Unit 8 Vitamins

Christiaan Eijkman

Christiaan Eijkman was Dutch physician who showed that the disease Beriberi was actually a nutritional defect. Interestingly, Eijkman discovery was accidental where he noted that chicken fed with polished rice developed Beriberi like symptoms, and feeding them back with unpolished rice made the chicken normal. This eventually led to the identification of the vitamin thiamine (B1). He was awarded Nobel prize along with Sir Fredrick Hopkins for the discovery of vitamins in 1929

Learning Objectives

After studying this unit the students will be able to:

- Distinguish fat and water soluble vitamins
- List the natural sources & dietary requirement of vitamins
- Describe the structure, function and the mode of storage of vitamins in our body
- Explain the different diseases associated with vitamin deficiencies
- Relate vitamins and co-enzyme functions.

Introduction

Vitamins are low molecular weight organic compounds indispensable for the normal activity of the organisms. Their absence causes deficiency symptoms. Most of the vitamins or their derivatives are coenzymes which are essential for many important enzymatic reactions in the cells.

Vitamins are required in small quantities for a variety of biochemical functions in our body. Most of them cannot be synthesised by the body and must be supplied through the diet. Unlike

carbobydrates and lipids, they are not metabolised for providing energy. Normally, a well balanced diet will supply all the necessary vitamins in sufficient quantities.

Classification:

Vitamins are broadly classified into two groups based on their solubility.

i. Fat soluble vitamins

Vitamins A, D, E and K

ii. Water soluble vitamins

Vitamins B complex (B_1, B_2, B_3, B_6 B_{12}, Biotin, Folic acid, Pantothenic acid) and C

8.1 Fat soluble vitamins

The members of this group are vitamin A, vitamin D, vitamin E and vitamin K. All these vitamins are not soluble in water but are readily soluble in fat. These vitamins are present in the liver and fatty tissues. These vitamins can be stored in human body and hence getting too much of these vitamins can also cause problems.

8.1.1 Vitamin A (Retinol):

Vitamin A or Retinol is a poly isoprenoid compound containing a cyclohexenyl ring (Fig. 8.1) . It is found only in foods of animal origin. It is present in almost all species of fish, birds and mammals. The precursor of vitamin A, carotenoid is found in foods of plant origin. The body has the ability to convert carotenoid compound present in the diet into vitamin A. For example beta carotene found in vegetables such as carrot is converted into vitamin A by the symmetrical cleavege by the enzyme β-carotene -15,15'-dioxygenase.

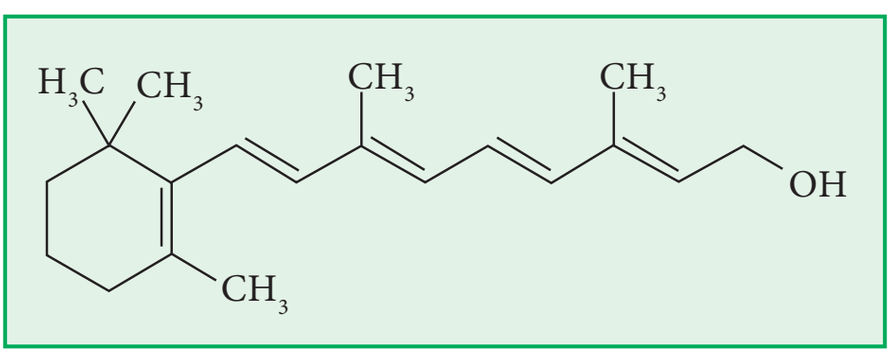

Figure 8.1 Structure of vitamin A

Table 8.1 Comparison of fat and and water soluble vitamins

S. No.	Characteristics	Fat soluble vitamins	Water soluble vitamins
1	Solubility	Fat soluble	Water soluble
2	Absorption	Bile salts are required	Simple intestinal absorption
3	Transportation	Transported by carrier protein	Travels freely in the body without requiring carrier protein (except Vitamin B_{12})
4	Storage	Stored in liver and fatty tissues	Not stored (except vitamin B_{12})
5	Excretion	Usually the surplus vitamins are stored	Surplus vitamins are detected in kidney and removed in urine
6	Accumulation	Usually hypervitaminosis occurs	Usually hypervitaminosis deosn't occur (except in high dosage and slow release of some B vitamins)
7	Deficiency compensation	Required in periodic doses (weeks or months)	Required in frequent doses (1 - 3 days)

Sources:

Liver, oil, butter, milk, egg-yolk, tomato, carrot, green yellow vegetables, spinach and fruits such as mango and papaya (Figure 8.2).

Vitamin-A

Meat : 25000 IU / 100 g

Spinach (Cooked): 1200 IU / 100 g

Beta Carotene

Carrots (Cooked) : 2500 IU / 100 g

Drumstick leaves: 7000-8000 microgram / 100g

Figure 8.2 Sources of vitamin A

Functions of vitamin A:

- Vitamin A plays a significant role in the visual cycle (as a component of rhodopsin).
- Retinoic acid plays a key role in glycoprotein synthesis.
- It is essential for the normal structure and functions of epithelial tissues.
- Retionic acid inhibits the enzyme collagenase and thus prevents the breakdown of collagen.
- Retinoic acid is essential for sulfation of the mucopolysaccharides.
- It promotes fertility.
- It is needed for the formation of bone and teeth.
- β-carotene is an antioxidant and plays a role in trapping peroxy radicals in tissues.

Absorption and storage

Vitamin A and carotene are absorbed from the small intestine into the lymphatic system. The maximum absorption is reached after 3 to 5 hours of food consumption. The rate of absorption of vitamin A is more rapid than that of carotene. In the adult healthy human, only 3% of β-carotene is converted into vitamin A. About 95% of the vitamin A stored in our body is found in the liver and small amount is present in the lungs, adipose tissue and kidneys.

DO YOU KNOW?

Cooking and mashing the vegetables, is it good or bad for β-carotene absorption?

We increase the absorption of β-carotene by steaming, juicing or mashing vegetables. We have to chew well the raw vegetables and fruits in order to maximise the absorption. This causes the cell membranes to rupture and releases more carotene for absorption.

Also the raw vegetables and fruits contain β-carotene in all-trans configuration and cooked vegetables and fruits contain cis-configuration of β-carotene which are more stable and more bioavailable. Therefore, it is best to cook vegetables and fruits in order to maixmise the β-carotene absorption.

