

Chapter 11 - Lipids

Hydrocarbon derivatives

Defining feature = insolubility in water

Functions

- Energy storage
- Biological membranes
- Coenzymes
- Electron carriers
- Light-absorbing pigments
- Emulsifiers
- Hormones
- Intracellular messengers

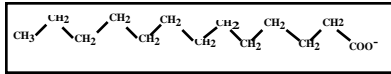
1

Storage lipids

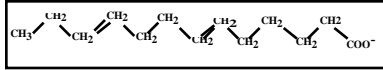
- Fatty acids
- Triacylglycerol
- Waxes
- Fatty acids
 - Hydrocarbons - lack multiple hydroxyl groups of carbs
 - Similar in oxidation state to fossil fuels
 - Oxidation to CO₂ and H₂O highly exergonic

2

Structure and nomenclature



4-36 carbons long



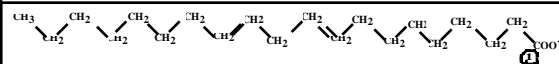
Double bonds = "unsaturated"

16:0 Saturated (palmitic acid)

18:1 Unsaturated (oleic acid)

3

Double bond positions



20:2 ($\Delta^{9,12}$)

Most common fatty acids (FA's) have even numbers of C's in unbranched chains of 12-24 carbons

4

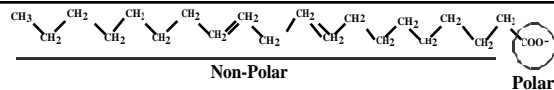
Physical Properties of fatty acids

- Size
- Solubility
- Melting point

Largely determined by length and degree of

Unsaturation

- Solubility



5

Melting points

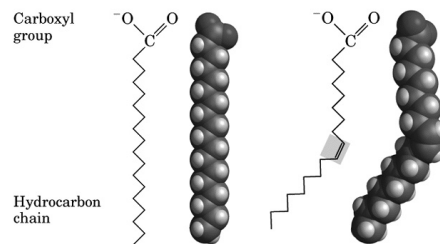
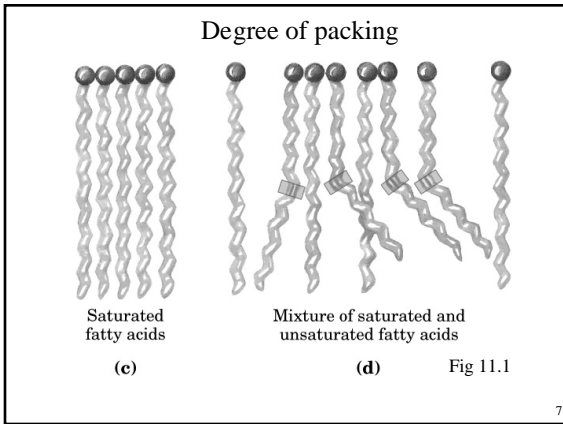


Fig 11.1 (a)

(b)

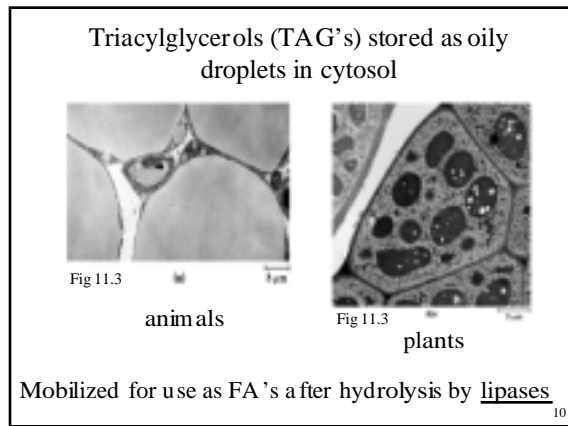
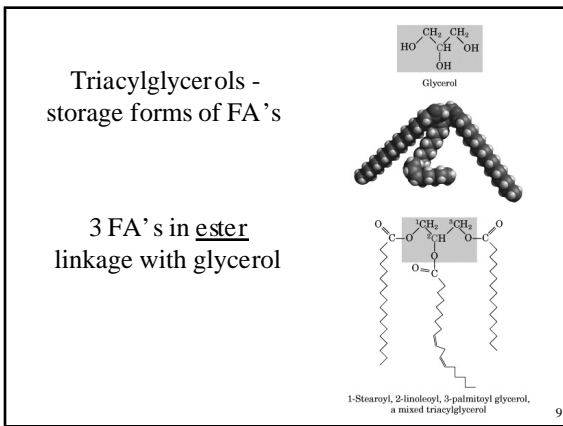
Length & degree of unsaturation

