# VITAMINS

A **vitamin** is an organic molecule (or related set of molecules) that is an essential micronutrient which an organism needs in small quantities for the proper functioning of its metabolism. Essential nutrients cannot be synthesized in the organism, either at all or not in sufficient quantities, and therefore must be obtained through the diet. Vitamin C can be synthesized by some species but not by others; it is not a vitamin in the first instance but is in the second. The term *vitamin* does not include the three other groups of essential nutrients: minerals, essential fatty acids, and essential amino acids.[2] Most vitamins are not single molecules, but groups of related molecules called vitamers. For example, vitamin E consists of four tocopherols and four tocotrienols. The thirteen vitamins required by human metabolism[*citation needed*] are vitamin A (as all-*trans*-retinol, all-*trans*-retinyl-esters, as well as all-*trans*-beta-carotene and other provitamin A carotenoids), vitamin $B_1$ (thiamine), vitamin $B_2$ (riboflavin), vitamin $B_3$ (niacin), vitamin $B_5$ (pantothenic acid), vitamin $B_6$ (pyridoxine), vitamin $B_7$ (biotin), vitamin $B_9$ (folic acid or folate), vitamin $B_{12}$ (cobalamins), vitamin C (ascorbic acid), vitamin D (calciferols), vitamin E (tocopherols and tocotrienols), and vitamin K (quinones).

Vitamins have diverse biochemical functions. Vitamin A acts as a regulator of cell and tissue growth and differentiation. Vitamin D provides a hormone-like function, regulating mineral metabolism for bones and other organs. The B complex vitamins function as enzyme cofactors (coenzymes) or the precursors for them. Vitamins C and E function as antioxidants.[3] Both deficient and excess intake of a vitamin can potentially cause clinically significant illness, although excess intake of water-soluble vitamins is less likely to do so.

Before 1935, the only source of vitamins was from food. If intake of vitamins was lacking, the result was vitamin deficiency and consequent deficiency diseases. Then, commercially produced tablets of yeast-extract vitamin B complex and semi-synthetic vitamin C became available. This was followed in the 1950s by the mass production and marketing of vitamin supplements, including multivitamins, to prevent vitamin deficiencies in the general population. Governments mandated addition of vitamins to staple foods such as flour or milk, referred to as food fortification, to prevent deficiencies. Recommendations for folic acid supplementation during pregnancy reduced risk of infant neural tube defects.

The term *vitamin* is derived from the word *vitamine*, which was coined in 1912 by Polish biochemist Casimir Funk, who isolated a complex of micronutrients essential to life, all of which he presumed to be amines. When this presumption was later determined not to be true, the "e" was dropped from the name. All vitamins were discovered (identified) between 1913 and 1948

## Classification

Vitamins are classified as either water-soluble or fat-soluble. In humans there are 13 vitamins: 4 fat-soluble (A, D, E, and K) and 9 water-soluble (8 B vitamins and vitamin C). Water-soluble vitamins dissolve easily in water and, in general, are readily excreted

from the body, to the degree that urinary output is a strong predictor of vitamin consumption. Because they are not as readily stored, more consistent intake is important. Fat-soluble vitamins are absorbed through the intestinal tract with the help of lipids (fats). Vitamins A and D can accumulate in the body, which can result in dangerous hypervitaminosis. Fat-soluble vitamin deficiency due to malabsorption is of particular significance in cystic fibrosis.

| **Vitamin** | **Soluble in Water** | **Stable to Air Exposure** | **Stable to Light Exposure** | **Stable to Heat Exposure** |
|---|---|---|---|---|
| Vitamin K | no | no | yes | no |
| Vitamin E | no | yes | yes | no |
| Vitamin D | no | no | no | no |
| Vitamin C | very unstable | yes | no | no |
| Vitamin $B_6$ | yes | ? | yes | ? |
| Vitamin A | no | partially | partially | relatively stable |
| Thiamine ($B_1$) | highly | no | ? | > 100 °C |
| Riboflavin ($B_2$) | slightly | no | in solution | no |
| Pantothenic Acid ($B_5$) | quite stable | no | no | yes |
| Niacin ($B_3$) | yes | no | no | no |