Deficiency:

The earliest sign of vitamin A deficiency is concerned with vision. Initially, there is a loss of sensitivity to green light, followed by impairment to adapt to dim light. This condition leads to night blindness. On prolonged or severe deficiency, ulceration of cornea occurs and this condition is known as xerophthalmia or keratomalacia (Figure 8.3).

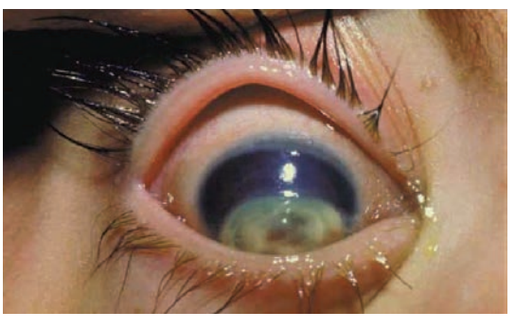

Figure 8.3 keratomalacia.

8.1.2 Vitamin D:

Vitamin D is a sterol compound. It is represented by a group of steroids occuring chiefly in animals, plants and yeast. There are two distinct forms of Vitamin D, namely Vitamin D_2 and Vitamin D_3. Vitamin D_3 is more active than D_2.

Vitamin D_2:

Vitamin D_2 is also known as ergocalciferol. It is produced by the exposure of ergosterol to UV radiation. Ergosterol occurs in plants, milk and yeast.

Vitamin D_3:

Vitamin D_3 is also known as cholecalciferol. It is the natural form of the vitamin ingested from food. It can also be formed by the exposure of 7-dehydrocholesterol present in the skin to sunlight (UV radiation).

Transformation from inactive provitamin D to the active form is accomplished by exposure to sunlight (UV rays). Cholecalciferol is converted to calcifediol (25-hydroxy cholecalciferol) in the liver. Similarly, Ergocalciferol is converted to 25-hydroxyergocalciferol. These calicifediols are further hydroxylated to form calcitriols (1,25-dihydroxy cholecalciferol & 1,25-dihydroxy ergocalciferol), the biologically active form of vitamin D. The calcitriol circulates as a hormone in the blood.

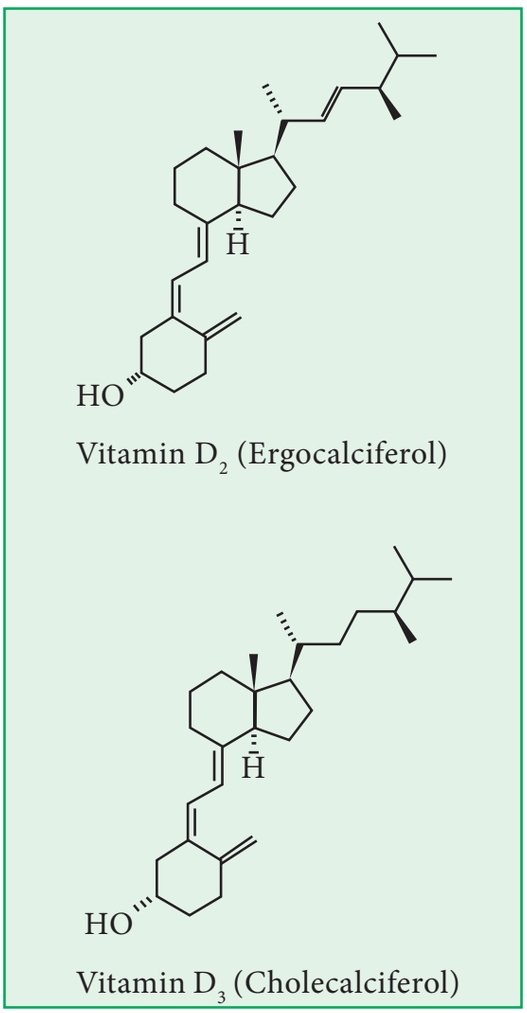

Figure 8.4 Structure of vitamin D

Sources:

Fish liver oil is the richest source of vitamin D. Milk, butter and egg yolk also contain considerable quantity of vitamin D (Fig. 8.5).

Egg yolks: 3- 10 microgram/g

Functions:

- Vitamin D is required for normal growth in mammals. This is probably related to absorption and utilization of calcium and phosphorous.
- It helps in the normal development of bone and teeth.

Absorption and storage

- Vitamin D absorption occurs from small intestine. Fat and bile are essential for its absorption. Vitamin D enters into the general circulation via lymph and stored mainly in liver and kidneys.

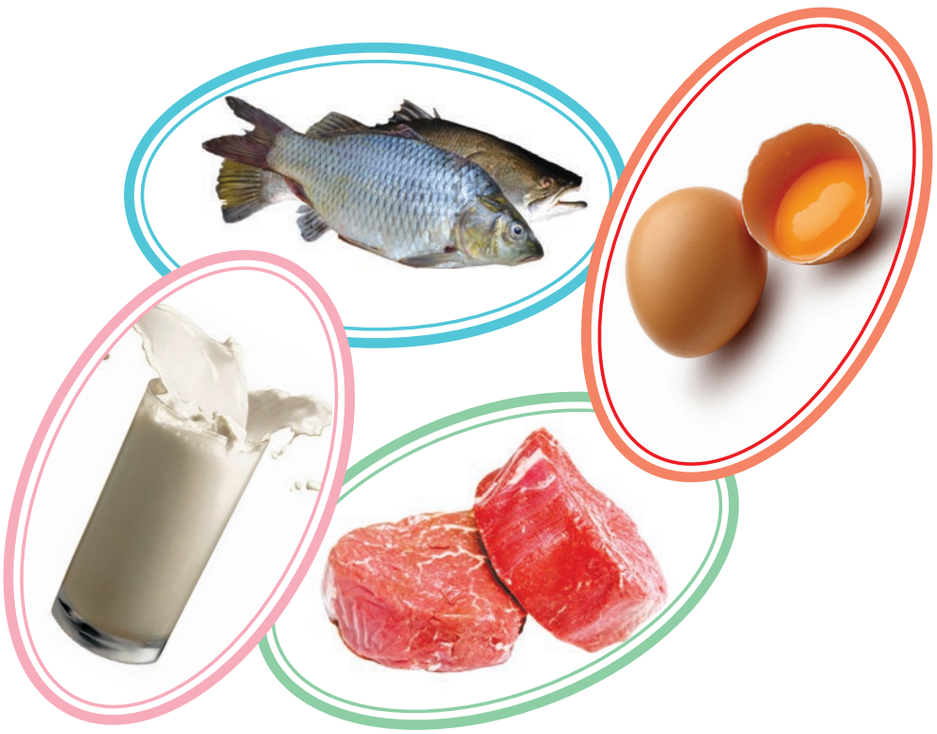

Figure 8.5 Sources of vitamin D

Deficiency:

Deficiency of this vitamin causes rickets in growing children and osteomalacia in adults (Fig. 8.6). It is due to softening of bones resulting from lack of calcium and phosphate.

