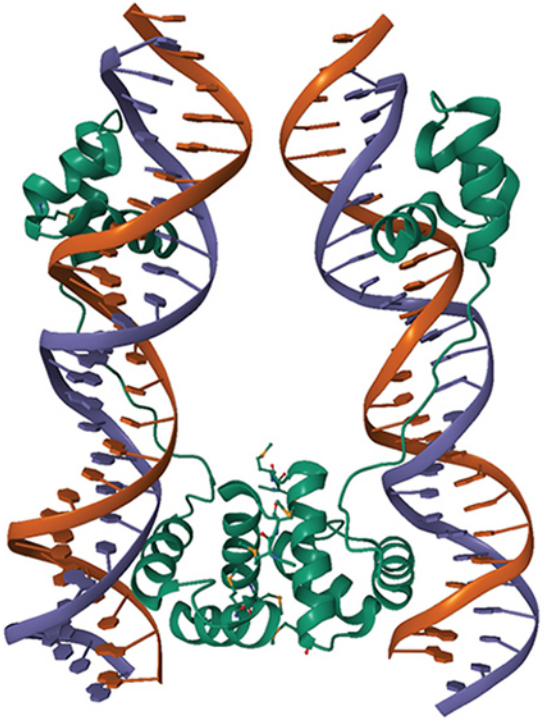
14th Edition

BIOCHEMISTRY

FOR STUDENTS



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CHAPTER

12

Vitamins

INTRODUCTION

In addition to oxygen, water, proteins, fats, carbohydrates and inorganic salts, a number of organic compounds are also necessary for the life, growth and health of animals including man. These compounds are known as the accessory dietary factors or vitamins and are only necessary in very small amount. Vitamin cannot be produced by the body and hence, must be supplied in the diet.

Vitamins are defined as organic compounds, occurring in natural food either as such or as utilizable precursors which are required in minute amounts for normal growth, maintenance and reproduction. They differ from other organic foodstuffs in that they do not enter into the tissue structure and do not undergo degradation for the purpose of providing energy. The absence of these results in deficiency disease.

Most of the vitamins are supplied by the diet. Very few vitamins which are synthesized in the intestine belongs to the vitamin B group.

Vitamins which are synthesized in the intestinal flora are: Vitamin K, thiamine, riboflavin, pyridoxine, folic acid, niacin and biotin.

But the entire requirement of these vitamins are not met by the endogenous synthesis.

Vitamin deficiencies are must often the result of consuming monotonous diet, i.e., diet-based on limited number of food sources. The requirements for vitamins are usually greatest during the neonatal period.

The vitamins have been classified into:

1. **Fat-soluble vitamins:** They are soluble in fat solvents. Vitamins in this group are vitamins A, D, E and K.
2. **Water-soluble vitamins:** They are water soluble and includes vitamin C and vitamins of B-complex.

   Most of the vitamins form the integral part of coenzymes.

Fat-soluble vitamins are stored in our fat deposits (liver and adipose tissue) and water-soluble vitamins are constantly flushed from our bodies. Therefore, we can do without lipid soluble vitamins for a reasonable amount of time but we must keep replacement of the water-soluble vitamins. Vitamins acts as **coenzyme, antioxidants**, (free radical quenching agents) as signaling agents in the cells, as regulator of gene expression and as redox.

Vitamin-like Compounds

Those compounds which are highlighted because of their known role as coenzymes in prokaryotes eukaryotes or roles as a probiotic (growth promoting substance) in higher animals are defined as vitamin like.

Vitamin like substances are taurine, queuosine, coenzyme Q, pteridines (other than folic acid), such as biopterin and the molybdenum containing pteridine cofactor, pyrroloquinoline quinone (PQQ).

