Unit Six

Chemistry of Vitamins

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Unit 6. Chemistry of Vitamins

Definition of Vitamins

Vitamins may be defined as organic compounds occurring in small quantities in different natural foods and necessary for growth and maintenance of good health in human beings. Vitamins are essential food factors, which are required for the proper utilization of the proximate principles of food like carbohydrates, lipids and proteins. In other words, A vitamin is a substance that makes you ill if you don't eat it. Discovery of vitamins started from observation of deficiency manifestations, e.g. scurvy, rickets, beriberi, etc. In general, deficiency of vitamins may occur due to reduced intake, impaired absorption, impaired metabolism, additional requirements and increased losses.

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Classification of Vitamins

The vitamins are mainly classified into two:

1- Fat Soluble Vitamins: They are vitamins A, D, E and K

2- Water Soluble Vitamins: They are named as B complex and vitamin C.

The major differences between these two groups of vitamins are given in the Table below:

Property	Fat Soluble Vitamins	Water Soluble Vitamins
Absorption	Along with lipids Requires bile salts	Absorption simple
Carrier proteins	Present	No carrier proteins
Storage	Stored in liver	No storage
Excretion	Not excreted	Excreted
Deficiency	Manifests only when stores are depleted	Manifests rapidly as there is no storage
Toxicity	Hypervitaminosis may result	Unlikely, since excess is excreted
Treatment of Deficiency	Single large doses may prevent deficiency	Regular dietary supply is required

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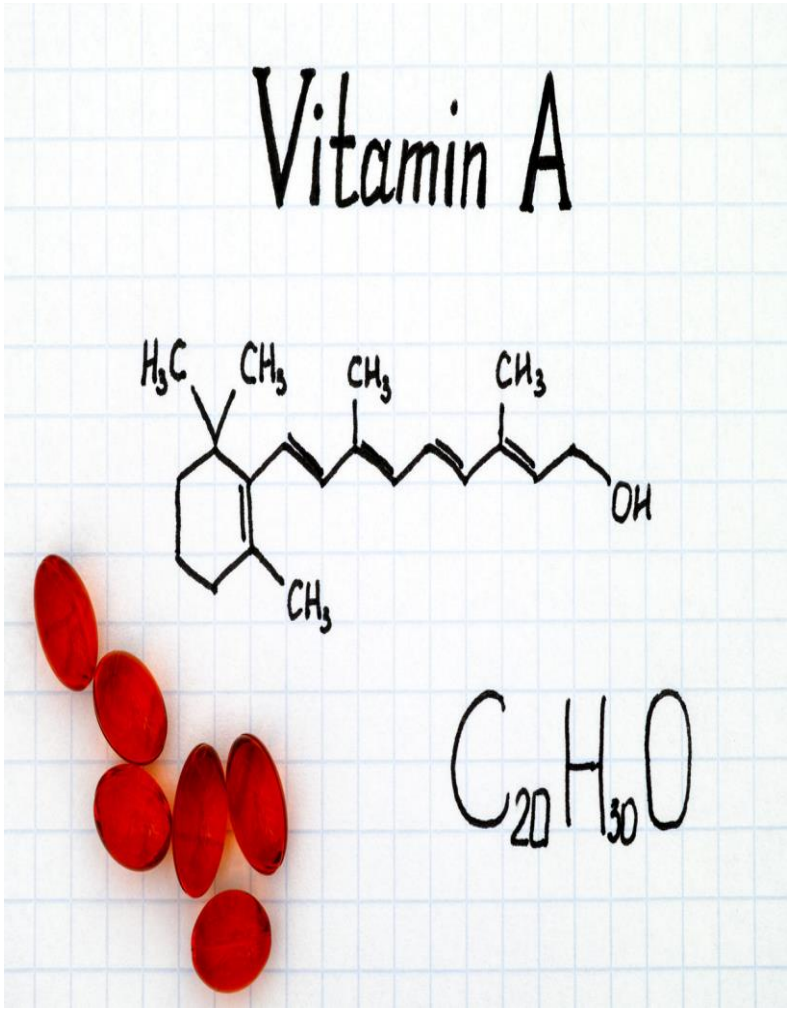
Vitamin A (Retinol or Beta-Carotene)

Vitamin A is a fat soluble. The active form is present only in animal tissues. Intestine is the major site of absorption. The absorption is along with other fats and requires bile salts. In biliary tract obstruction and steatorrhea, vitamin A absorption is reduced. Within the mucosal cell, the retinol is transported to liver. In the liver stellate cells, vitamin A is stored. Vitamin A has a major role in vision, the regulation of gene expression and differentiation of tissues, reproductive system, antioxidant, immune system, preventing heart attacks and maintenance of normal epithelium and skin. Deficiency of Vitamin A could be seen in Night Blindness or Nyctalopia, Xerophthalmia and Keratomalacia.

Excessive intake can lead to toxicity. Symptoms of toxicity include anorexia, irritability, headache, peeling of skin, drowsiness and vomiting. Sometimes swelling over long bones (bony exostosis) may occur with painful bones. Hypercarotenemia can result from persistent excessive consumption of foods rich in carotenoids. The skin becomes yellow, but no staining of sclera as in jaundice is observed.



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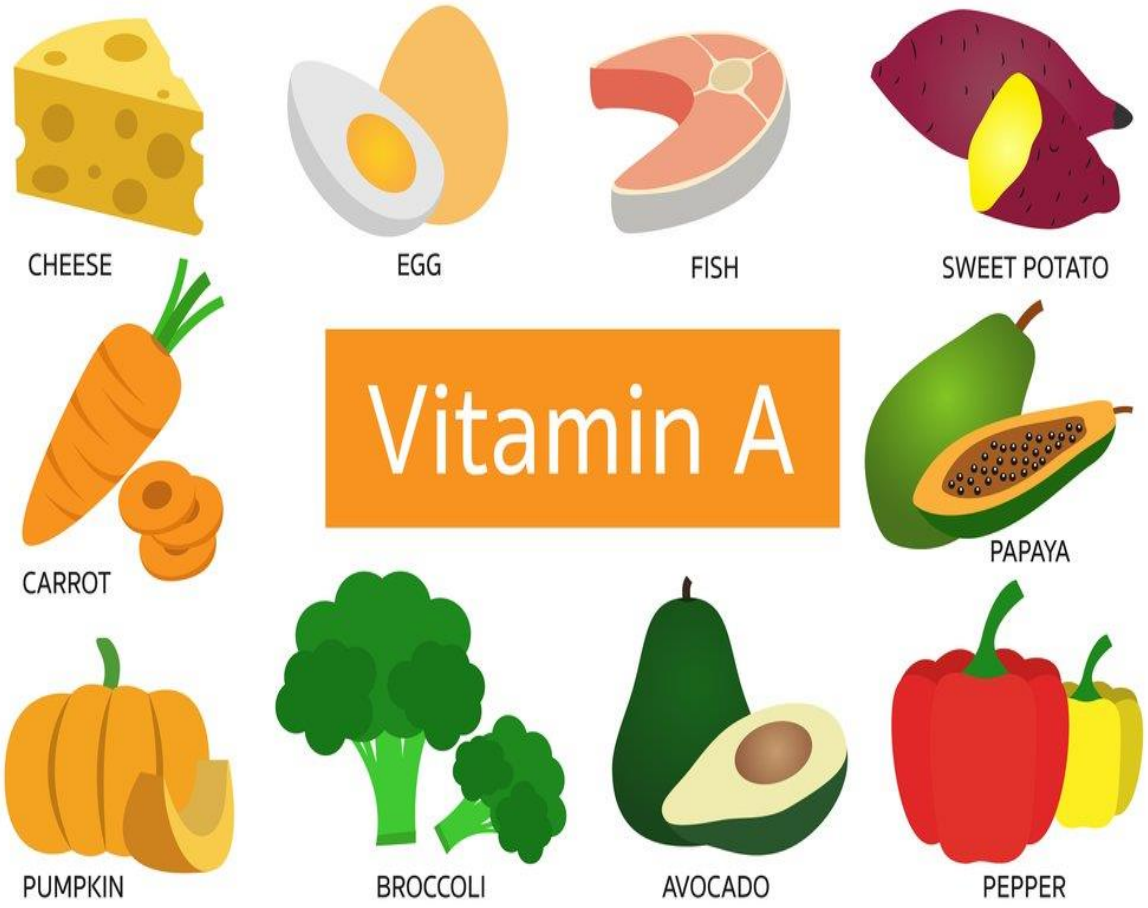
Dietary Sources of Vitamin A

