



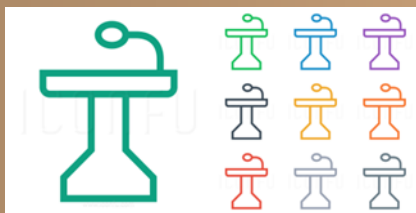
Biological Chemistry Department

Biological Chemistry

Nomenclature and Classification of the Vitamins. Fat-soluble Vitamins. Water-soluble Vitamins. Interaction of Vitamins. Vitamin Products.

Speciality: Pharmacy for foreign students (Language of instructions - English)

Lecturer: ass. prof. Kravchenko G.B.



Lecture Plan

1. Definition and classification of vitamins.
- 2.1. Fat-soluble vitamins.
 - 2.1. Vitamin A: structure, functions, deficiency, food sources, toxicity.
 - 2.2. Vitamin D: structure, functions, deficiency, food sources, toxicity.
 - 2.3. Vitamin E: structure, functions, deficiency, food sources.
 - 2.4. Vitamin K: structure, functions, deficiency, food sources.
3. Water-soluble vitamins.
 - 3.1. Group B vitamins: structure, functions, deficiency, food sources.
 - 3.2. Vitamin C: structure, functions, deficiency, food sources.
 - 3.3. Vitamin P: structure, functions, deficiency, food sources.

Individual work

1. Vitamin interaction.
2. Vitamin-like compounds.

Information Resources

1. *Biological Chemistry: Textbook* / A.L. Zagayko, L.M. Voronina, G.B. Kravchenko, K.V. Strel`chenko. - Kharkiv: NUPh; Original, 2011. - 195-211 p.
2. *Training Journal for Licensed Exam "KROK-1": Study Material in Biological Chemistry.* - Kharkiv: NUPh, 2017. - 117-142 p.
3. *Laboratory Manual on Biochemistry.* Kharkiv: NUPh, 2017. - 65-68 p.
4. *Vitamins: Water and Fat Soluble: The Medical Biochemistry Page.* Available on:
<https://themedicalbiochemistrypage.org/vitamins.php>.
5. *Minerals: Critical Micronutrients: The Medical Biochemistry Page.* Available on:
<https://themedicalbiochemistrypage.org/minerals.php>.



VITAMINS -

an organic substance required in small quantities in the diet.

Most of vitamins are synthesized in the plants, but some of them can be synthesized by microphlora of the intestine.

*Early nutritional studies identified two general classes of such compounds: those soluble in nonpolar organic solvents (fat-soluble vitamins) and those that could be extracted from foods with aqueous solvents (water-soluble vitamins). Eventually the fat-soluble group was resolved into the four vitamins **A, D, E, and K**. The rest of vitamins are water-soluble (**B₁, B₂, B₆, C, P** and etc.).*



Some of vitamins can be synthesized in the organism of monkey, the rats, but the human being don't synthesized it.

Hypovitaminosis – is a lack of some vitamins.

Hypervitaminosis – is a excess of some vitamins.

Avitaminosis – is an absence of some vitamins.

Provitamins – are precursors of vitamins.

Antivitamins – is chemical compounds which restrict activity of some vitamins.

The water-soluble vitamins generally functions as a component of a coenzyme. The fat-soluble vitamins as a rule are not of part of coenzyme, but their influence on metabolism connected with their roles in creating of optimal condition for activity enzymes on the cells membranes. The fat-soluble vitamins posses an antioxidative properties. That's why they can eliminate active oxygen species and inhibits of lipid peroxidation in the cell membranes preventing the distraction of unsaturated fatty acids in the phospholipids of membranes. They stabilized the cell membranes and regulate their penetration.

Water Soluble Vitamins

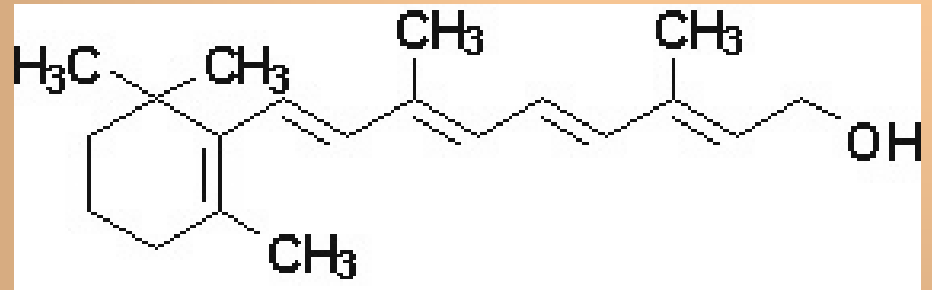
- *Thiamin (B₁)*
- *Riboflavin (B₂)*
- *Niacin (B₃)*
- *Pantothenic Acid (B₅)*
- *Pyridoxal, Pyridoxamine, Pyridoxine (B₆)*
- *Biotin*
- *Cobalamin (B₁₂)*
- *Folic Acid*
- *Ascorbic Acid*

Fat Soluble Vitamins

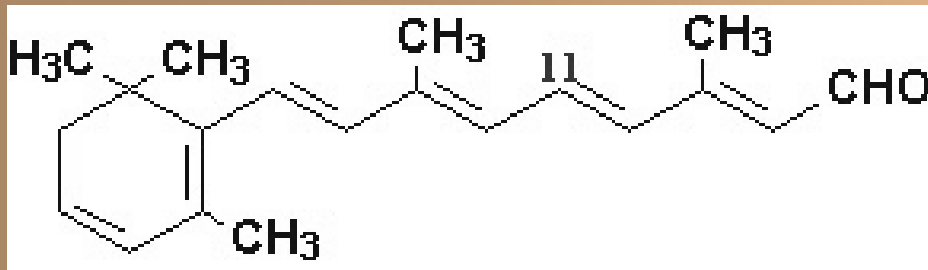
- *Vitamin A*
- *Vitamin D*
- *Vitamin E*
- *Vitamin K*

Vitamin A

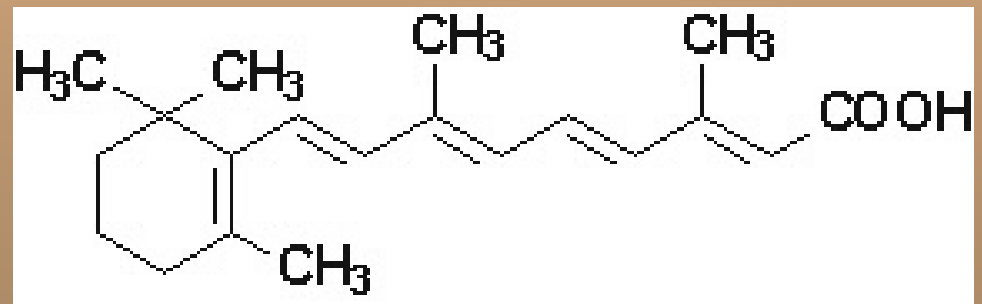
Vitamin A consists of three biologically active molecules, retinol, retinal (retinaldehyde) and retinoic acid.



