Lecture 7
Discipline: Bioorganic Chemistry
Lecturer: Associate Professor, Dr. Gulnaz Seitimova

Title: Water-soluble and fat-soluble vitamins. The mechanism of action of vitamins.

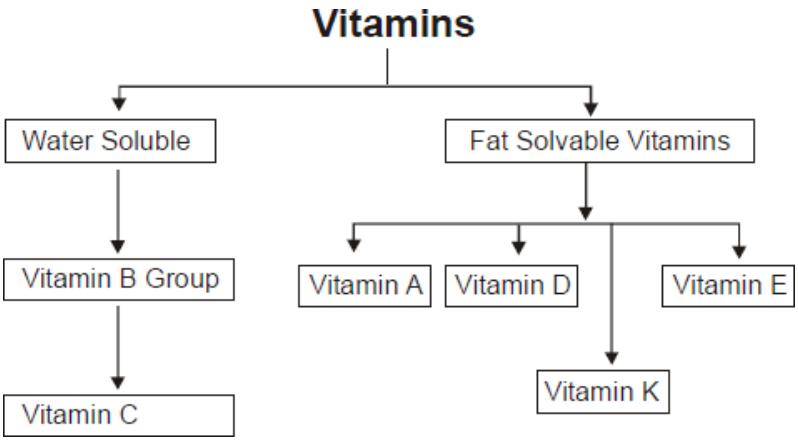
Objective: To provide an understanding of the chemical nature, classification, and physiological roles of vitamins. To explain the structural differences and absorption pathways of water-soluble vs. fat-soluble vitamins. To describe the biochemical mechanisms by which vitamins exert their biological functions, including their participation as coenzymes, antioxidants, and regulators of gene expression.

Main Questions: Classification of vitamins: water-soluble and fat-soluble. Chemical structure and physicochemical characteristics of each vitamin group. Absorption, transport, storage, and excretion of vitamins. Mechanisms of vitamin action at the molecular level. Role of water-soluble vitamins in metabolism (as coenzymes). Role of fat-soluble vitamins in vision, bone health, antioxidation, blood clotting, and gene regulation. Vitamin deficiencies and hypervitaminosis.

Key Notes and Theses

General Characteristics of Vitamins

- Vitamins are low-molecular-weight organic compounds essential in small quantities for metabolic regulation.
- They are not synthesized in sufficient amounts by the human body and must be obtained from the diet.
- Vitamins function mainly as coenzymes, antioxidants, and hormone-like regulators of gene expression.



Water-Soluble Vitamins

Includes: Vitamin C and B-complex vitamins (B1, B2, B3, B5, B6, B7, B9, B12).
Characteristics:

- Highly polar, readily soluble in water.
- Poor storage in the body → require continuous dietary intake.
- Excess amounts are excreted in urine.
- Most function as coenzymes in metabolic pathways.

Key Examples:

- Vitamin B_1 (Thiamine): coenzyme TPP in carbohydrate metabolism.
- Vitamin B_2 (Riboflavin): part of FMN and FAD in redox reactions.
- Vitamin B_3 (Niacin): precursor to NAD^+/$NADP^+$.
- Vitamin B_6 (Pyridoxine): coenzyme PLP in amino acid metabolism.
- Vitamin B_9 (Folate): essential for nucleotide biosynthesis.
- Vitamin B_{12}: involved in DNA synthesis and methylation cycles.
- Vitamin C: antioxidant and cofactor for collagen synthesis.

Fat-Soluble Vitamins

Includes: Vitamins A, D, E, K.

Characteristics:

- Non-polar, require dietary fats for absorption in the intestine.
- Can accumulate in liver and adipose tissues → risk of hypervitaminosis.
- Function in vision, antioxidation, blood coagulation, and gene regulation.

Key Examples:

- Vitamin A (Retinoids): essential for vision cycle (retinal), epithelial integrity, immune function.
- Vitamin D (Calciferols): steroid-like regulator of calcium metabolism; acts via nuclear receptors.
- Vitamin E (Tocopherols): lipid-phase antioxidant protecting membranes.
- Vitamin K: cofactor for γ-carboxylation of clotting factors (II, VII, IX, X).

Comparison of fat- and water-soluble vitamins

S. No.	Characteristics	Fat soluble vitamins	Water soluble vitamins
1	Solubility	Fat soluble	Water soluble
2	Absorption	Bile salts are required	Simple intestinal absorption
3	Transportation	Transported by carrier protein	Travels freely in the body without requiring carrier protein (except Vitamin B_{12})
4	Storage	Stored in liver and fatty tissues	Not stored (except vitamin B_{12})
5	Excretion	Usually the surplus vitamins are stored	Surplus vitamins are detected in kidney and removed in urine
6	Accumulation	Usually hypervitaminosis occurs	Usually hypervitaminosis deosn't occur (except in high dosage and slow release of some B vitamins)
7	Deficiency compensation	Required in periodic doses (weeks or months)	Required in frequent doses (1 - 3 days)

Mechanism of Action of Vitamins

1. As Coenzymes (mainly water-soluble)

- Vitamins convert to active coenzyme forms (TPP, FAD, NAD^+, PLP, CoA, THF).
- They participate in:
  - Redox reactions
  - Transamination
  - Carboxylation
  - Acyl group transfer
  - Nucleotide synthesis

2. As Antioxidants

- Vitamins C and E neutralize free radicals.
- Vitamin E protects lipid membranes, while Vitamin C regenerates oxidized Vitamin E.

3. As Hormone-Like Regulators (fat-soluble)

- Vitamins A and D bind to nuclear receptors and regulate gene expression.
- Vitamin D affects calcium homeostasis; retinoic acid regulates epithelial differentiation.

4. As Cofactors in Post-Translational Modifications

- Vitamin K participates in the γ-carboxylation of glutamate residues.
- Vitamin C is required for hydroxylation of proline and lysine during collagen synthesis.

Questions for Knowledge Assessment

1. What are the main structural differences between water-soluble and fat-soluble vitamins?
2. Explain how vitamins function as coenzymes in biochemical reactions.
3. Why do water-soluble vitamins require daily intake?
4. Describe the mechanism of action of vitamins A and D at the molecular level.
5. What is the physiological role of Vitamin K in blood coagulation?
6. Discuss the antioxidant functions of Vitamins C and E.
7. Provide examples of vitamin deficiencies and their metabolic consequences.

Recommended Literature

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