Animal sources include milk, butter, cream, cheese, egg yolk and liver. Fish liver oils (cod liver oil and shark liver oil) are very rich sources of the vitamin. Vegetable sources contain the yellow pigment beta carotene. Carrot contains significant quantity of beta carotene . Papaya, mango, pumpkins, green leafy vegetables (spinach, amaranth) are other good sources for vitamin A activity. During cooking the activity is not destroyed.



Daily Requirement of Vitamin A

The recommended daily allowance (RDA) for:
1. Children = 400–600 µg/day
2. Men = 750–1000 µg/day
3. Women = 750 µg/day
4. Pregnancy = 1000 µg/day

Normal blood level of vitamin A is 25 to 50 mg/dL.

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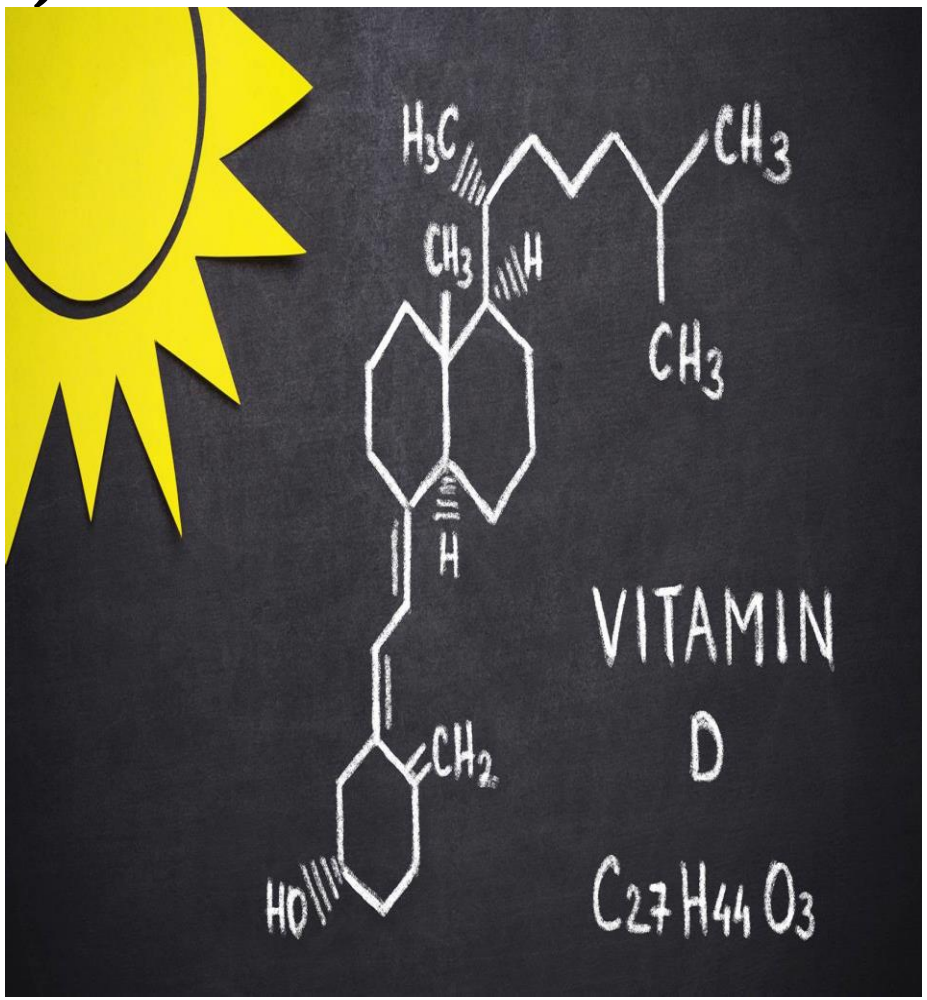
Vitamin D (Cholecalciferol or Calcitriol)

Vitamin D is derived from cholesterol by the action of ultraviolet radiations from the sun. So, vitamin D is called the “sun-shine vitamin”. Vitamin D is activated in the liver and kidney. Vitamin D promotes the absorption of calcium and phosphorus from the intestine. Vitamin D coordinates the remodeling of bone and increases bone mineral density because it has action on all three types of bone cells. It increases the reabsorption of calcium and phosphorus by renal tubules, therefore both minerals are conserved. Vitamin D has been found to be a modulator of immune response. The deficiency diseases are Rickets in children and Osteomalacia in adults. Hence vitamin D is known as antirachitic vitamin. Vitamin D deficiency is associated with increased risks for hypertension, glucose intolerance, impaired synthesis and secretion of insulin, insulin resistance, T2DM, obesity, myocardial infarction, stroke, peripheral vascular disease and asthma.



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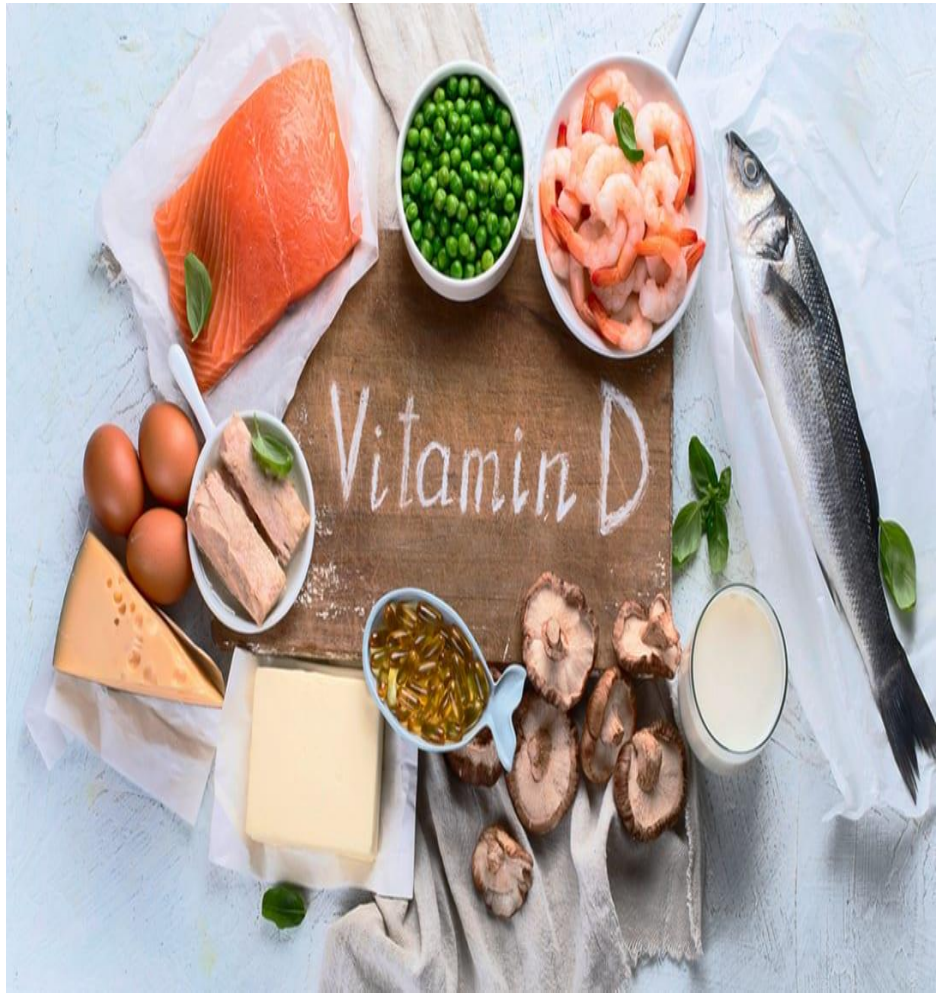
Dietary Sources of Vitamin D

