Department of biology

Biochemistry

Second Stage – Second Course

Lecture 4

Lipids

By

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LIPIDS

Biochemistry

Introduction

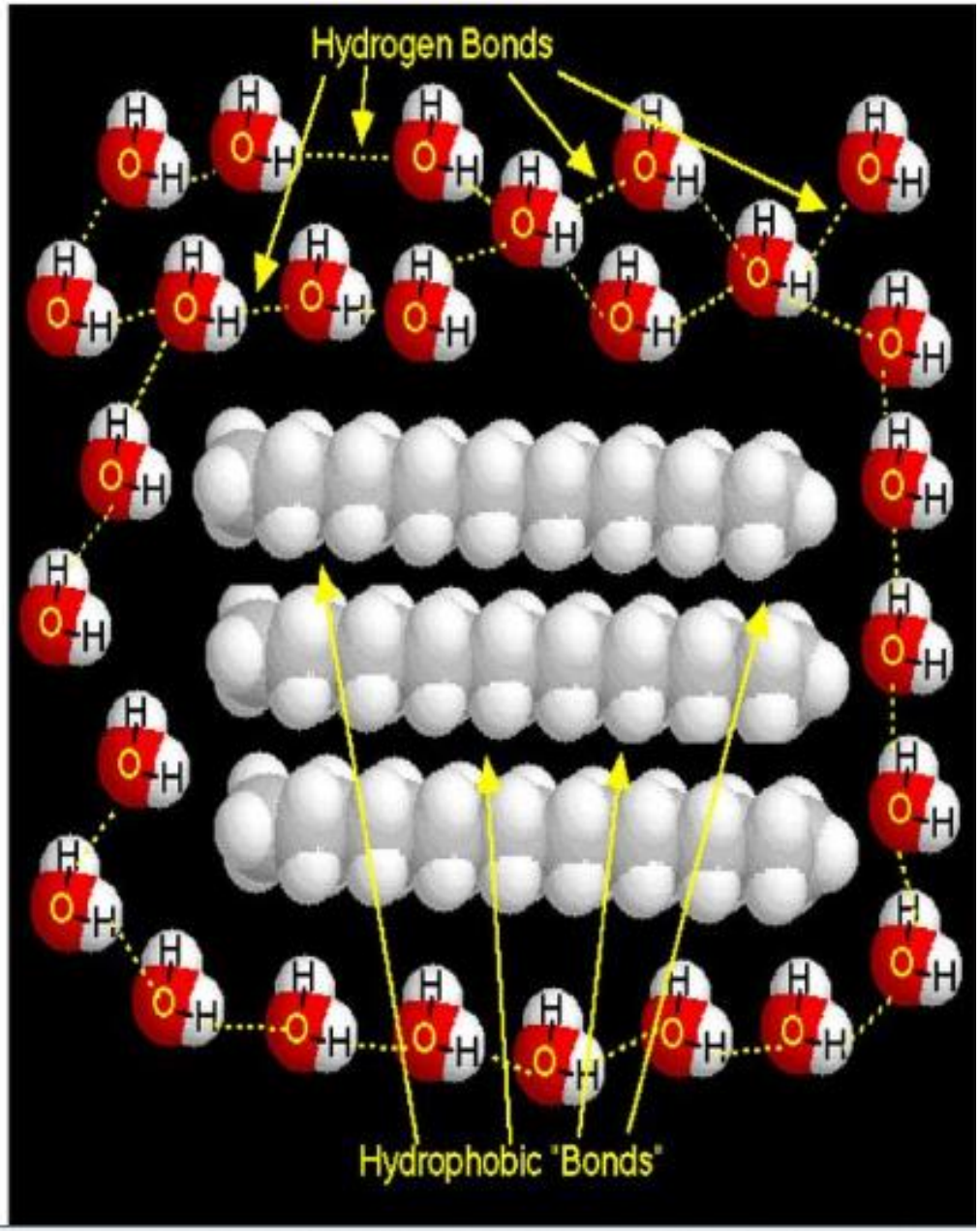
- Definition of lipids: family of biochemicals that are **soluble in organic solvents** but not in water
  - Most lipids are fatty acids or ester of fatty acid
  - Soluble in non-polar solvents (petroleum ether, benzene, chloroform)
- Functions
  - Energy storage
  - Structure of cell membranes
  - Thermal blanket and cushion
  - Precursors of hormones (steroids and prostaglandins) etc