Vitamins as Coenzymes

Vitamins	*Active form*	*Functions performed*
Thiamine	Thiamine pyrophosphate	Aldehyde group transfer
Riboflavin	Flavin mononucleotide (FMN)	Hydrogen group transfer
	Flavin adenine dinucleotide (FAD)	Hydrogen group transfer
Pantothenic acid	Coenzyme A	Acyl group transfer
Nicotinamide	Nicotinamide adenine dinucleotide (NAD^+)	Hydrogen transfer
	Nicotinamide adenine dinucleotide phosphate (NADP)	Hydrogen transfer
Pyridoxine	Pyridoxal phosphate	Amino group transfer
Biotin	Biocytin	Carboxyl group transfer, i.e., CO_2 fixing
Folic acid	Tetrahydrofolic acid, i.e., Folacin	Methyl, methylene, formyl or formimino group transfer
Cyanocobalamin	Cobamides	Alkyl group transfer
Lipoic acid	Lipoyl lysine	Acyl group transfer

FAT-SOLUBLE VITAMINS

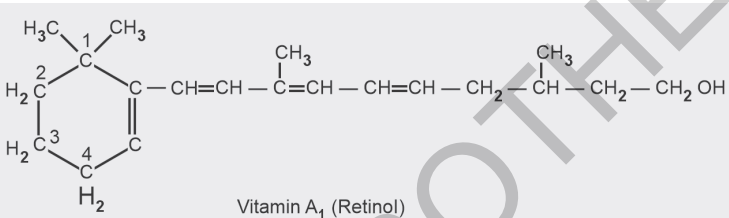
VITAMIN A

Retinol, growth promoting vitamin, anti-infective vitamin, antixerophthalmia.

Structure

Vitamin A occurs in two forms, vitamin A_1 and vitamin A_2.

The structure of vitamin A_1 is:



Vitamin A_1 (Retinol)

Vitamin A_2 contains an additional double bond between C-3 and C-4.

Vitamin A_2 is 40 % active to vitamin A_1.

Certain carotenes called provitamins are converted into vitamin A in the body. β-carotenes give rise to two molecules of vitamin A whereas α- and γ-carotenes give rise to one molecule each of vitamin A.

Functions

1. The most important function of vitamin A is in the visual cycle (page 253).

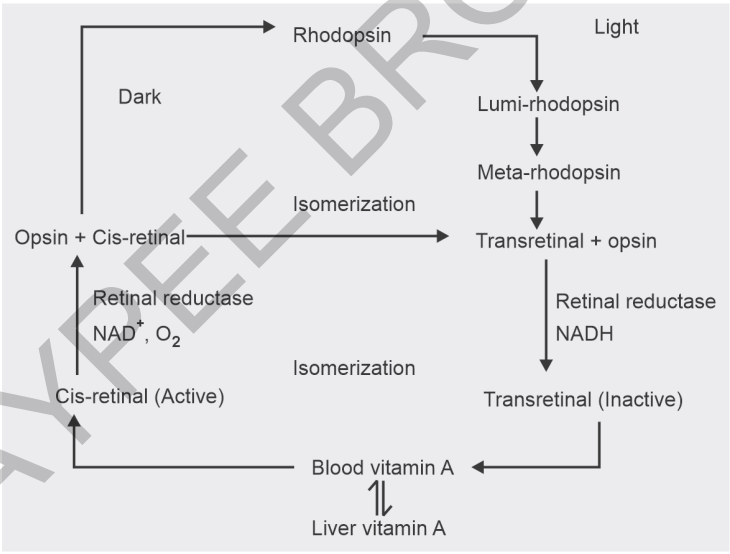
   Retina contains conjugated protein rhodopsin. Rhodopsin consists of protein 'opsin' and vitamin A_1 aldehyde. Rhodopsin is the major light receptor of rod cells. Under the influence of light rhodopsin is converted to transretinal and opsin. Transretinal is inactive in the resynthesis of rhodopsin. Transretinal is converted to transretinal by reductase which is also inactive in rhodopsin synthesis, is passed into blood stream. During resynthesis of rhodopsin, which occurs in dim light and in the dark, active cis-retinal enters the retina from the blood and is oxidized to cis-retinal by retinal action of retinal reductase. Now cis-retinal couples with opsin to form rhodopsin. The visual process involves

the removal of active retinal isomer from the blood by the retina which returns the inactive isomer to the circulation.
2. In the maintenance of proper health of epithelium tissues.
3. For the stability and integrity of cellular and subcellular membranes.
4. Necessary for the synthesis of mucopolysaccharides as it helps in the incorporation of sulfur in chondroitin sulfate.
5. It is also involved in the nucleic acid metabolism.
6. It is also involved in the election transport chain and in oxidative phosphorylation.

