Lipids

Prof. Narkunaraja Shanmugam
Dept. Of Biomedical Science
School of Basic Medical Sciences
Bharathidasan University

Part 1: Lipid Characteristics

- Lipid = a compound that is insoluble in water, but soluble in an organic solvent (e.g., ether, benzene, acetone, chloroform)
- “lipid” is synonymous with “fat”, but also includes phospholipids, sterols, etc.
- chemical structure: glycerol + fatty acids

Lipid Molecule

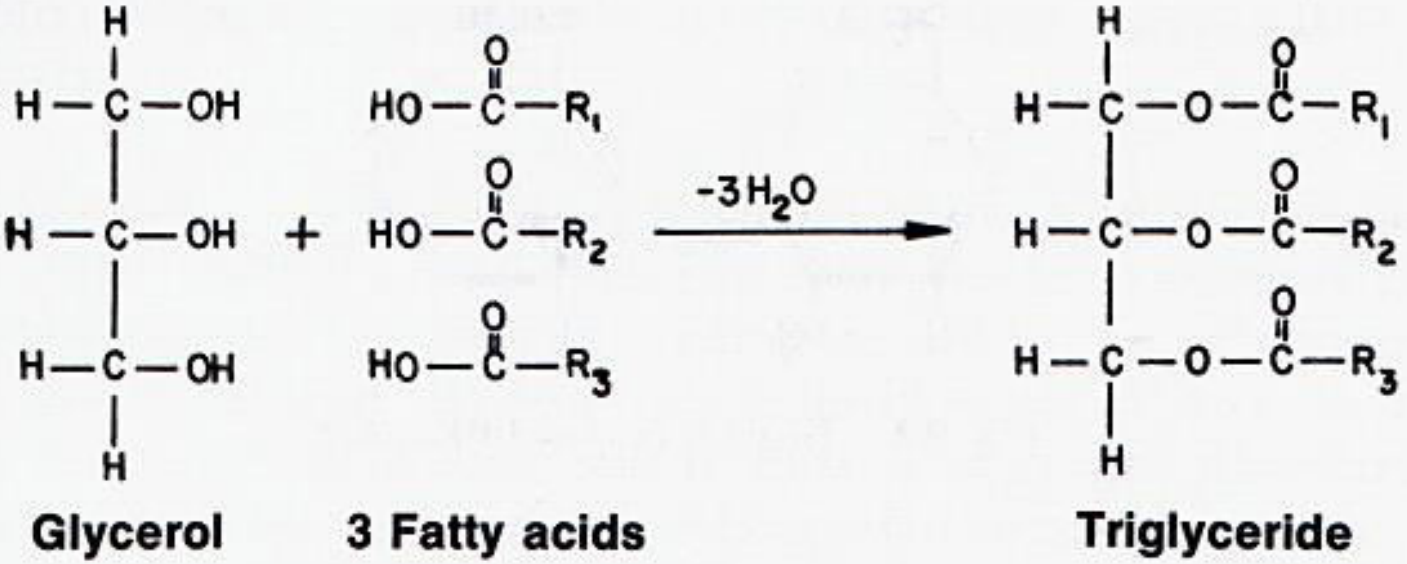


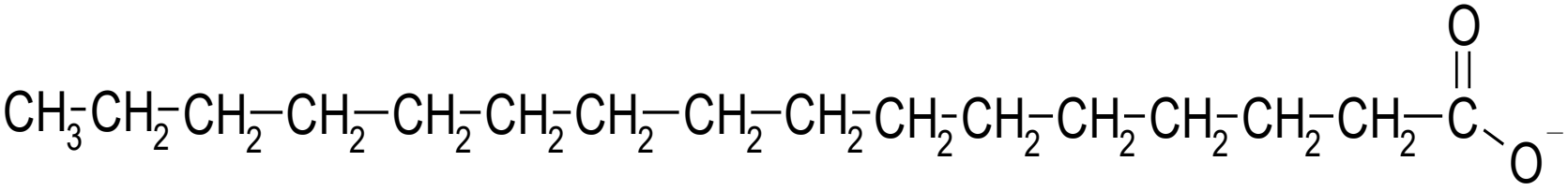
Fig. 2.6. Lipids.

Introduction

- Fatty acids play several important roles:

1. Building blocks for phospholipids and glycolipids
2. Target proteins to membranes
3. High energy source of fuel
4. Fatty acid derivatives are used as hormones and intracellular messengers

What are fatty acids? **FATTY ACIDS ARE ALIPHATIC CARBOXYLIC ACIDS**



$CH_3\text{-}(CH_2)_{16}\text{-}COO^-$

Lipid Classes

1. **simple:** FA's esterified with glycerol
2. **compound:** same as simple, but with other compounds also attached
    a) **phospholipids:** fats containing phosphoric acid and nitrogen (lecithin)
    b) **glycolipids:** FA's compounded with CHO, but no N
3. **derived lipids:** substances from the above derived by hydrolysis
4. **sterols:** large molecular wt. alcohols found in nature and combined w/FA's (e.g., cholesterol)

CLASSIFICATION

Simple lipids

Esters of fatty acids with various alcohols.

1. **Esters of fatty acids with glycerol (Fat)**
2. **Esters of fatty acids with** monohydric alcohols. (Wax)

Complex lipids

Simple lipids +
ADDITIONAL GROUPS

Phospholipids:
Glycerophospholipids

Glycolipids
glycosphingolipids

Other complex :
sulfo lipids and **amino lipids**

Precursor & derived lipids

1. Fatty acids,
2. glycerol,
3. steroids,
4. other alcohols,
5. fatty aldehydes,
6. ketone bodies
7. hydrocarbons,
8. lipid-soluble vitamins, & hormones.

uncharged, so termed as **neutral lipids.**

Fatty acids that occur in natural fats are usually straight-chain derivatives containing an **even number of carbon atoms**.

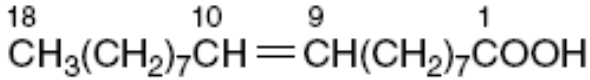
FATTY ACIDS ARE

Saturated
(containing **no double bonds**),

end in **–anoic** ex. Octanoic

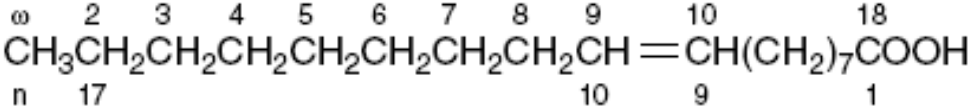
Unsaturated
(containing **one or more double bonds**)
end in **-enoic,** ex.oleic acid.

