Lecture 13
Discipline: Bioorganic Chemistry
Lecturer: Associate Professor, Dr. Gulnaz Seitimova

Title: Phospholipids. Their classification, structure, chemical properties. Physiological role. Unsaponifiable lipids (terpenes, steroids). Their classification, structure, chemical properties. Physiological role.

Objective: To provide a detailed understanding of phospholipids and unsaponifiable lipids, including their classification, structure, chemical behavior, and essential physiological roles, as well as their significance in biological membranes, signaling pathways, and metabolic processes.

Main Questions: General characteristics and classification of phospholipids. Structural features of phospholipids. Chemical properties and reactivity of phospholipids. Physiological role of phospholipids in the cell. Classification and structure of unsaponifiable lipids: terpenes and steroids. Biosynthetic origin and chemical properties of terpenes and steroids. Biological and physiological functions of terpenes and steroids.

Key Notes and Theses

Introduction to Complex Lipids

Lipids are hydrophobic or amphipathic biomolecules essential for membrane structure, energy storage, and cellular signaling. Among them, **phospholipids** represent key structural components of biological membranes, while **unsaponifiable lipids** such as terpenes and steroids perform vital regulatory, structural, and metabolic functions. Understanding their chemistry is crucial for studying membrane biology, endocrinology, and bioenergetics.

Part I – Phospholipids

Classification of Phospholipids

Phospholipids are saponifiable lipids containing **phosphoric acid residues**, nitrogen-containing bases, and fatty acids. They possess amphiphilic nature with a hydrophilic "head" and hydrophobic "tails."

I. Glycerophospholipids

Derived from glycerol-3-phosphate.

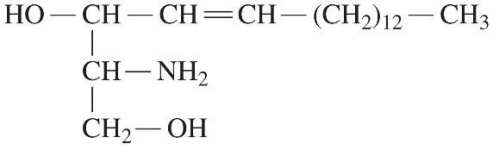
Main representatives:

1. Phosphatidylcholines (lecithins)
2. Phosphatidylethanolamines (cephalins)
3. Phosphatidylserines
4. Phosphatidylinositols
5. Cardiolipins (diphosphatidylglycerol)

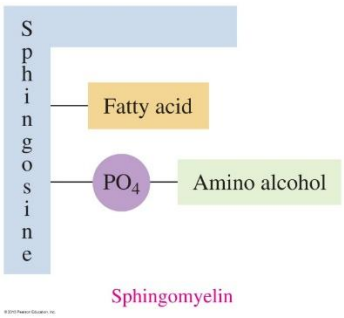
II. Sphingophospholipids

Based on sphingosine instead of glycerol.

1. Sphingomyelin — major membrane phospholipid of myelin sheath.



Sphingosine



Sphingomyelin

Structure of Phospholipids

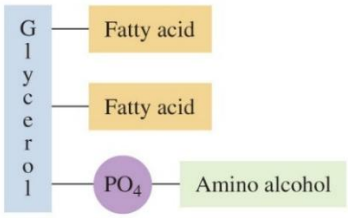
Basic structural features

- Alcohol backbone (glycerol or sphingosine)
- Two hydrophobic fatty acid chains
- A phosphate group
- A nitrogenous base (choline, ethanolamine, serine) or inositol

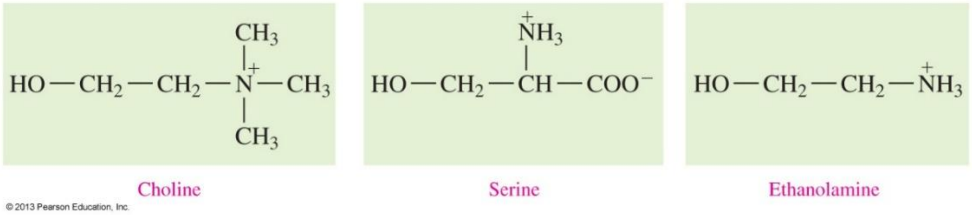
Amphipathic character

- Hydrophilic polar head
- Hydrophobic nonpolar tails

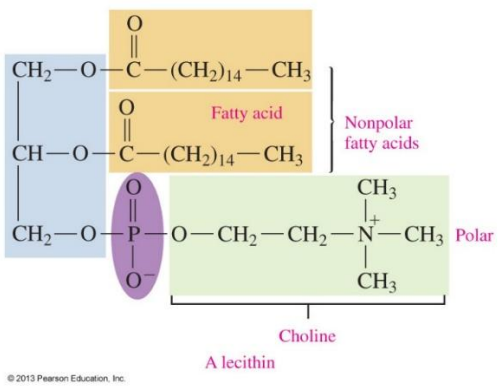
This duality determines their ability to form bilayers, micelles, and liposomes.