Sources

Provitamin sources: Food rich in carotenoid such as carrot, papayas, tomatoes, etc.

Readymade or preformed sources: Fish liver oils such as shark, cod, halibut fish, egg yolk, butter, milk products.



Visual cycle

Daily requirement: 5,000 IU

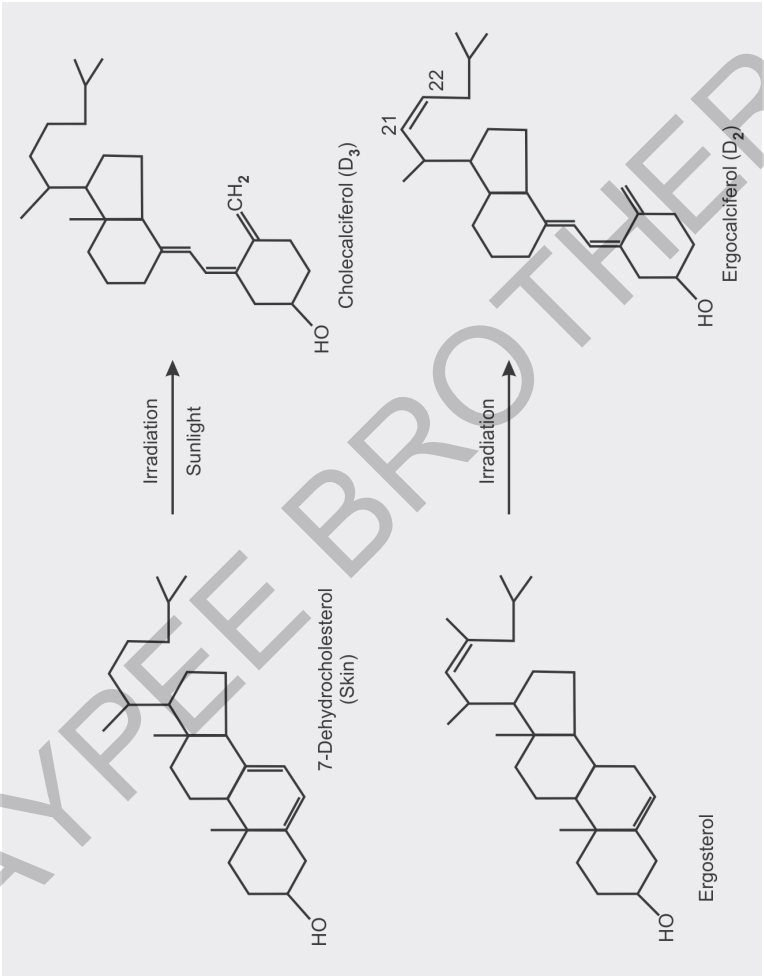
Deficiency Disease

Deficiency of vitamin A gives rise to night blindness.

Hypervitaminosis A

Excessive intake of vitamin A gives rise to hypervitaminosis A.

The symptom of this toxicity include anorexia, irritability, headache, peeling of skin, vomiting.



VITAMIN D

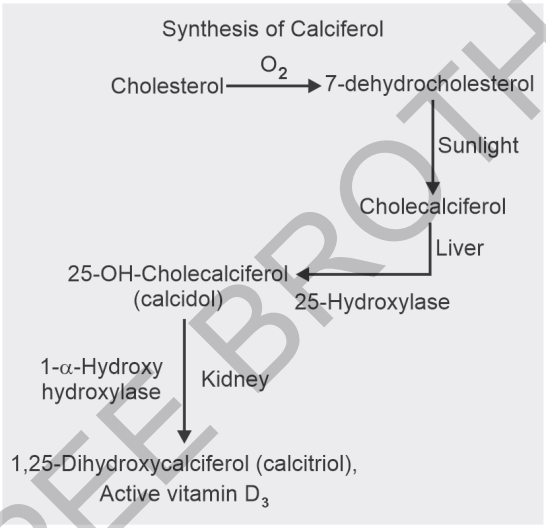
The term vitamin D does not refer to a single dietary factor but to a number of chemically related compounds, all of which have the

property of preventing or curing rickets. The two most active substances in this respect are vitamin D_2 and vitamin D_3.