Figure 8.6 Rickets and Osteomalacia

Toxicity:

Vitamin D toxicity can occur if one consumes over 10,000 IU per day (1000 IU per day in children) for several months. This causes hypervitaminosis D, which increases the blood calcium levels. This results in bone loss and kidney stones. Long-term overconsumption of vitamin D can cause calcification of organs such as the heart, blood vessels and the kidneys.

8.1.3 Vitamin E:

Vitamin E comprises of a group of isoprenoid substituted compounds called tocopherols (Fig. 8.7). It also includes tocotrienols. The most common form of vitamin E is alpha tocopherol which is present in large quantities in human body. The most abundant form of vitamin E in diet is gamma tocopherol.

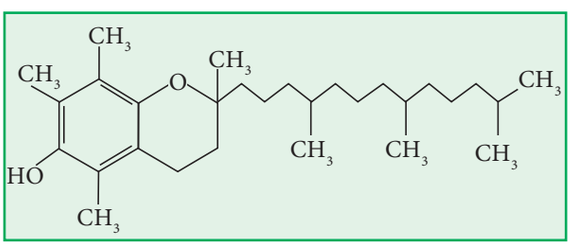

Figure. 8.7 Structure of vitamin E (alpha tocopherol)

Sources:

Cotton seed oil, sun flower oil, wheat germ oil and leafy vegetables are the rich natural sources (Figure. 8.8).

Groundnut oil: 261mg/100g

Wheat germ oil: 150 mg/100g

Figure 8.8 Sources of vitamin E

Functions:

- **Antioxidant property**:

Vitamin E is involved in removal of free radicals and prevents their effects on unsaturated lipids of membrane and thus helps maintain the integrity of cell membrane.

- It protects the red blood cells against hemolysis.
- It plays a role in normal functioning of muscles.
- Vitamin E is essential for reproductive processes.
- It plays an important protective role during ageing of cells.
- Vitamin E is essential for biosynthesis of coenzyme Q.

Absorption and storage:

Vitamin E, like other fat soluble vitamins, is absorbed along with fat in the small intestines. It is stored in the liver, muscle and body fat.

Deficiency:

Vitamin E deficiency causes the following conditions in animals.

- Reproductive failure
- Muscular dystrophy
- Combined deficiency of vitamin E and selenium causes hepatic necrosis.

8.1.4 Vitamin K:

Vitamins belonging to the K group are poly isoprenoid substituted naphthoquinones. It is known as the anti-hemorrhagic vitamin.

Three compounds which have the biological activity of vitamin K are:

- Phylloquinone,which is found in green leafy vegetables.
- Menaquinones, which are a family of closely related compounds synthesized by the intestinal bacteria, with different lengths of the side chain.
- Menadione, a synthetic compound which can be metabolized to yield phylloquinone.

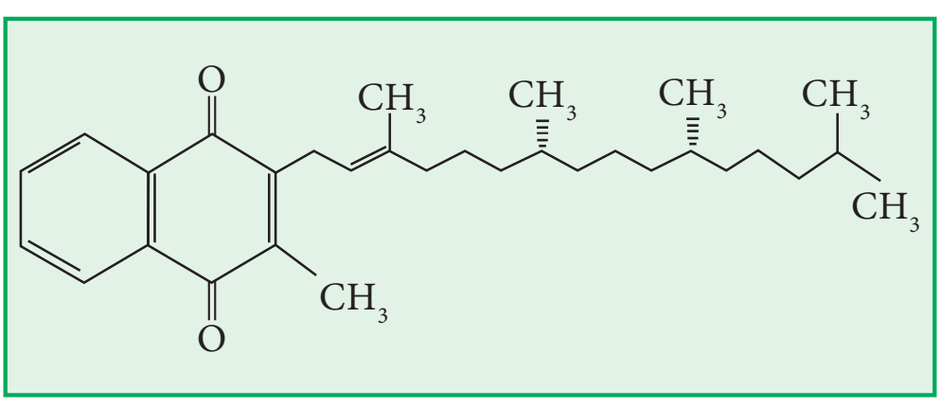

Figure 8.9 Structure of vitamin K

Sources:

Green vegetables, soybean oils, tomatoes, spinach and cabbage are chief plant sources (Fig. 8.10).