Retinol



Retinal



Retinoic acid

Gene Control Exerted by Retinol and Retinoic Acid

Vitamin A can get in cell membranes due to it fat-soluble and penetrate into nuclear. Within nuclear both retinol and retinoic acid bind to specific receptor proteins. Following binding, the receptor-vitamin complex interacts with specific sequences in several genes involved in growth and differentiation and affects expression of these genes. Several genes whose patterns of expression are altered by retinoic acid are involved in the earliest processes of embryogenesis.

Vision and the Role of Vitamin A

Photoreception in the eye is the function of two specialized cell types located in the retina; the rod and cone cells. Both rod and cone cells contain a photoreceptor pigment in their membranes. The photosensitive compound of most mammalian eyes is a protein called opsin to which is covalently coupled an aldehyde of vitamin A.

When the it's light, rhodopsin is exposed and when it's dark rhodopsin is synthesized. That's why we can see in the darkness only when we have enough retinal.

Additional Role of Retinol

Retinol also functions in the synthesis of certain glycoproteins and mucopolysaccharides necessary for mucous production and normal growth regulation. It's known that retinol and carotene possess antihistamine properties.

Clinical Significances of Vitamin A Deficiency

Vitamin A is stored in the liver and deficiency of the vitamin occurs only after prolonged lack of dietary intake. The earliest symptoms of vitamin A deficiency are night blindness. Additional early symptoms include follicular hyperkeratinosis. Prolonged lack of vitamin A leads to deterioration of the eye tissue through progressive keratinization of the cornea, a condition known as xerophthalmia.

The increased risk of cancer in vitamin deficiency is thought to be the result of a depletion in β -carotene. Beta-carotene is a very effective antioxidant and is suspected to reduce the risk of cancers known to be initiated by the production of free radicals.

Hypervitaminosis

Hypervitaminosis A is caused by overconsumption of preformed vitamin A, not carotenoids. Preformed vitamin A is rapidly absorbed and slowly cleared from the body, so toxicity may result acutely from high-dose exposure over a short period of time, or chronically from much lower intake. Vitamin A toxicity is relatively rare. Symptoms include nausea, headache, fatigue, loss of appetite and dizziness.



Food sources

Free retinol is not generally found in foods. Retinyl palmitate, a precursor and storage form of retinol, is found in foods from animals. Plants contain carotenoids, some of which are precursors for vitamin A. Yellow and orange vegetables contain significant quantities of carotenoids. A food sources of vitamin A are egg, butter and milk.

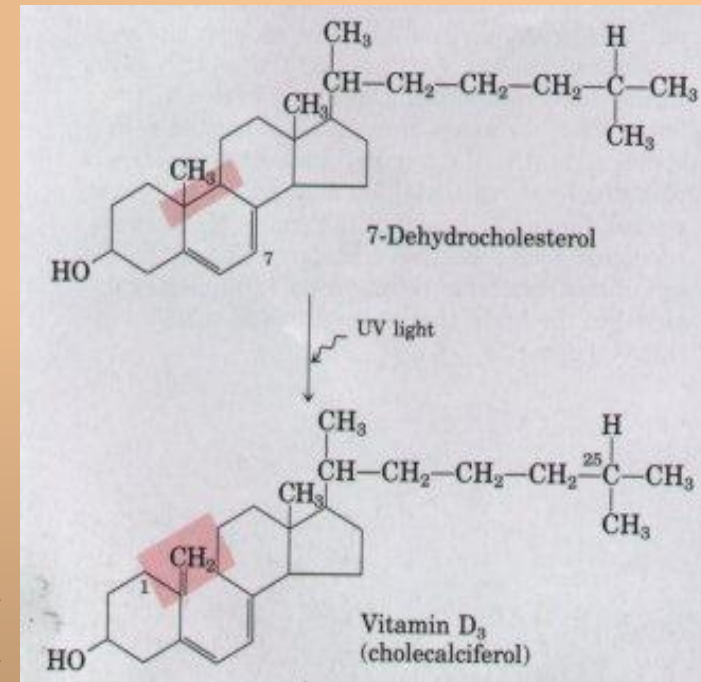
Recommended Dietary Allowance (RDA) for Vitamin A as Preformed Vitamin A (Retinol)

	Males: mcg/day (IU/day)	Females: mcg/day (IU/day)
Adults	900 (3000 IU)	700 (2333 IU)



VITAMIN D

Vitamin D is a fat-soluble vitamin that is essential for maintaining normal calcium metabolism. Vitamin D3 (cholecalciferol) can be synthesized by humans in the skin from 7-dehydrocholesterol upon exposure to ultraviolet-B (UVB) radiation from sunlight, or it can be obtained from the diet. Plants synthesize vitamin D2 (ergocalciferol). When exposure to UVB radiation is insufficient for the of adequate amounts of vitamin D3 in the skin, adequate intake of vitamin D from the diet is essential for health.