Exposure to sunlight produces Vitamin D. Moreover, fish liver oil, fish and egg yolk are good sources of the vitamin. Milk contains moderate quantity of the vitamin. The current recommendation is to fortify dairy products with vitamin D and adequate exposure to sunlight without sunscreen before 10 am and after 3 pm at least 15 minutes a day (safe sun).



Daily Requirement of Vitamin D

The recommended daily allowance (RDA) for:

1. Children = 10 µg (400 IU)/day
2. Adults = 5 -10 µg (200 IU)/day
3. Pregnancy and lactation = 10 µg/day
4. Above the age of 60 = 600 IU per day.

High doses of vitamin D may cause toxicity. Symptoms include weakness, polyuria, intense thirst, difficulty in speaking, hypertension and weight loss. Hypercalcemia leads to calcification of soft tissues, (calcinosis), especially in vascular and renal tissues. Although vitamin D is toxic in higher doses, excessive exposure to sunlight does not result in vitamin D toxicity, because excess D3 is destroyed by sunlight itself.

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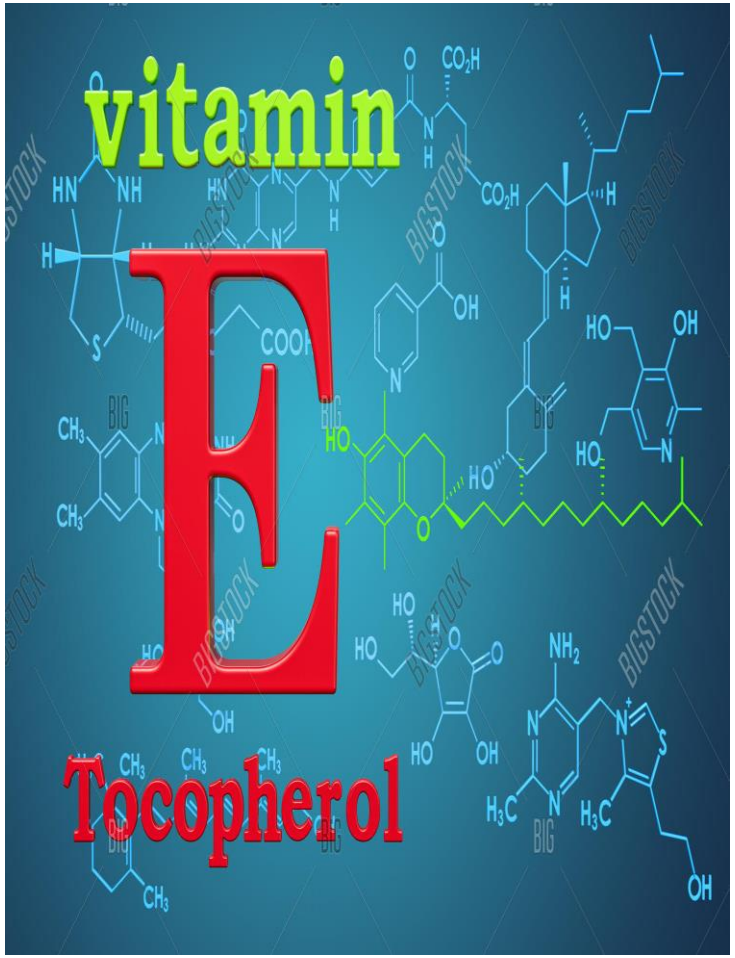
Vitamin E (Tocopherol)

The active vitamin E was isolated from wheat germ oil. Normal blood level of it is 0.5–1 mg/dL. It is absorbed along with other fats and needs the help of bile salts. Vitamin E is a known biological antioxidant able to quench the lipid peroxidation chain and to protect the plasma membranes from the attack of free radicals. Vitamin E also boosts immune response. It reduces the risk of atherosclerosis by reducing oxidation of LDL. Initial studies of induced vitamin E deficiency in laboratory animals resulted in infertility and therefore the vitamin came to be known as anti-infertility vitamin. Vitamin E deficiency causes neurological problems due to poor nerve conduction. These include neuromuscular problems such as spinocerebellar ataxia, retinopathy, peripheral neuropathy and myopathies. Deficiency can also cause anemia, due to oxidative damage to red blood cells. Vitamin E supplementation may be beneficial in Alzheimer's disease. Excessive intake of vitamin E may increase risk of bleeding. At doses above 1000 IU per day, it may cause tendency to hemorrhage, as it is a mild anti-coagulant.



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Dietary Sources of Vitamin E

Vegetable oils are rich sources of vitamin E; e.g. wheat germ oil, sunflower oil, safflower oil, cotton seed oil, etc. Fish liver oils are devoid of vitamin E.

Daily Requirement of Vitamin E

The recommended daily allowance (RDA) for:
1. Males: 10 mg per day
2. Females: 8 mg/day
3. Pregnancy: 10 mg/day

15 mg of vitamin E is equivalent to 33 international units. The requirement increases with higher intake of PUFA. Pharmacological dose is 200–400 IU per day.

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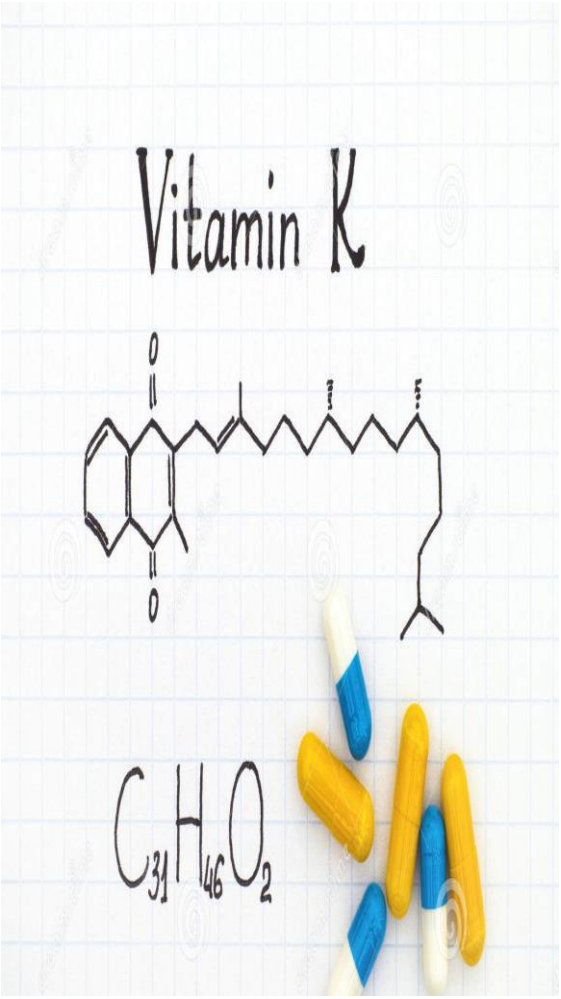
Vitamin K (Naphthoquinone)

