

# Introduction to Vitamins

[See online here](#)

**Vitamins are organic compounds that are required in small quantities for normal growth and functioning of the human body. They are different from other organic compounds because they do not undergo degradation to provide energy. Moreover, several B vitamins act as coenzymes in various metabolic reactions in the body. Vitamins differ from hormones in that they are not produced by the body and have to be obtained through diet. They are classified on the basis of their biological and chemical activities.**



## Overview

The **13 vitamins** that are required for the functioning of the human body are as follows:

1. Vitamin A
  - **B vitamins:**
2. Vitamin B1 - Thiamine
3. Vitamin B2 - Riboflavin
4. Vitamin B3 - Niacin
5. Vitamin B5 - Pantothenic acid
6. Vitamin B6 - Pyridoxine
7. Vitamin B7 - Biotin
8. Vitamin B9 - Folate (Folic Acid)
9. Vitamin B12 - Cobalamin

10. Vitamin C
11. Vitamin D
12. Vitamin E
13. Vitamin K

Vitamins can be **classified based on their biological and chemical functions**. They are also often categorized based on their solubility as follows:

- **Fat-soluble** (vitamins A, D, E, and K)
- **Water-soluble** (vitamins B and C, and vitamin A in its beta-carotene form)

**Fat-soluble vitamins** are **hydrophobic** and can be easily stored in the body. They circulate in the body through the lymphatics of the small intestine after being absorbed by the **chylomicrons**.

An increased intake of fat-soluble vitamins predisposes an individual to **hypervitaminosis**. The primary storage sites are the [liver](#) and adipose tissue. Only small amounts of vitamins are required by the body and a deficiency can lead to diseases, such as [rickets](#).

**Pancreatic enzymes are responsible for the digestion** of vitamins. Absorption of fat-soluble vitamins requires bile and pancreatic enzymes. Excessive fat in the stool, i.e., **steatorrhea**, is seen in the following conditions:

- [Pancreatitis](#)
- [Pancreatic cancer](#)
- [Liver disease](#)
- [Crohn's disease](#)
- [Celiac disease](#)
- [Cystic fibrosis](#)
- [Gallstones](#)

**Water-soluble vitamins** cannot be stored in the body, thus, daily intake is essential to avoid deficiency. Owing to their **hydrophilic nature and the presence of polar groups**, these vitamins are water-soluble. Any excess is simply excreted by the kidneys and later via urine; therefore, toxicity caused by water-soluble vitamins is less common.

## Vitamin A – Retinol, Retinoic Acid, Retinal

Vitamin A refers to several compounds, such as retinol, retinoic acid, and retinal, collectively known as retinoids. It is found in fruits and vegetables as provitamin A carotenoids.

- **Dietary sources:** butter, milk, cheese, egg yolks, tomatoes, carrots, spinach, mangoes, and corn
- **Daily requirement:** 400 µg for a 2,000-calorie diet
- A higher requirement for growing children, [expectant women](#), and patients with hepatic disease

## Functions

- Rhodopsin, composed of opsin and retinaldehyde, plays a role in night vision
- **Epithelialization:** it prevents keratinization of epithelial cells
- Helps in **bone metabolism and teeth formation**
- Required for **growth**

- Plays a role in the **metabolism of DNA and protein synthesis**

## Therapeutic uses

- Oral leukoplakia
- [Acute myeloid leukemia](#)
- [Acne](#)

## Deficiency

- **Nyctalopia** (poor night vision)
- Dry and scaly skin
- Decreased endochondral bone formation and osteoblastic activity

## Toxicity

- Nausea
- [Headache](#)
- Irritability
- Teratogenicity
- Skin irritation and hair shedding

## Vitamin E – Tocopherols

Vitamin E refers to a group of compounds that include tocopherols and tocotrienols.  $\gamma$ -tocopherol is the most prevalent form of vitamin E found in the diet, while  $\alpha$ -tocopherol is the most active type.

