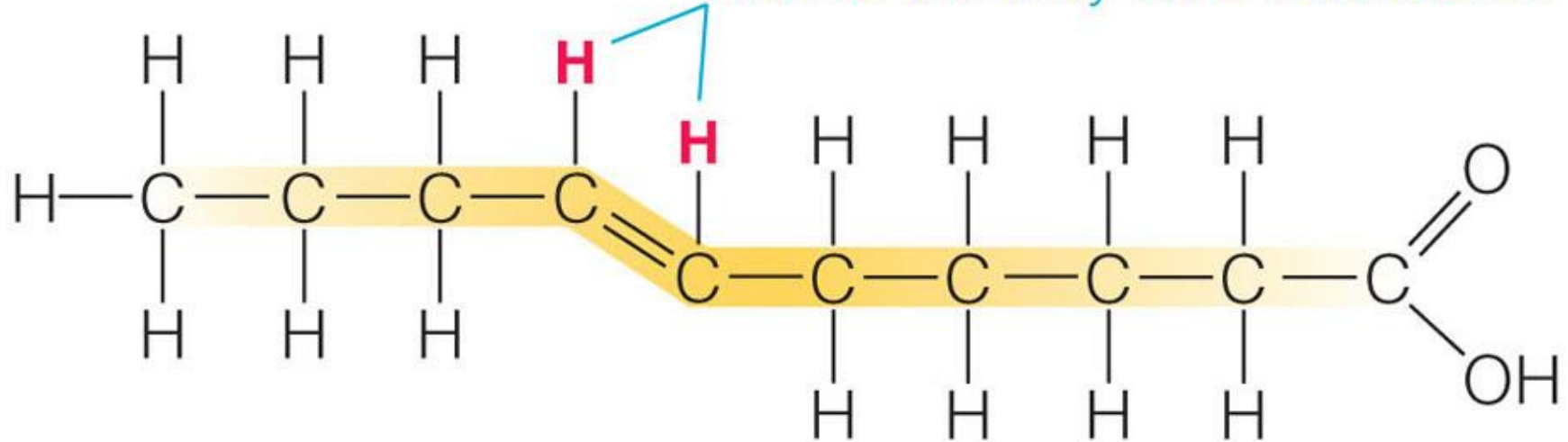


trans (Elaidic acid)



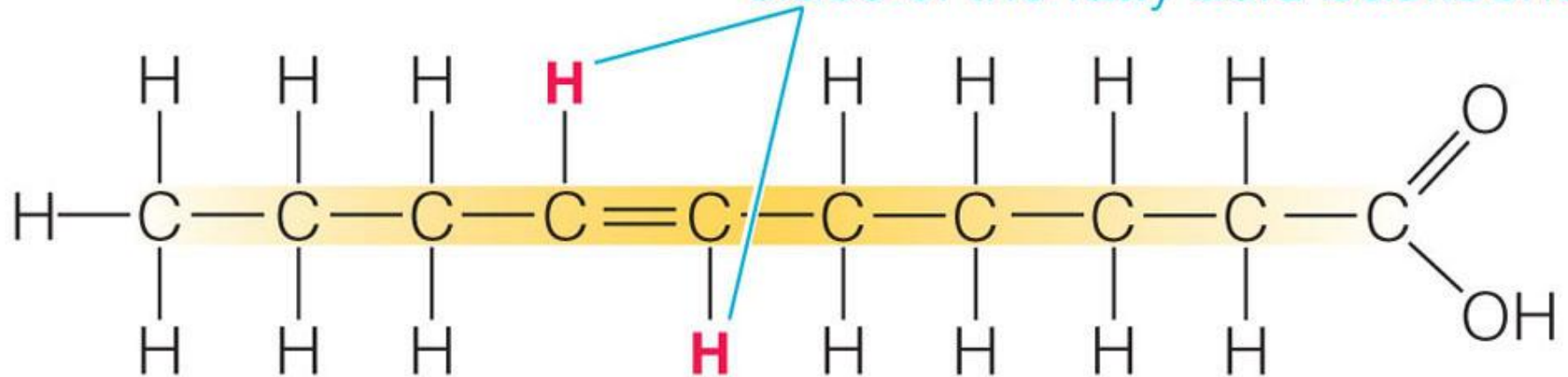
A *cis* fatty acid

Hydrogens are on the same side of the fatty acid backbone.



A *trans* fatty acid

Hydrogens are on opposite sides of the fatty acid backbone.