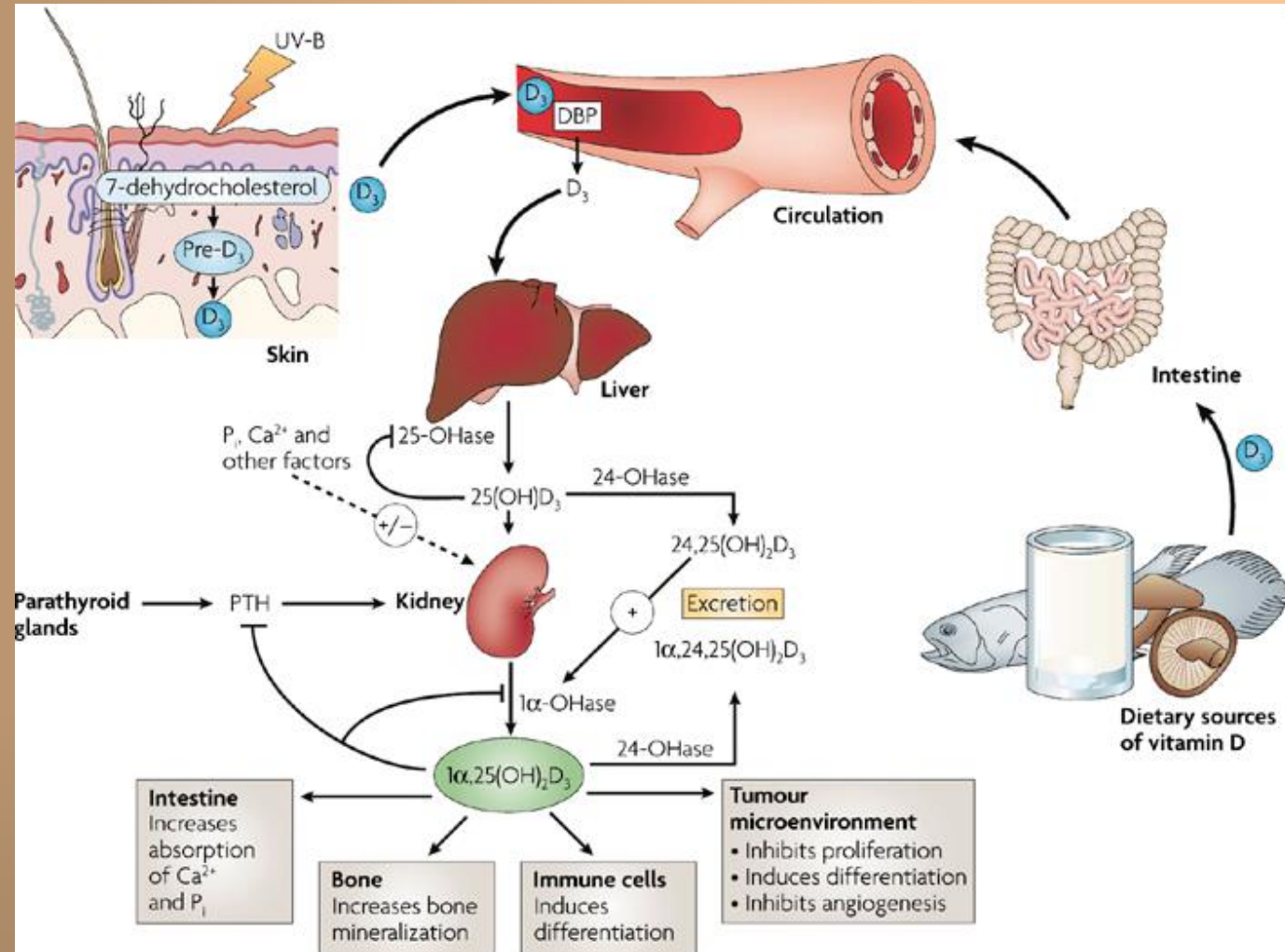


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The biologically active form of the vitamin is 1,25-dihydroxy vitamin D3 (1,25-(OH)₂D₃, also termed calcitriol). Calcitriol functions primarily to regulate calcium and phosphorous homeostasis.

Function

The active form of vitamin D, 1,25(OH)₂D, inhibits proliferation and stimulates the differentiation of cells. Calcitriol functions to regulate serum calcium and phosphorous levels.



In the intestinal epithelium, calcitriol activates the synthesis of special protein involved in intestinal calcium absorption. When plasma calcium levels fall the major sites of action of calcitriol are bone where they stimulate bone resorption and the kidneys where they inhibit calcium excretion by stimulating reabsorption by the distal tubules.

Maintenance of serum calcium levels within a narrow range is vital for normal functioning of the nervous system, as well as for bone growth, and maintenance of bone density. Vitamin D is essential for the efficient utilization of calcium by the body.

Additional Role of Vitamin D

Vitamin D in the form of 1,25(OH)₂D is a potent immune system modulator. There is considerable scientific evidence that 1,25(OH)₂D has a variety of effects on immune system function that may enhance innate immunity and inhibit the development of autoimmunity.

Clinical Significance of Vitamin D Deficiency

As a result of the addition of vitamin D to milk, deficiencies in this vitamin are rare in your country. The main symptom of vitamin D deficiency in children is **rickets** and in adults is **osteomalacia**.

Rickets: In infants and children, severe vitamin D deficiency results in the failure of bone to mineralize. Rapidly growing bones are most severely affected by rickets. The growth of bones continue to enlarge, but in the absence of adequate mineralization, weight-bearing limbs (arms and legs) become bowed.



Osteomalacia is characterized by demineralization of previously formed bone leading to increased softness and susceptibility to fracture.

Hypervitaminosis D

Vitamin D toxicity induces abnormally high serum calcium levels (hypercalcemia), which could result in bone loss, kidney stones, and calcification of organs like the heart and kidneys if untreated over a long period of time.

Food sources

Vitamin D is found naturally in very few foods. Foods containing vitamin D include some fatty fish (mackerel, salmon, sardines), fish liver oils, and eggs from hens that have been fed vitamin D.

<i>Tolerable Upper Intake Level (UL) for Vitamin D</i>	
<i>Age Group</i>	<i>mcg/day (IU/day)</i>
<i>Adults 19 years and older</i>	<i>50 mcg (2000 IU)</i>



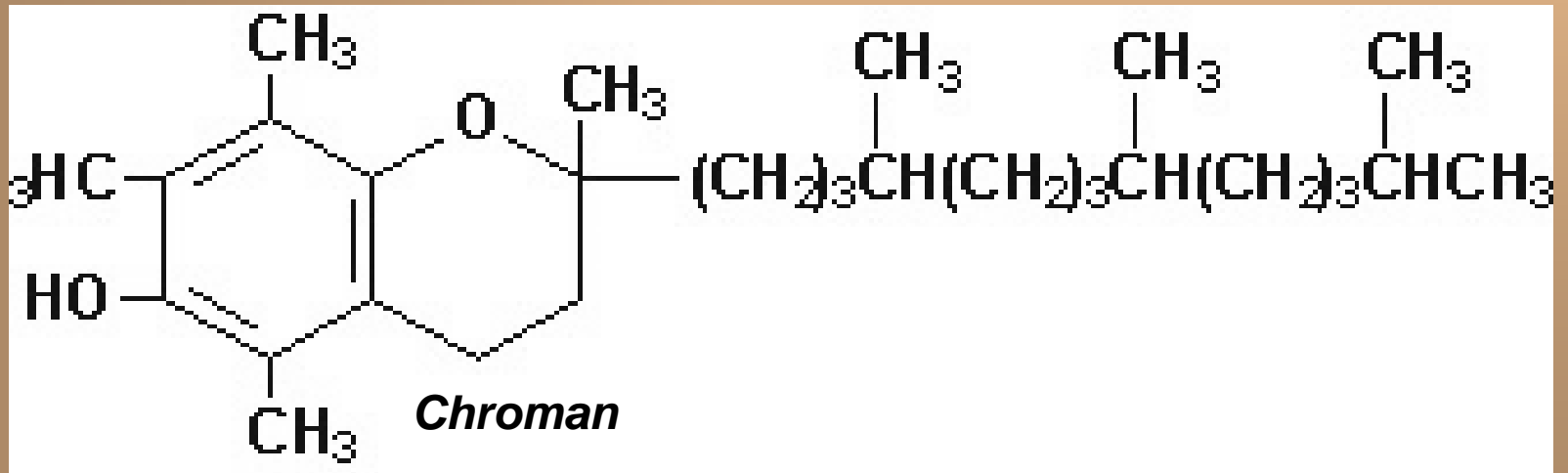
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Vitamin E

The term vitamin E describes a family of antioxidants, alpha-, beta-, gamma- and delta-tocopherols. Because α -tocopherol is the form of vitamin E that appears to have the greatest nutritional significance, it will be the primary topic of the following discussion.



α -Tocopherol

The main function of α -tocopherol in humans appears to be that of an antioxidant. Free radicals are formed primarily in the body during normal metabolism and also upon exposure to environmental factors such as cigarette smoke or pollutants. Phospholipids (they consist o lot of unsaturated fatty acids), which are an integral part of all cell membranes, are vulnerable to destruction through oxidation by free radicals. The fat-soluble vitamin, α -tocopherol, is uniquely suited to intercepting free radicals and preventing a chain reaction of lipid destruction. Aside from maintaining the integrity of cell membranes, α -tocopherol also protects the fats in low density lipoproteins from oxidation.