- **Dietary sources:** wheat, sunflower, grape seed, canola, almond, margarine, cottonseed oil, spinach, and corn oil
- **Daily requirement:** 10 mg for a 2,000-calorie diet
- A higher requirement during pregnancy and [lactation](#)

## Functions

- Owing to its **antioxidant properties**, it contributes to the **oxidation of free fatty acids**
- Plays a role in **aerobic cellular respiration**
- Reduces oxidative stress in conjugation with vitamin C
- Provides more oxygen to RBCs

## Therapeutic uses

- Nocturnal muscular cramps
- [Atherosclerosis](#)
- [Fibrocystic breast disease](#)
- Intermittent claudication

## Deficiency

- [Hemolytic anemia](#)
- [Muscular dystrophy](#)

- Hepatic necrosis
- Immune impairment

## Toxicity

- Interferes with vitamin K and impacts **clotting**. Considered to be synergistic with warfarin and may lead to bleeding
- Can increase oxidant activity, cellular breakdown, and increase the incidence of mortality in cancer
- Can inhibit the synthesis of vitamin K and cause its deficiency

## Vitamin K – Quinone

- **Dietary sources:** fish, meat, broccoli, parsley, lettuce, kale, collard
- Synthesized by **normal intestinal flora**; however, newborns cannot produce vitamin K due to their sterile gut
- **Daily requirement:** 80 µg for a 2,000-calorie diet

## Functions

- Promotes **blood coagulation**; factors II, VII, IX, and X are vitamin-K dependent coagulation factors
- Co-factor in **oxidative phosphorylation**
- Enhances the capacity of calcium-binding proteins to deposit calcium in the required tissues

Although rare, the prolonged use of antibiotics and drugs, such as warfarin, may lead to a deficiency of vitamin K.

## Vitamin D – Calciferol, Calcitriol

- **Dietary sources:** fish liver oil, egg yolk, margarine, lard
- **Daily requirement:** 5 µg for a 2,000-calorie diet; sun exposure is important for conversion into its active form
- There is a higher requirement in infants, children, pregnant, and lactating women

## Activation

Upon exposure to sunlight, **7-dehydrocholesterol** in the skin is converted into **cholecalciferol** (vitamin D3). It then combines with vitamin D2 (ergocalciferol) and is converted to 25-hydroxyvitamin D3 (calcidiol) in the [liver](#). It further undergoes hydroxylation in the kidney to get converted into the active form, 1,25-dihydroxy vitamin D3 (calcitriol).

## Functions

- **Absorption of calcium and phosphate** from the intestines and kidneys
- Enhances bone **mineralization**
- **Lowers colon pH**
- **Increases the citrate content of blood and bones**



**Image:** "Vitamin D deficiency causes rickets in children." by [http://wellcomeimages.org/indexplus/obf\\_images/41/45/54127c3cb9dbd83c3e5ca87e90e6.jpg](http://wellcomeimages.org/indexplus/obf_images/41/45/54127c3cb9dbd83c3e5ca87e90e6.jpg)  
Gallery: <http://wellcomeimages.org/indexplus/image/L0014375.html> License: [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)

## Deficiency

- **Rickets** in children
- **Osteomalacia** in adults
- Renal osteodystrophy

## Toxicity

Hypervitaminosis D occurs if consumed in doses as high as 500 times the normal dose. Toxicity produces the following effects:

- **Immediate:** [anorexia](#), [constipation](#), lassitude, thirst, polyuria, nausea, [vomiting](#), [diarrhea](#)
- **Delayed:** metastatic calcification, urinary lithiasis

## Vitamin B1 – Thiamine

- **Dietary sources:** rice, peas, beans, whole white bread, bran, prunes, nuts, liver, meat, eggs, and milk; also synthesized by the intestinal flora
- **Daily requirement:** 1.4 mg (related to the carbohydrate content in the diet and not the calorific value of food)
- A higher requirement during hemorrhage, increased alcohol intake, prolonged illnesses, use of [antibiotics](#), increased caloric burnout, fever, [hyperthyroidism](#), pregnancy, and [lactation](#)

## Functions

- As a coenzyme in multiple metabolic reactions including oxidative decarboxylation and trans-ketolation in glucose metabolism

- Required for the activity of **tryptophan pyrrolase** during tryptophan metabolism

## Deficiency

Deficiency is rare owing to the wide distribution of vitamin B1 in foods. **Beriberi** results from thiamine deficiency and can be categorized as follows:

- **Dry beriberi**
  - Symmetric muscle wasting
  - Peripheral neuropathy
  - Confusion
  - Difficulty in speech
  - Involuntary eye movements
- **Wet beriberi**
  - Signs and symptoms of dry beriberi
  - **Shortness of breath**
  - **Increased heart rate**
  - **Edema in lower extremities**
  - **Cardiac failure**
- **Wernicke-Korsakoff** syndrome
  - Confusion
  - Nystagmus
  - **Ataxia**
  - Confabulation
  - Mammary body damage
  - Aphasia

