

# Advanced Cell Biology. Lecture 5

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# Outline

## Questions and answers

### Fatty acids and lipids

Storage lipids: oils and fats

Membrane lipids

Signal lipids: sterols and others

Lipid vitamins

### Amino acids

Structure and classification



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## Previous final question: the answer

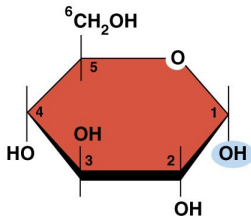
What is the difference between  $\alpha$ - and  $\beta$ - glucose?



## Previous final question: the answer

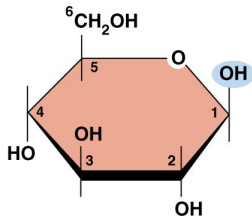
What is the difference between  $\alpha$ - and  $\beta$ - glucose?

$\alpha$  down (axial position),  $\beta$  up (equatorial position)



**$\alpha$ -D-glucose, the repeating unit of starch and glycogen**

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**$\beta$ -D-glucose, the repeating unit of cellulose**



# Fatty acids and lipids

## Storage lipids: oils and fats



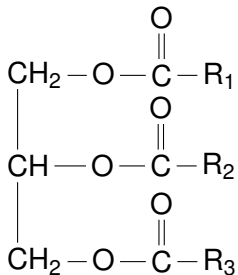
# Storage lipids: oils and fats

- ▶ Fatty acids are massive ( $C > 15$ ) hydrocarbon acids
- ▶ Oils and fats are esters (complex ethers) of glycerol and (often different) fatty acids: **triacylglycerols**, or **triglycerides**
- ▶ Stable, hydrophobic and high-energetic molecules





# Triacylglycerols (triglycerides)

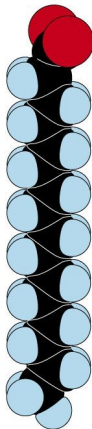
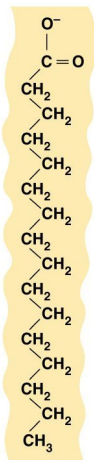


# Diversity of fatty acids

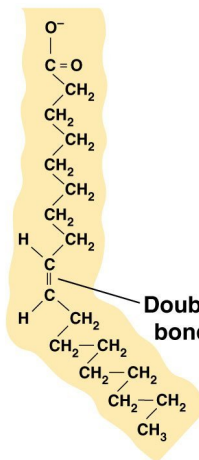
- ▶ **Saturated:** contain only single bonds between carbons
- ▶ **Unsaturated:** contain also double bonds
- ▶ Unsaturated typically have bend chain, and much lower melting temperature
- ▶ Trans fats contain hydrogenated unsaturated oils



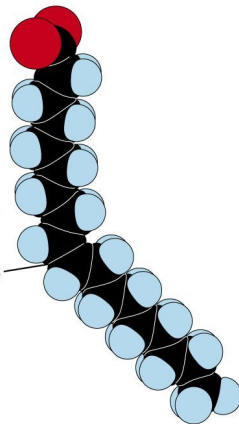
# Saturated and unsaturated fatty acids



**(a) Palmitate (saturated)**



Double bond

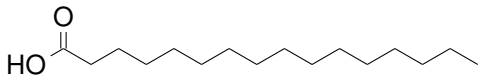


**(b) Oleate (unsaturated)**

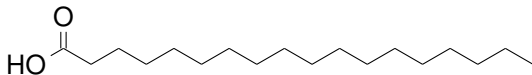


## Examples of fatty acids

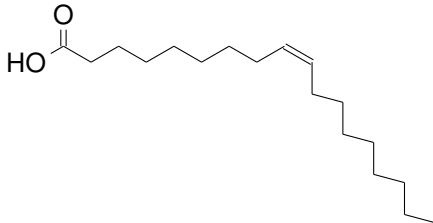
- ▶ *Palmitic acid* (COOH-C<sub>15</sub>): from animal fats