When a molecule of α -tocopherol neutralizes a free radical, it is altered in such a way that its antioxidant capacity is lost. However, other antioxidants, such as vitamin C, are capable of regenerating the antioxidant capacity of α -tocopherol.

Additional Role of Vitamin E

Several other functions of α -tocopherol have been identified, which likely are not related to its antioxidant capacity. α -Tocopherol is known as an important cell signaling molecule, as well as to affect the expression and activity of immune and inflammatory cells.

***Deficiency of vitamin E* is very rare in humans, but when laboratory animals are fed diets depleted of vitamin E, they develop scaly skin, muscular weakness and sterility.**

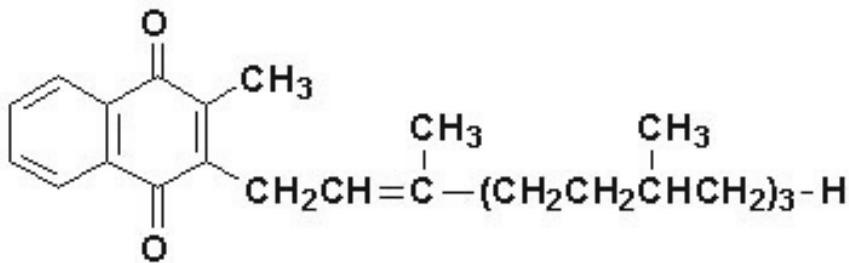
Major sources of α -tocopherol in the standard diet include vegetable oils (olive, sunflower, safflower oils), nuts, whole grains, and green leafy vegetables. All forms of vitamin E (alpha-, beta, gamma-, and delta-tocopherols) occur naturally in foods, but in varying amounts.

<i>Tolerable Upper Intake Level (UL) for Alpha-Tocopherol</i>	
<i>Age Group</i>	<i>mg/day (IU/day d-alpha-tocopherol)</i>
<i>Adults</i>	<i>1,000 mg (1,500 IU)</i>

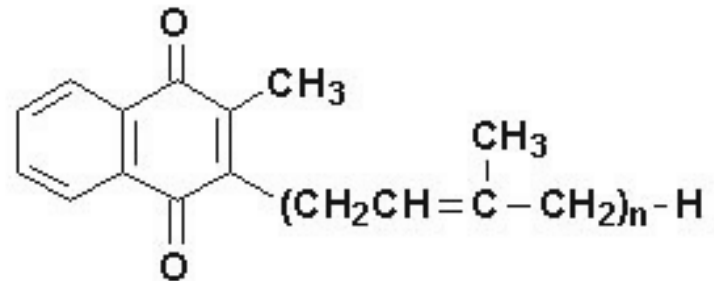


VITAMIN K

Vitamin K is a fat-soluble vitamin. The "K" is derived from the German word "koagulation". Coagulation refers to blood clotting, because vitamin K is essential for the functioning of several proteins involved in blood clotting. There are two naturally occurring forms of vitamin K. Plants synthesize phyloquinone, also known as vitamin K₁. Vitamin K₂ can be synthesized by bacteria in the intestina. That's why we have deficiency of this vitamin if microphlora in our intestine have been killed by antibiotics or sulfanilamide medicine.



Vitamin K1



Vitamin K2

FUNCTION

The known biological role of vitamin K is that of the required coenzyme for synthesis of key factors of blood coagulation in the liver. Some oral anticoagulants, such as warfarin, aspirin, gerudin (substance which can be synthesized in leech) inhibit coagulation through antagonism of the action of vitamin K.

DEFICIENCY

Vitamin K deficiency results in impaired blood clotting. Symptoms include easy bruising and bleeding. Adults at risk of vitamin K deficiency include those taking vitamin K antagonist anticoagulant drugs and individuals with significant liver damage or disease. Newborn babies that are exclusively breast-fed are at increased risk of vitamin K deficiency for the following reasons: 1) human milk is relatively low in vitamin K compared to formula, 2) the newborn's intestines are not yet colonized with bacteria that synthesize menaquinones. Vitamin K deficiency in newborns may result in a bleeding disorder called vitamin K deficiency bleeding of the newborn (hemorrhagic syndrome).

Food sources

Phylloquinone (vitamin K₁) is the major dietary form of vitamin K. Green leafy vegetables and some vegetable oils (soybean, cottonseed and olive) are major contributors of dietary vitamin K. Bacteria that normally colonize the large intestine synthesize menaquinones (vitamin K₂), which are an active form of vitamin K.

<i>Adequate Intake (AI) for Vitamin K</i>		
Life Stage	Males (mcg/day)	Females (mcg/d)
Adults	120	90



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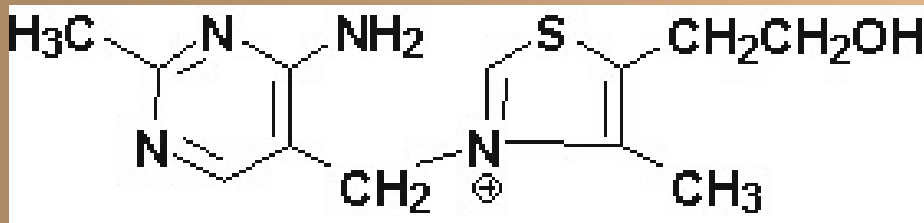
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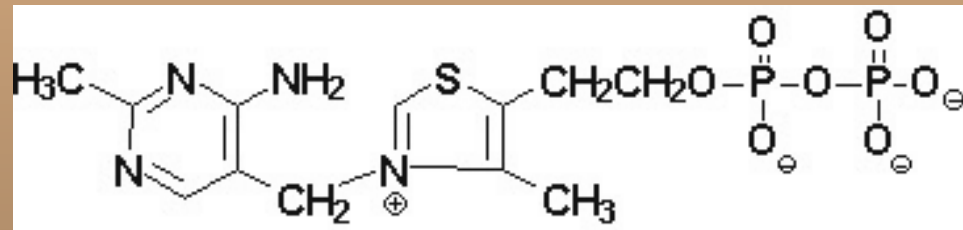
Water Soluble Vitamins



Thiamin is also known as vitamin **B₁**. Thiamin is derived from a substituted pyrimidine and a thiazole which are coupled by a methylene bridge. Thiamin is rapidly converted to its active form, **thiamin pyrophosphate**, TPP, in the brain and liver by a specific enzymes, **thiamin diphosphotransferase**.