18:1;9 *or* Δ^9 18:1

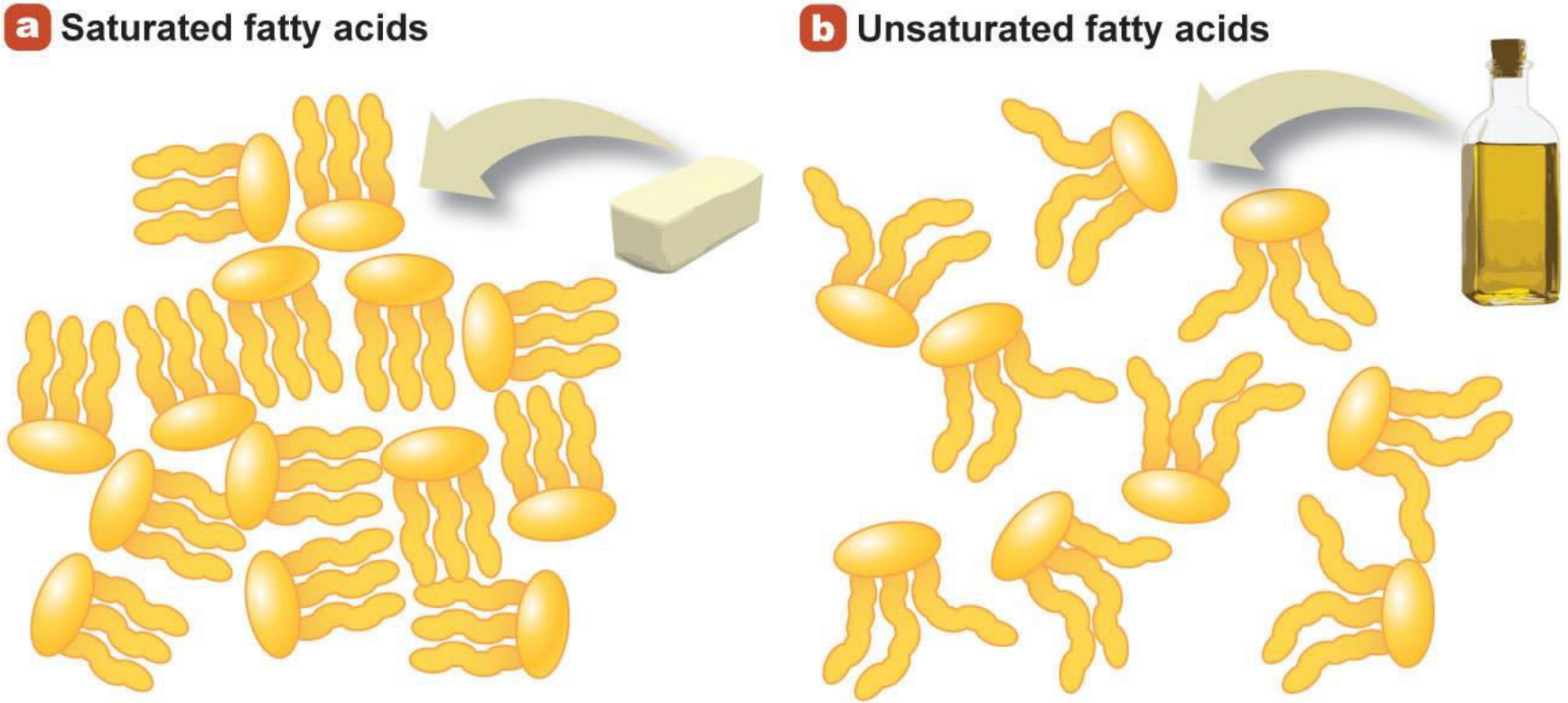


or

ω9,C18:1 *or* n–9, 18:1



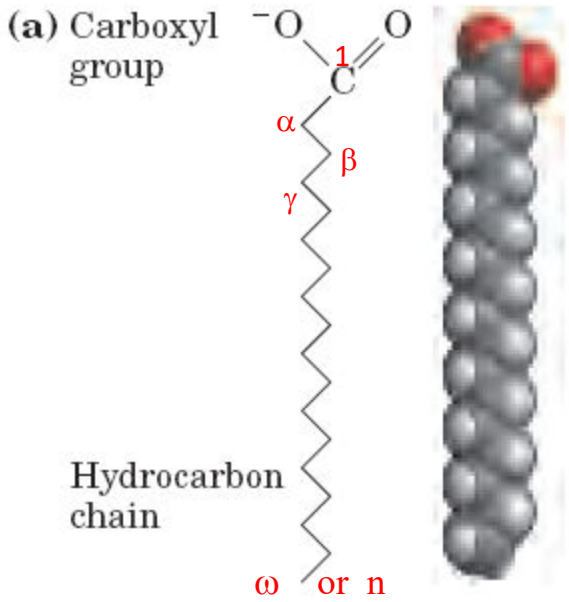
Saturated and Unsaturated Fatty Acids Help Shape Foods



Saturated Fatty acids

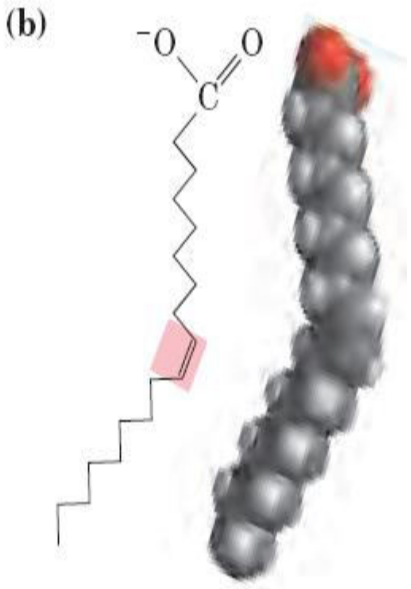
Carbon atoms are numbered from the carboxyl carbon (carbon No. 1).

The carbon atoms adjacent to the carboxyl carbon (Nos. 2, 3, and 4) are named as the α, β, and γ carbons, respectively, and the terminal methyl carbon is known as the ω or n-carbon.



Common Name	Number of C Atoms	
Acetic	2	Major end product of carbohydrate fermentation by rumen organisms[1]
Propionic	3	An end product of carbohydrate fermentation by rumen organisms[1]
Butyric	4	In certain fats in small amounts (especially butter). An end product of carbohydrate fermentation by rumen organisms[1]
Valeric	5	
Caproic	6	
Lauric	12	Spermaceti, cinnamon, palm kernel, coconut oils, laurels, butter
Myristic	14	Nutmeg, palm kernel, coconut oils, myrtles, butter
Palmitic	16	Common in all animal and plant fats
Stearic	18	

Unsaturated Fatty acids



Various conventions are used

Δ for indicating the number
and position of the double bonds eg, Δ^9 indicates a double bond between carbons 9 and 10 of the fatty acid;