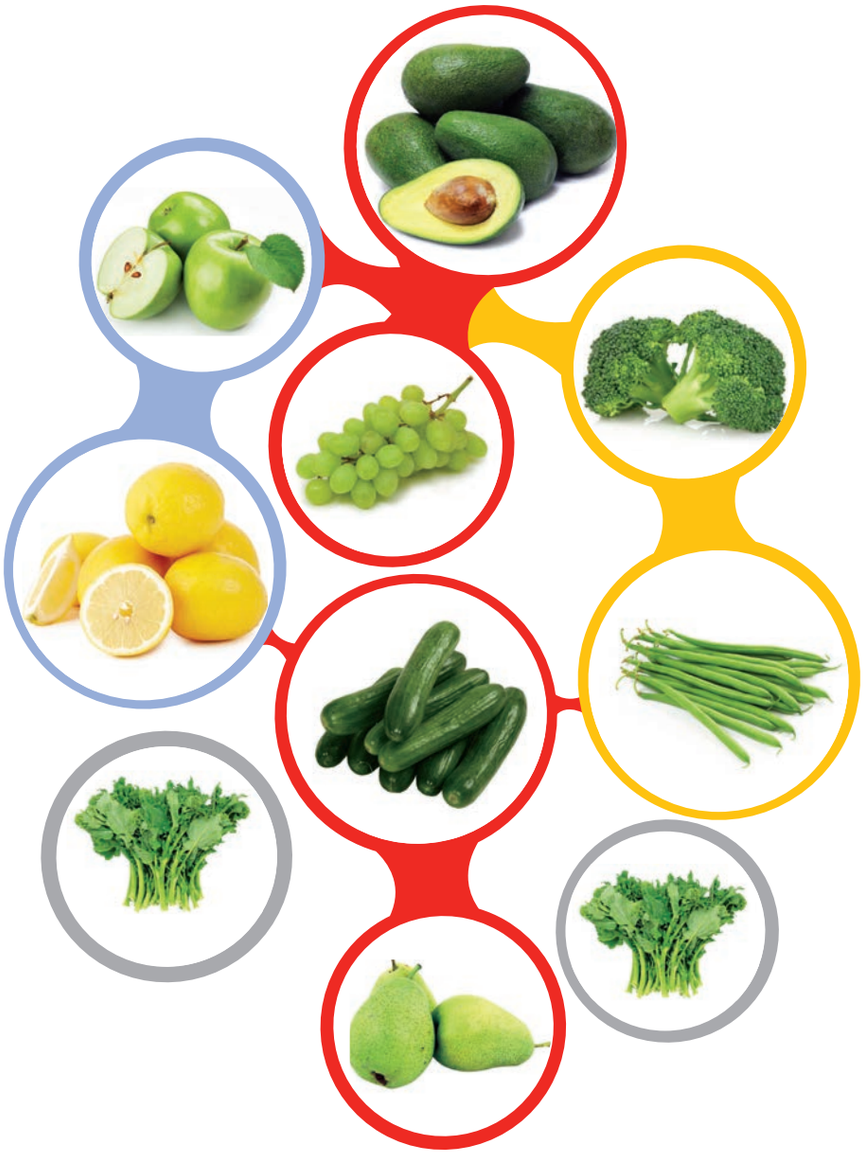

Figure 8.10 Sources of vitamin K

Functions:

- Vitamin K is essential for the synthesis of prothrombin, a substance necessary for blood clotting. That is why it is called as an anti-haemorrhagic vitamin.
- Vitamin K is needed to carboxylate specific glutamate residues of calcium binding proteins of bones, spleen and kidneys. This enhances the capacity of these proteins to deposit calcium in the tissues concerned.
- It plays a key role in the respiratory chain mechanism and oxidative phosphorylation.

Absorption and storage

- Absorption occurs in intestine. Being fat-soluble, its absorption is enhanced by sufficient amount of bile salts. mainly in the jejunum by the way of lymphatus. Liver stores appreciable amounts of vitamin K.

Deficiency:

- Deficiency of vitamin K is very rare, as most of the daily foods contain this vitamin. In addition, intestinal flora of micro organisms synthesize adequate quantity of vitamin K.
- The deficiency of vitamin K leads to a lowering of prothrombin level and increased clotting time of blood. This may lead to hemorrhagic conditions (Figure. 8.11).

Figure 8.11 Hemorrhagic condition

8.2 Water soluble vitamins:

The members of this group are B-complex vitamins and vitamin C . They are readily soluble in water and can be transported freely in the blood and the watery fluids between the cells. However, vitamin B_{12} needs a binding protein for the transport. Excess of these vitamins are eliminated via kidneys. Unlike other members of this family the vitamin B_{12} is eliminated through bile. As these are readily soluble in water these vitamins are easily lost during cooking.

8.2.1 B-complex vitamins

The vitamin B has a group of vitamins (B_1, B_2, B_3, B_5, B_6, B_{12}, biotin and folate). All these vitamins needs to be converted into the corresponding coenzymes which is their active form. They are useful in the synthesis of many neurotransmitters such as acetylcholine.

i. Vitamin B_1 (Thiamine)

Vitamin B_1 which is also called as thiamine contains pyrimidine and thiazole ring. Thiamine pyrophosphate (TPP) is known as active thiamine. Thiamine pyrophosphotransferase (ATP dependent enzyme) present in brain and liver is responsible for conversion of thiamine to thiamine pyrophosphate.

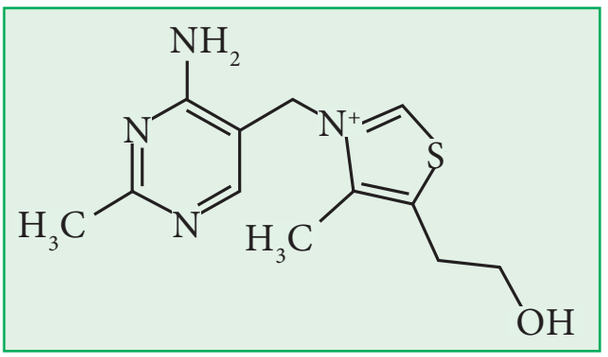

Figure 8.12 Thiamine

Sources:

Liver, pork, meat, and rice are rich sources. Other good sources are beans and nuts (Figure 8.13).

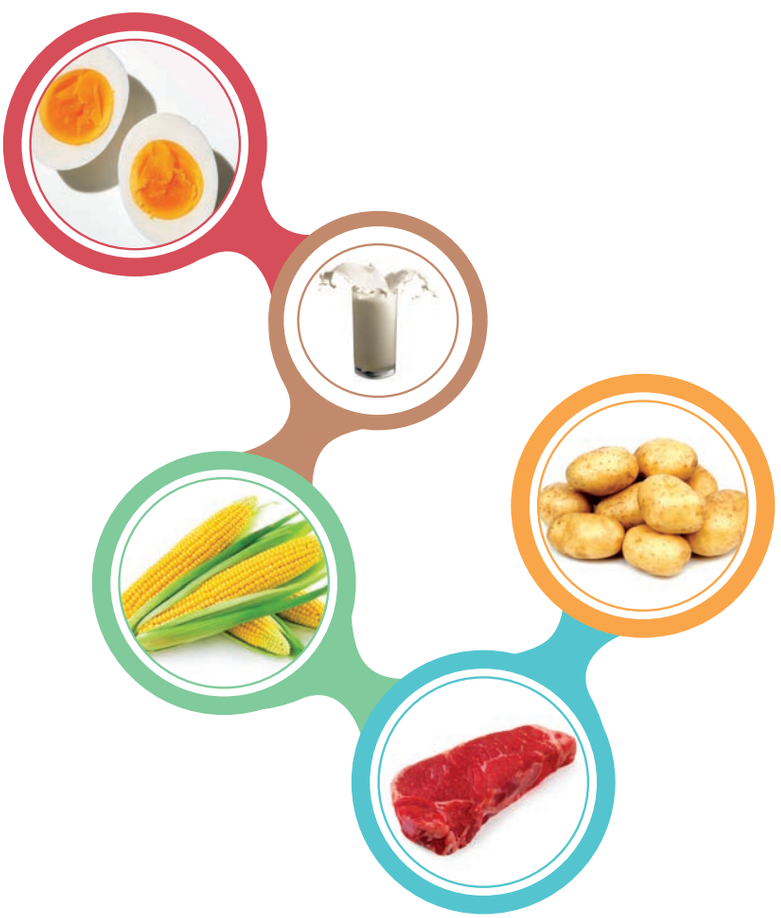

Figure. 8.13 Sources of vitamin B1

Functions:

- Thiamine act as a coenzyme in the form of thiamine pyrophosphate (TPP) in many enzymatic reactions. These are involved mainly in the breakdown of glucose to yield energy.
- Thiamine pyrophosphate (TPP) also acts as a coenzyme for transketolase reactions in the phosphogluconate oxidative pathway of carbohydrate metabolism. This reaction is essential for ribose formation, a constituent of DNA and RNA.
- Vitamin B_1 is also required in tryptophan metabolism for the activity of the enzyme tryptophan pyrolase.
- The adequate level of thiamine provides healthy nerves, a good mental outlook, a normal appetite and digestion.

Absorption and storage:

Free thiamine is readily absorbed by the small intestine. Thiamine is not stored in the human body. The excess thiamine is excreted in urine and also degraded by the enzyme thiaminase.

Deficiency:

The symptoms of thiamine deficiency occur because the tissue cells are unable to receive sufficient energy from glucose. Therefore, they cannot carry out their normal functions. Early symptoms of thiamine deficiency include fatigue, irritability, depression and numbness of the leg and poor tone of the gastrointestinal tract together with constipation.

Beriberi is the disease caused by thiamine deficiency. Beriberi is characterized by oedema in the legs. Usually, beriberi is caused by carbohydrate rich and low thiamine diets such as polished rice.

Figure 8.14 Deficiency due to vitamin B1

ii. Vitamin B_2 (Riboflavin)

Vitamin B_2 which is also known as riboflavin consists of a heterocyclic isoalloxazine ring attached to ribitol (a pentose alcohol). It is a yellow coloured compound.

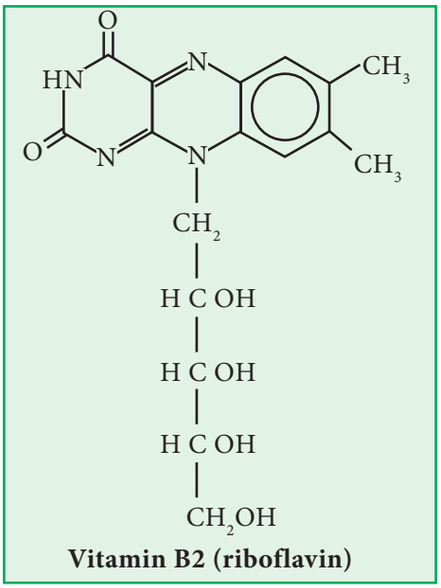

Figure 8.15 Structure of vitamin B_2

Sources:

It is widely distributed in plants. Soy beans, green vegetables are good sources of this vitamin. High concentration occurs in yeasts, milk and egg (Figure 8.16).

Figure 8.16 Sources of vitamin B_2

Functions:

Riboflavin is a component of two important coenzymes, namely flavin mono nucleotide (FMN) and flavin adenine dinucleotide (FAD). They play key roles in various enzymatic reactions.

FMN and FAD are synthesized as follows.

$$\text{Riboflavin} + \text{ATP} \rightarrow \text{FMN} + \text{ADP}$$

$$\text{FMN} + \text{ATP} \rightarrow \text{FAD} + \text{PP}_i$$

FMN and FAD combine with different apoenzymes to form a large number of redox enzymes.

Eg. FMN is associated with the enzyme cytochrome c reductase.

FAD is found in xanthine oxidase and acyl CoA dehydrogenase

Riboflavin is essential for a healthy skin and for good vision in bright light.

Absorption and storage

The vitamin is phosphorylated in the intestinal mucosa during absorption. It is absorbed by the small intestine through the portal vein and is distributed to all tissues. The major part is excreted in urine and a small part is metabolized in the body.

Deficiency:

Riboflavin deficiency leads to cheilosis. It is characterised by the development of fissures developing in the lips and at the corners of the mouth.

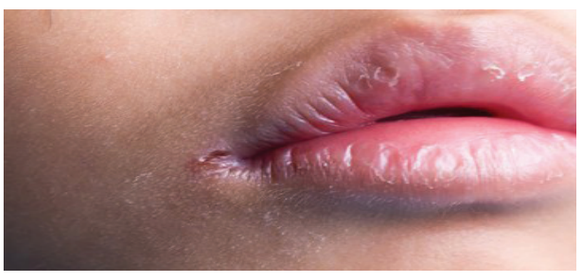

Figure 8.17 Deficiency due to vitamin B_2

Riboflavin is extremely sensitive to strong light. Due to sensitivity, riboflavin deficiency may occur in new born infants with hyper bilirubinemia who are treated by phototherapy.

iii. Vitamin B3 (Niacin)

Vitamin B_3 which is also called as niacin or nicotinic acid is pyridine 3-carboxylic acid. It occurs in tissues as nicotinamide (Figure 8.18).

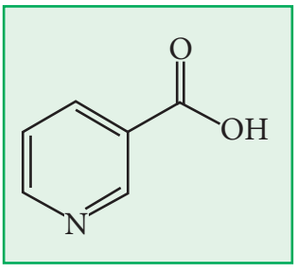

Figure 8.18 Structure of vitamin B_3

Sources:

This vitamin is widely distributed in cereals, dark green leafy vegetables. Liver and kidney are rich sources of this vitamin.