- ▶ *Stearic acid* (COOH-C<sub>17</sub>): from animal fats



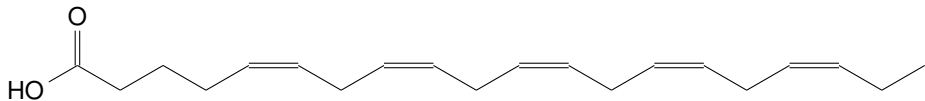
- ▶ *Oleic acid* (COOH-C<sub>9</sub> = C<sub>8</sub>): from olive



- ▶ *Linoleic acid* (COOH-C<sub>8</sub> = C<sub>3</sub> = C<sub>6</sub>): from flax



## EPA, eicosapentaenoic acid (omega-3)



*Omega-3* fatty acids are considered now as important health factors.  
Probably, decrease the human depression

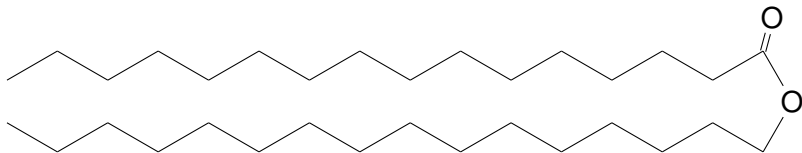


# Waxes

- ▶ Waxes are esters of fatty acids and fatty alcohols (alcohols with long chains)
- ▶ Have high melting temperatures
- ▶ Use as structural and protective molecules, both in animals and plants



# Cetyl palmitate wax



Primary constituent of spermaceti, the wax found in the skull of sperm whales



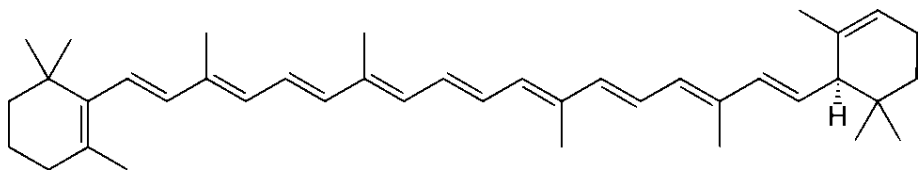
# Plant lipids: isoprenoids

- ▶ Derivatives of isoprene,  $\text{CH}_2=\text{CH}-\text{C}(\text{CH}_3)=\text{CH}_2$
- ▶ Simple polyisoprenoids (*terpenes*) form some aroma compounds
- ▶ Complex polyisoprenoids (*terpenoids*) are carotenes and other plant pigments, and also components of latex





# $\alpha$ -carotene (terpenoid: complex polyisoprenoid)

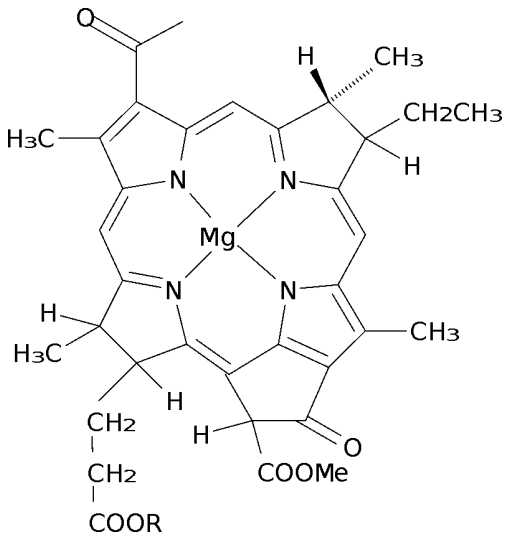


# Porphyrins

- ▶ Occur in plants and animals
- ▶ Easily form complexes with metals and gases
- ▶ *Chlorophyll* and *heme* (red blood pigment) are examples of porphyrins