Lipid Characteristics

- Hydrophobic
- Ratio of **H** to **O** is *much greater* than 2:1

  For example…

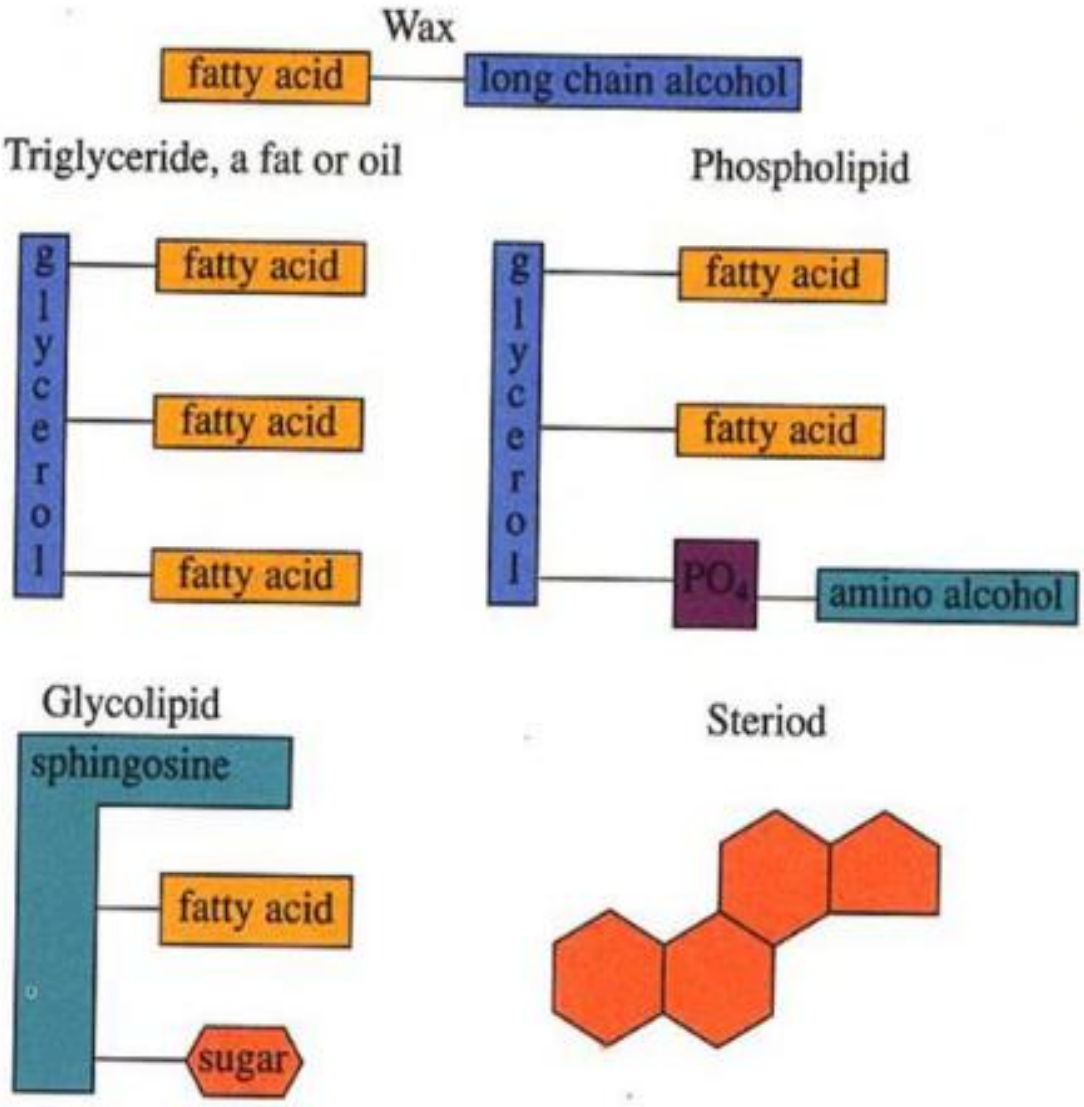
$C_{18}H_{34}O_3$

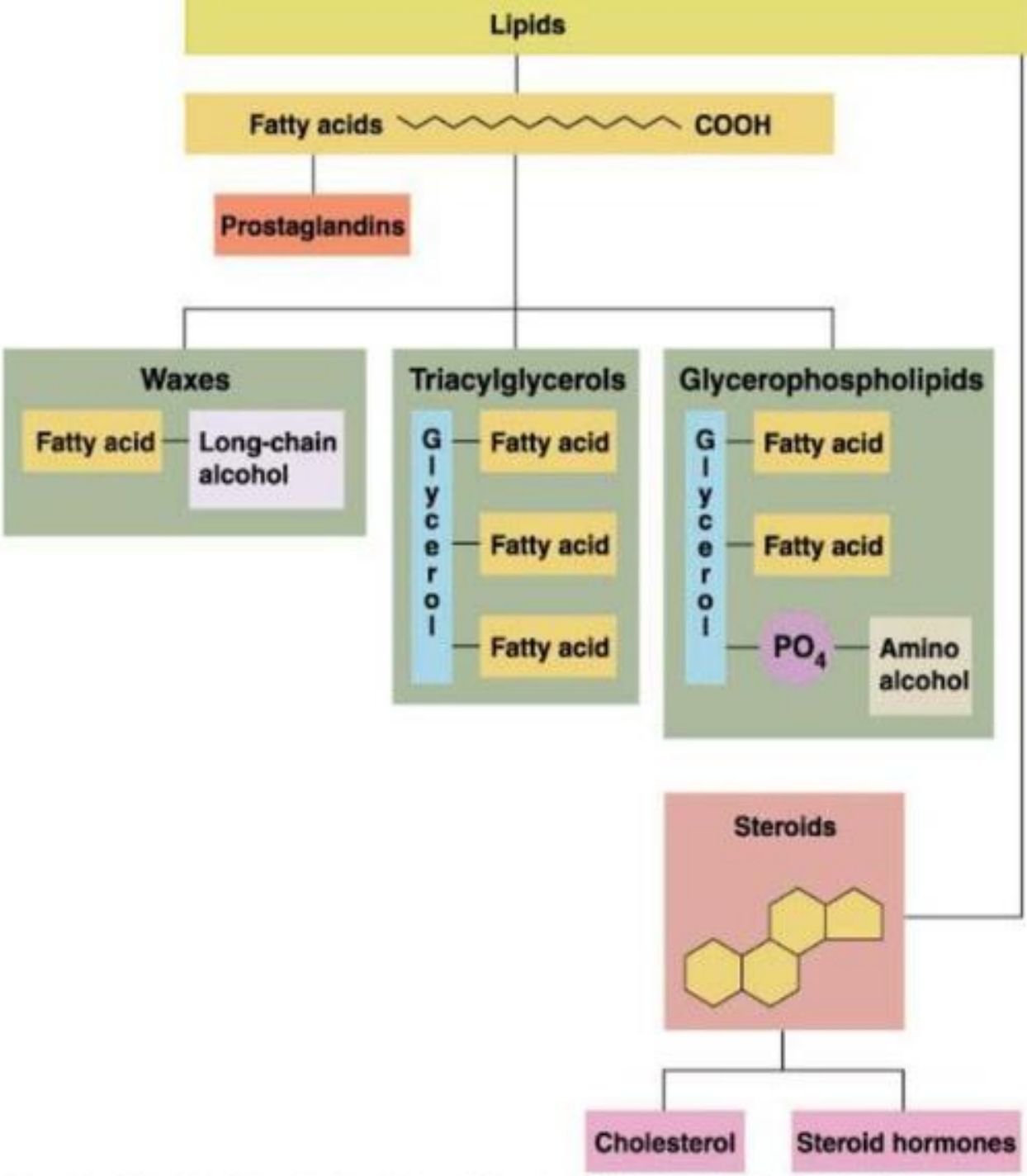


Classification of Lipids

- Waxes: fatty acid + a long-chain alcohol
- Triglycerides (fats & oils): glycerol + 3 fatty acids
- Phospholipids: glycerol + 2 fatty acids + phosphate + amino alcohol
- Glycolipids: glycerol or spinogosine + fatty acid + monosaccharide
- Steroids: 3 cyclohexanes + 1 cyclopentane fused together