Vitamin K is necessary for coagulation. Absorption of vitamin K occurs in the intestine along with chylomicrons. Bile salts are required for the normal absorption. It is stored in the liver and transported in plasma along with lipoproteins. It is also necessary for the functional activity of bones and structural proteins of kidney, lung and spleen. Deficiency can occur in conditions of malabsorption of lipids. This can result from obstructive jaundice or chronic pancreatitis. Prolonged antibiotic therapy and gastrointestinal infections with diarrhea will destroy the bacterial flora and can also lead to vitamin K deficiency. Hemorrhagic disease of the newborn is attributed to vitamin K deficiency. The newborns, especially the premature infants have relative vitamin K deficiency due to lack of hepatic stores, limited oral intake (breast milk has very low levels) and absence of intestinal bacterial flora. In children and adults, Vitamin K deficiency may be manifested as bruising tendency, echymotic patches, mucous membrane hemorrhage, post-traumatic bleeding and internal bleeding. Prolongation of prothrombin time and delayed clotting time are characteristic of vitamin K deficiency. Warfarin and Dicoumarol will competitively inhibit the action of vitamin K. Hence they are widely used as anticoagulants for therapeutic purposes.



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Dietary Sources of Vitamin K

Green leafy vegetables are good dietary sources. Even if the diet does not contain the vitamin, intestinal bacterial synthesis will meet the daily requirements, as long as absorption is normal.

Daily Requirement of Vitamin K

Recommended daily allowance is 50–100 mg/day. This is usually available in a normal diet.

Hemolysis, hyperbilirubinemia, kernicterus and brain damage are the manifestations of toxicity. Administration of large quantities of vitamin K may result in toxicity. This should be kept in mind in treating premature babies.

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Vitamin B1 (Thiamine)

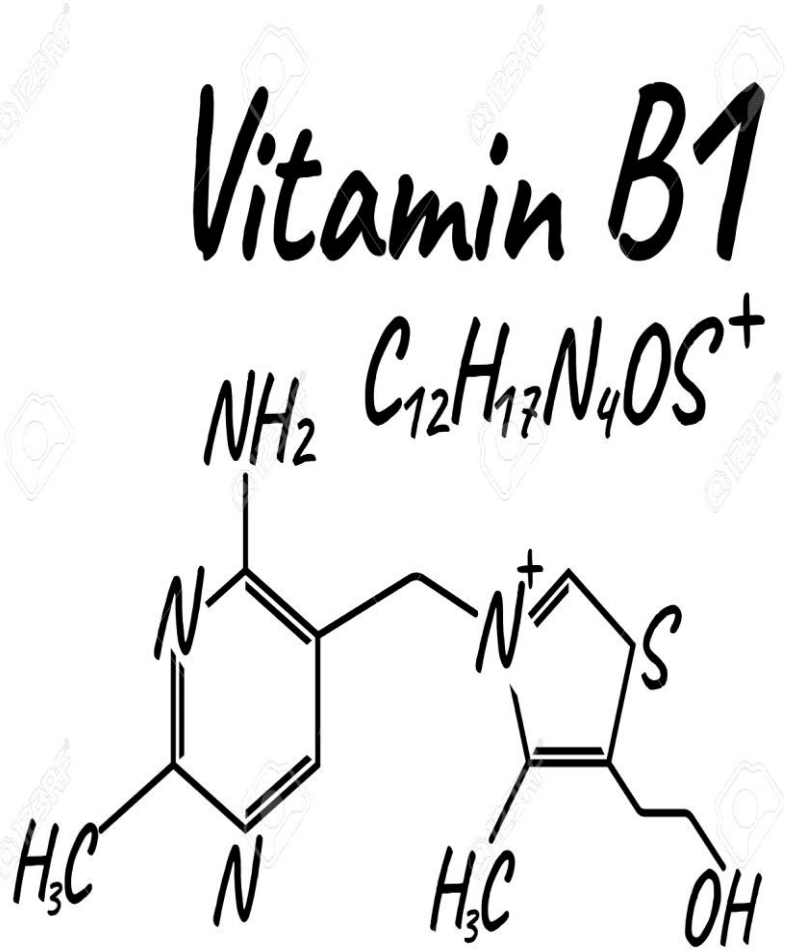
Thiamine plays as co-enzyme in oxidative decarboxylation of alpha keto acids. The main role of thiamine is in carbohydrate metabolism. So, the requirement of thiamine is increased along with higher intake of carbohydrates. Deficiency of thiamine leads to:

1- Beriberi: (meaning "weakness") with these symptoms anorexia, dyspepsia, heaviness and weakness. Subjects feel weak and get easily exhausted.

2- Wet Beriberi: here cardiovascular manifestations are prominent. Edema of legs, face, trunk and serous cavities are the main features. Palpitation, breathlessness and distended neck veins are observed. Death occurs due to heart failure.

3- Dry Beriberi: In this condition, CNS manifestations are the major features. Walking becomes difficult. Peripheral neuritis with sensory disturbance leads to complete paralysis.

4- Infantile Beriberi: It occurs in infants born to mothers suffering from thiamine deficiency. Restlessness and sleeplessness are observed.



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Dietary Sources of Vitamin B1

Aleurone layer of cereals (food grains) is a rich source of thiamine. Therefore, whole wheat flour and unpolished handpound rice have better nutritive value than completely polished refined foods. When the grains are polished, aleurone layer is usually removed. Yeast is also a very good source. Thiamine is partially destroyed by heat.

Daily Requirement of Vitamin B1

It depends on calorie intake (0.5 mg/1000 calories). Requirement is 1–1.5 mg/day. Thiamine is useful in the treatment of beriberi, alcoholic polyneuritis, neuritis of pregnancy and neuritis of old age.

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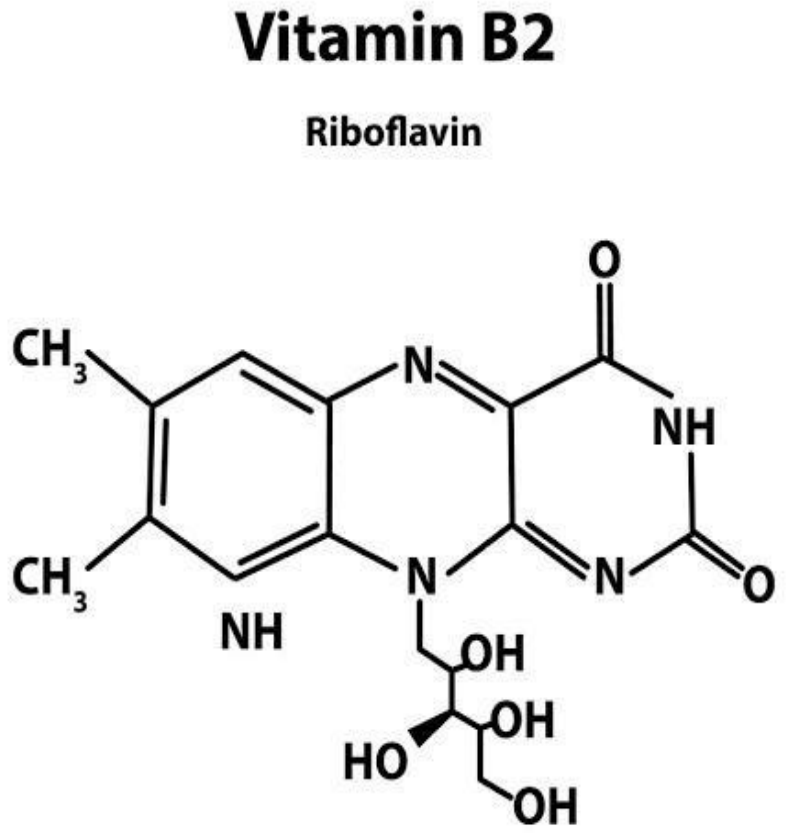
Vitamin B2 (Riboflavin)