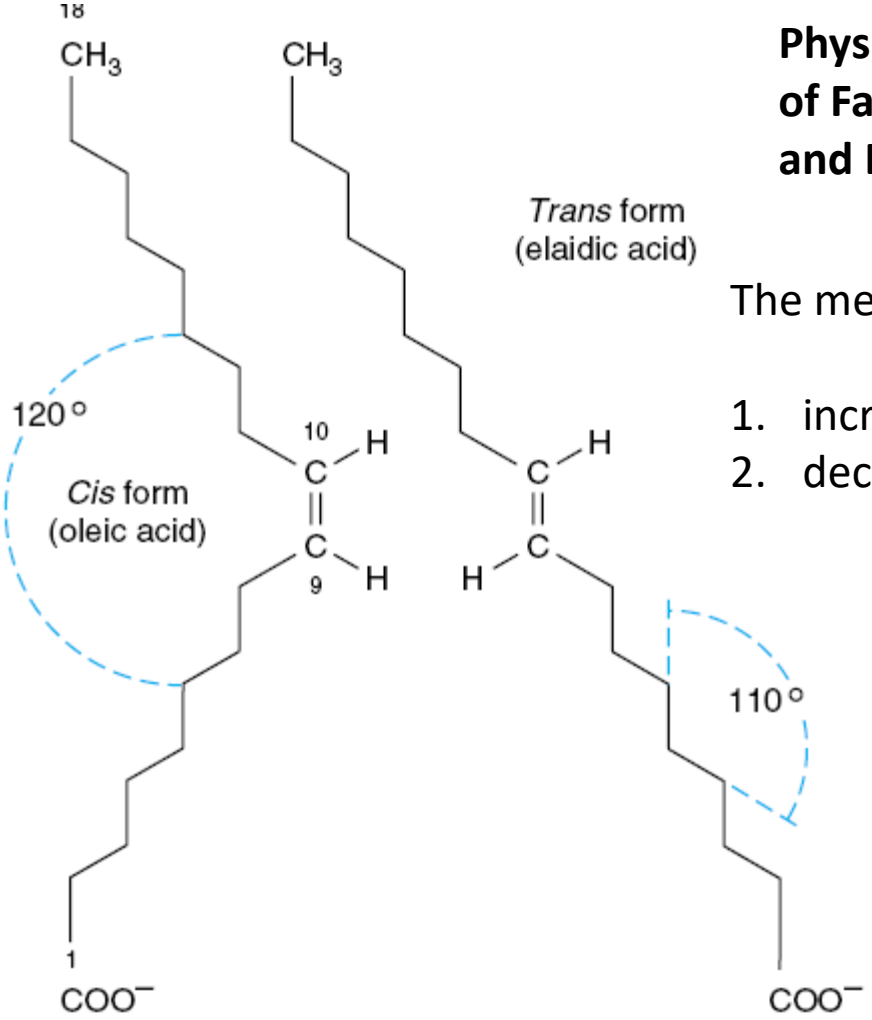
ω9 indicates a double bond on the
ninth carbon counting from the ω- carbon.

There are two forms of double bonds

a. cis form

b. trans form

Most Naturally Occurring Unsaturated Fatty Acids Have *cis Double Bonds*



Physical and Physiologic Properties of Fatty Acids Reflect Chain Length and Degree of Unsaturation

The melting points of fatty acids

1. increase with increasing chain length
2. decrease with increasing unsaturation.

Saturated fatty acids of 18 carbons is solid at body temp.

Unsaturated fatty acid of 18:2 carbon is liquid even below 0 °C.

Unsaturated fatty acids

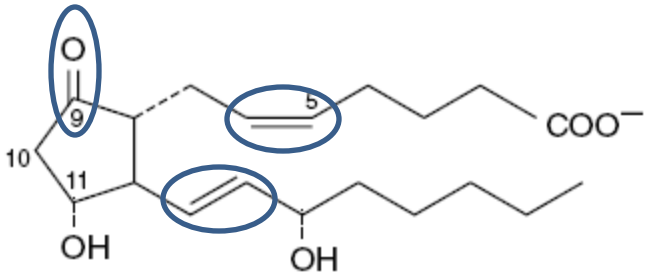
Monounsaturated FA
containing one double bond

Polyunsaturated FA
containing more than one double bond

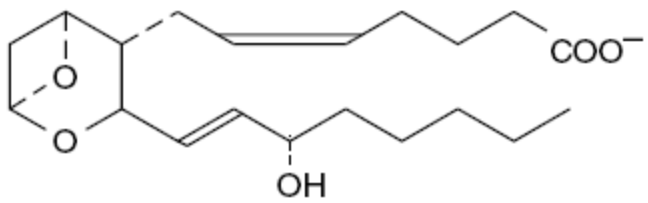
Eicosanoids:
eicosa- polyenoic fatty acids (20C)

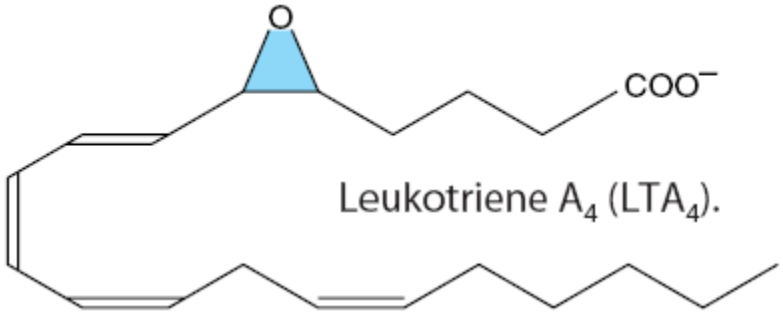
1. (prostaglandins (PGs), prostacyclins (PGIs), thromboxanes (TXs)
2. leukotrienes (LTs), and
3. lipoxins (LXs).

Prostaglandin E_2 (PGE_2).



Thromboxane A_2 (TXA_2).

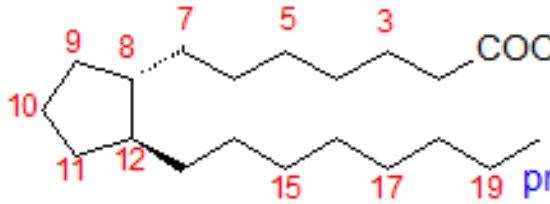




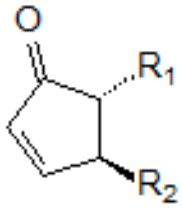
Leukotriene A_4 (LTA_4).

the “E” type of prostaglandin (as in PGE2) has a keto group in position 9,
whereas the “F” type has a hydroxyl group in this position.