| Vitamin | Soluble in Water | Stable to Air Exposure | Stable to Light Exposure | Stable to Heat Exposure |
|---|---|---|---|---|
| Folic Acid ($B_9$) | yes | ? | when dry | at high temp |
| Cobalamin ($B_{12}$) | yes | ? | yes | no |
| Biotin ($B_7$) | somewhat | ? | ? | no |

| Vitamin generic descriptor name | Vitamer chemical name(s) | Sol. | | Deficiency disease | | Food sources |
|---|---|---|---|---|---|---|
| **Vitamin A** | all-*trans*-Retinol, Retinals, and alternative provitamin A-functioning Carotenoids including all-*trans*-beta-carotene | Fat | | Night blindness, hyperkeratosis, and keratomalacia | | from animal origin as Vitamin A / all-*trans*-Retinol: Fish in general, liver and dairy products;<br>from plant origin as provitamin A / all-*trans*-beta-carotene: orange, ripe yellow fruits, |

| Vitamin generic descriptor name | Vitamer chemical name(s) | Sol. | | Deficiency disease | | Food sources |
|---|---|---|---|---|---|---|
| | | | | | | leafy vegetables, carrots, pumpkin, squash, spinach; |
| **Vitamin $B_1$** | Thiamine | Water | | Beriberi, Wernicke-Korsakoff syndrome | | Pork, wholemeal grains, brown rice, vegetables, potatoes, liver, eggs |
| **Vitamin $B_2$** | Riboflavin | Water | | Ariboflavinosis, glossitis, angular stomatitis | | Dairy products, bananas, green beans, asparagus |
| **Vitamin $B_3$** | Niacin, Niacinamide, Nicotinamide riboside | Water | | Pellagra | | Meat, fish, eggs, many vegetables, mushrooms, tree nuts |
| **Vitamin $B_5$** | Pantothenic acid | Water | | Paresthesia | | Meat, broccoli, avocados |
| **Vitamin $B_6$** | Pyridoxine, Pyridoxamine, Pyridoxal | Water | | Anemia, Peripheral neuropathy | | Meat, vegetables, tree nuts, bananas |
| **Vitamin $B_7$** | Biotin | Water | | Dermatitis, enteritis | | Raw egg yolk, liver, peanuts, leafy green |

| Vitamin generic descriptor name | Vitamer chemical name(s) | Sol. | | Deficiency disease | | Food sources |
|---|---|---|---|---|---|---|
| | | | | | | vegetables |
| **Vitamin $B_9$** | Folates, Folic acid | Water | | Megaloblastic anemia and deficiency during pregnancy is associated with birth defects, such as neural tube defects | . | Leafy vegetables, pasta, bread, cereal, liver |
| **Vitamin $B_{12}$** | Cyanocobalamin, Hydroxocobalamin, Methylcobalamin, Adenosylcobalamin | Water | | Vitamin $B_{12}$ deficiency anemia | | Meat, poultry, fish, eggs, milk |
| **Vitamin C** | Ascorbic acid | Water | | Scurvy | | Many fruits and vegetables, liver |
| **Vitamin D** | Cholecalciferol (D3), Ergocalciferol (D2) | Fat | | Rickets and osteomalacia | | Lichen, eggs, liver, certain fish species such as sardines, certain mushroom species such as shiitake |
| **Vitamin E** | Tocopherols, Tocotrienols | Fat | | Deficiency is very rare; mild hemolytic anemia in newborn infants[15] | | Many fruits and vegetables, nuts and seeds, and seed oils |
| **Vitamin K** | Phylloquinone, Menaquinones | Fat | | Bleeding diathesis | | Leafy green vegetables such as |

| Vitamin generic descriptor name | Vitamer chemical name(s) | Sol. | | Deficiency disease | | Food sources |
|---|---|---|---|---|---|---|
| | | | | | | spinach; egg yolks; liver |

## Anti-vitamins

Anti-vitamins are chemical compounds that inhibit the absorption or actions of vitamins. For example, avidin is a protein in raw egg whites that inhibits the absorption of biotin; it is deactivated by cooking. Pyrithiamine, a synthetic compound, has a molecular structure similar to thiamine, vitamin $B_1$, and inhibits the enzymes that use thiamine.