Thiamin structure

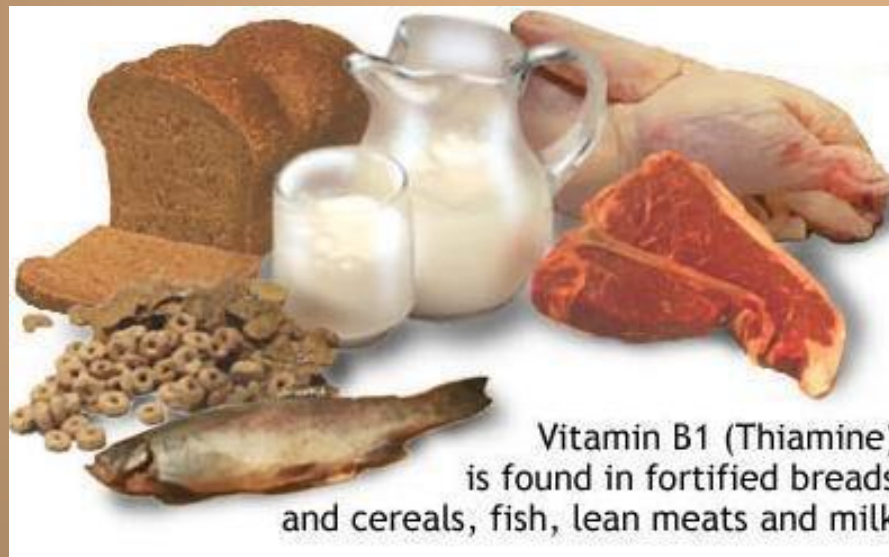


Thiamin pyrophosphate structure

Function

TPP is necessary as a cofactor for the enzyme decarboxylase which catalyzed reactions of decarboxylation of α -ketoacids, for example pyruvate and α -ketoglutarate. TPP is a cofactor for transketolase catalyzed reactions of the pentose phosphate pathway. A deficiency in thiamin intake leads to a severely reduced capacity of cells to generate energy as a result of its role in these reactions.

Food sources of B₁



Vitamin B1 (Thiamine)
is found in fortified breads
and cereals, fish, lean meats and milk

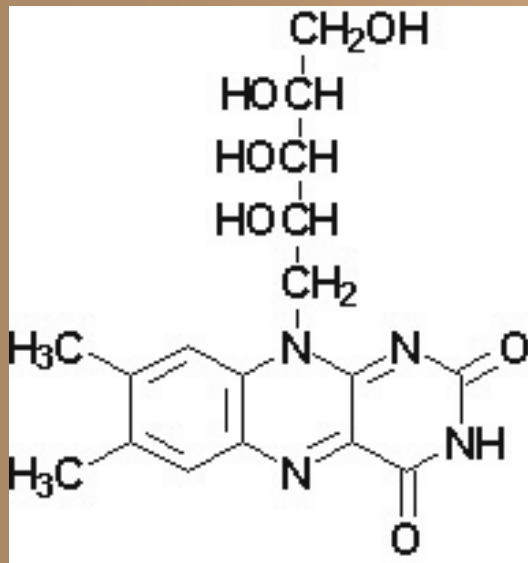
Deficiency

The earliest symptoms of thiamin deficiency include appetite suppression, nausea as well as mental depression, peripheral neuropathy and fatigue. Chronic thiamin deficiency leads to more severe neurological symptoms including ataxia, mental confusion and loss of eye coordination. Other clinical symptoms of prolonged thiamin deficiency are related to cardiovascular and musculature defects.

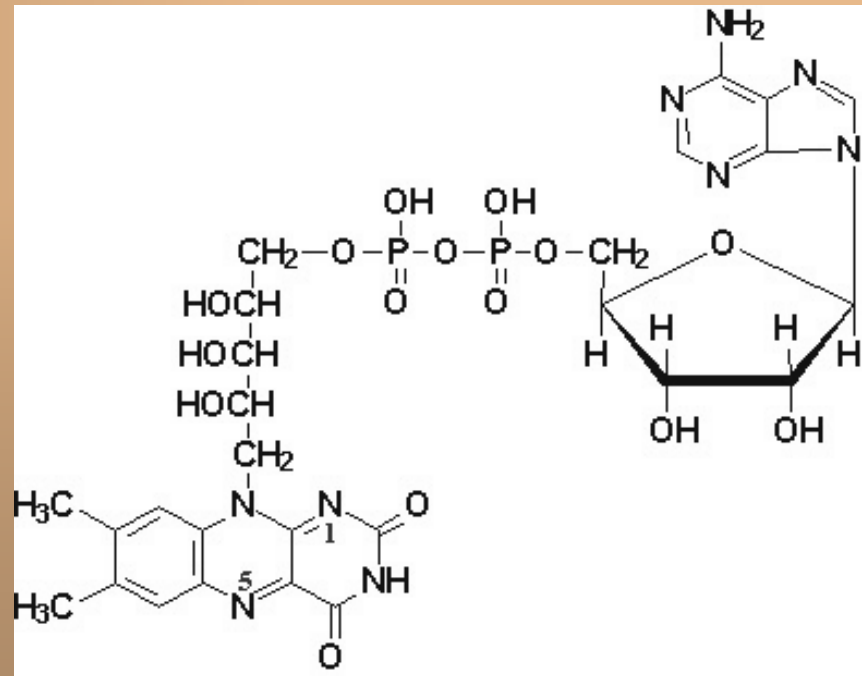
The severe thiamin deficiency disease known as *Beriberi*, is the result of a diet that is carbohydrate rich and thiamin deficient (polyneuritis).

The dietary requirement for thiamin is proportional to the caloric intake of the diet and ranges from 1,0 – 1,5 mg/day for normal adults.

Riboflavin is also known as vitamin B₂. Riboflavin is the precursor for the coenzymes, flavin mononucleotide (**FMN**) and flavin adenine dinucleotide (**FAD**). The enzymes that require FMN or FAD as cofactors are flavin-dependent dehydrogenase (the second enzyme of electron transport chain). Vitamin B₂ is also known as cofactor of amino acids oxidase which provide the process of transamination.



Riboflavin structure



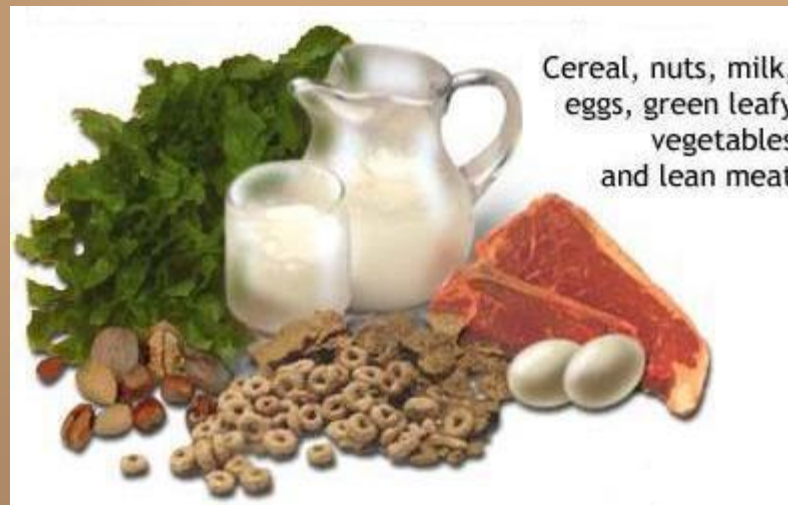
FAD structure

Deficiency

Riboflavin deficiencies are rare in a civilized country due to the presence of adequate amounts of the vitamin in eggs, milk, meat and cereals. Riboflavin deficiency is often seen in chronic alcoholics due to their poor dietetic habits. The normal daily requirement for riboflavin is 1.2 - 1.7 mg/day for normal adults.