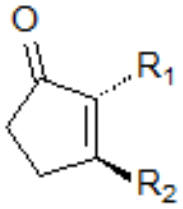
The prostaglandins



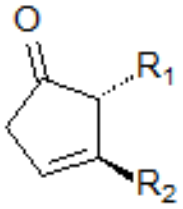
prostanoic acid



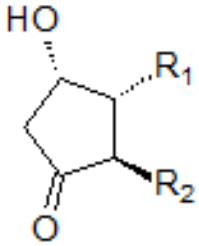
PGA



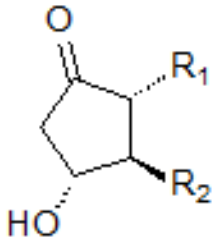
PGB



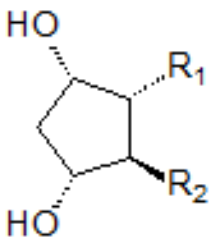
PGC



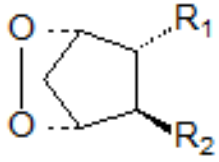
PGD



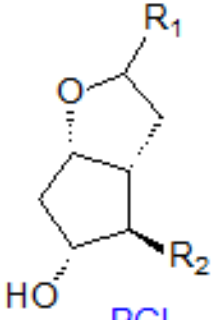
PGE



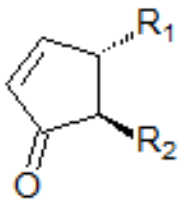
PGFα



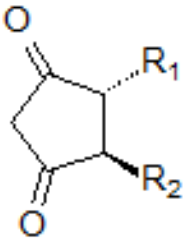
PGG
PGH



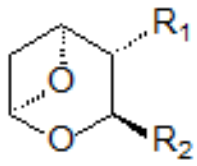
PGI



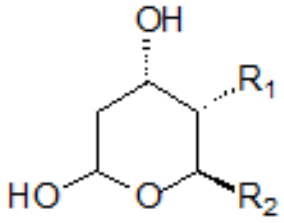
PGJ



PGK



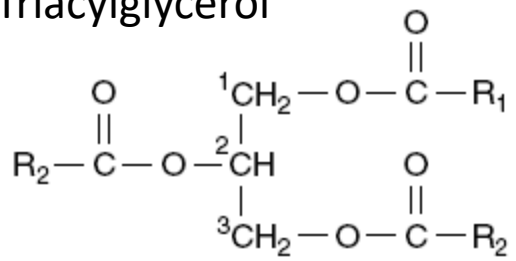
TXA



TXB

TRIACYLGLYCEROLS (TRIGLYCERIDES) ARE THE MAIN STORAGE FORMS OF FATTY ACIDS

Triacylglycerol

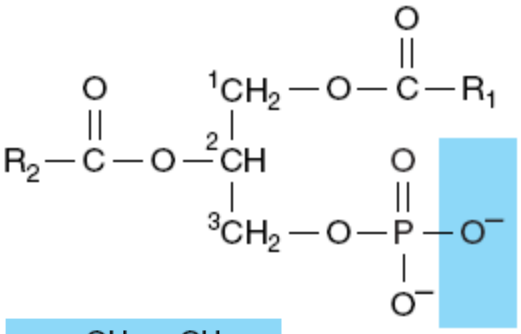


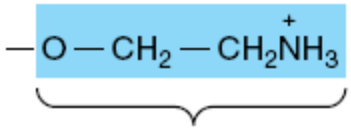
Carbons 1 & 3 of Glycerol Are Not Identical

Enzymes readily distinguish between them
Eg, glycerol is always phosphorylated on *sn-3 by glycerol kinase* to give glycerol 3-phosphate and not glycerol 1-phosphate.