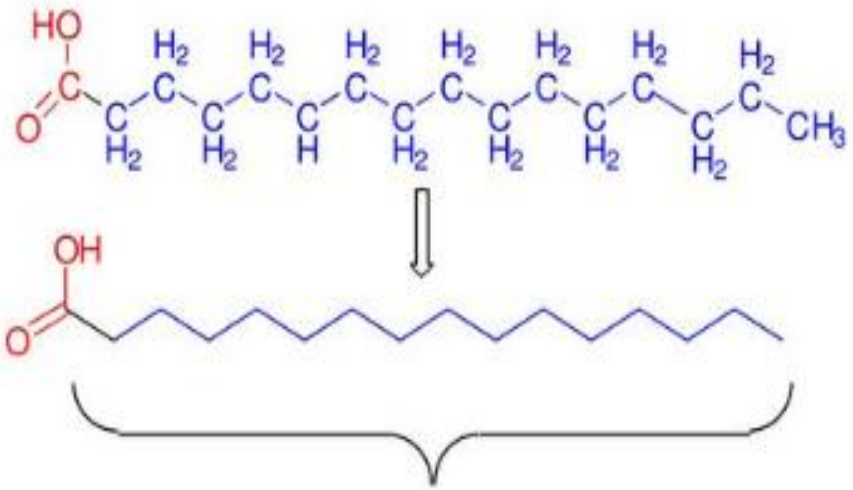
Family of Lipids



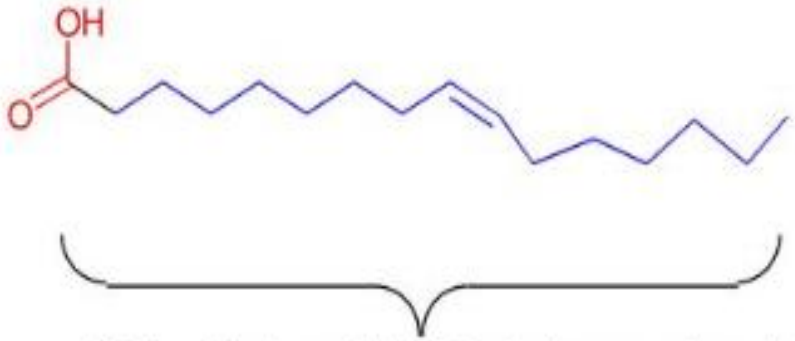

Lipids
Fatty acids
COOH
Prostaglandins
Waxes
Fatty acid
Long-chain alcohol
Triacylglycerols
Glycerol
Fatty acid
Fatty acid
Fatty acid
Glycerophospholipids
Glycerol
Fatty acid
Fatty acid
PO_4
Amino alcohol
Steroids
Cholesterol
Steroid hormones

Fatty Acids

Fatty acids = carboxyl group + a long hydrocarbon chain



16:0 =Palmitic Acid=Hexadecanoic acid



18:1 =Oleic acid=9-Octadecenoic acid

Saturated fatty acids are single bonds in all carbon-carbon bonds;
Unstaurated fatty acids contain one or more double bonds in hydrocarbon chains;

Fatty acids (FAs)

Structure and nomenclature

- Basic formula: $CH_3(CH_2)_nCOOH$
- Carboxylic acids with hydrocarbon chains of 4-24 carbons
- Free FAs are found in trace quantities in cells

FAs are either:

(i) part of a lipid molecule

(ii) complexed to a carrier protein (e.g. albumin on blood)

- Saturated or unsaturated

Naturally occurring fatty acids

There is a common pattern in the location of double bonds:

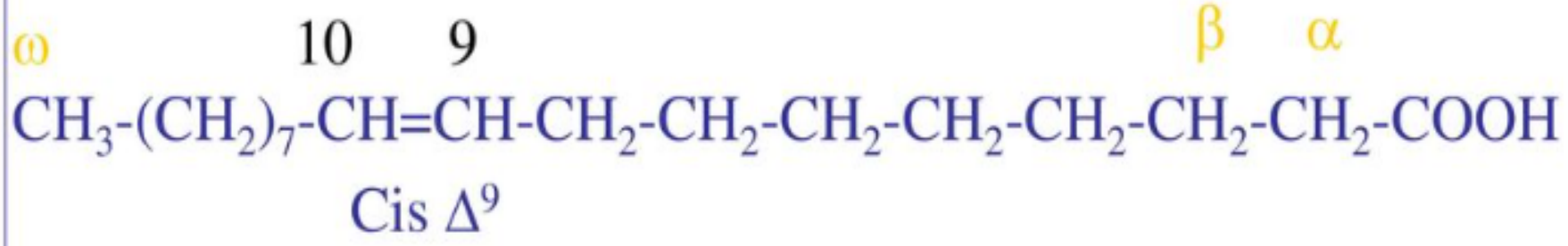
Unsaturated FA: Δ^9, Δ^{12}, Δ^{15} .....

Polyunsaturated FA:

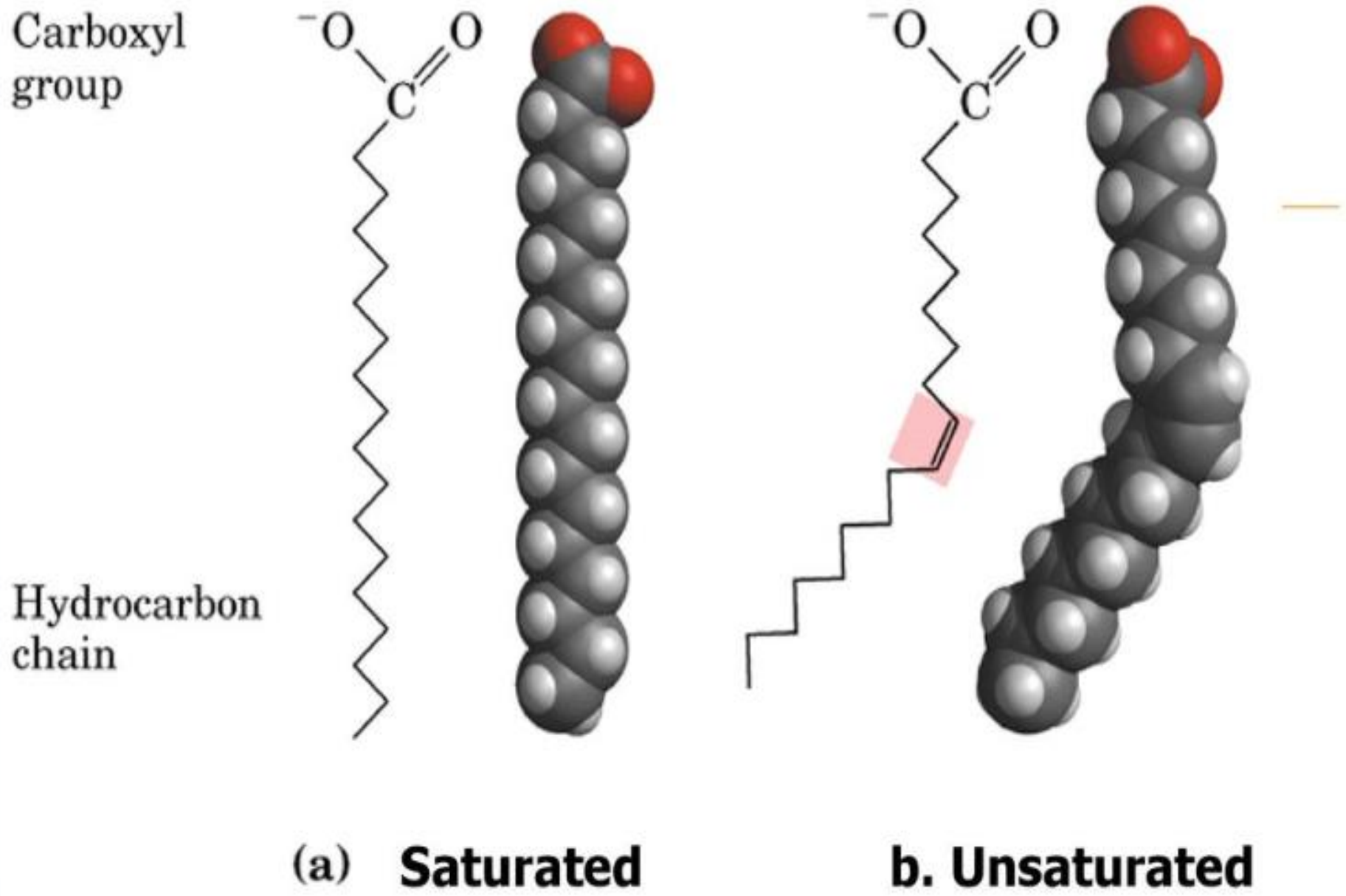
double bonds are never conjugated and are seperated by–CH2 (-CH=CH-CH_2-CH=CH-)n