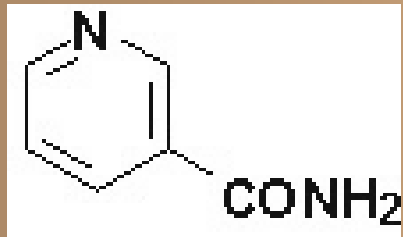
Symptoms associated with riboflavin deficiency include, glossitis, seborrhea, angular stomatitis.

Food sources of B₂

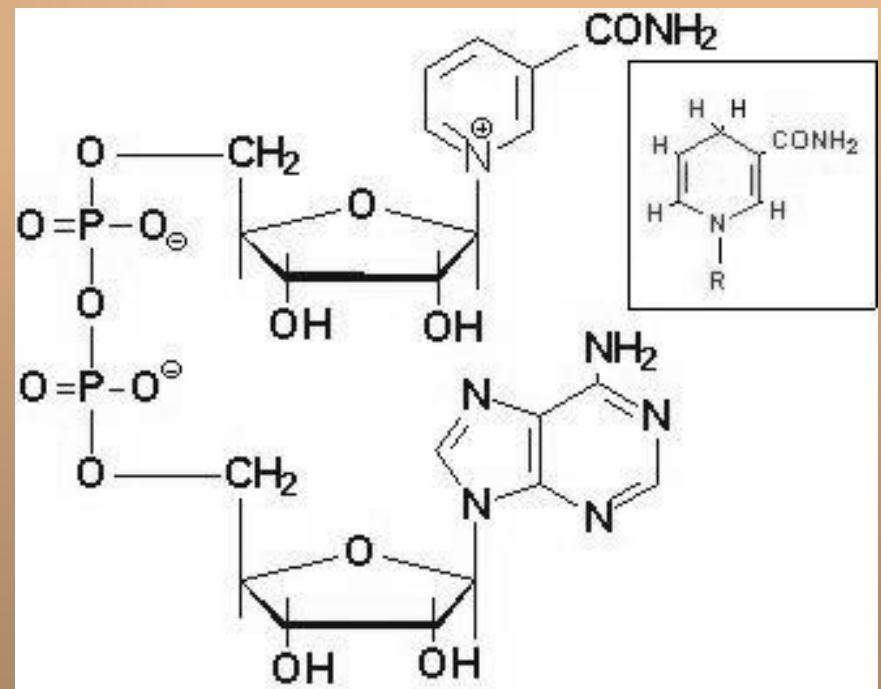


Cereal, nuts, milk,
eggs, green leafy
vegetables
and lean meat

Niacin (nicotinic acid and nicotinamide) is also known as vitamin **B₃**. Both nicotinic acid and nicotinamide can serve as the dietary source of vitamin B₃. Niacin is required for the synthesis of the active forms of vitamin B₃, nicotinamide adenine dinucleotide (**NAD⁺**) and nicotinamide adenine dinucleotide phosphate (**NADP⁺**). Both NAD⁺ and NADP⁺ function as cofactors for numerous dehydrogenase, e.g., lactate and malate dehydrogenases.



Nicotinamide structure

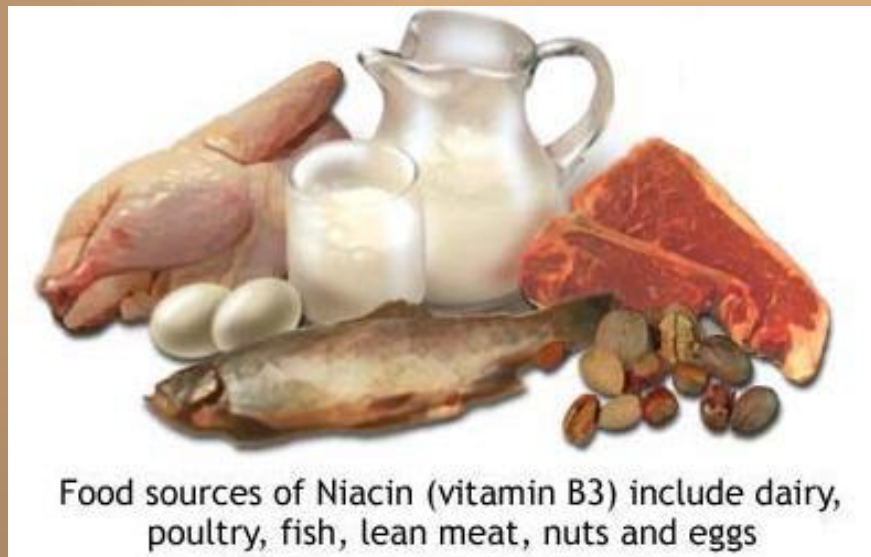


NAD⁺ structure

Nicotinic acid can reduce plasma cholesterol levels and has been shown to be a useful therapeutic for hypercholesterolemia. The major action of nicotinic acid in this capacity is a reduction in fatty acid mobilization from adipose tissue. But nicotinic acid can be synthesized in our cells from amino acid tryptophane in the presence in the presence of vitamin B₆

The recommended daily requirement for niacin is 13-19 niacin equivalents (NE) per day for a normal adult. One NE is equivalent to 1 mg of free niacin).

Food sources of B₃



Food sources of Niacin (vitamin B3) include dairy, poultry, fish, lean meat, nuts and eggs

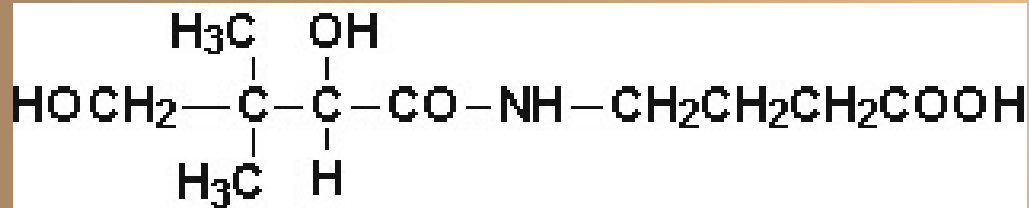
Deficiency

A diet deficient in niacin leads to glossitis of the tongue, dermatitis, weight loss, diarrhea, depression and dementia. The severe symptoms, depression, dermatitis and diarrhea, are associated with the condition known as pellagra.