6

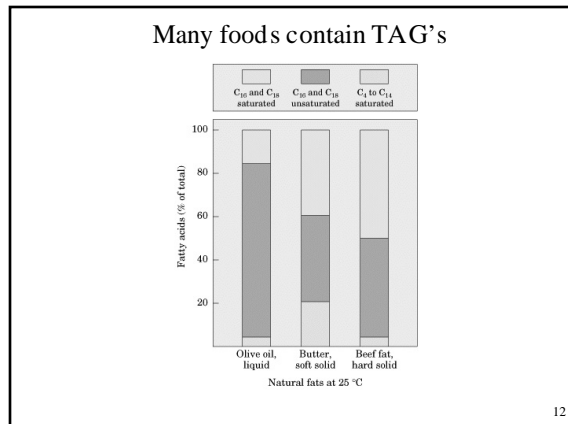


Characteristics of common fatty acids

Carbon Skeleton	Common name	Melting Point	Solubility Water (mg/g)	Solubility Benzene (mg/g)
12:00	Lauric acid	44.2 C	0.063	2600
16:00	Palmitic acid	63.1	0.0083	874
20:00	Arachidic acid	76.5		
18:01	Oleic acid	13.4		
18:03	Linoleic acid	-11		



- Advantages of TAG's vs. polysaccharides
- FA's more reduced
 - 2X more energy released per gram
 - TAG's hydrophobic
 - Reduces extra weight of water associated with carb's
 - TAG's can serve as biological insulation
 - Thick layers under skin and in body cavity



Waxes
esters of long chain FA's & long chain alcohols

$$\text{CH}_3(\text{CH}_2)_{14}\text{C}(=\text{O})\text{OCH}_2(\text{CH}_2)_{28}\text{CH}_3$$

Palmitic acid 1-Triacontanol

(a)

Water repellent
Energy stores

13

Lipid functions - Structural

Membrane Lipids:

- Glycerophospholipids
- Sphingolipids
- sterols

14

Comparative structures

Glycerol or sphingosine backbone
Membrane lipids have polar head groups

15

Membrane lipids - Glycerophospholipids

Fig 11.8

16

g to

Name of phospholipid	Name of R	Name of S	Net charge at pH 7
Phosphatidic acid	—	—OH	-1
Phosphatidylcholine	Choline	—CH ₂ —CH ₂ —N(CH ₃) ₃ ⁺	0
Phosphatidylethanolamine	Ethanolamine	—CH ₂ —CH ₂ —NH ₂	0
Phosphatidylserine	Serine	—CH ₂ —CH ₂ —NH ₂ ⁺ and —COO ⁻	-1
Phosphatidylinositol	Inositol	—CH ₂ —CH ₂ —OH	-1
Phosphatidylcholine & Phosphatidylethanolamine	non-saturated C18 hydrocarbon	—CH ₂ —CH ₂ —N(CH ₃) ₃ ⁺ and —CH ₂ —CH ₂ —OH	-1
Cardiolipin	Phosphatidylcholine	—CH ₂ —CH ₂ —N(CH ₃) ₃ ⁺	-1