## Vitamin B2 – Riboflavin

- **Dietary source:** yeast, beans, peas, green vegetables, nuts, organ meats (livers and kidneys), milk, crab meat, and eggs
- **Daily requirement:** 1.6 mg for a 2,000-calorie diet
- A higher requirement in the case of burns, acute illness, during the use of **broad-spectrum antibiotics**, **pregnancy**, and lactation

## Functions

- Acts as a coenzyme in certain H-transfer reactions in metabolism
- Erythropoiesis

## Deficiency

**Vitamin B2 deficiency is rare but may manifest as the following:**

- **Stomatitis**
- Chapped and fissured lips
- Angular stomatitis
- Scaly skin rashes (scrotum, nasolabial folds, vulva)
- Photophobia
- Normochromic normocytic anemia

## Vitamin B3 – Niacin

- **Dietary sources:** organ meats, fish, legumes, coffee, tea, and nuts
- **Synthesized from tryptophan** and in a limited amount by the gut flora
- **Daily requirement:** 18 mg for a 2,000-calorie diet
- A higher requirement during illnesses, infections, high corn or maize diet, pregnancy, and lactation

## Functions

- **Synthesis of NAD<sup>+</sup> and NADP**, which are co-enzymes in different metabolic reactions
- Nicotinamide formation
- Cholesterol production
- Maintaining function of the nervous system

## Deficiency

Vitamin B3 or tryptophan deficiency can result in a condition called **pellagra**. Its clinical features are known as the 4Ds of pellagra, namely, dermatitis, [diarrhea](#), [dementia](#), and death.

## Therapeutic use

- Reducing high cholesterol levels

## Toxicity

- Skin irritation
- Liver damage
- Flushing of skin

## Vitamin B5 – Pantothenic Acid

- **Dietary sources:** organ meats (kidneys and livers), yeast, egg yolk, skimmed milk, chicken, royal jelly (richest source), and molasses
- **Daily requirement:** 6 mg for a 2,000-calorie diet
- A higher requirement in cases of burns, acute illness, severe injury, use of [broad-spectrum antibiotics](#), growing children, during convalescence, pregnancy, and lactation

## Functions

- Formation of active acetate, acetyl Co-A
- Formation of succinyl Co-A, involved in heme synthesis and degradation of ketone bodies
- Oxidation of fatty acids
- Role in adrenal cortical function

## Deficiency

Although rarely observed owing to its wide distribution in food and synthesis by the gut flora, vitamin B5 deficiency can lead to **burning feet syndrome**.

## Vitamin B6 – Pyridoxine

- **Dietary sources:** yeast, rice bran, egg yolk, royal jelly, and cereals
- **Daily requirement:** 2 mg for a 2,000-calorie diet
- A higher requirement in the second half of pregnancy and during antituberculosis treatment using isoniazid

## Functions

- Coenzyme in transamination and decarboxylation reactions
- Coenzyme for deaminases and kynureninase
- Participates in transsulfuration reactions
- Coenzyme for desulfhydrase
- Synthesis of neurotransmitters
- Protein metabolism (transaminases)
- Erythropoiesis

## Therapeutic uses

- Morning sickness during pregnancy
- [Muscular dystrophy](#)
- Hyperoxaluria
- Recurrent oxalate renal calculi
- Radiation sickness

## Deficiency

A lack of vitamin B6 does not cause any disease; however, the following clinical manifestations are observed:

- Decreased immunity
- Oxaluria
- Peripheral neuropathy
- [Epileptiform convulsions in infants](#)
- [Anemia](#)

The most common cause of deficiency is due to treatment with isoniazid.