## Biochemical functions

Each vitamin is typically used in multiple reactions, and therefore most have multiple functions.

### On fetal growth and childhood development

Vitamins are essential for the normal growth and development of a multicellular organism. Using the genetic blueprint inherited from its parents, a fetus develops from the nutrients it absorbs. It requires certain vitamins and minerals to be present at certain times. These nutrients facilitate the chemical reactions that produce among other things, skin, bone, and muscle. If there is serious deficiency in one or more of these nutrients, a child may develop a deficiency disease. Even minor deficiencies may cause permanent damage.

### On adult health maintenance

Once growth and development are completed, vitamins remain essential nutrients for the healthy maintenance of the cells, tissues, and organs that make up a multicellular organism; they also enable a multicellular life form to efficiently use chemical energy provided by food it eats, and to help process the proteins, carbohydrates, and fats required for cellular respiration.

### Sources

For the most part, vitamins are obtained from the diet, but some are acquired by other means: for example, microorganisms in the gut flora produce vitamin K and biotin; and one form of vitamin D is synthesized in skin cells when they are exposed to a certain wavelength of ultraviolet light present in sunlight. Humans can produce some vitamins from precursors they consume: for example, vitamin A is synthesized from beta carotene; and niacin is synthesized from the amino acid tryptophan. The Food

Fortification Initiative lists countries which have mandatory fortification programs for vitamins folic acid, niacin, vitamin A and vitamins B1, B2 and B12.

### Deficient intake

The body's stores for different vitamins vary widely; vitamins A, D, and $B_{12}$ are stored in significant amounts, mainly in the liver, and an adult's diet may be deficient in vitamins A and D for many months and $B_{12}$ in some cases for years, before developing a deficiency condition. However, vitamin $B_3$ (niacin and niacinamide) is not stored in significant amounts, so stores may last only a couple of weeks. For vitamin C, the first symptoms of scurvy in experimental studies of complete vitamin C deprivation in humans have varied widely, from a month to more than six months, depending on previous dietary history that determined body stores.[27]

Deficiencies of vitamins are classified as either primary or secondary. A primary deficiency occurs when an organism does not get enough of the vitamin in its food. A secondary deficiency may be due to an underlying disorder that prevents or limits the absorption or use of the vitamin, due to a "lifestyle factor", such as smoking, excessive alcohol consumption, or the use of medications that interfere with the absorption or use of the vitamin. People who eat a varied diet are unlikely to develop a severe primary vitamin deficiency, but may be consuming less than the recommended amounts; a national food and supplement survey conducted in the US over 2003-2006 reported that over 90% of individuals who did not consume vitamin supplements were found to have inadequate levels of some of the essential vitamins, notably vitamins D and E.

Well-researched human vitamin deficiencies involve thiamine (beriberi), niacin (pellagra, vitamin C (scurvy), folate (neural tube defects) and vitamin D (rickets). In much of the developed world these deficiencies are rare due to an adequate supply of food and the addition of vitamins to common foods. In addition to these classical vitamin deficiency diseases, some evidence has also suggested links between vitamin deficiency and a number of different disorders.

### Excess intake

Some vitamins have documented acute or chronic toxicity at larger intakes, which is referred to as hypertoxicity. The European Union and the governments of several countries have established Tolerable upper intake levels (ULs) for those vitamins which have documented toxicity (see table). The likelihood of consuming too much of any vitamin from food is remote, but excessive intake (vitamin poisoning) from dietary supplements does occur. In 2016, overdose exposure to all formulations of vitamins and multi-vitamin/mineral formulations was reported by 63,931 individuals to the American Association of Poison Control Centers with 72% of these exposures in children under the age of five. In the US, analysis of a national diet and supplement survey reported that about 7% of adult supplement users exceeded the UL for folate and 5% of those older than age 50 years exceeded the UL for vitamin A.