Essential Fatty Acids

- **Are Polyunsaturated fatty acids that cannot be synthesized by the body and therefore should be supplied in diet**
- **Serve as precursors for other important fatty acids**
- **Required for normal growth and metabolism.**

Essential Fatty Acids



- **Why the body can't synthesize essential fatty acids?**
- **Due to absence of desaturase enzymes needed to insert double bonds at the omega-3 and omega-6 positions(Δ & Δ) on a fatty acid chain.**

Essential Fatty Acids

1. Linoleic acid (Omega-6):

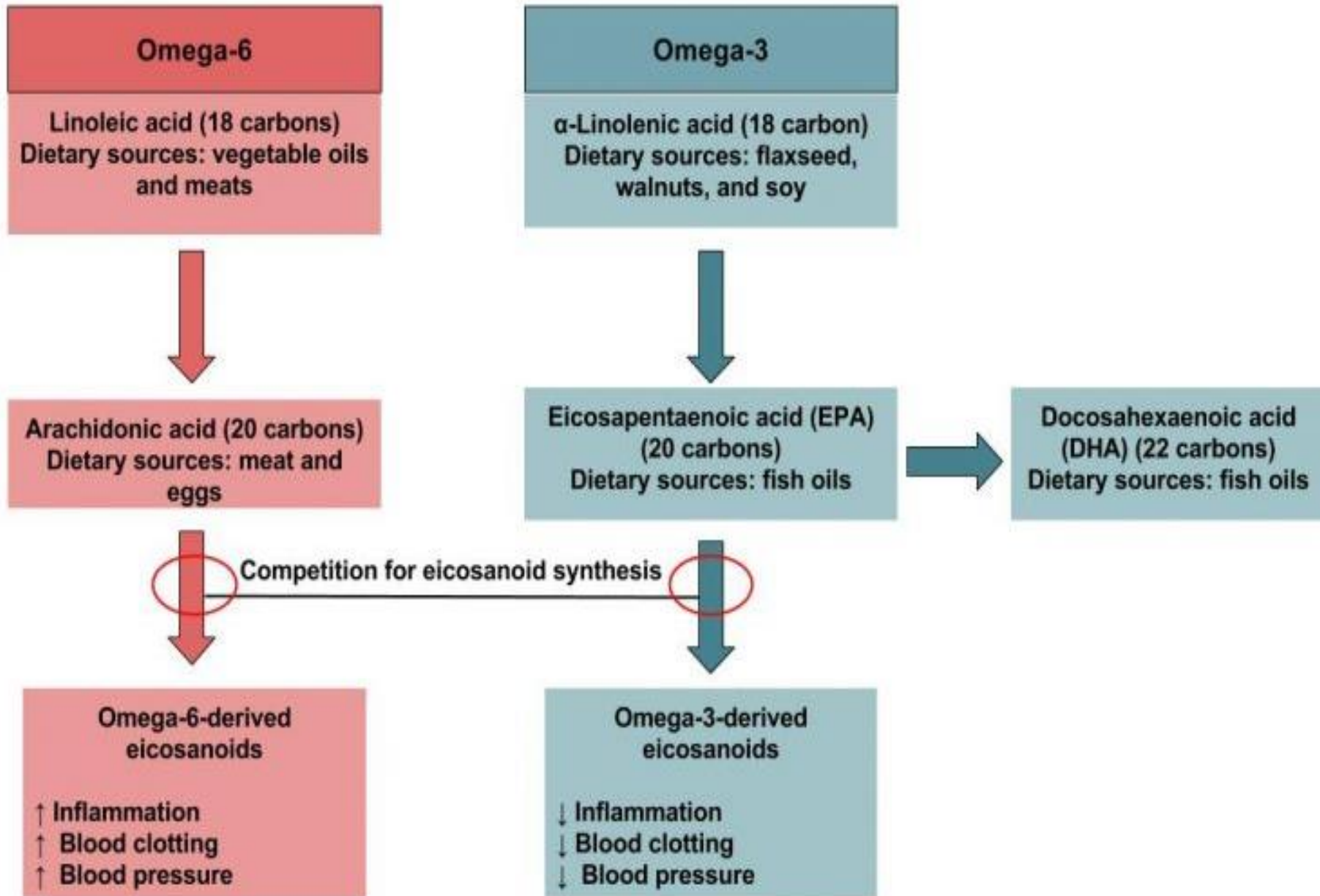
- Act as a building block for **arachidonic acid**
→  **Inflammatory response:** Linoleic acid can be converted to **arachidonic acid**, which produces eicosanoids involved in inflammation and immune responses.

Essential Fatty Acids

2. Alpha-linolenic acid (Omega-3):

- Precursor to omega-3s: **EPA** (eicosapentaenoic acid) and **DHA** (docosahexaenoic acid) 
 **Anti-inflammatory effects:** EPA and DHA give rise to lipid mediators that help regulate inflammation.

The Essential Fatty Acids



Derivatives of omega-3 & omega-6



eicosapentaenoic acid (C20:5 ω -3)



docosahexaenoic acid (C22:6 ω -3)



arachidonic acid (C20:4 ω -6)

Functions of Essential Fatty Acid

1. **Cell membrane structure:** Maintain the integrity and fluidity of cell membranes.
2. **Growth and development:** Essential for normal growth, especially in infants and children.
3. **Brain and eye health:** Support normal development and function of the brain and retina.
4. **Production of eicosanoids:** regulate inflammation, blood clotting, and immune responses.

Functions of Essential Fatty Acid

- 5. Skin health:** Help maintain healthy skin and prevent dryness and dermatitis.
- 6. Cardiovascular health:** Support normal heart function, help regulate blood pressure, and may reduce the risk of heart disease.
- 7. Immune function**
- 8. Reproductive health**

THE END