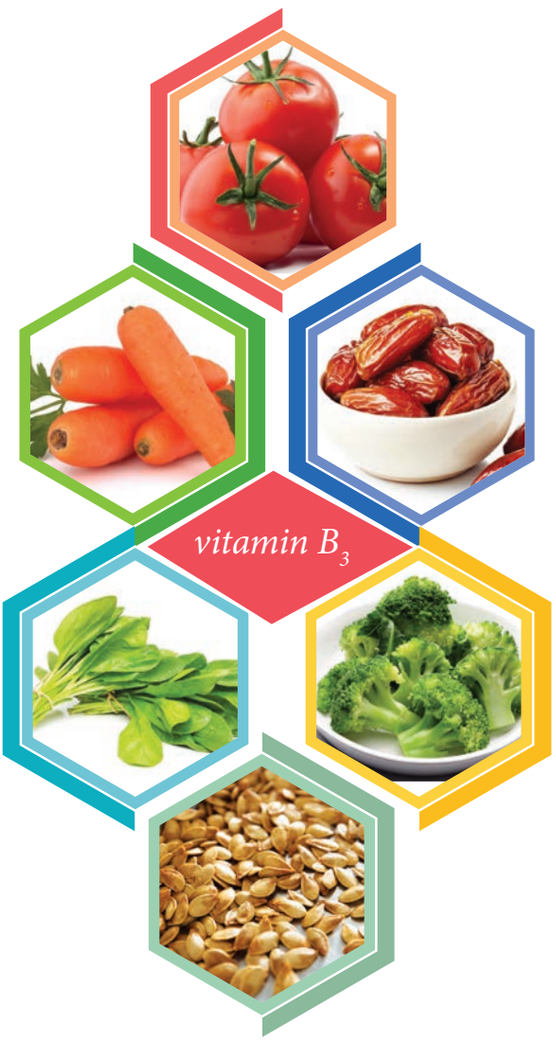

Figure 8.19 Sources of vitamin B_3

Functions:

- Niacin is found in the form of its amide which is an important constituent of the coenzymes NAD^+ and $NADP^+$ and they take part in redox reactions which are associated with many dehydrogenases. For example NAD^+ is the coenzyme for lacate dehydrogenase. $NADP^+$ is the coenzyme for glutathione reductase.
- It promotes the formation of fat from carbohydrates.
- Niacin is essential for healthy skin, normal functions of the gastro intestinal tract and maintenance of the nervous system.

Absorption and storage

Nicotinic acid and nicotinamide are absorbed by the intestine through the portal vein into the general circulation. Excess nicotinic acid is not stored in the body.

Deficiency:

- Nicotinic acid deficiency causes a disease called pellagra (Figure 8.20).
- Dermatitis-skin exposed to the sun, soreness of the mouth and swelling of the tongue.
- Diarrhoea.
- Dementia-mental changes including depression and confusion.

Figure 8.20 Deficiency due to Vitamin B_3 (Pellagra)

iv. Vitamin B_6 (Pyridoxine)

Vitamin B_6 or Pyridoxine is also called as adermin. Vitamin B_6 consists of three closely related pyridine derivatives.

- Pyridoxine
- Pyridoxal
- Pyridoxal amine

The metabolically active form of vitamin B_6 is pyridoxal phosphate. It is formed from pyridoxal.

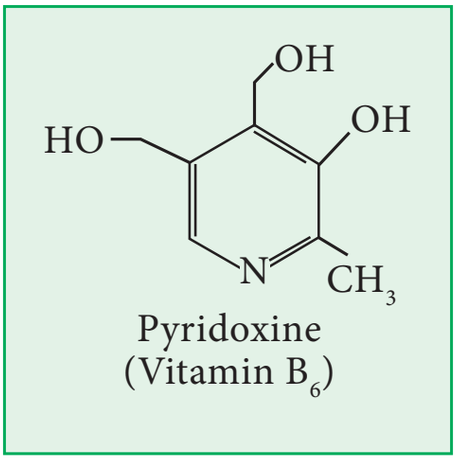

Figure 8.21 Structure of vitamin B_6

Sources:

Rich sources of this vitamin are yeast, whole grain, cereals and egg-yolk. Moderate amounts are present in organ meats like liver and kidney.

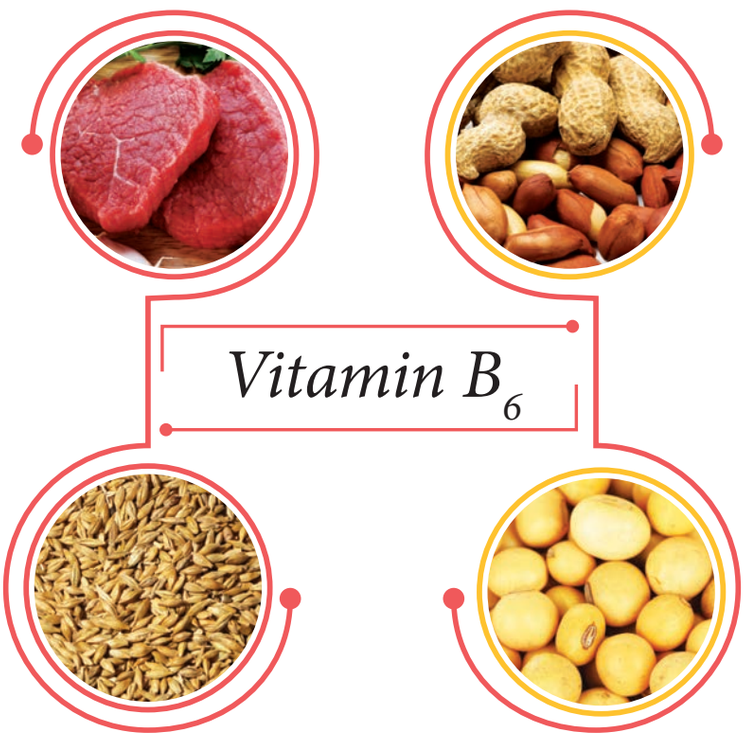

Figure 8.22 Sources of vitamin B_6

Functions:

- Pyridoxal phosphate acts as coenzyme for several enzymes of amino acid metabolism.

Example:

Glutamate + Oxaloacetate $\xrightarrow{\text{AST}}$ α-Ketoglutarate + Aspartate

- It is involved in the formation of heme in hemoglobin.
- Pyridoxal phosphate acts as a coenzyme for the decarboxylase in decarboxylation reactions. Amino acids are decarboxylated to form their corresponding amines.

Histidine $\xrightarrow[B_6 \text{ - phosphate}]{\text{Decarboxylase}}$ Histamine

- Vitamin B_6 is involved in the synthesis of coenzyme A from pantothenic acid.
- It is also involved in the production of antibodies.
- Pyridoxal phosphate plays a key role in glycogenolysis.