Structure

Vitamin D_2 is also known as ergocalciferol and vitamin D_3 as cholecalciferol.

Irradiation of 7-dehydrocholesterol with ultraviolet radiations produces cholecalciferol whereas irradiation of ergosterol produces ergocalciferol.



Vitamin D_2 differs from vitamin D_3 with respect to the double bond additionally present in the side chain at position 20 and 21.

The biologically active form of vitamin D are 25-hydroxy-cholecalciferol (25-HCC) and 1,25-cholecalciferol.

Liver converts cholecalciferol to 25-HCC, whereas kidney converts 25-HCC to 1,25 dihydroxycholecalciferol (1,25-DHCC).

Another important active form formed by the kidney is 24,25-dihydroxycholecalciferol (24,25-DHCC) but very little is known of biological function of this form.

1,25-DHCC perform the following functions:

1. It promotes calcium absorption from the intestine.
2. It promotes mobilization of calcium from bones.

Functions

1. The basic action of vitamin D is to increase the absorption of calcium and phosphorus from the intestines.
2. Vitamin D promotes resorption of bone and mobilization of calcium from bones.
3. Vitamin D increases excretion of phosphate by the kidney.

Sources

Fish liver oils (i.e., cod, shark, halibut), egg yolk, milk, etc.

Daily requirement

- 400 IU infants and children
- 100 IU adults
- 400 IU pregnancy and lactation

Deficiency Disease

Deficiency of vitamin D gives rise to rickets in children and osteomalacia in adults.

In rickets, there is a fall in intestinal absorption of calcium and phosphate, increased excretion of urinary phosphate and loss of calcium from the bones, leading to softness and deformities of bones.

In rickets and osteomalacia, there is an increase in serum alkaline phosphatase activity.

Hypervitaminosis D

Doses above 1,500 units per day for long period give rise to vitamin D toxicity.

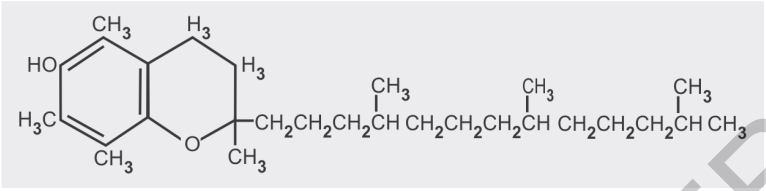
Excessive intake of vitamin D causes loss of appetite, nausea, irritability, excessive mobilization of calcium from bones into blood.

VITAMIN E (ANTISTERILITY VITAMIN, FERTILITY FACTOR)

Vitamin E refers to a group of compounds having vitamin E activity and are known as tocopherols. Four unsaturated alcohols, i.e., α-, β-, γ-, and δ-tocopherols occur in nature. These tocopherols differ slightly in structure in their side chain, α-tocopherol is most potent of them.

Structure

The structure of α-tocopherol is:



They are thermostable and sensitive to the effects of oxidizing agents and ultraviolet rays.

Functions

1. Tocopherols act as powerful antioxidants:
   a. They prevent the autoxidation of vitamin A and carotenes.
   b. They prevent the formation of fatty acid peroxidases in tissues due to the autoxidation of unsaturated fatty acids with oxygen.
   c. They protect the lipids of biological membranes against oxygen by acting as antioxidants (i.e., prevent the pero-xidation of polyunsaturated fatty acids that occur in membranes throughout the body).
2. Vitamin E prevents rancidity.

Sources

Wheat germ oil, corn oil, peanut oil, soyabean oil, sunflower oil, egg yolk, leaves of spinach, alfalfa, sweet potatoes.

Daily Requirement 15 IU

Vitamin E intake is related to the intake of polyunsaturated fatty acids, i.e., 0.4 mg/g of polyunsaturated fatty acids.