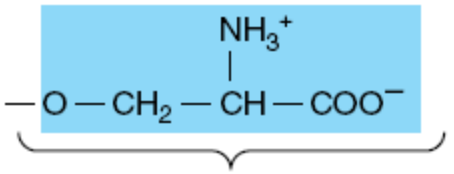
PHOSPHOLIPIDS ARE THE MAIN LIPID CONSTITUENTS OF MEMBRANES

as derivatives of **phosphatidic acid**

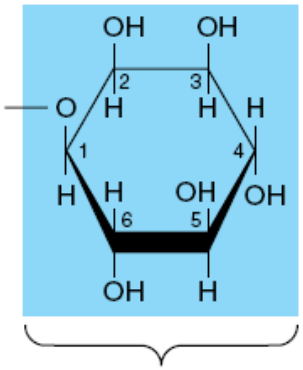




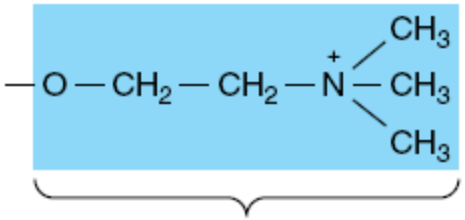
cephalin **Ethanolamine**



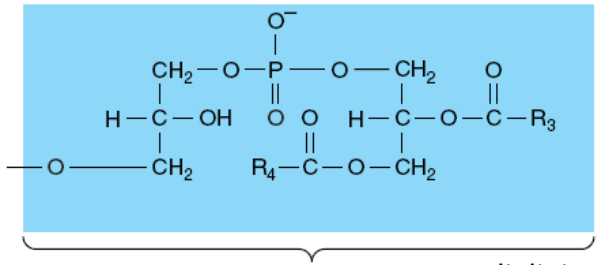
Serine



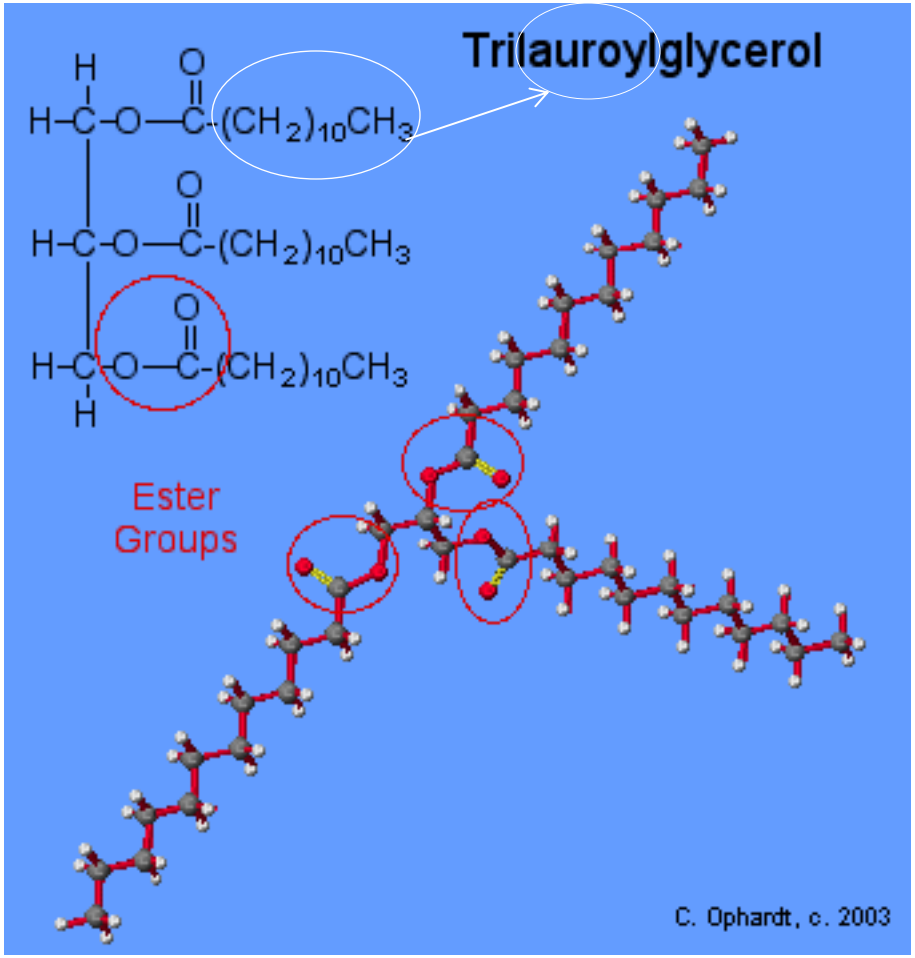
Myoinositol
Second Messengers

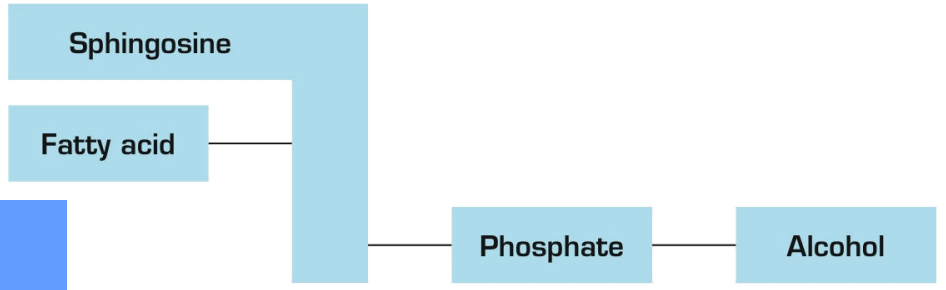


Choline
Cell Membranes

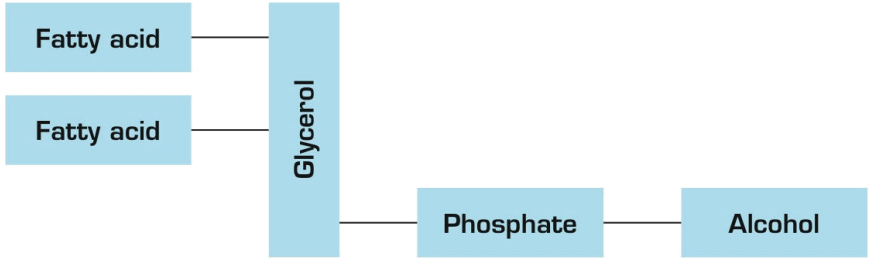


Phosphatidylglycerol cardiolipin
Mitochondrial Membranes



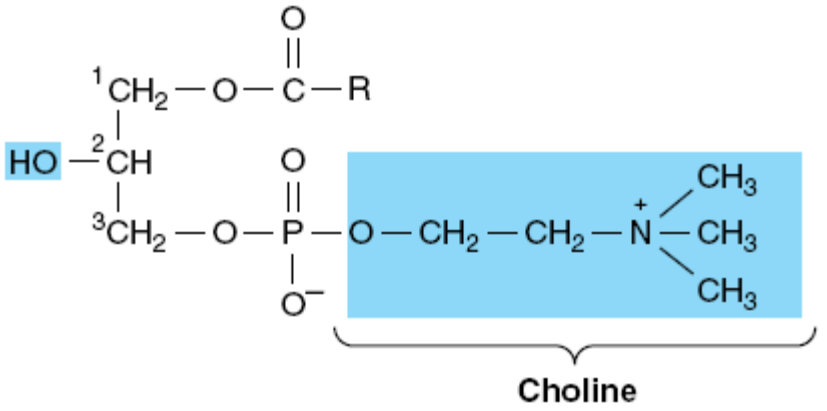


Structure of a sphingolipid

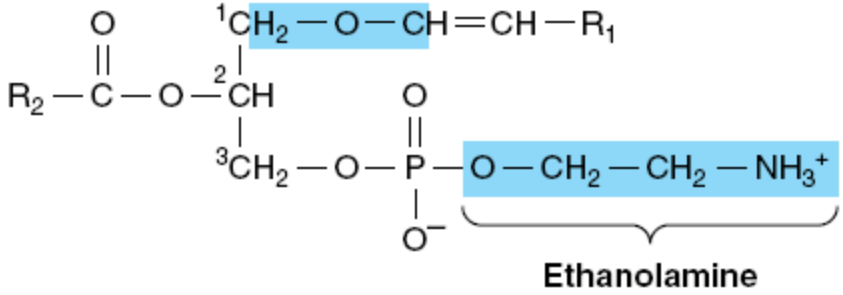


Structure of a glycerophospholipid

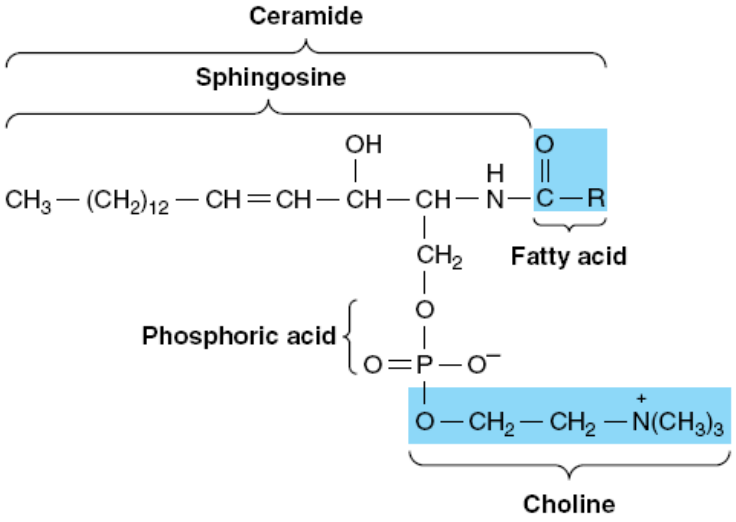
Lysophospholipids Are Intermediates in the Metabolism of Phosphoglycerols



Plasmalogens Occur in Brain & Muscle



Sphingomyelins Are Found in the Nervous System



GLYCOLIPIDS

Glycolipids are widely distributed in every tissue of the body, in the outer leaflet of the plasma membrane,