17

Ether-linked Phospholipids

Specific biological roles

18

Membrane lipids - Sphingolipids



Fig 11.10

Ceramide

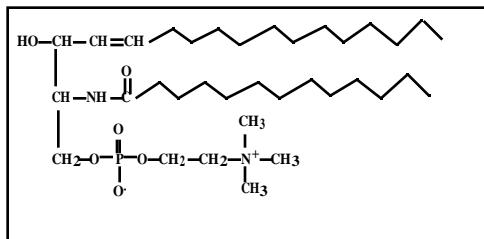
19

Name of sphingolipid	Name of R	Formula of R
Ceramide	-	-H
Sphingomyelin	Phosphocholine	$-\text{O}-\text{CH}_2-\text{CH}_2-\text{N}^+(\text{CH}_3)_3$
Neutral glycolipids (Sphingolipids)	Glucose	
Lactosylceramide (a glycolipid)	Di-, tri-, or tetrasaccharide	
Ganglioside (GM)	Complex oligosaccharide	

Sphingomyelins, Neutral glycolipids & gangliosides

20

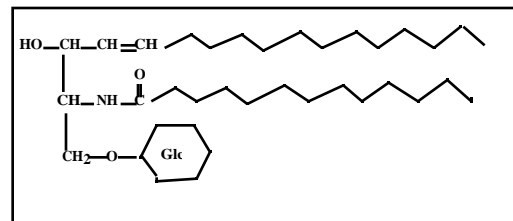
Sphingomyelin



- Phosphocholine or phosphoethanolamine head group
- No net charge on head group

21

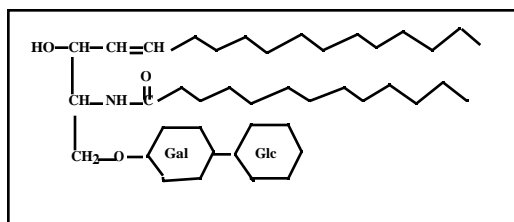
Glycosphingolipids - Cerebrosides



- Single Glucose or Galactose head group
- Uncharged, polar

22

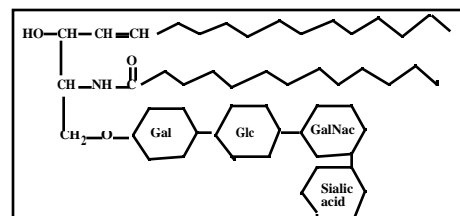
Glycosphingolipids - Globosides



- 2 or more sugars in head group
- Glc, Gal or GalNac
- Polar, uncharged

23

Gangliosides



- Oligosaccharide head group
- 1 or more Sialic acid residues (charged)
 - GM = 1 sialic acid residue
 - GD = 2 sialic acid residues, etc
- Polar, charged

24

Biological functions of Sphingolipids

Ceramide
 Sphingosine
 Fatty acid
 Gal
 GalNAc
 Fuc
 O Antigen
 A Antigen
 B Antigen

- Myelin sheath (neurons)
- Blood groups (O, A, etc.)
- Embryonic, tumor development

25

Phospholipid & Sphingolipid degradation

Phospholipase A₁
 Phospholipase A₂
 Phospholipase C
 Phospholipase D

Specific lipases remove FA's at particular positions (C1, C2, C3) in lysosome

26

Sterols

Polar head (OH)
 Steroid nucleus
 Alkyl side chains

- Structural lipids - present in most membranes
- Promote fluidity
- Nonpolar hydrocarbon tail
- Polar head group (-OH)

27

Lipids as Signals, Coenzymes & Pigments

- Phosphatidylinositol
- Eicosanoids
- Steroid hormones
- Vitamins (A, D, E, K)
- Dolichols
- Ubiquinone
- etc

28

Phosphatidylinositol - Intracellular messenger

IP3
 DAG

- Hydrolysis releases inositol 1,4,5 triphosphate (IP3)
- IP3 causes release of intracellular Ca²⁺
- Ca²⁺ and diacylglycerol stimulate protein kinase C

29

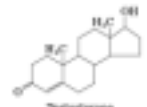
Eicosanoids

Arachidonic acid
 NSAIDs
 Prostaglandin E₁ (PGE₁)
 Thromboxane A₂
 Leukotriene A₄
 Eicosanoids (b)

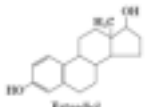
- Paracrine hormones - act on cells near synthesis
- Derived from arachidonic acid
- Inflammation, fever, pain, blood pressure
- Synthesis inhibited by NSAIDs (Aspirin, tylenol, ibuprofen)