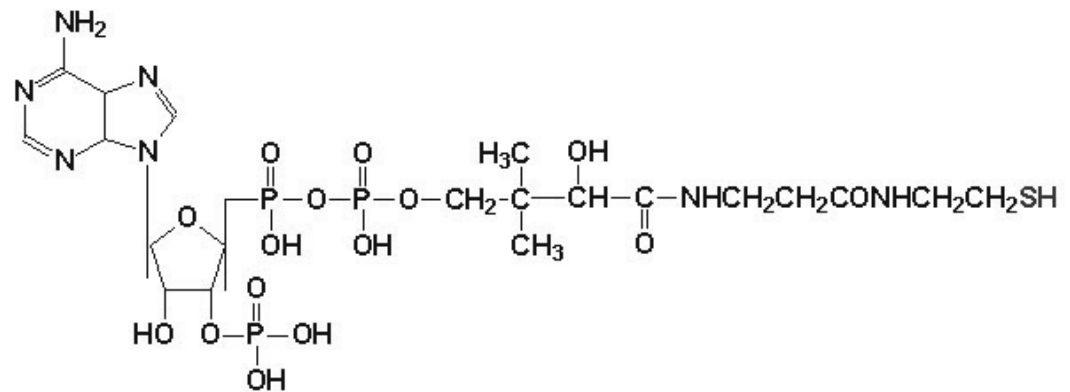


The glossitis and dermatitis under pellagra conditions

Pantothenic acid is also known as vitamin B₅. Pantothenic acid is formed from β-alanine and pantoic acid. Pantothenate is required for synthesis of coenzyme A.



Pantothenic acid structure



Coenzyme A structure

Deficiency of pantothenic acid is extremely rare due to its widespread distribution in whole grain cereals, legumes and meat.

Food sources of pantothenic acid: eggs, fish, milk and milk products, whole-grain cereals, legumes, yeast, broccoli and other vegetables in the cabbage family, white and sweet potatoes, lean beef .

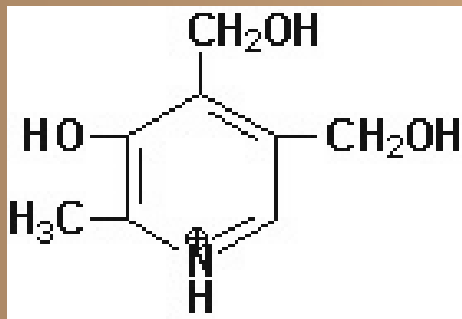


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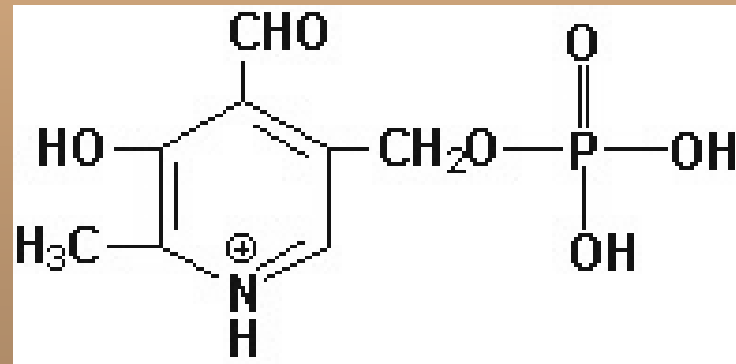
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Pyridoxol, pyridoxamine and **pyridoxine** are collectively known as vitamin **B₆**. All three compounds are efficiently converted to the biologically active form of vitamin B₆, **pyridoxal phosphate**. This conversion is catalyzed by the ATP requiring enzyme, **pyridoxal kinase**.

Pyridoxal phosphate functions as a cofactor in enzymes involved in transamination reactions required for the synthesis and catabolism of the amino acids.



Pyridoxal structure



Pyridoxal phosphate structure

The requirement for vitamin B₆ in the diet is proportional to the level of protein consumption ranging from 1.4 - 2.0 mg/day for a normal adult.

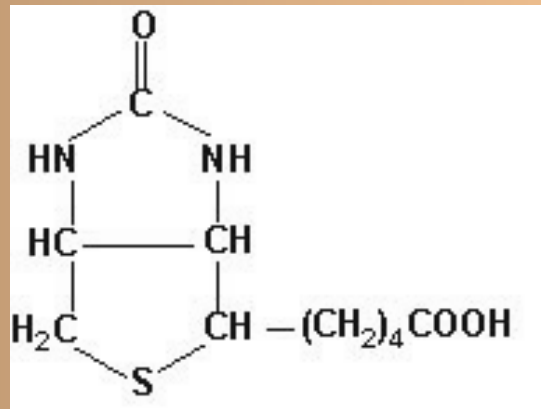
Deficiencies of vitamin B₆ are rare and usually are related to an overall deficiency of all the B-complex vitamins. Isoniazid and penicillamine (used to treat rheumatoid arthritis and cystinurias) are two drugs that complex with pyridoxal and pyridoxal phosphate resulting in a deficiency in this vitamin. Please, pay attention to it.

Food sources of B₆

Food sources of vitamin B₆ (pyridoxine) include beans, legumes, nuts, eggs, meats, fish breads and cereals



Biotin is the cofactor required of enzymes that are involved in carboxylation reactions, e.g. acetyl-CoA carboxylase and pyruvate carboxylase.



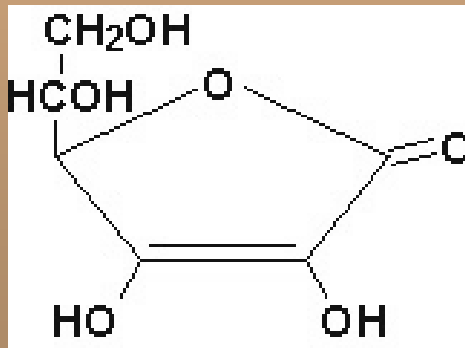
Biotin structure

Biotin is found in numerous foods and also is synthesized by intestinal bacteria and as such deficiencies of the vitamin are rare. Deficiencies are generally seen only after long antibiotic therapies which deplete the intestinal fauna or following excessive consumption of raw eggs. The latter is due to the affinity of the egg white protein, avidin, for biotin preventing intestinal absorption of the biotin.

Ascorbic acid is more commonly known as **vitamin C**.

Vitamin C is responsible for over 300 functions in the body, ranging from being the top anti-oxidant, producing collagen, keeping the immune system healthy, lowering blood pressure and relieving stress. The main function of ascorbate is as a **reducing agent** in a number of different reactions. The most important reaction requiring ascorbate as a cofactor is the hydroxylation of proline residues in collagen. Vitamin C is, therefore, required for the maintenance of normal connective tissue as well as for wound healing since synthesis of connective tissue is the first event in wound tissue remodeling.

Several other metabolic reactions require vitamin C as a cofactor. These include the catabolism of tyrosine and the synthesis of epinephrine from tyrosine and the synthesis of the bile acids.



Ascorbic acids structure

Thereby, vitamin C acts as an electron donor for eight different enzymes:

Three enzymes participate in collagen hydroxylation. These reactions add hydroxyl groups to the amino acids proline or lysine in the collagen molecule via prolyl hydroxylase and lysyl hydroxylase, both requiring vitamin C as a cofactor. Hydroxylation allows the collagen molecule to assume its triple helix structure, and thus vitamin C is essential to the development and maintenance of scar tissue, blood vessels, and cartilage.

Two enzymes are necessary for synthesis of carnitine. Carnitine is essential for the transport of fatty acids into mitochondria for ATP generation.

The remaining three enzymes have the following functions in common, but have other functions as well:

dopamine beta hydroxylase participates in the biosynthesis of norepinephrine from dopamine.

another enzyme adds amide groups to peptide hormones, greatly increasing their stability.

one modulates tyrosine metabolism.