Riboflavin was the first B complex component to be isolated in a pure state. This vitamin is synthesized by green plants and microorganisms. Riboflavin is heat stable and act as co-enzyme. Natural deficiency of riboflavin in man is uncommon because riboflavin is synthesized by the intestinal flora. Riboflavin deficiency usually accompanies other deficiency diseases such as beriberi, pellagra and Kwashiorkor. Symptoms are confined to skin and mucous membranes such as Glossitis, Magenta colored tongue, Cheilosis, Angular stomatitis (inflammation at the corners of mouth) and Circumcorneal vascularization. Proliferation of the bulbar conjunctival capillaries is the earliest sign of riboflavin deficiency.



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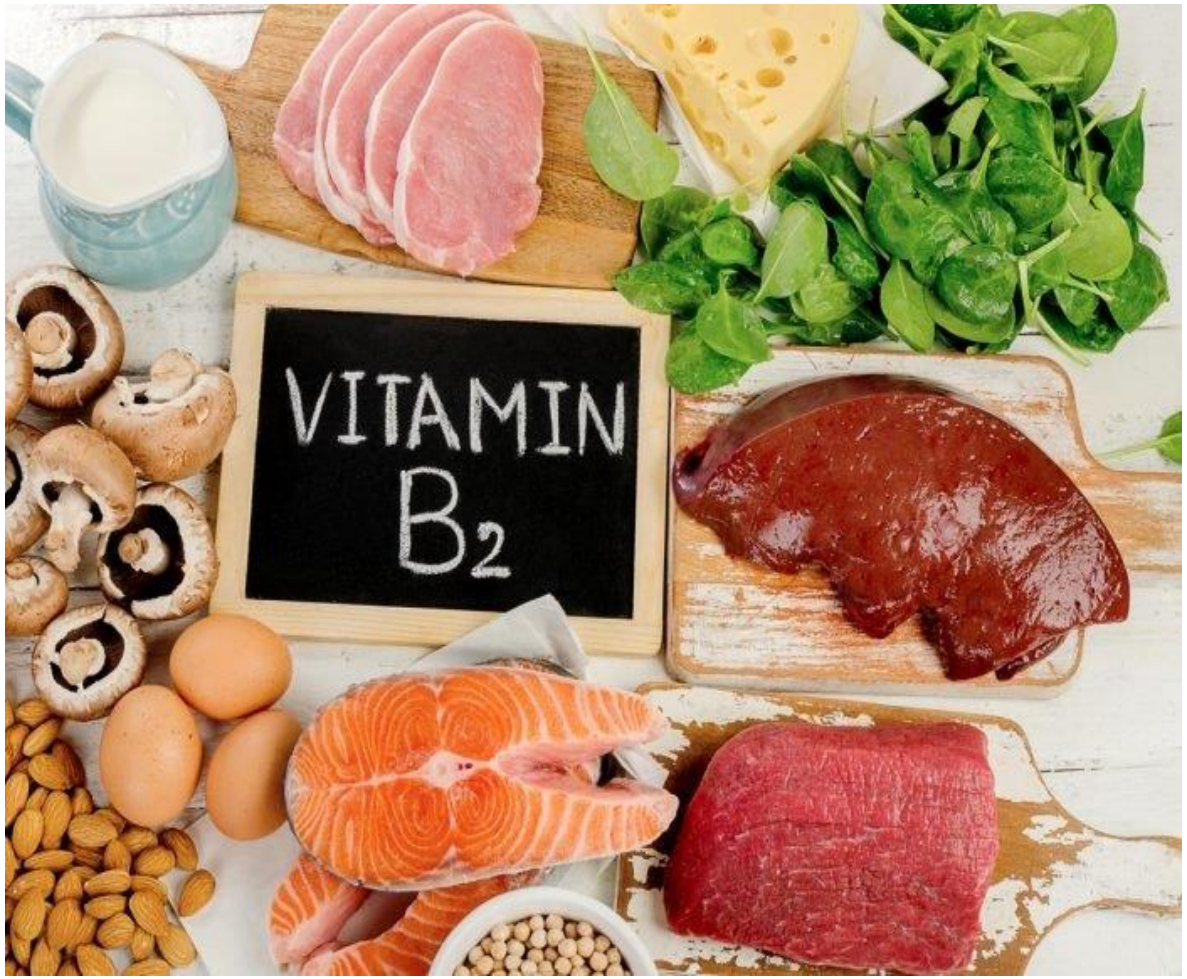
Dietary Sources of Vitamin B2

Rich sources are liver, dried yeast, egg and whole milk. Good sources are fish, whole cereals, legumes and green leafy vegetables.



Daily Requirement of Vitamin B2

Riboflavin is concerned mainly with the metabolism of carbohydrates and requirement is related to calorie intake. Adults on sedentary work require about 1.5 mg per day. During pregnancy, lactation and old age, additional 0.2 to 0.4 mg/day are required.

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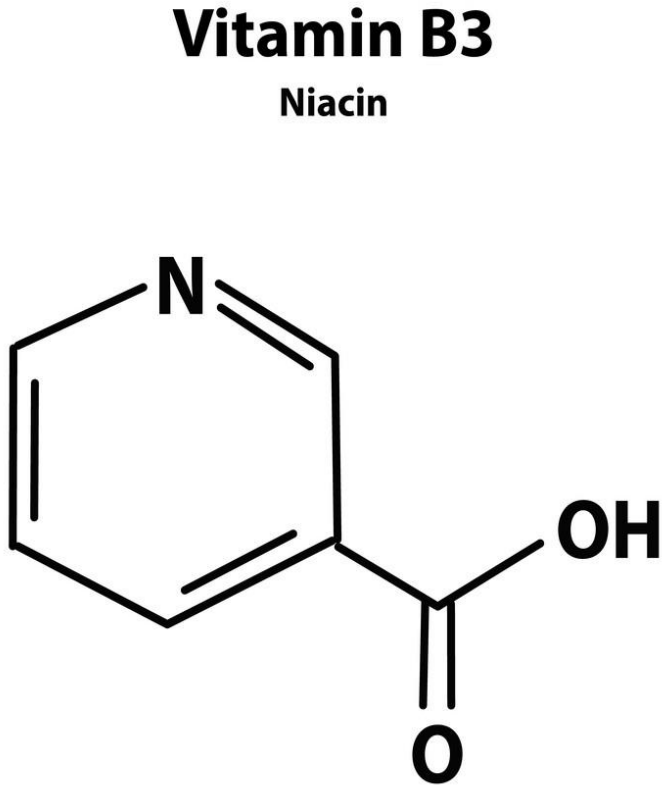
Vitamin B3 (Niacin or Nicotinic Acid)

Niacin is act as co-enzyme. It has very important role in carbohydrate metabolism. Deficiency of niacin and tryptophan leads to the clinical condition called Pellagra. Pellagra is an Italian word, meaning “rough skin”. Pellagra is seen more in women; this may be because tryptophan metabolism is inhibited by estrogen metabolites. The symptoms of pellagra are Dermatitis, Diarrhea and Dementia.