# Bacteriochlorophyll *a* (porphyrin)



# Fatty acids and lipids

## Membrane lipids



# Membrane lipids

- ▶ Membrane lipids are structural units of membrane double layer
- ▶ Their chemical structure is similar to triacylglyceroles (fats) but one of fatty acids is replaced with other molecule

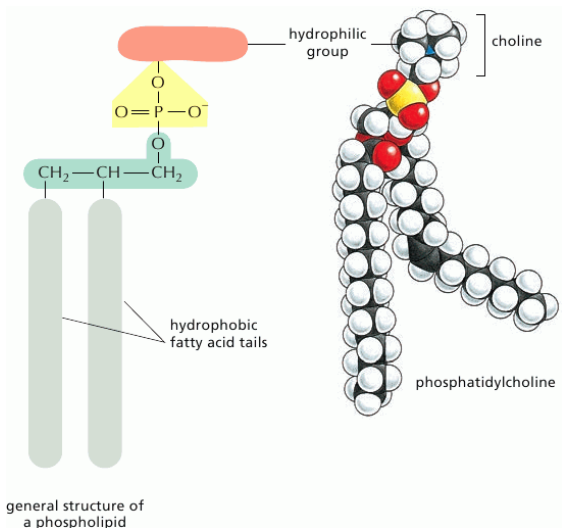


# Phospholipids

- ▶ Phospholipids are esters of glycerol (or sphingoside), fatty acids and phosphorous acid
- ▶ Head + two tails structure
- ▶ Glycerol + phosphate head is hydrophilic whereas fatty acid tail is hydrophobic



# Phospholipids



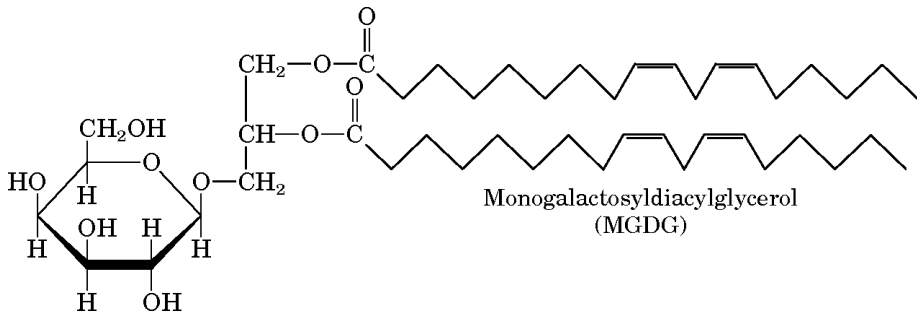
# Glycolipids

- ▶ Glycolipids have two hydrocarbon tails and sugar head
- ▶ Often occur in plant cells, especially in chloroplasts





# Glycolipids

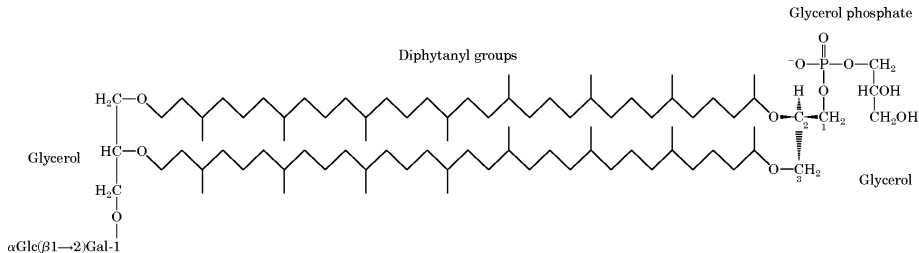


# Archaea membrane lipids

- ▶ Archaea (or archebacteria) have highly specific biochemistry
- ▶ Their membranes contain glycerol dialkyl glycerol tetraethers (GDGTs) which are double esters (have glycerol from both ends) and span the whole membrane
- ▶ These membranes are much more stable to high temperatures and low pH