Naming of fatty acids

C18



18:0, stearic acid :	octadecanoic acid
18:1 (Δ^9), oleic acid :	octadecenoic acid
18:2 ($\Delta^{9,12}$), linoleic acid :	octadecadienoic acid
18:3 ($\Delta^{9,12,15}$), α-linolenic acid :	octadecatrienoic acid


Carboxyl group
Hydrocarbon chain
(a) Saturated
b. Unsaturated

Common Fatty Acids

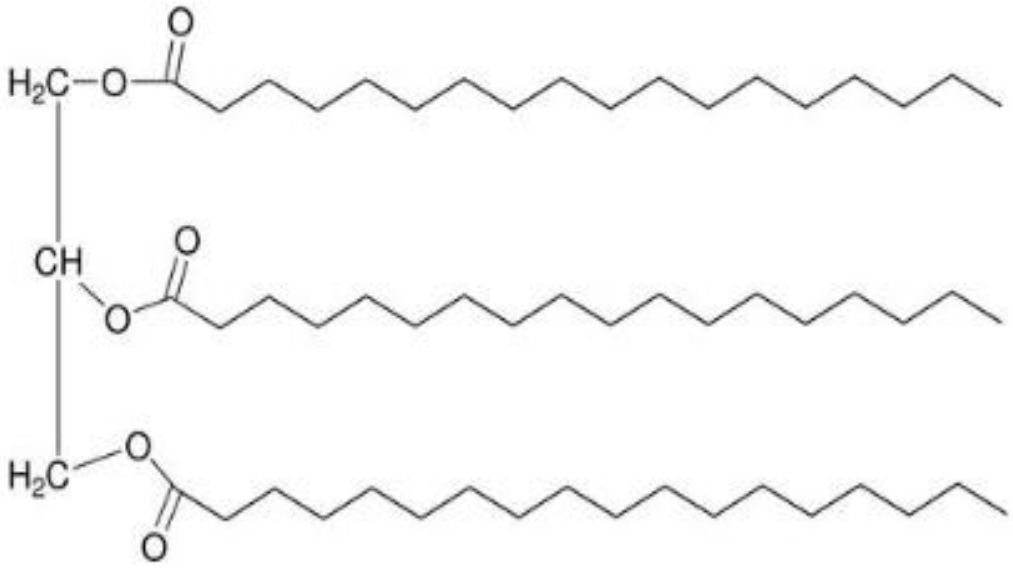
- Saturated fatty acids:
  - Lauric acid 12:0
  - Myristic acid 14:0
  - Palmitic acid 16:0
  - Stearic acid 18:0
- Unsaturated fatty acids:
  - Palmitoleic acid 16:1
  - Oleic acid 18:1
  - Linoleic acid 18:2
  - A-linoleic acid 18:3 (9,12,15)
  - G-linoleic acid 18:3 (6,9,12)

Structural Consequences of Unsaturation

- Saturated chains pack tightly and form more rigid, organized aggregates (i.e., membranes);
- Unsaturated chains bend and pack in a less ordered way, with greater potential for motion.

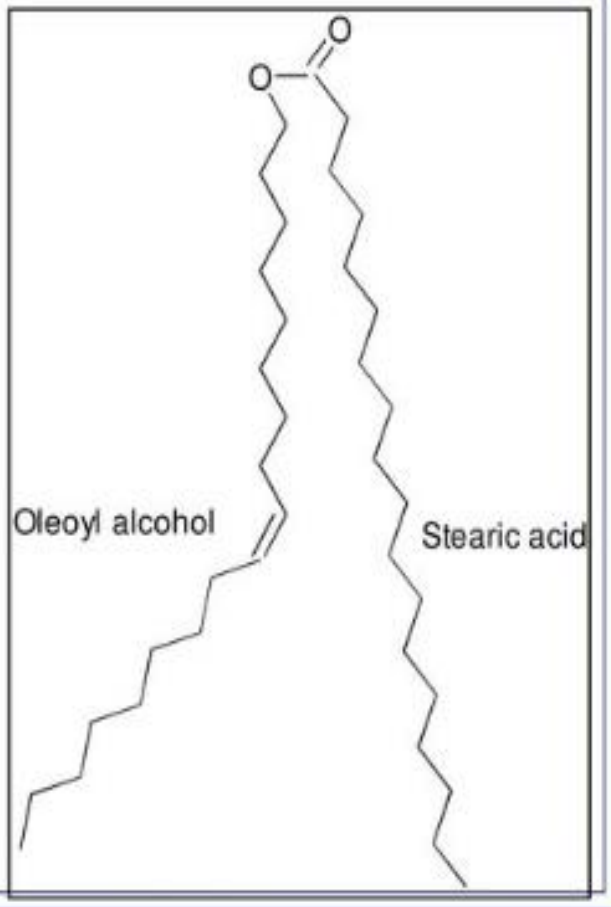
Triglycerols (triglycerides)

- Triglycerols consist of a glycerol esterified with three fatty acids
- If all fatty acid chains are the same, the molecule is called triacylglycerol (e.g., tristearin)