Niacin deficiency may caused by Dietary deficiency of tryptophan, Deficient synthesis, Isoniazid (INH) which is an antituberculous drug, Hartnup disease (congenital disease) and Carcinoid syndrome. Nicotinic acid when given orally or parenterally produces a transient vasodilatation of the cutaneous vessels and histamine release. The reaction is accompanied by itching, burning and tingling. Intake of nicotinic acid in excess of 50 mg/day may lead to liver damage.



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Dietary Sources of Vitamin B3

The richest natural sources of niacin are dried yeast, rice polishing, liver, peanut, whole cereals, legumes, meat and fish. About half of the requirement is met by the conversion of tryptophan to niacin. About 60 mg of tryptophan will yield 1 mg of niacin.

Daily Requirement of Vitamin B3

Normal requirement is 20 mg/day. During lactation, additional 5 mg is required.

Nicotinic acid inhibits the flux of free fatty acids from adipose tissue; so acetyl CoA pool is reduced; and hence serum cholesterol is lowered. In high doses niacin is useful to reduce lipoproteins levels.

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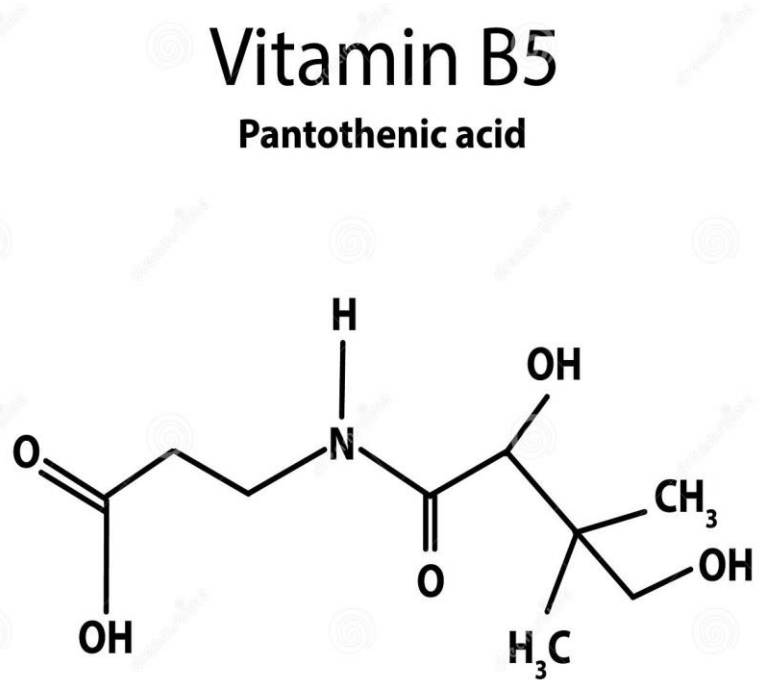
Vitamin B5 (Pantothenic Acid)

Vitamin B5 is widely distributed in nature and it is part of co-enzyme A. Gopalan's Burning Foot Syndrome is manifested as paresthesia (burning, lightning pain) in lower extremities, staggering gait due to impaired coordination and sleep disturbances. These deficiency manifestations are rare in human beings. The syndrome is seen during famine, in prison camps, in chronic alcoholics and in some renal dialysis patients. In experimental animals, deficiency has resulted in anemia (due to reduced heme synthesis), reduced steroidogenesis (due to lack of acetyl CoA), dermatitis, fatty liver and adrenal necrosis.



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Dietary Sources of Vitamin B5

It is widely distributed in plants and animals. Moreover, it is synthesized by the normal bacterial flora in intestines. Therefore, deficiency is very rare. Yeast, liver and eggs are good sources.

Daily Requirement of Vitamin B5

RDA is assumed to be about 10 mg/day.

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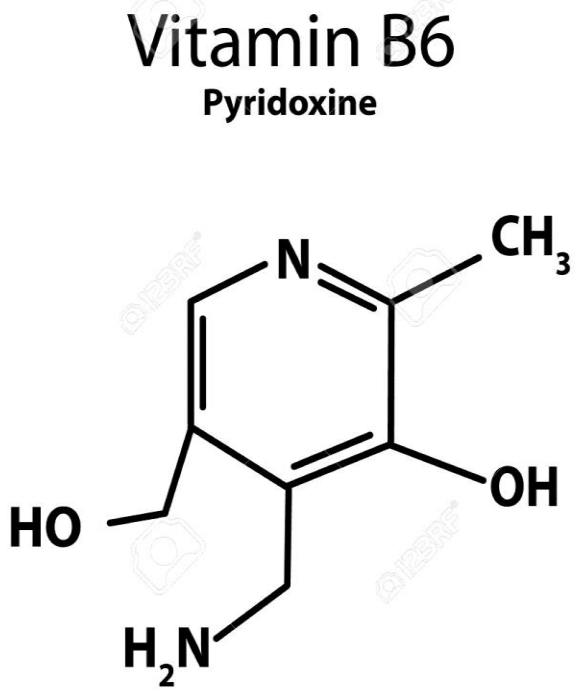
Vitamin B6 (Pyridoxine)

Vitamin B6 acts as co-enzyme for many reactions in amino acid metabolism, heme biosynthesis, niacin biosynthesis and glycogenolysis. Deficiency of Pyridoxine could be seen in Neurological, Dermatological (Pellagra), Hematological manifestations. In adults, hypochromic microcytic anemia may occur due to the inhibition of heme biosynthesis. Impaired antibody formation is also reported. The metabolic disorders which respond to vitamin B6 therapy are xanthurenic aciduria and homocystinuria. There are some drugs lead to vitamin B6 deficiency such as INH, Cycloserine and Oral contraceptives.