# Glycerol dialkyl glycerol tetraethers (GDGTs)

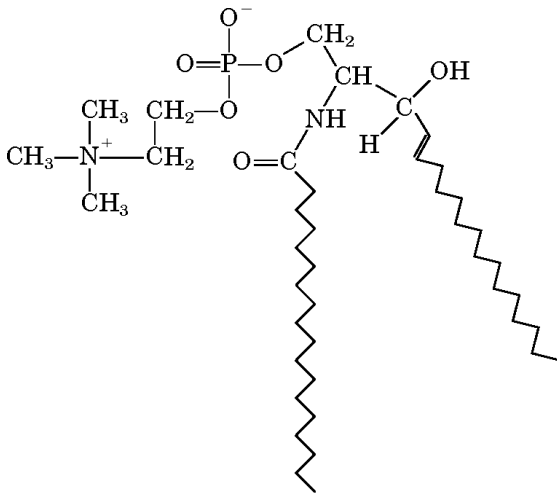


# Sphingolipids

- ▶ Sphingolipids are composed of one *sphingosine* (long chain amino-alcohol), one polar head and one fatty acid
- ▶ Again, head + two tails structure
- ▶ Sphingolipids in the membrane are important sites of biological recognition; nervous cells are especially rich of sphingolipids



# Sphingomyelin



Sphingomyelin

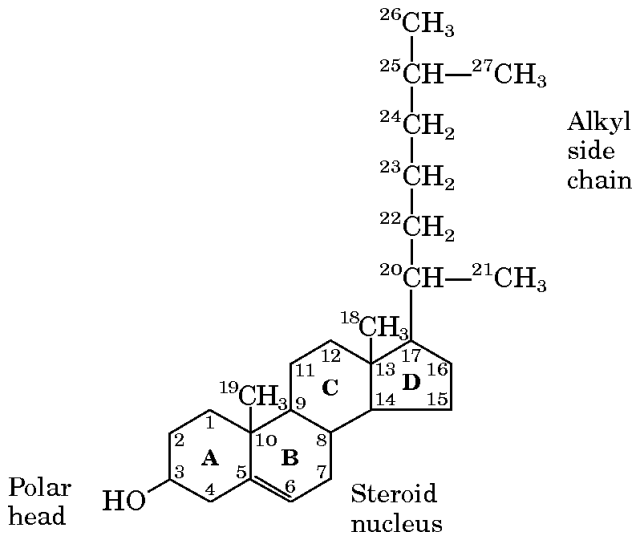


# Cholesterol

- ▶ Cholesterol is a *sterol*: molecule with four fused carbon rings
- ▶ One of main components of membrane, and also precursor to steroid hormones and other molecules
- ▶ Coronary disease is directly connected with cholesterol metabolism



# Cholesterol



# Fatty acids and lipids

## Signal lipids: sterols and others



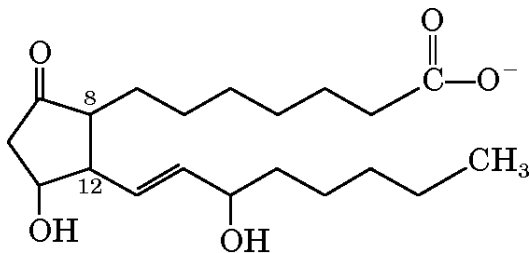


# Eicosanoids: derivatives of fatty acids

- ▶ *Eicosanoids* are hormones—biochemical signals
- ▶ They are structurally similar to membrane lipids
- ▶ Some of them, e.g., *prostaglandins*, play important physiological roles



# Prostaglandin, one of eicosanoids



Prostaglandin E<sub>1</sub>  
(PGE<sub>1</sub>)