Absorption and storage

Pyridoxine is readily absorbed by the small intestine. The excess amount if ingested is not stored in the body, and is excreted in urine.

Deficiency:

Deficiency of vitamin B6 is extremely rare. In infants its deficiency causes irritabilities, insomnia, muscular weakness and convulsion. The cause of the convulsions are severe impairment of the activity of the enzyme glutanate ecarboxylase, which is dependant on pyridoxal phosphate. The product of Glutamate decarboxcylase is γ-aminobutyric acid (GABA), which is a reguletory neurotransmitter in the central nervous system.

v. Vitamin B_{12}:

Vitamin B_{12} has complex ring structure, similar to porphyrin ring which has a cobalt ion (Co^{3+}) at its center (Figure. 8.23). The active coenzyme forms of vitamin B_{12} are methylcobalamine and deoxyadenolsyl cobalamine. The six co-ordination valencies of cobalt ion (Co^{3+}) are satisfied by the four nitrogens of reduced tetrapyrrole and the fifth by the nitrogen of 5, 6 dimethyl benzimidazole moiety and the sixth one either by CN^- (cyanocobalamine) or H_2O (aquacobalamine) or OH^- (Hydroxycobalamine) or CH_3 (methylcobalamine)

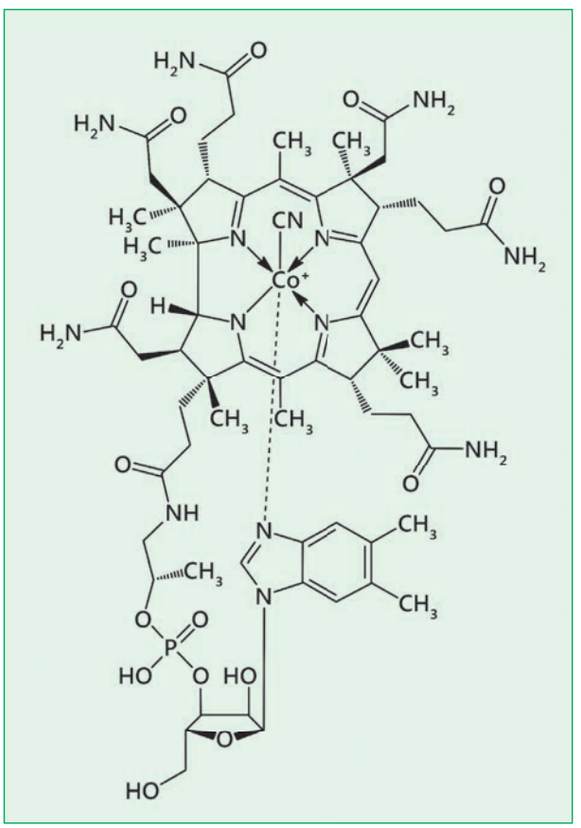

Figure 8.23 Structure of Vitamin B_{12}

Sources:

Vitamin B_{12} is found in animal but not in vegetable foods and is unique in that it is the only known vitamin that holds an ion of metal (cobalt) in its molecule. Eggs and meat supply ample amounts of this vitamin.

Functions:

- Many microorganisms require vitamin B_{12} for growth.
- Vitamin B_{12} is required as coenzyme for the conversion of L-methylmalonyl CoA to Succinyl CoA by the enzyme methylmelonyl CoA mutase. This reaction is essential for in the metabolisom of some branched-chain amino acids and odd-chain fatty acids
- Vitamin B_{12} is required for the maturation of red blood cells in the bone marrow and for the synthesis of proteins.

Absorption and Storage

Vitamin B_{12} is absorbed from ileum. For the absorption of vitamin B_{12} from the intestines, a factor called "Intrinsic Factor" (IF) secreted by the stomach is essential. Vitamin B_{12} is stored in fair amounts in the liver.

Deficiency:

When absorption is prevented by lack of intrinsic factor, it leads to the condition called pernicious anemia. It is characterized by a drastic decrease in red blood cell count and leads to formation of macrocytic red blood cells.

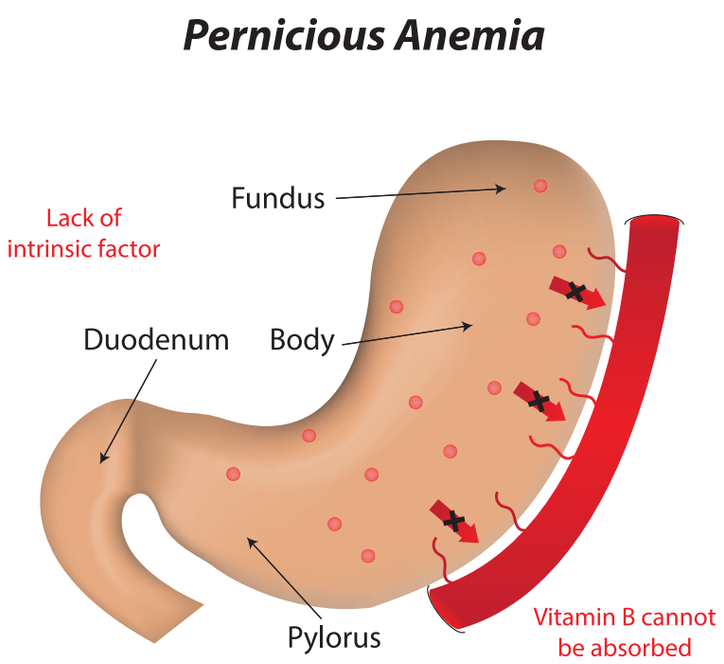

Figure 8.24 Pernicious Anemia

Vitamin B_{12} deficiency causes an increased concentration of methyl malonic acid, which competes with malonyl CoA and impairs fatty acid synthesis.

vi. Biotin (Vitamin B_7):

Biotin is a heterocyclic monocarboxylic acid. It is a Sulphur-containing water soluble vitamin.