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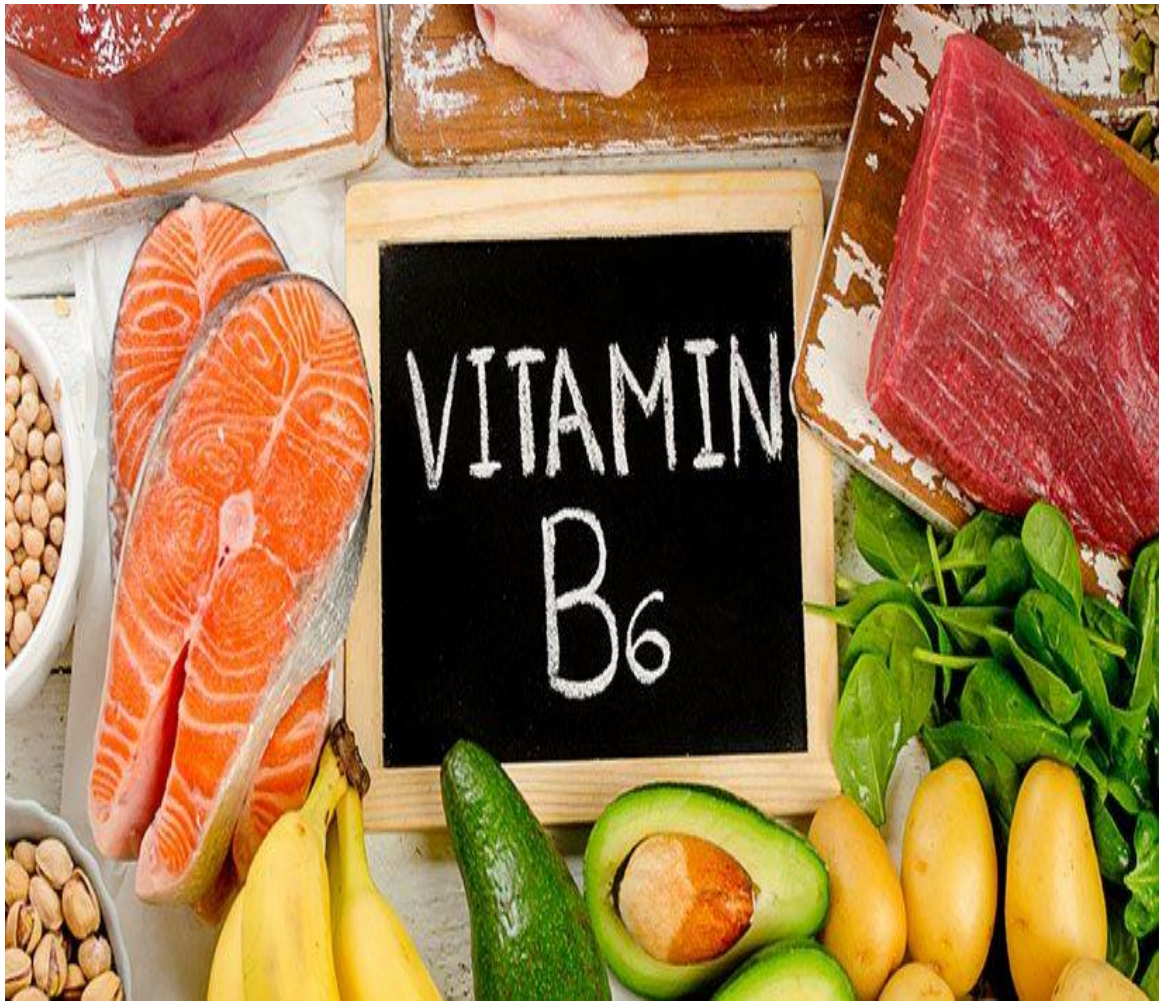
Dietary Sources of Vitamin B6

Rich sources are yeast, rice polishing, wheat germs, cereals, legumes (pulses), oil seeds, egg, milk, meat, fish and green leafy vegetables.



Daily Requirement of Vitamin B6

Vitamin B6 requirements are related to protein intake and not to calorie intake. It is recommended that adults need 1 to 2 mg/day. During pregnancy and lactation, the requirement is increased to 2.5 mg/day. Doses over 100 mg may lead to sensory neuropathy. Further excess is manifested by imbalance, numbness, muscle weakness and nerve damage.

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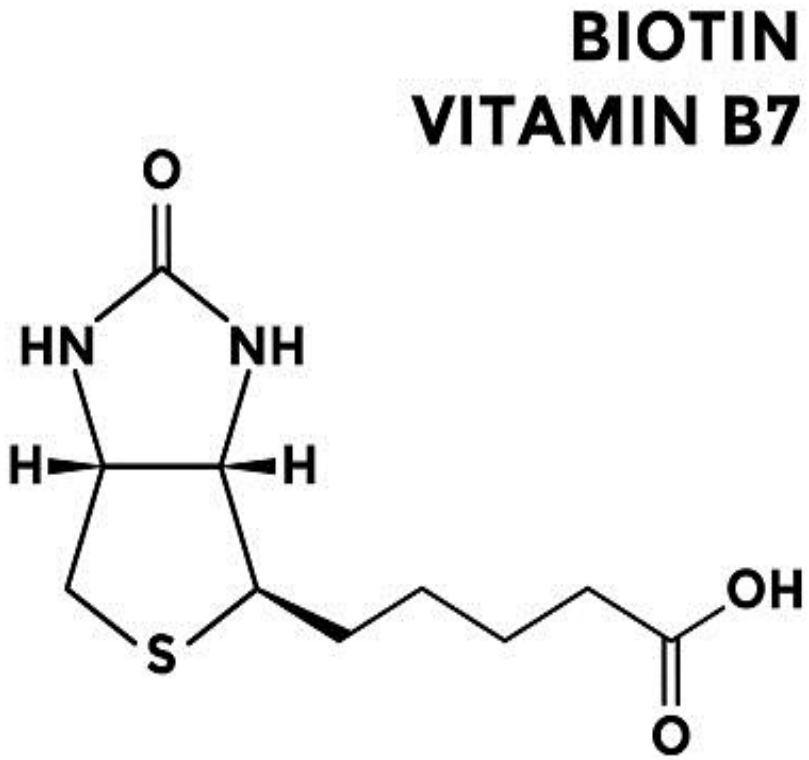
Vitamin B7 (Biotin)

Biotin acts as co-enzyme for carboxylation reactions, urea and pyrimidine synthesis. Biotin was originally named as anti-egg white injury factor. Avidin, a protein present in egg white has great affinity to biotin. Hence intake of raw (unboiled) egg may cause biotin deficiency. Deficiency of biotin may also occur due to Prolonged use of antibacterial drugs. Biotin deficiency symptoms include dermatitis, atrophic glossitis, hyperesthesia, muscle pain, anorexia and hallucinations. Injection of biotin 100–300 mg will bring about rapid cure of these symptoms.



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Dietary Sources of Vitamin B7

Normal bacterial flora of the gut will provide adequate quantities of biotin. Moreover, it is distributed ubiquitously in plant and animal tissues. Liver, yeast, peanut, soybean, milk, egg yolk are rich sources.

Daily Requirement of Vitamin B7

About 200–300 mg will meet the daily requirements.

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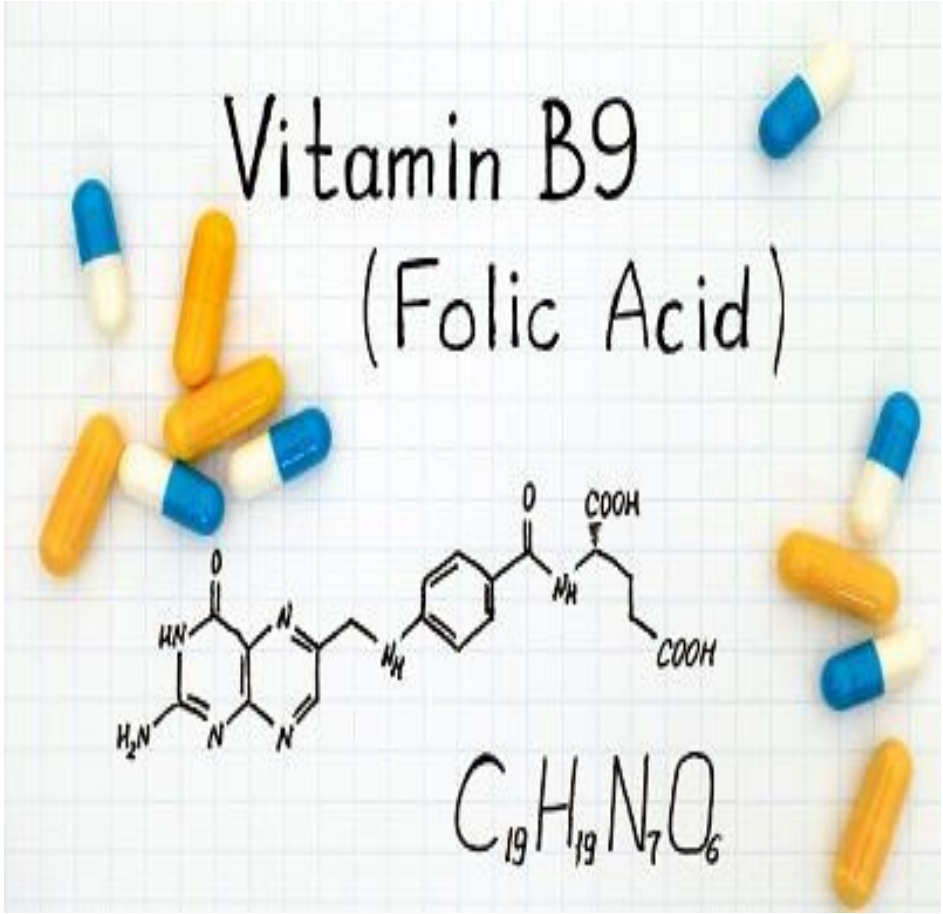
Vitamin B9 (Folic Acid)