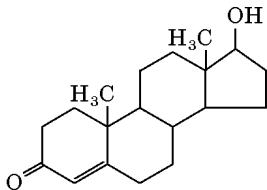


# Steroids

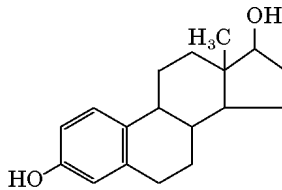
- ▶ *Steroids* are derivatives of *sterols* (mostly cholesterol)
- ▶ Occur both in plants and animals
- ▶ Have high specificity to receptors and therefore are produced in small quantities
- ▶ In vertebrates, play a role of sex hormones



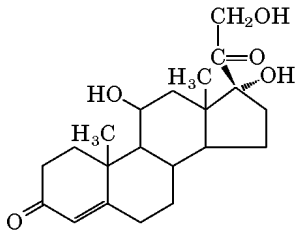
# Steroids



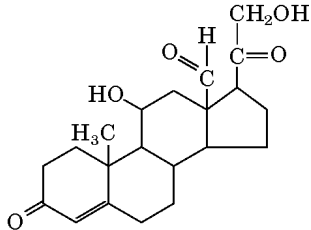
Testosterone



Estradiol



Cortisol



Aldosterone



# Fatty acids and lipids

## Lipid vitamins

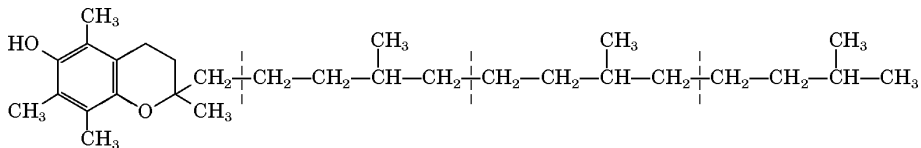


# Lipid vitamins

- ▶ Vitamin **D** (close to sterols) transforms into hormone regulating calcium uptake
- ▶ Vitamin **A** (retinol) transforms into retinal which is a main light response pigment of eye
- ▶ Vitamin **E** (tokoferol) assists in numerous biosynthetic processes



# Vitamin E, tokoferol



# Amino acids

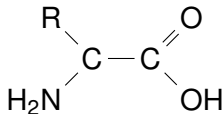
## Structure and classification





# Structure

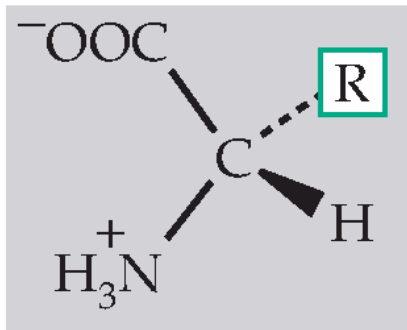
- ▶ Typical formula is  $\text{H}_2\text{NCHR}\text{COOH}$  where R is organic radical:



- ▶ Amino group is normally attached to the first carbon in the chain:  
*α*-aminoacids



# Amino acid

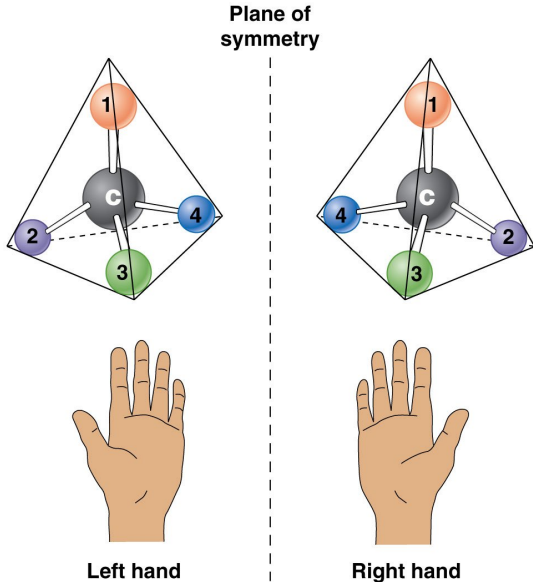


# Isomerism

- ▶  $\alpha$ -carbon is an asymmetric atom
- ▶ Therefore, two optical isomers are possible
- ▶ However, in nature only L-isomers occur