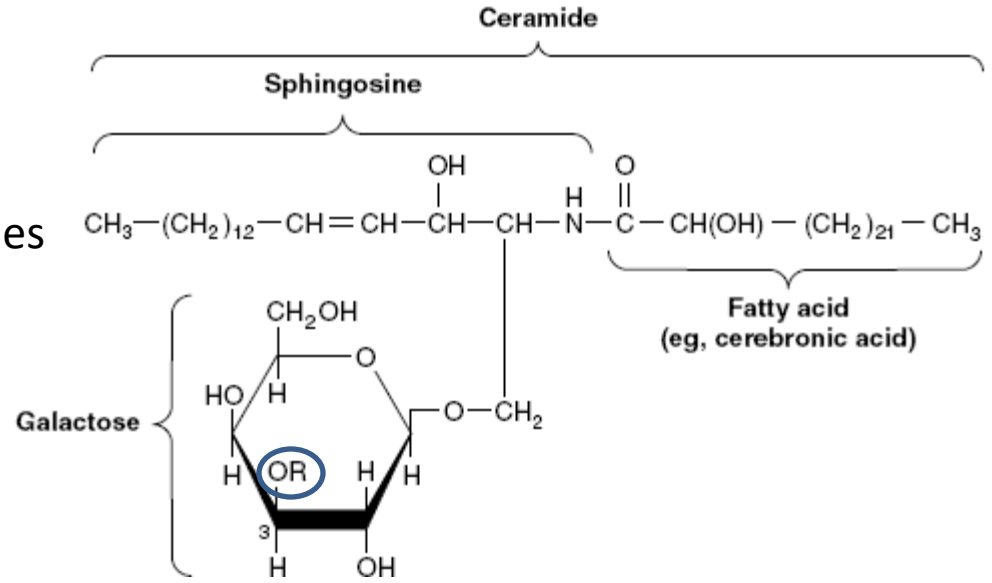
The major glycolipids found in animal tissues are glycosphingolipids.

contain ceramide and one or more sugars.

Galactosylceramide

sphingolipid of brain and other nervous tissue, found in relatively low amounts elsewhere.

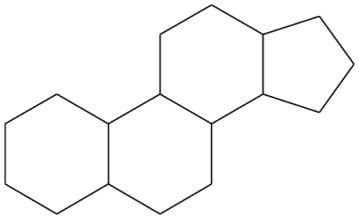
It contains a number of characteristic C_{24} fatty acids, eg cerebronic acid.



galactocerebroside, R = H

Sulfogalactosylceramide R = SO_4^{2-}

STEROIDS PLAY PHYSIOLOGICALLY IMPORTANT ROLES



Ring structure of a steroid

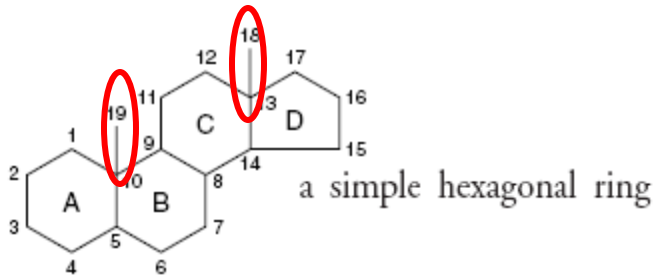
steroids have a similar cyclic nucleus (2 cyclic molecules) resembling

1. phenanthrene (rings A, B, and C) to which a
2. cyclopentane ring (D) is attached.

Cholesterol

Precursor of a large number of equally important steroids that include

1. the bile acids,
2. adrenocortical hormones,
3. sex hormones,
4. D vitamins,
5. cardiac glycosides,
6. Sitosterols of the plant kingdom.



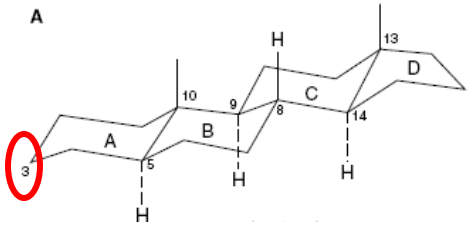
a simple hexagonal ring

compound has one or more OH (hydroxyl) groups and no carbonyl or carboxyl groups, it is a **sterol,** and the name terminates in **-ol.**

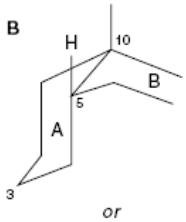
six-carbon rings of the steroid nucleus is capable of existing in the three-dimensional conformation either of a “chair” or a “boat”

“Chair” form

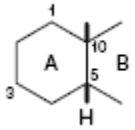
“Boat” form



cis



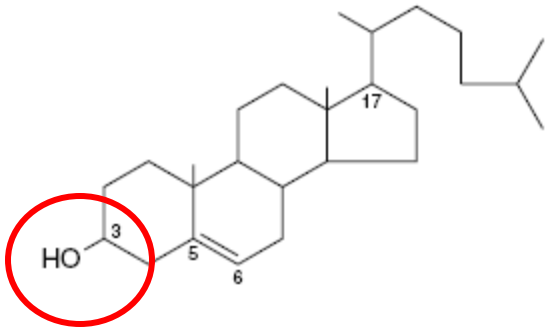
The junction between the A and B rings can be *cis or trans in naturally occurring* Steroids



Cholesterol Is a Significant Constituent of Many Tissues

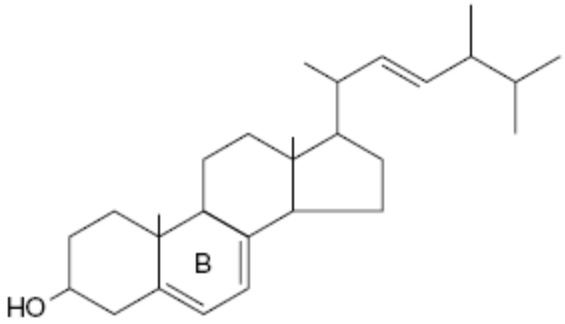
Cholesterol is widely distributed in all cells of the body but particularly in nervous tissue. It is a major constituent of the plasma membrane and of plasma lipoproteins. It is often found as **cholesteryl ester**, where the hydroxyl group on position 3 is esterified with a long-chain fatty acid.

It occurs in animals but not in plants.



Ergosterol Is a Precursor of Vitamin D

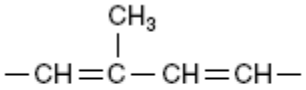
Ergosterol occurs in plants and yeast and is important as a precursor of vitamin D



Polyprenoids

They include **ubiquinone** a member of the respiratory chain in mitochondria,

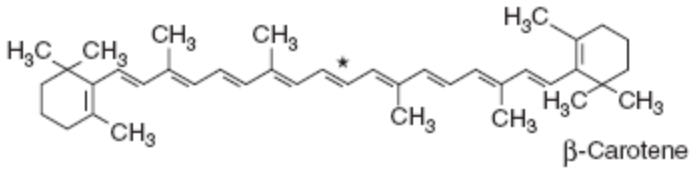
Longchain alcohol **dolichol** which takes part in glycoprotein synthesis by transferring carbohydrate residues to asparagine residues of the polypeptide.