Folic acid is abundant in vegetables and readily absorbed by the upper part of jejunum. It is act as co-enzymes for many reactions. Folic acid is not stored in tissues. Folic acid deficiency is very common and seen in Pregnancy, Defective absorption (celiac disease and sprue), Hemolytic anemias, Dietary deficiency and vitamin B12 deficiency. Some drugs could lead to folic acid deficiency such as Anticonvulsant drugs (hydantoin, dilantin, phenytoin, phenobarbitone). Folic acid deficiency could lead to Reduced DNA synthesis, Macrocytic Anemia, coronary artery diseases, Birth Defects and Cancer.



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Dietary Sources of Vitamin B9

Rich sources of folate are yeast, green leafy vegetables.
Moderate sources are cereals, pulses, oil seeds and egg.
Milk is a poor source for folic acid.

Daily Requirement of Vitamin B9

The requirement of free folate is 200 µg/day. In pregnancy the requirement is increased to 400 µg/day and during lactation to 300 µg/day.
Doses over 1 mg may cause aggravation of vitamin B12 deficiency and may precipitate nerve damage. Since solubility of folic acid is low, large doses should not be given parenterally, as there is danger of crystallization in kidney tubules leading to renal damage.

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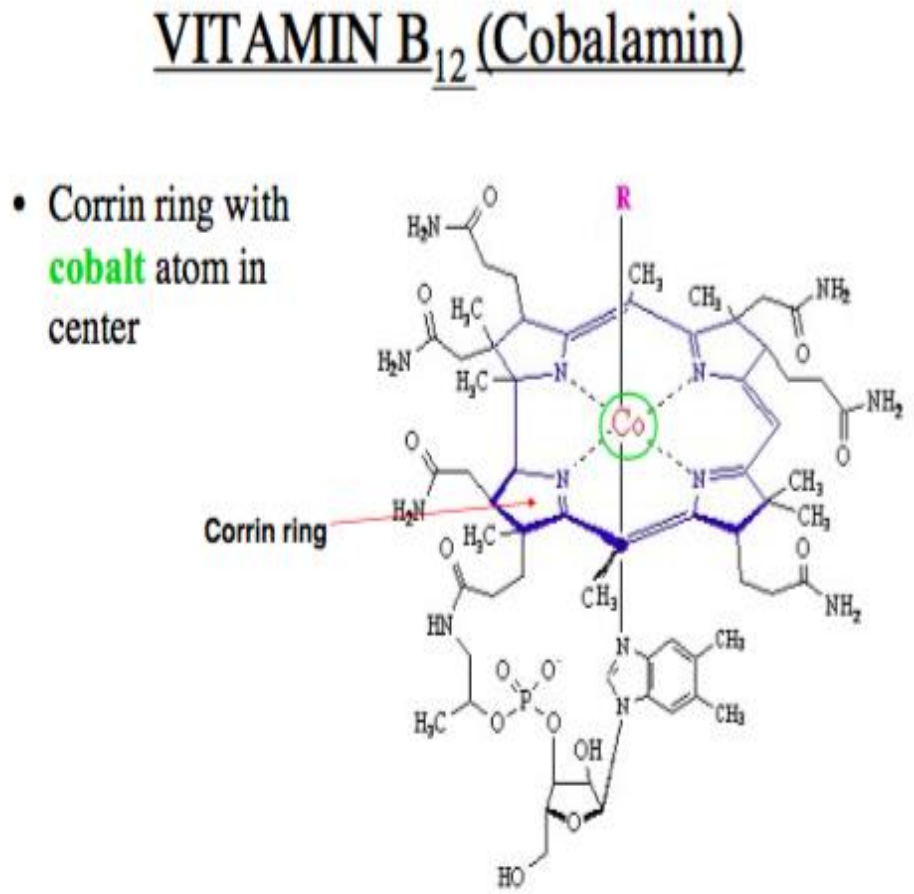
Vitamin B12 (Cobalamin)

Vitamin B12 is heat stable and red in color. It contains 4.35% cobalt by weight. It contains one cobalt atom. Generally, B complex vitamins are not stored in the body, B12 is an exception. Vitamin B12 is act as co-enzyme in many reactions. Its deficiency could be due to Nutrition, Decrease in Absorption, Addisonian Pernicious Anemia, Gastric Atrophy and Pregnancy. This deficiency could lead to Megaloblastic anemia, myocardial infarction, Damage to nervous system and absence of acid in gastric juice. If megaloblastic anemia is treated with folic acid alone, the anemia may improve, but associated neurological symptoms are aggravated. Hence all macrocytic anemias are generally treated with folate and vitamin B12. Therapeutic dose of B12 is 100 to 1000 microgram by intramuscular injections.



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Dietary Sources of Vitamin B12

Vitamin B12 is not present in vegetables. Liver is the richest source. Curd is a good source, because lactobacillus can synthesize B12.

Daily Requirement of Vitamin B12

Normal daily requirement is 1–2 µg/day. During pregnancy and lactation, this is increased to 2 µg/day. Those who take folic acid, should also take vitamin B12. Elderly people are advised to take B12 supplementation.

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Vitamin C (Ascorbic Acid)

Vitamin C is easily destroyed by heat or storage. In the process of cooking, 70% of vitamin C is lost. Most animals and plants can synthesize ascorbic acid from glucose except humans, higher primates, guineapigs and bats are the only species which cannot synthesize it. Therefore, it should be supplied in the diet of these species. Ascorbic acid is readily absorbed from gastrointestinal tract. The ascorbic acid level varies between 0.7 to 1.2 mg/100 mL of plasma and 25 mg/100 cc of WBC. A low level in blood is noted in women taking contraceptive pills and also in chronic alcoholics. Vitamin C is essential for wound healing and immune system. Vitamin C is shared in many reaction, act as anti-oxidant and reduces the risk of cataract formation in the eye. Vitamin C is used as an adjuvant in infections. Beneficial effect of ascorbic acid is reported in the treatment of tuberculosis, when plasma level is kept near to saturation point. Clinical dose is 500 mg per day. Because of its power to heal wounds, vitamin C has been recommended for treatment of ulcer, trauma, and burns. Vitamin C Deficiency could lead to Scurvy, Barlow's Disease, Hemorrhagic Tendency, Internal Hemorrhage, bone disease and Anemia. Since it is a water soluble substance, excess vitamin C is excreted, and not accumulated in the body. However, more than 2000 mg of vitamin C daily for a long time can cause iron overload, because vitamin C helps in absorption of iron.

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Dietary Sources of Vitamin C

Rich sources are amla (Indian gooseberry) (700 mg/100 g), guava (300 mg/100 g), lime, lemon and green leafy vegetables

Daily Requirement of Vitamin C

Recommended daily allowance is 75 mg/day (equal to 50 mL orange juice). During pregnancy, lactation, and in aged people requirement may be 100 mg/day. Smokers and those on oral contraceptives have lower vitamin C levels. Aspirin has been found to block the uptake of vitamin by white blood cells. Hence these people require around 100 mg/day.