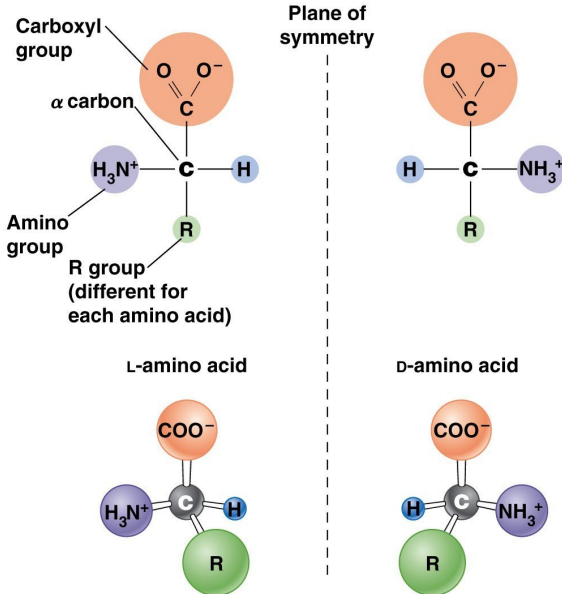
# 3D isomers



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# L- and D- isomers

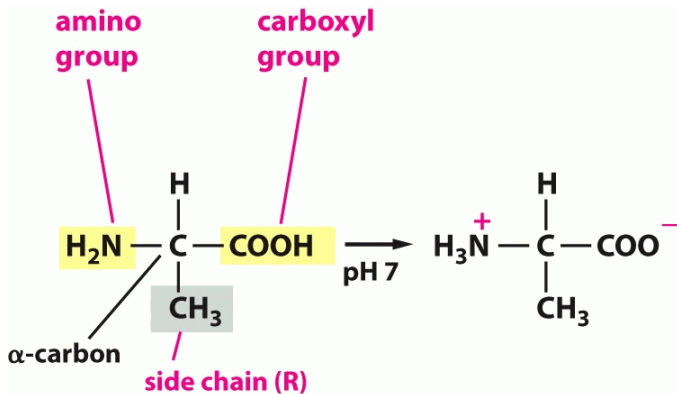


# Zwitterions

- ▶ If radical is neutral, amino acid could behave as both acid and base
- ▶ Many amino acids are present in water solution as **zwitterions**: polar structures similar to both acids and bases



# Zwitterion



## Diversity: 20 standard and 2 additional

- ▶ Standard amino acids are structural units of proteins; they are encoded via DNA triplets
- ▶ There are exactly 20 standard amino acids
- ▶ In addition, there are two amino acids (selenocysteine and pyrrolysine) which may be coded in deviated genetic codes of some organisms





# Essential and non-essential

- ▶ Essential amino acids could not be synthesized in human body
- ▶ Non-essential amino acids are derivatives of essential
- ▶ In all, there are eight essential amino acids:
  1. Isoleucine
  2. Leucine
  3. Lysine
  4. Methionine
  5. Phenylalanine
  6. Threonine
  7. Tryptophan
  8. Valine



# Final question (2 points)



## Final question (2 points)

Which role in the cell lipids do NOT play?



# Summary

- ▶ Lipids are extremely diverse; the only character uniting them is their hydrophobic behavior
- ▶ Lipids are extremely diverse; the only character uniting them is their hydrophobic behavior
- ▶ There are 20 (+2) standard amino acids classifying in 9 groups



# For Further Reading



## A. Shipunov.

*Advanced Cell Biology* [Electronic resource].

2011—onwards.

Mode of access:

[http://ashipunov.info/shipunov/school/biol\\_250](http://ashipunov.info/shipunov/school/biol_250)



## B. Alberts et al.

*Essential Cell Biology*. 3rd edition.

Garland Science, 2009.

*Chapter 2*: : Molecules in cells, Panels 2–5.