Waxes

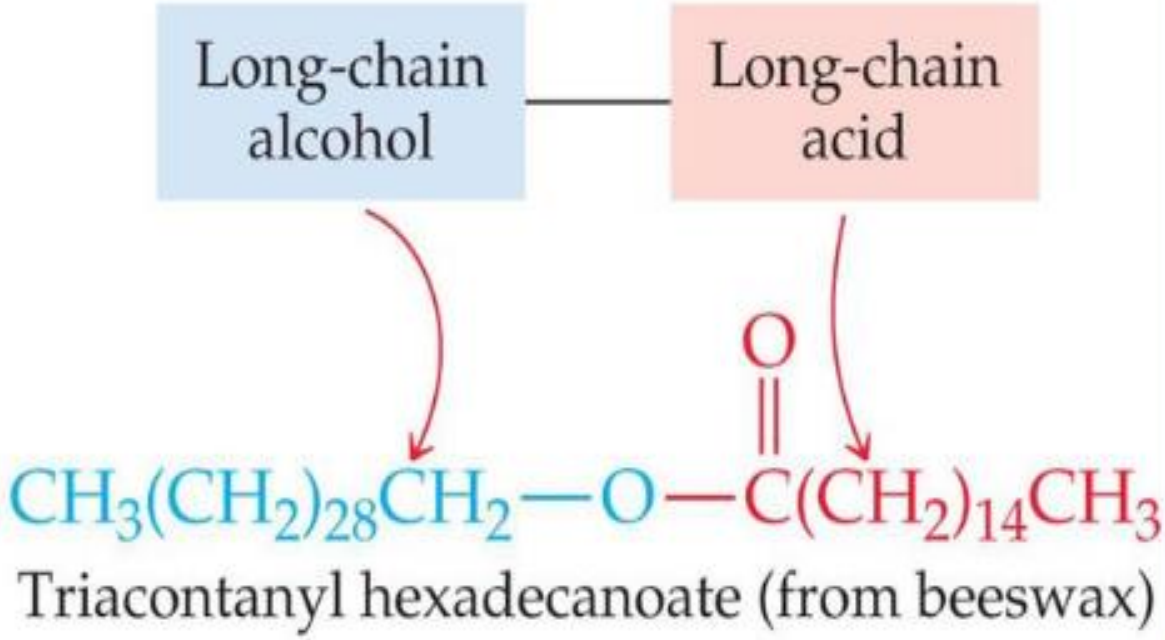
- Esters of long chain fatty acids
  - (C14-36) with long chain
  - (C16-30) alcohols
  - High melting points (60-100°C)
- Energy storage
  (Plankton, 浮游生物)
- Water repellant
  (birds and plants)



- Waxes are the simplest fatty acid esters in nature
- A **wax** is a mixture of fatty acid—long-chain alcohol esters.
- The fatty acids (16 - 36 carbons)

Example of a wax

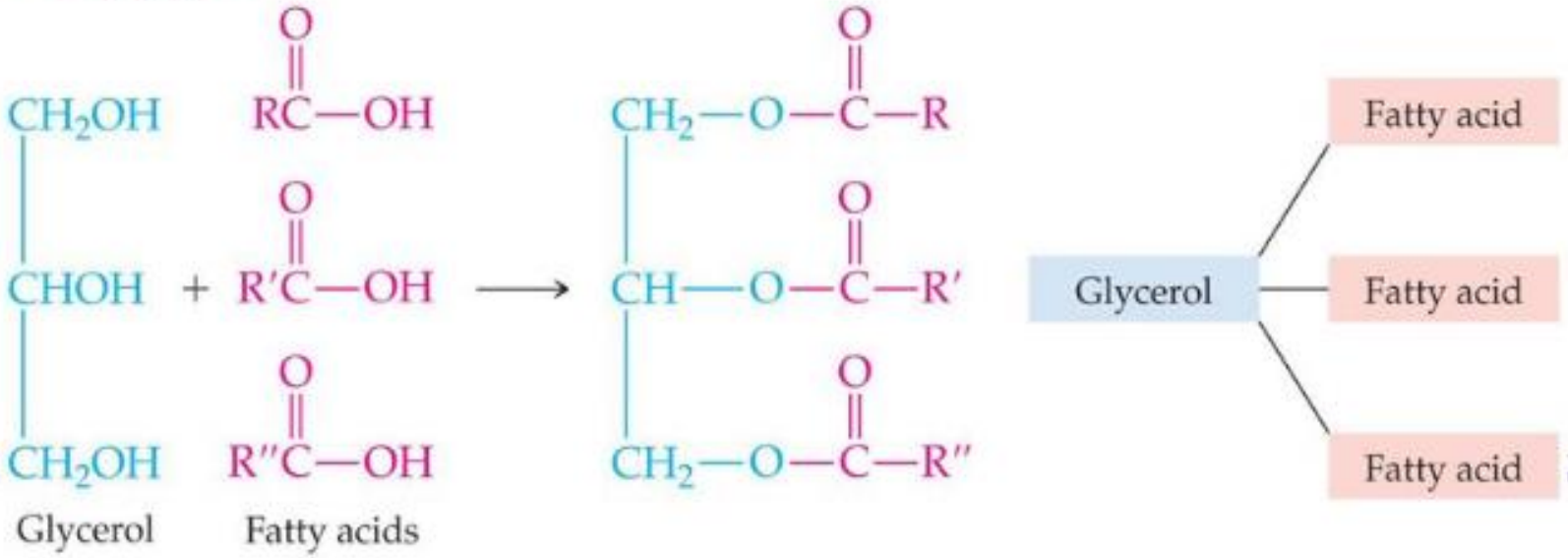
- A component in beeswax is the ester formed from a 30-C alcohol (triacontanol) and a 16-C acid (palmitic acid).



Triglycerides / triacylglycerols

- Animal fats and vegetable oils are the most plentiful lipids in nature.
- Composed of triesters of glycerol / glycerine) with three fatty acids.

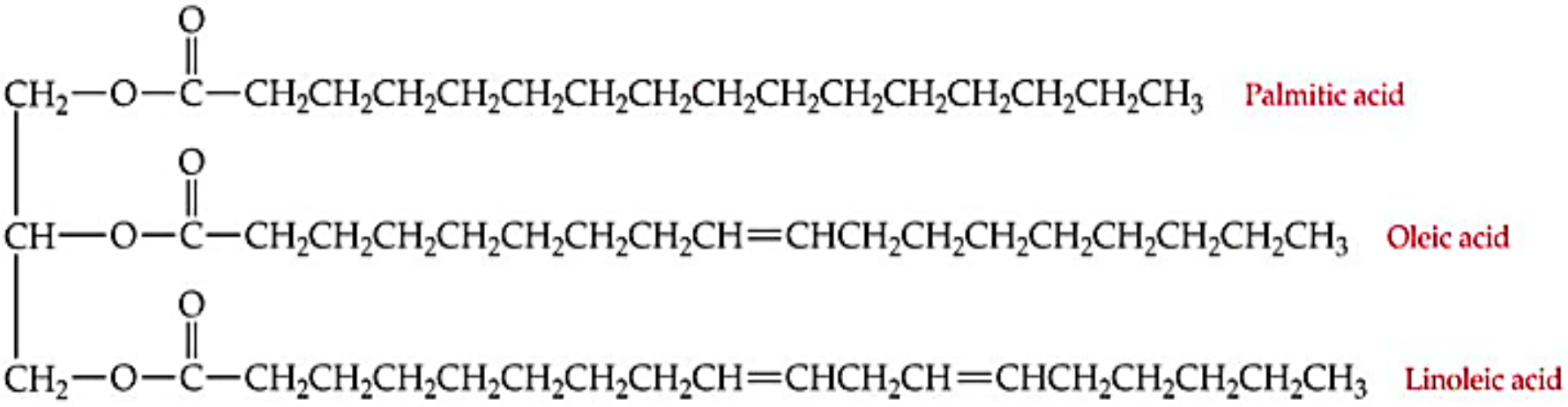
Triacylglycerols



- The three fatty acids of any specific triacylglycerol are not necessarily the same. The fat or oil from a given natural source is a complex mixture of many different triacylglycerols.