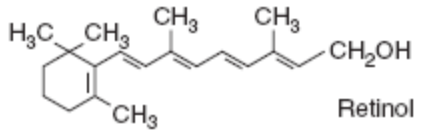
Isoprene unit.

Dolichol—a C95 alcohol.

Plant-derived isoprenoid compounds include rubber, camphor, the fat-soluble vitamins A, D, E, and K, and β-carotene (provitamin A).

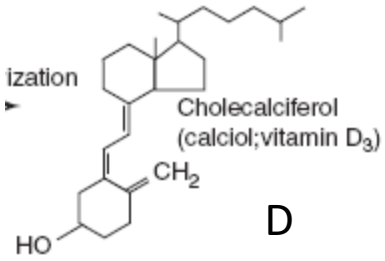


β-Carotene

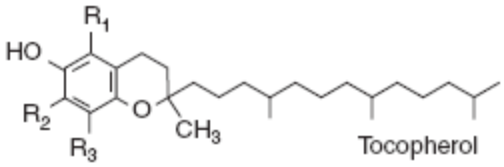


Retinol

A

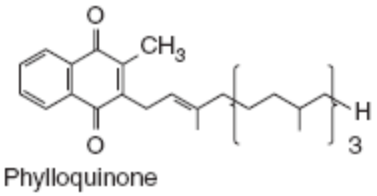


D



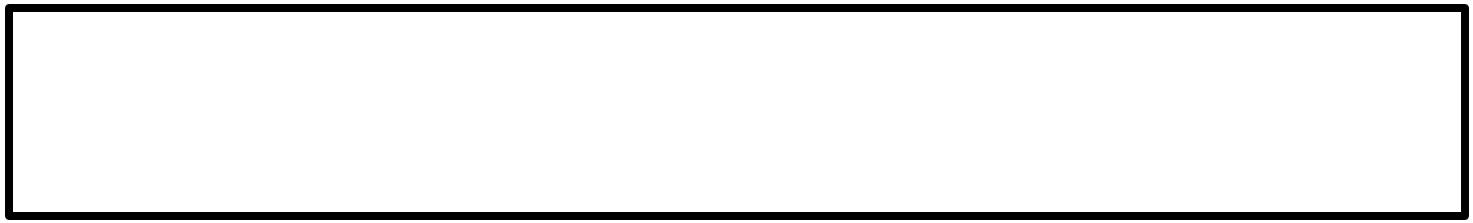
Tocopherol

E



Phylloquinone

K



$^1O_2$
Singlet Oxygen

OH°
Hydroxyl Radical

OH° + PUFA → $PUFA^\circ$

PUFA Radical

$PUFA^\circ$ → $PUFAO_2^\circ$

PUFA Peroxide Radical

$PUFAO_2^\circ$ → $PUFAO_2H$ + $PUFA^\circ$

Lipid Hydroperoxide

⇩

Breakdown Products (toxic)