30

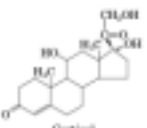
Steroid Hormones



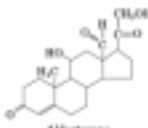
Testosterone



Estradiol



Cortisol




Aldosterone

- Oxidized at C-17
- Travel in blood bound to carrier proteins
- Major target is nucleus
- Major target is nucleus

31

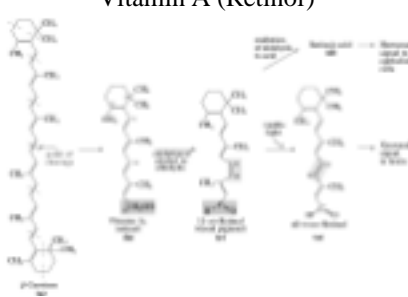
Vitamin D (Cholecalciferol)



- Cholesterol derivative
- UV light-induced transformation and chemical modification in liver & kidneys
- Regulates Ca^{2+} metabolism in bone, kidneys & intestine

32

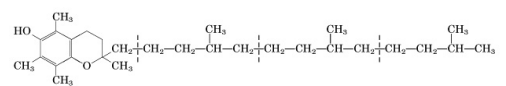
Vitamin A (Retinol)



- Visual pigment of vertebrate eye
- Hormone - regulates gene expression in epithelia
- Consumed in diet as β -carotene or from liver, eggs

33

Vitamin E (tocopherols)

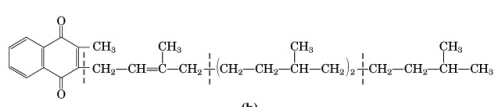


(a)
Vitamin E: an antioxidant

- Biological antioxidants
- Substituted aromatic ring w/ isoprenoid side chain
- Protect membranes from damage which could cause cell fragility
- Found in eggs, vegetable oils, wheat germ

34

Vitamin K (Phylloquinone)




(b)
Vitamin K₁: a blood-clotting cofactor (phylloquinone)

- Similar in structure to Vitamin E
- Important for blood clot formation
- Found in green plant leaves

35

Other biologically important lipid derivatives



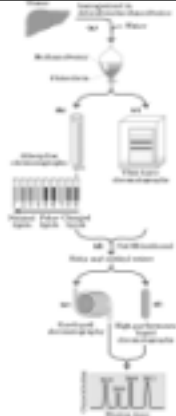
- Warfarin - blood clotting
- Ubiquinone/plastiquinone - mitochondrial e^- carrier
- Dolichols - activation of sugars for transfer

36

Lipid analysis

Separation on basis of solubility and polarity

- Extraction in polar solvents
 - solubility
- Chromatography
 - Differences in polarity
 - Gas-liquid chromatography
 - volatility



37

Summary

- Lipids
 - Water-insoluble cellular compounds
 - Membrane structural components
 - Energy storage
 - Coenzymes, hormones, signals, etc.
- Simplest lipids = fatty acids
 - Long-chain carboxylic acids (usually 12-24 carbons)
 - Highly reduced
 - Saturated or unsaturated
 - Double bonds in cis configuration

38

- Triacylglycerols
 - 3 FA's esterified to the 3 hydroxyl (-OH) groups of glycerol
 - Simple or mixed FA's
 - Primarily serve as storage fats
- Structural Lipids
 - Polar heads & nonpolar tails
 - Major components of membranes
 - Glycerophospholipids
 - Sphingolipids
 - Sterols

39

- Biologically active lipids
 - Phosphatidylinositol - intracellular messenger
 - Prostaglandins, thromboxanes & leukotrienes
 - Inflammation, blood clotting, immune response
 - Steroid hormones
 - Vitamins A,D,E,K - functions
 - Ubiquinone & plastoquinone - e⁻ carriers
 - Dolichols - sugar transfer
- Lipid Analysis
 - Solubility (extraction, Gas Chromatography)
 - Polarity (Chromatography)

40