Ascorbic acid is well known for its antioxidant activity, acting as a reducing agent to reverse oxidation in liquids. When there are more free radicals (reactive oxygen species, ROS) in the human body than antioxidants, the condition is called oxidative stress, and has an impact on cardiovascular disease, hypertension, chronic inflammatory diseases, diabetes as well as on critically ill patients and individuals with severe burns.

Deficiency

Deficiency in vitamin C leads to the disease scurvy due to the role of the vitamin in the post-translational modification of collagens. Scurvy is characterized by easily bruised skin, muscle fatigue, soft swollen gums, decreased wound healing and hemorrhaging, osteoporosis, anemia, and loose teeth.



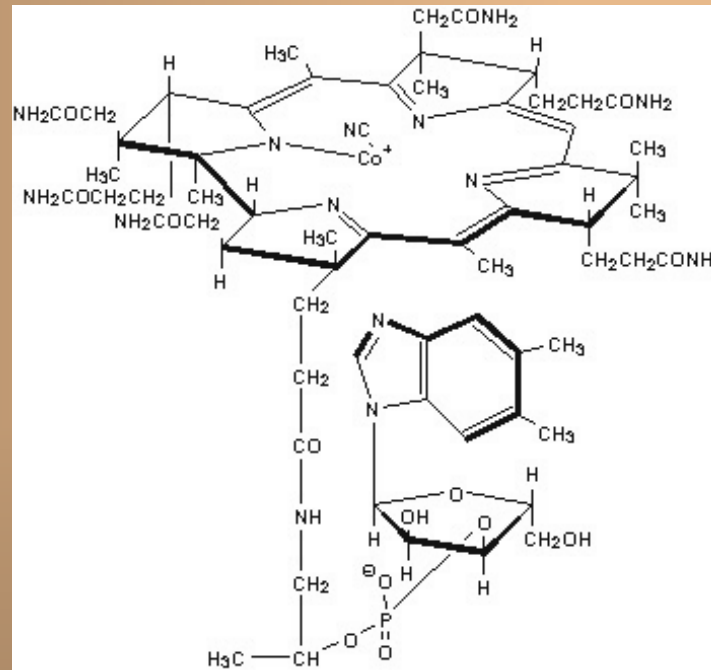
Connective tissue destruction under scurvy

Food sources of C

Citrus fruits, green peppers, strawberries, tomatoes, broccoli and sweet and white potatoes are all excellent food sources of vitamin C (ascorbic acid)



Cobalamin is more commonly known as vitamin **B₁₂**. Vitamin B₁₂ is composed of a complex tetrapyrrol ring structure (corrin ring) and a cobalt ion in the center. Vitamin B₁₂ is synthesized exclusively by microorganisms and is found in the liver of animals bound to protein as methycobalamin or 5'-deoxyadenosylcobalamin. The vitamin is then bound by intrinsic factor (Kastle factor), a protein secreted by parietal cells of the stomach, and carried to the ileum where it is absorbed.



Cobalamin structure

The vitamin B_{12} is necessary for purine and thymidine biosynthesis which are part of DNA.

The liver can store up to six years worth of vitamin B_{12} , hence deficiencies in this vitamin are rare. Pernicious anemia is a megaloblastic anemia resulting from vitamin B_{12} deficiency that develops as a result a lack of intrinsic factor in the stomach leading to malabsorption of the vitamin. The anemia results from impaired DNA synthesis due to a block in purine and thymidine biosynthesis. The block in nucleotide biosynthesis is a consequence of the effect of vitamin B_{12} on folate metabolism.

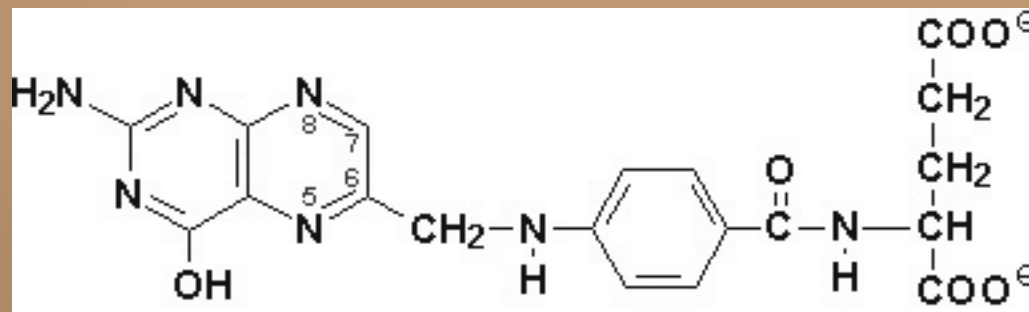
Food sources of B_{12}



Folic acid is a conjugated molecule consisting of a pteridine ring structure linked to para-aminobenzoic acid (PABA) that forms pteronic acid. Folic acid itself is then generated through the conjugation of glutamic acid residues to pteronic acid. Folic acid is obtained primarily from yeasts and leafy vegetables as well as animal liver. Animal cannot synthesize PABA nor attach glutamate residues to pteronic acid, thus, requiring folate intake in the diet.

The function of THF derivatives is to carry and transfer various forms of one carbon units during biosynthetic reactions. The one carbon units are either methyl, methylene, methenyl, formyl or formimino groups.

These one carbon transfer reactions are required in the biosynthesis of serine, methionine, glycine, choline and the purine nucleotides.

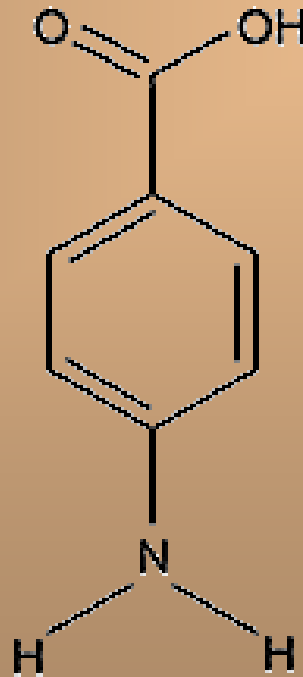


Food sources of B₉

Food sources of folate include beans and legumes, citrus fruits and juices, whole grains, dark green leafy vegetables, poultry, pork, shellfish and liver



p-Aminobenzoic acid a vitamin-like substance and a growth factor required by several types of microorganisms. In bacteria, PABA is used in the synthesis of the vitamin folic acid. The drug sulfanilamide is effective in treating some bacterial diseases because it prevents the bacterial utilization of PABA in the synthesis of folic acid.



Conclusions

1. Vitamins - organic compounds necessary for the normal physiological function, which must be obtained in the diet, because the organism itself cannot synthesized them.
2. Vitamins are traditionally distinguished as being either water-soluble or fat-soluble.
3. The water-soluble vitamins are all components or precursors of coenzymes.
4. The fat-soluble vitamins play essential roles in a variety of critical biological processes, including vision, maintenance of the bone structure, and blood coagulation.
5. The lack of vitamins in the diet results in overt symptoms of deficiency (hypovitaminosis, avitaminosis), the excess of vitamins results in hypervitaminosis.

Do you have any questions?

Thank you for your attention!