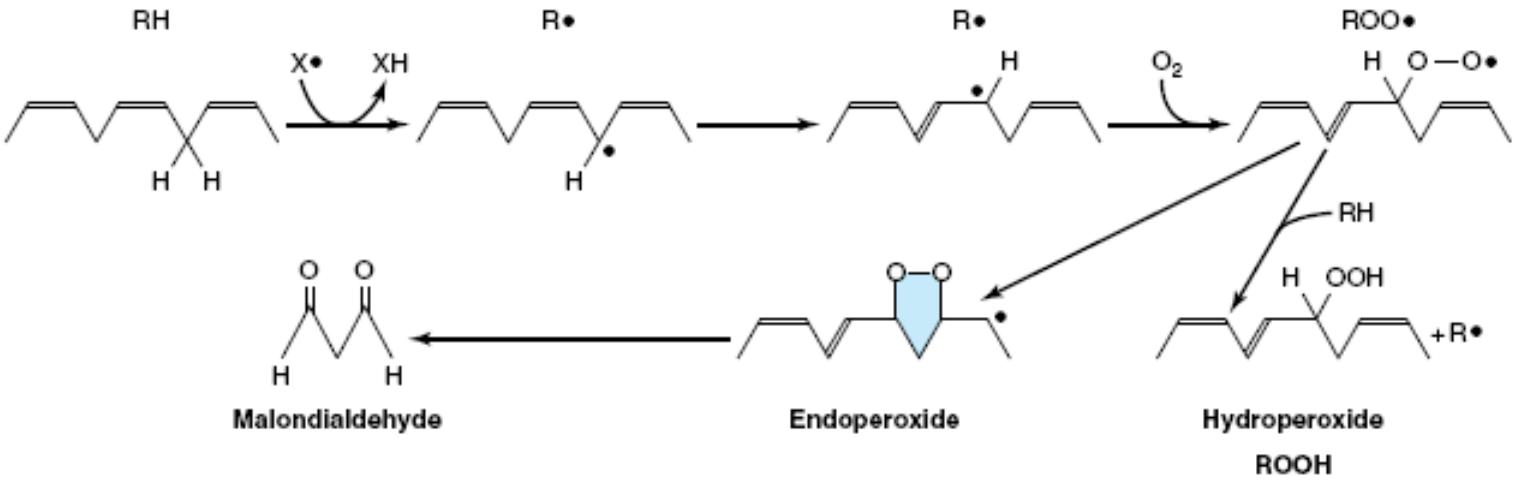
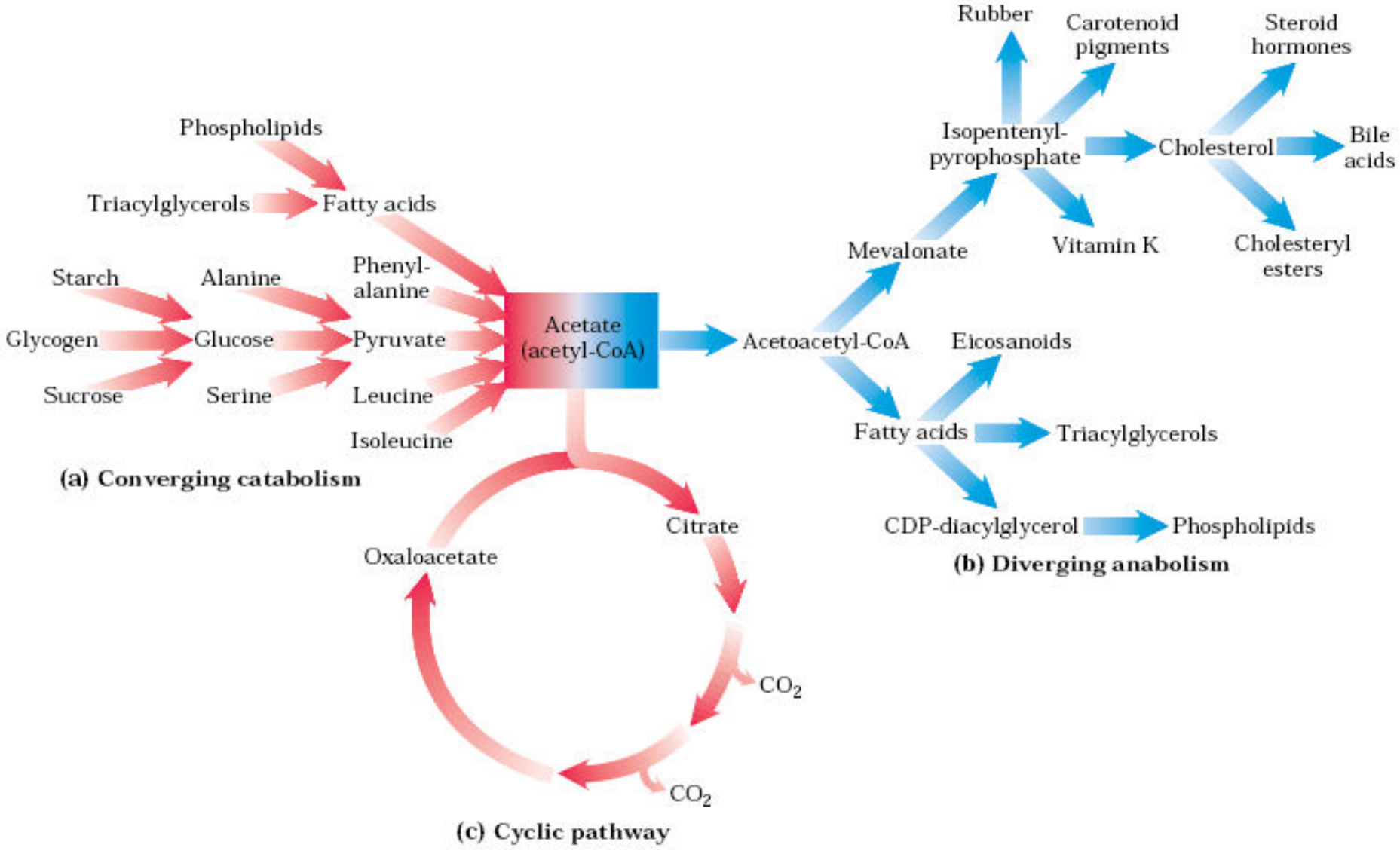
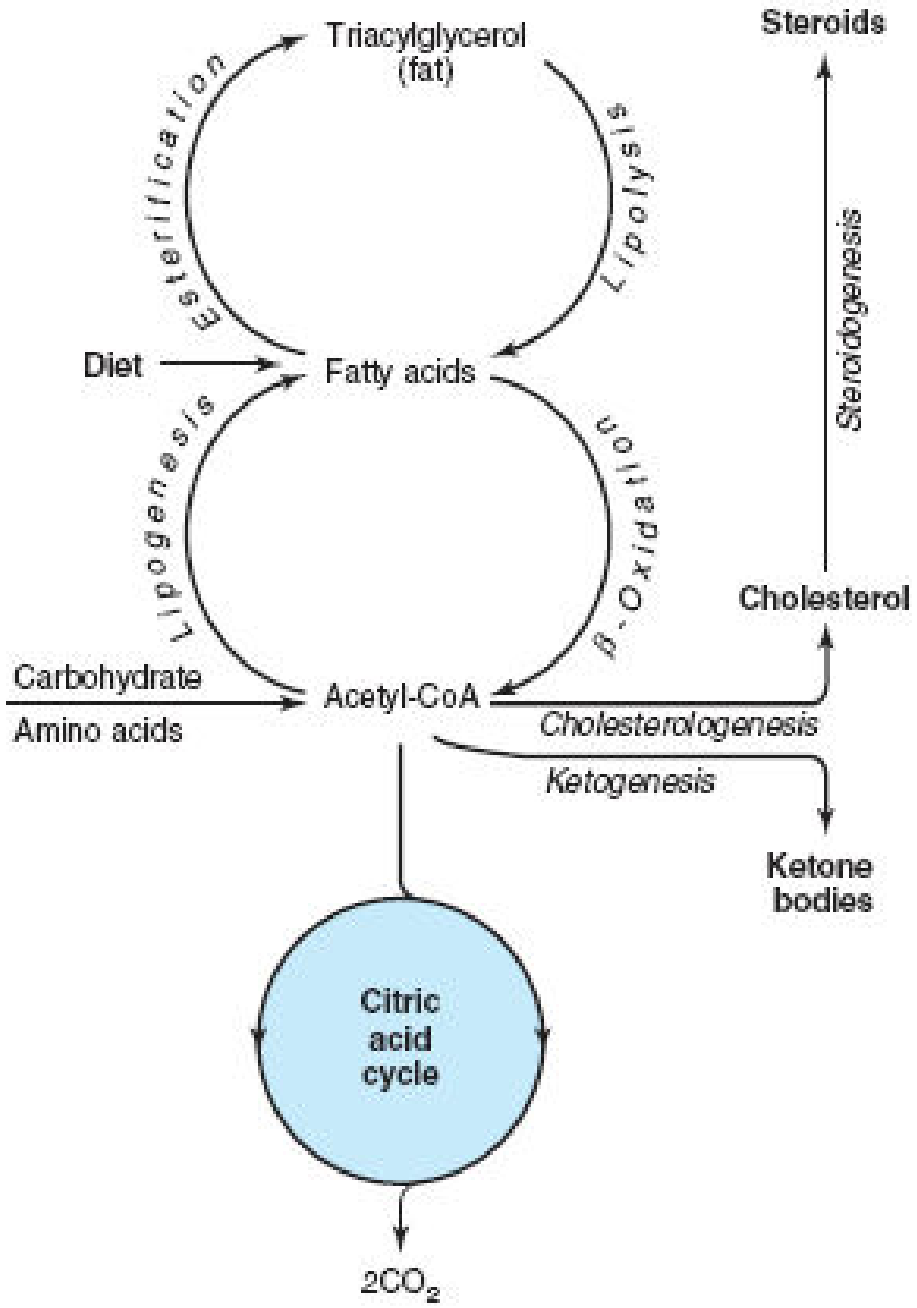


Figure 14–21. Lipid peroxidation. The reaction is initiated by an existing free radical (X•), by light, or by metal ions. Malondialdehyde is only formed by fatty acids with three or more double bonds and is used as a measure of lipid peroxidation together with ethane from the terminal two carbons of ω3 fatty acids and pentane from the terminal five carbons of ω6 fatty acids.

Overview of fatty acid metabolism




Triacylglycerol
(fat)
Steroids
Esterification
Lipolysis
Steroidogenesis
Diet
Fatty acids
Lipogenesis
β-Oxidation
Cholesterol
Carbohydrate
Amino acids
Acetyl-CoA
Cholesterologenesis
Ketogenesis
Ketone
bodies
Citric
acid
cycle
2CO2