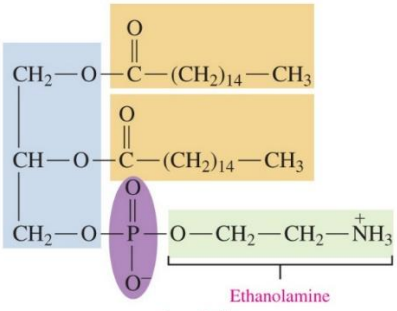
Glycerophospholipid



Choline Serine Ethanolamine



A lecithin



A cephalin

Chemical Properties of Phospholipids

1. Hydrolysis
   - Acidic → cleavage of ester bonds
   - Enzymatic → phospholipases A_1, A_2, C, D
2. Oxidation
   - Unsaturated fatty acids prone to lipid peroxidation
3. Formation of liposomes
   - Due to their amphiphilic structure
4. Interaction with proteins
   - Formation of membrane–protein complexes

Physiological Role of Phospholipids

1. Structural function
   - Main components of biological membranes
2. Barrier and transport
   - Regulation of membrane fluidity and permeability
3. Signal transduction
   - Phosphatidylinositol derivatives act in intracellular signaling
4. Lipid mediators
   - Arachidonic acid (from phospholipids) → eicosanoids
5. Surfactant function
   - Lung surfactant contains dipalmitoyl phosphatidylcholine
6. Lipoproteins
   - Phospholipids stabilize lipid transport particles

Part II – Unsaponifiable lipids: terpenes and steroids

Unsaponifiable lipids do not contain ester bonds and cannot be hydrolyzed by alkaline solutions. Their structural basis is **isoprene (C_5H_8) units** or **cyclopentanoperhydrophenanthrene nucleus**.

Terpenes

Classification of Terpenes

Based on the number of isoprene units:

- Monoterpenes (C_{10}) – menthol, limonene
- Sesquiterpenes (C_{15}) – farnesol
- Diterpenes (C_{20}) – phytol, vitamin A
- Triterpenes (C_{30}) – squalene
- Tetraterpenes (C_{40}) – carotenoids
- Polyterpenes – natural rubber

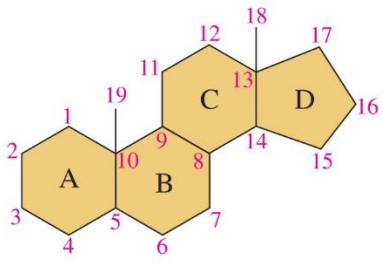
Structure

- Built from linked isoprene (C_5) units
- Linear or cyclic
- Often contain double bonds, oxygenated groups (–OH, =O)

Chemical Properties
1. Easily oxidized
2. Undergo polymerization
3. Form esters
4. Participate in cyclization reactions

Physiological Role
- Components of essential oils
- Precursors of vitamins (A, E, K)
- Photosynthetic pigments (carotenoids)
- Plant defense molecules
- Anti-inflammatory and antimicrobial activity

Steroids
Classification
Main steroid categories:
1. Sterols – cholesterol
2. Steroid hormones
   - Glucocorticoids
   - Mineralocorticoids
   - Sex hormones (estrogens, androgens, progesterone)
3. Bile acids
4. Cardiac glycosides
5. Vitamin D derivatives



Steroid numbering system

Structure
All steroids contain a cyclopentanoperhydrophenanthrene core:
- Three fused six-membered rings (A, B, C)
- One five-membered ring (D)

Chemical Properties
1. Oxidation/reduction of hydroxyl or keto groups
2. Esterification
3. Isomerization of rings or side chains
4. Formation of conjugates with fatty acids or sulfuric acid

Physiological Role of Steroids

- Cholesterol: membrane stabilizer, precursor of bile acids and hormones
- Hormones: regulation of metabolism, reproduction, stress response
- Bile acids: emulsification of dietary fats
- Vitamin D: mineral homeostasis and bone formation

Questions for Knowledge Assessment

1. What structural features distinguish phospholipids from other lipids?
2. Describe the differences between glycerophospholipids and sphingophospholipids.
3. What chemical reactions are typical for phospholipids?
4. Explain the amphipathic behavior of phospholipids and its biological significance.
5. What are terpenes and how are they classified?
6. Describe the isoprene rule and its importance in terpene structure.
7. What is the structural basis of all steroids?
8. List the main physiological functions of steroids.
9. Why are terpenes and steroids classified as unsaponifiable lipids?

Recommended Literature

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