## Vitamin B7 – Biotin

- **Dietary sources:** organ meats (livers and kidneys), milk products, molasses, legumes, vegetables, and royal jelly; intestinal microflora synthesize biotin
- **Daily requirement:** 30 µg for a 2,000-calorie diet
- A higher requirement during pregnancy, [lactation](#), and long-term antibiotic therapy



## Functions

- Coenzyme for carboxylases
- Involved in CO<sub>2</sub> fixation
- [Fatty-acid metabolism](#)
- Cellular growth
- Erythropoiesis

## Deficiency

Although biotin deficiency does not result in a specific disease, the following conditions may be observed:

- Holocarboxylase synthase deficiency (inherited)
- Leiner's disease

## Vitamin B9 – Folate (Folic Acid)

- **Dietary sources:** organ meats (livers and kidneys), yeast, green leafy vegetables, cauliflower, spinach, wheat, meat, and fish
- **Daily requirement:** 400 µg for a 2,000-calorie diet
- A higher requirement during [pregnancy and](#) lactation, and in cancers and [hemolytic anemia](#)

## Functions

- Role in one-carbon metabolism reactions
- Important role in hematopoiesis
- Myelination
- Production of DNA nucleotides

## Deficiency

- [Macrocytic anemia](#)
- Weakness
- [Growth retardation](#)
- [Granulocytopenia](#)
- [Thrombocytopenia](#)
- [Megaloblastic anemia](#) (decreased hematocrit and RBC count, increased homocysteine levels, and increased MCV)

Trimethoprim and methotrexate inhibit folate production.

## Toxicity

- [Vitamin B12 deficiency](#)
- Renal damage

## Vitamin B12 – Cobalamin

- **Dietary sources:** organ meats (livers and kidneys), fish, egg, and meat; not present in plants

- **Daily requirement:** 6 µg for a 2,000-calorie diet
- A higher requirement during pregnancy, lactation, and pernicious anemia

## Absorption

**Gastric acid and digestive enzymes** are necessary to unbind vitamin B12 from proteins. The unbound form then binds to the **intrinsic factor** released by the parietal cells of the stomach, which chaperones vitamin B12 to the terminal ileum, where it is absorbed.

## Functions

- Conversion of homocysteine to methionine
- Maintaining neuronal function
- Erythropoiesis
- [Fatty-acid oxidation](#)

## Deficiency

Cobalamin deficiency is observed in the following situations:

- Pernicious anemia (autoimmune disease affecting parietal cells)
- [Crohn's disease](#)
- Bowel resection
- Use of metformin, antacids, and proton pump inhibitors

Since folate cannot be recycled, a deficiency of vitamin B12 leads to **megaloblastic anemia**.

Nervous system disorders arise due to demyelination caused by methylmalonic acid. Peripheral numbness, spasticity, and loss of proprioception are manifestations of vitamin B12 deficiency.

## Vitamin C – Ascorbic Acid

- **Dietary sources:** gooseberry/amla (highest concentration of vitamin C), citrus fruits, papaya, pineapple, banana, strawberry, cabbage, cauliflower, green peas, tomatoes, and potatoes
- **Daily requirement:** 75 mg for a 2,000-calorie diet
- A higher requirement during infections

## Functions



**Image:** "Deficiency of vitamin C causes scurvy." The main clinical manifestation is swollen gums. By Herbert L. Fred, MD and Hendrik A. van Dijk - <http://cnx.org/content/m14986/latest/>. License: [CC BY-SA 3.0](https://creativecommons.org/licenses/by-sa/3.0/)

- Involved in cellular redox reactions
- Collagen synthesis
- Required for the activity of osteoblasts and fibroblasts
- Cofactor in the hydroxylation of tryptophan
- Tyrosine metabolism
- Helps in the maturation of RBCs along with folic acid
- Formation of tissue ferritin
- Iron absorption
- Involved in the electron transport system of mitochondria
- Activates arginase and papain activity and inhibits beta-amylase and urease activity
- Coenzyme for dopamine hydroxylase
- Carnitine formation in the liver
- Alpha oxidation of fatty acids
- Plays an important role during stress

## Therapeutic uses

- Scurvy
- Methaemoglobinaemia
- [Wound healing](#)
- Infectious diseases

## Deficiency

A low intake of vitamin C leads to a disease known as scurvy. It has the following **clinical manifestations**:

- Delayed wound healing
- Poor dentine formation
- Fragile capillaries
- Swollen and bleeding gums
- Poor osteoid mineralization
- Hypochromic microcytic anemia
- Painful swelling of joints and bones
- Loose teeth

- Bruising

## References

Chatterjea, M. N., & Shinde, R. (2011). Textbook of medical biochemistry 8th edition (8th ed.). New Delhi: Jaypee Brothers Medical Publications (P).

[Recommended daily intake of vitamins and minerals](#) via lenntech.com

[Vitamins and minerals – B vitamins and folic acid](#) via nhs.uk

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Notes