Deficiency Disease

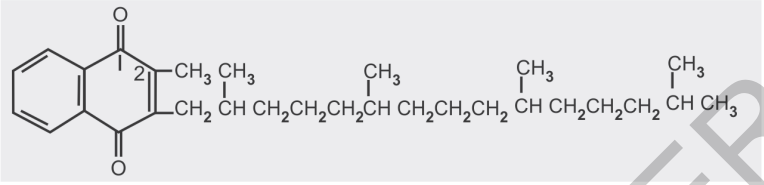
Deficiency of vitamin E gives rise to sterility in rats.

VITAMIN K (COAGULATION FACTOR)

Two naturally occurring vitamin K are vitamin K1 and vitamin K2. Both are naphthaquinone derivatives.

Structure

Vitamin K1 is phylloquinone and is chemically known as 2-methyl-3-phytyl-1,4-naphthoquinone.



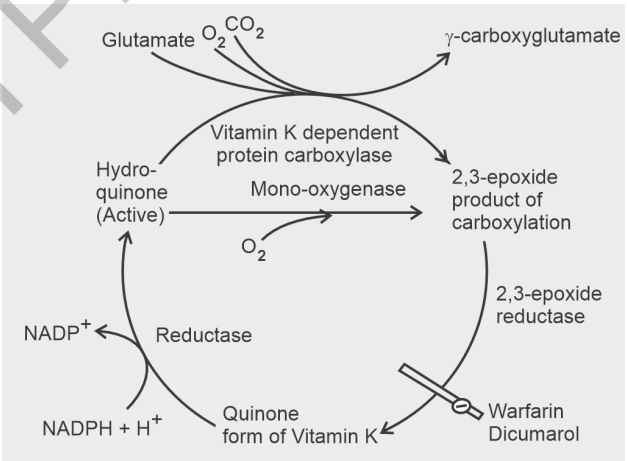
Vitamin K2 is farnesoquinone and is chemically known as 2-methyl-3-difarnesyl-1,4-naphthoquinone.

Vitamin K is thermostable can withstand reduction and is rapidly oxidized both in acidic and alkaline medium. It is completely destroyed by ultraviolet radiations.

Certain compounds having vitamin K activity are called vitamines. Vitamines are synthetic compounds possessing vitamin K activity (*Example:* Menadione). Menadione is more potent than vitamin K1 on weight basis.

Functions

1. In the synthesis of prothrombin.
2. It is involved in oxidative processes taking place in photosynthesis of plant kingdom.
3. It is involved in electron transport chain and is involved in oxidative phosphorylation.



Vitamin K cycle

Sources

Vitamin K1, is present in alfalfa, spinach, cabbage, cauliflower, egg yolk, liver.

Vitamin K2 is present in putrifying fish. It is also synthesized by intestinal flora.

Daily Requirement

Sufficient amounts of vitamin K are synthesized by intestinal bacteria so there is no dietary requirement under physiological condition.

Deficiency Disease

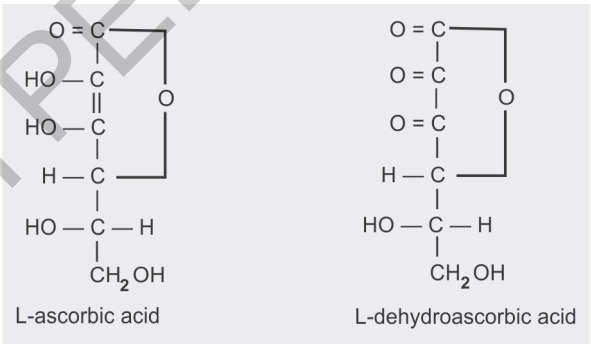
Vitamin K deficiency gives rise to hypoprothrombinemia which leads to prolongation of prothrombin time.

WATER-SOLUBLE VITAMINS

Water-soluble vitamins includes vitamin C and members of vitamin B complex.

VITAMIN C (ASCORBIC ACID, ANTISCORBUTIC VITAMIN)

Structure



Vitamin C, which is hydrophilic, acts as an antioxidant in solution.