- Vegetable oils consist almost entirely of unsaturated fatty acids, whereas animal fats contain a much larger percentage of saturated fatty acids. This difference in composition is the primary reason for the different melting points of fats and oils.

Example of a triacylglycerol



Properties of Fats and Oils

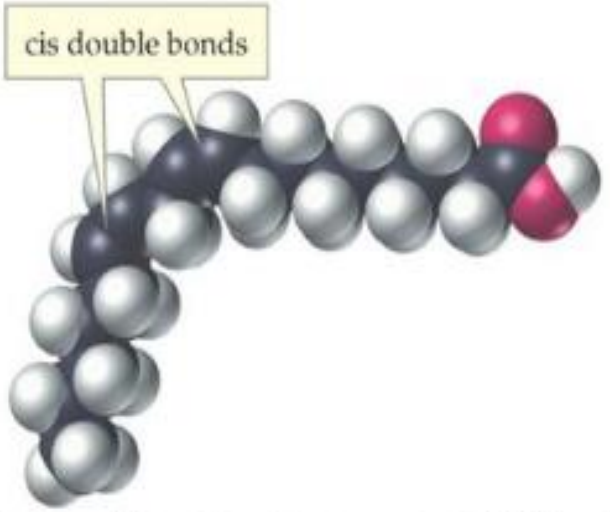
- Triacylglycerols in natural fats and oils are nonpolar, hydrophobic molecules with no ionic charges.
- **Oil:** A mixture of triacylglycerols that is liquid because it contains a high proportion of unsaturated fatty acids.
- **Fat:** A mixture of triacylglycerols that is solid because it contains a high proportion of saturated fatty acids.

The hydrocarbon chains in saturated acids are flexible and uniform in shape, allowing them to nestle together. By contrast, the carbon chains in unsaturated acids have rigid kinks wherever they contain cis double bonds. The kinks make it difficult for such

A saturated fat has only single C-C bonds and appears straight

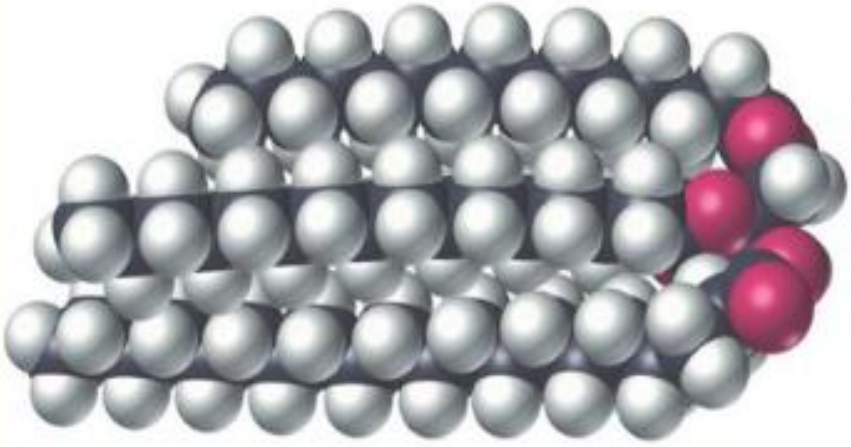
Unsaturated fats bend due to cis double bonds

Stearic acid, an 18-carbon saturated fatty acid



Linoleic acid, an 18-carbon unsaturated fatty acid

The more double bonds there are in a triacylglycerol, the harder it is for it to solidify.



A fat

An oil

Phospholipids

2 Classes of phospholipids (PL)

(i) glycerolphospholipids – glycerol backbone

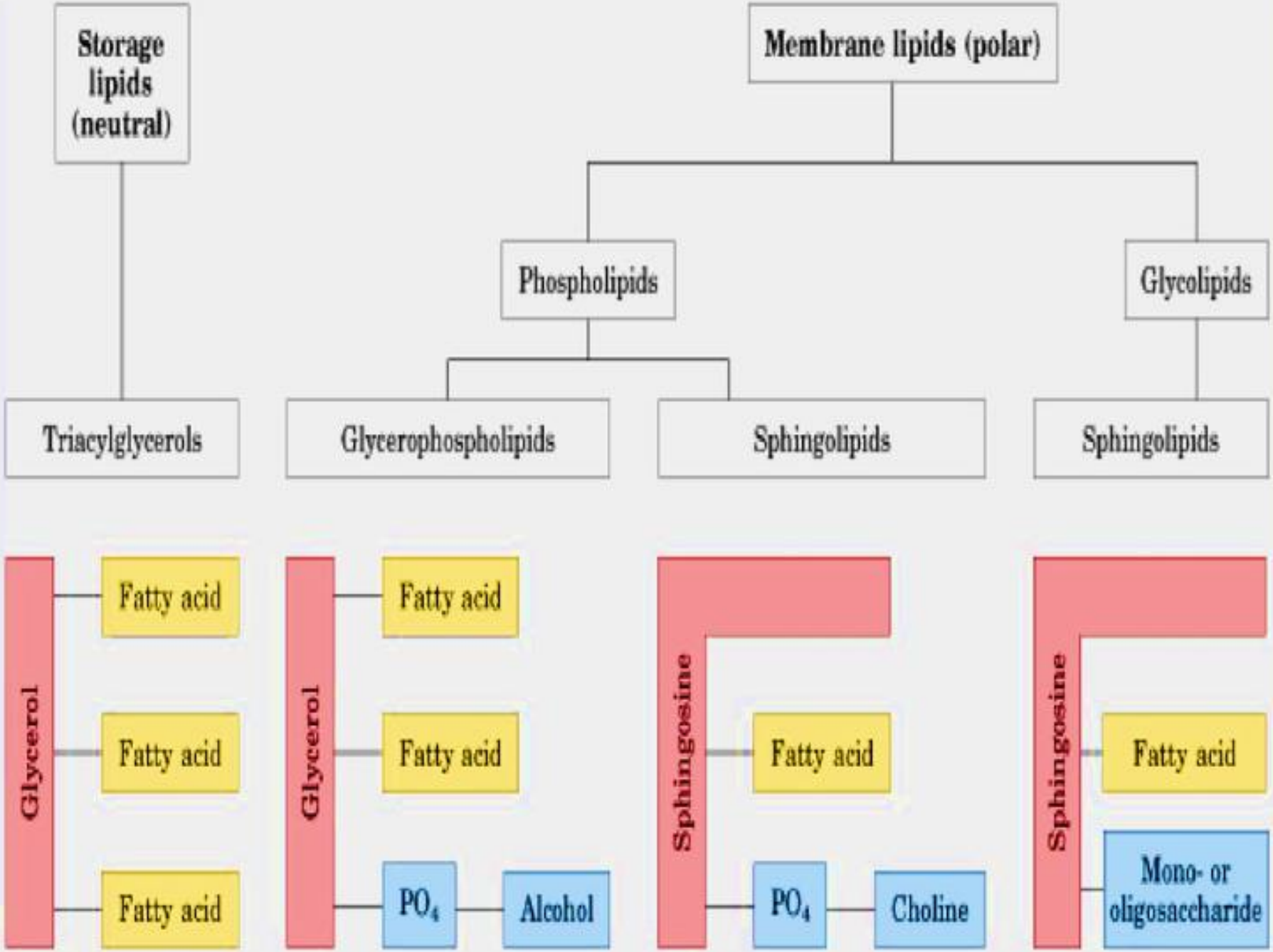
(ii) sphingomyelin – spingosine backbone

Glycerolphospholipids

- essential for membrane structure
- most abundant membrane lipids

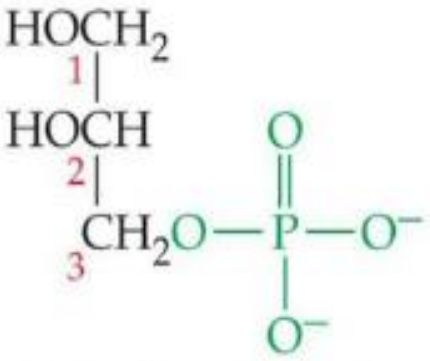
Sphingolipids

- Component of a certain membrane
- Sphingosine, fatty acid and glycoside

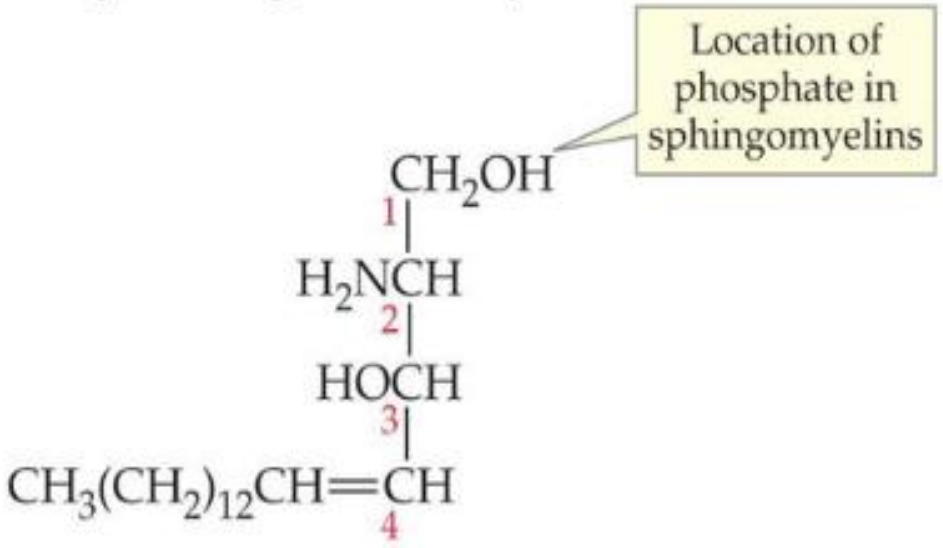

Storage lipids (neutral)
Membrane lipids (polar)
Phospholipids
Glycolipids
Triacylglycerols
Glycerophospholipids
Sphingolipids
Sphingolipids
Glycerol
Fatty acid
Fatty acid
Fatty acid
Glycerol
Fatty acid
Fatty acid
PO4
Alcohol
Sphingosine
Fatty acid
PO4
Choline
Sphingosine
Fatty acid
Mono- or oligosaccharide

Cell Membrane Lipids: Phospholipids and Glycolipids

Phospholipid: A lipid that has an ester link between phosphoric acid and an alcohol (either glycerol or sphingosine).



Glycerol 3-phosphate
(alcohol in glycerophospholipids)

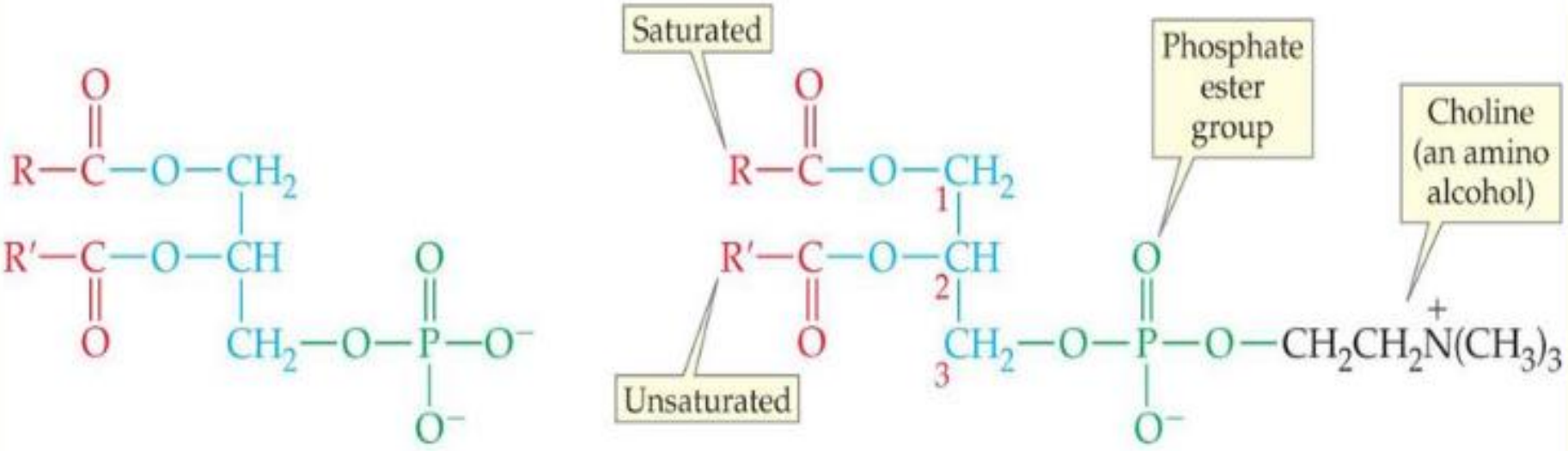


Sphingosine
(alcohol in sphingolipids)

- The **glycolipids** are also derived from sphingosine. They contain no phosphate group, but have an attached carbohydrate that is a monosaccharide or a short chain of monosaccharides.
- The classes of membrane lipids overlap.
- Glycolipids and sphingomyelins both contain sphingosine and are therefore classified as **sphingolipids**,
- Glycerophospholipids and sphingomyelins both contain phosphate groups and are therefore classified as phospholipids.