Vitamin C is a powerful reducing agent and is oxidized to dehydroascorbic acid. Both forms are biologically active. It is stable in acidic solution at low temperatures but undergoes destruction in alkaline solution when in contact with air.

Vitamin C is not synthesized by man and its entire requirement is met by diet.

The most rich sources of vitamin C in the body are adrenal cortex, corpus luteum, pituitary, pancreas, liver, etc.

Functions

1. Participation in the hydroxylation of proline and lysine present in collagen, an intracellular cementing substance.
2. Participates in the synthesis of steroid hormones both in adrenal cortex and corpus luteum.
3. Participates as cofactor in the following reaction:
   a. In phenylalanine metabolism.
      p-hydroxyphenylpyruvic acid → homogentisic acid
   b. Dopamine → Norepinephrine
   c. Folic acid → Folinic acid.
4. Vitamin C is necessary for the synthesis of carnitine in the liver.
5. Necessary for the absorption of iron by reducing ferric form to ferrous form.
6. In tissue respiration, i.e., oxidation-reduction phenomenon.
7. In bile acid formation, vitamin C is required at the 7-α-hydroxylase step.
8. Ascorbic acid may act as water-soluble antioxidant and inhibit the formation of nitrosamine.

Sources

Citrus fruits such as lemon, orange, pineapple, etc. Indian gooseberry, green pepper, cauliflower, tomatoes, spinach, potato.

Daily requirement: 60–80 mg.

Deficiency Disease

Deficiency of vitamin C gives rise to scurvy. The early manifestation in man are swelling of joints, hemorrhage in skin, muscle, gastrointestinal tract, inflammation of gums, ulceration, etc. In scurvy, vitamin C level in blood falls down.

VITAMIN B COMPLEX

The members of this group are:
1. Thiamine (B1).
2. Riboflavin (B2).

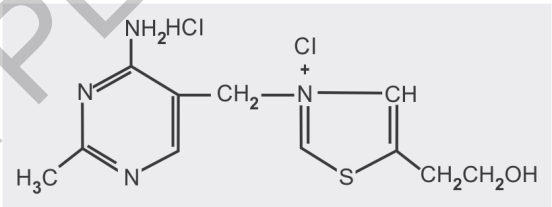
3. Pantothenic acid (B3).
4. Choline (B4).
5. Niacin (B5).
6. Pyridoxine (B6).
7. Biotin (B7).
8. Folic acid (B9).
9. Cyanocobalamin (B12).
10. Para aminobenzoic acid.
11. Inositol.
12. Lipoic acid.

The vitamins of this family have been grouped together because of the following fulfillment:

1. Usually present in yeast.
2. Present in the outer covering of seeds and cereals.
3. Synthesized by the microorganisms in the intestines.
4. They are water soluble.
5. Required in minute amounts and their deficiencies give rise to ordinary manifestations.
6. They usually serve as a coenzyme of various enzyme systems. Foods that are poor sources of one of the B vitamins level to be the poor sources of several B vitamins.

THIAMINE (VITAMIN B1, ANTINEURITIC VITAMIN, ANTIBERIBERI FACTOR, ANEURIN)

Structure



Thiamine consists of a substituted pyrimidine ring joined by a methylene bridge to substituted thiazole ring.

Thiamine is water soluble. It is thermolabile, destroyed in alkaline medium but thermostable in acidic medium.

Thiamine occurs in the cells largely as its active coenzyme form, i.e., thiamine pyrophosphate, also called cocarboxylase.

BIOCHEMISTRY
FOR STUDENTS

Biochemistry for Students serves as a quick reading material for students. The present 14th edition has been thoroughly revised and updated, and it is very popular among the students, medical practitioners, and the related community.

The primary aim of this book is to meet the needs of all students of health sciences in knowing the important applied aspects of various topics in biochemistry and from examination point of view. Important points are presented in tables and figures to facilitate students to grasp the matter effectively.

VK Malhotra PhD(Gold Medalist) had an Exchequer career in his student days with a Gold Medal in Medical Biochemistry from Maulana Azad Medical College (MAMC), New Delhi, India. He has more than 35 years of experience in teaching students of medical, dental, nursing, and allied sciences. He is an eminent scholar and has a vast teaching experience.

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