Glycerophospholipids with a phosphate ester link to the amino alcohol choline are known as **phosphatidylcholines / lecithins**.

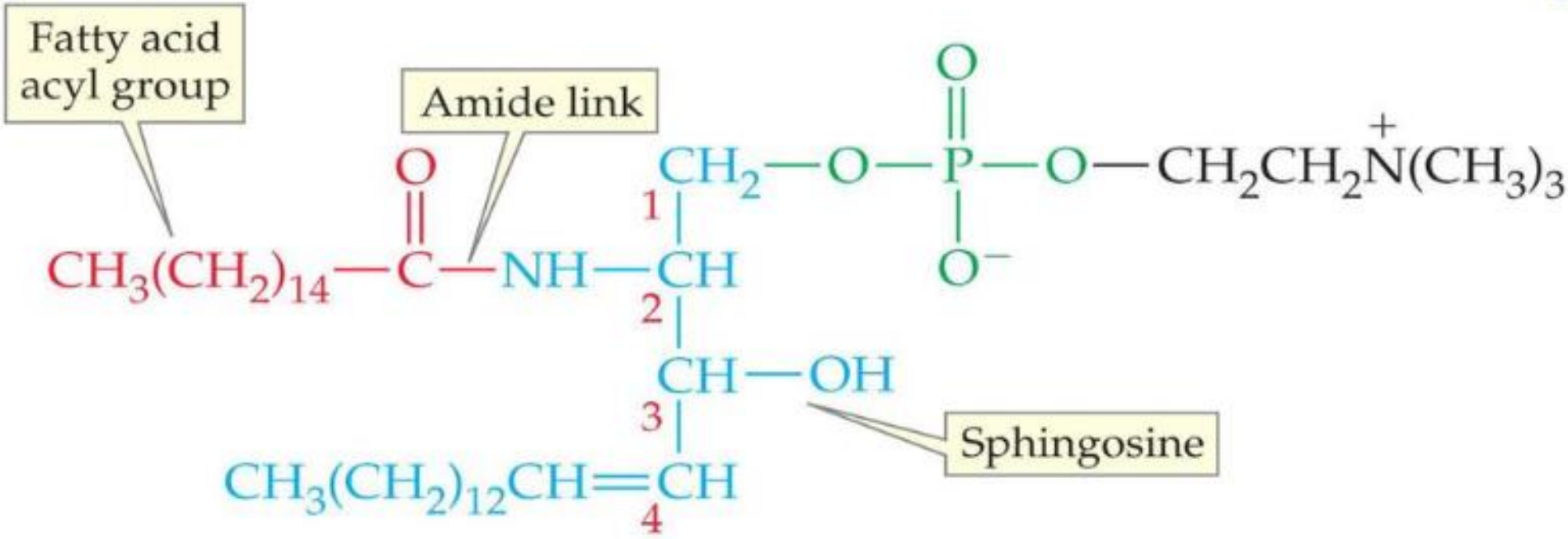
emulsifying agents, substances that surround droplets of nonpolar liquids and hold them in suspension in water.



A phosphatidate

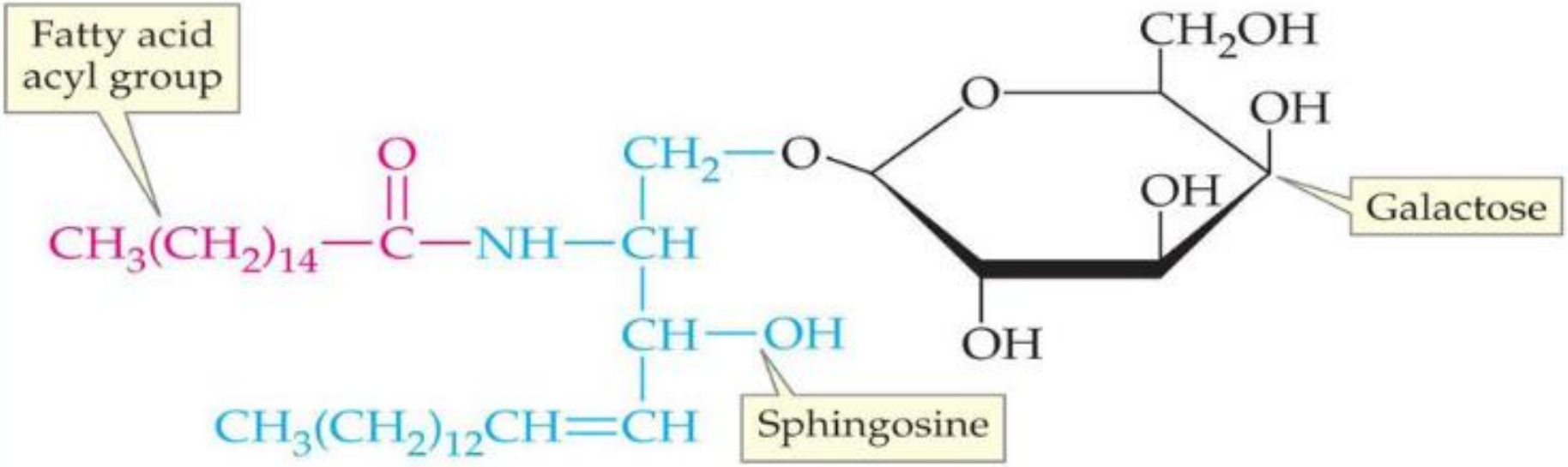
A phosphatidatidylcholine
(a glycerophospholipid that is a lecithin)

Sphingomyelins are sphingosine derivatives with a phosphate ester group at C1 of sphingosine. The sphingomyelins are major components of the coating around nerve fibers (the myelin sheath) and are present in large quantities in brain tissue.



A sphingomyelin (a sphingolipid)

Cerebrosides, glycolipids which contain a monosaccharide, are particularly abundant in nerve cell membranes in the brain, where the sugar is D-galactose. They are also found in other cell membranes, where the sugar unit is D-glucose.



A glycolipid
(A cerebroside)

Thank you