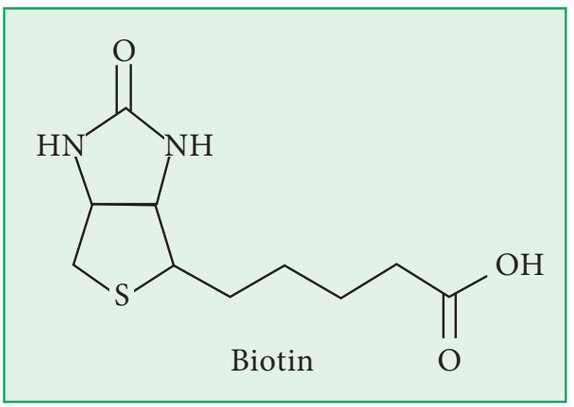

Figure 8.25 Structure of biotin

Sources:

Foods rich in biotin are liver, kidney milk and egg-yolk. Vegetables, grains are good sources.

Functions:

- It is essential for the synthesis of lipids.
- Biotin functions as the coenzyme for the enzyme called carboxylases, which catalyzes carboxylation reactions. Eg. Acetyl CoA carboxylase converts acetyl CoA to malonyl - CoA, which is required for fatty acid synthesis.

CO_2 + biotin- enzyme + ATP → Carboxy biotin - enzyme + ADP + Pi

Carboxy biotin enzyme + acetyl CoA $\xrightarrow{\text{Acetyl CoA carboxylase}}$ malonyl - CoA + biotin- enzyme

- It helps in the conversion of pyruvic acid to oxaloacetic acid. The enzyme that catalyzes this reaction is pyruvate carboxylase.
- It helps to maintain the skin and the nervous system in good condition.
- It involves in deamination of certain amino acids like aspartate, serine and threonine.

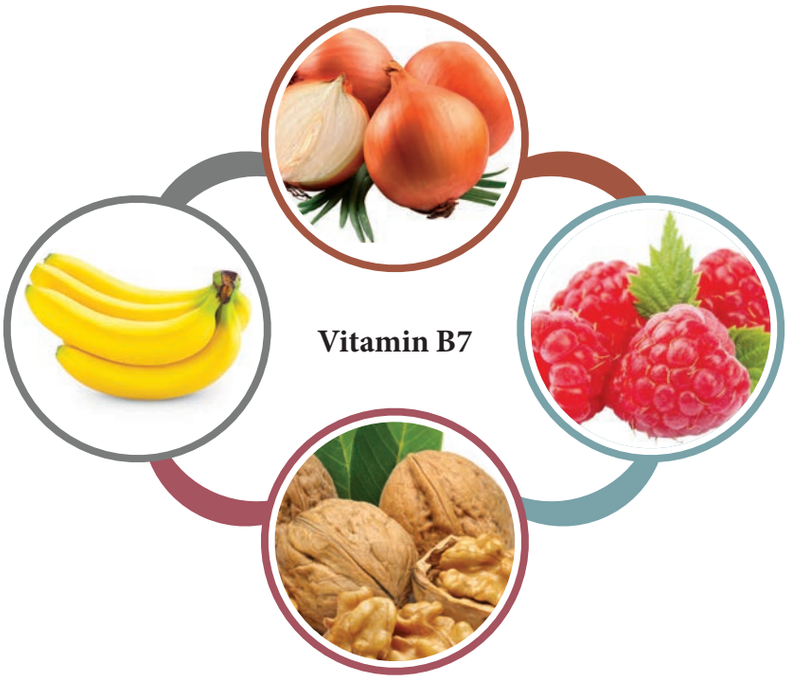

Figure. 8.26 Sources of biotin

Deficiency:

Egg white contains a protein called avidin (egg white injury factor) which binds very tightly with biotin, preventing its absorption and thereby inducing biotin deficiency. The symptoms include depression, hair loss and muscle pain.

vii. Folic acid (Vitamin B9):

Folic acid otherwise known as vitamin B9, folavin or folate is essential for cell division. Its active coenzyme is tetrahydrofolate (THF). The naturally occuring folate is susceptible to high heat and UV light and also be subject to oxidation.

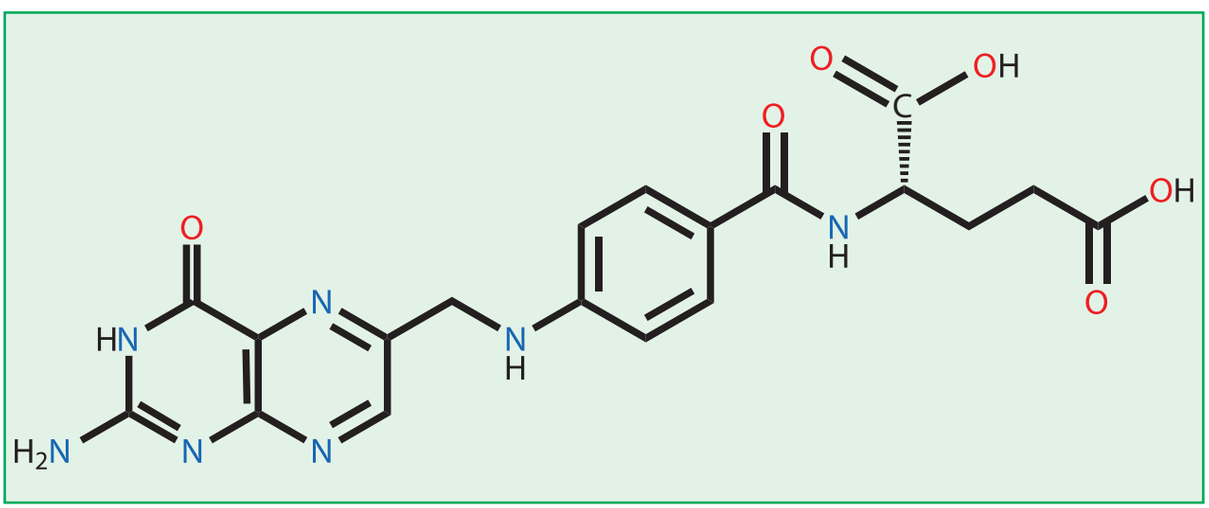

Fig. 8.27 Structure of folic acid

Sources

Folate naturally occurs in a wide variety of foods, including dark green leaf vegetables, fruits, nuts, soybeans, chickpeas, dairy products, poultry and meat, eggs, seafood, grains. Vegetables such as avocado, beetroot, spinach, liver, yeast, asparagus, kale, and brussels and sprouts are among the foods with the highest levels of folate.

Function

- Folic acid is essential for cell division and growth
- It is important for preventing birth defects.
- It is used in the synthesis of amino acid methionine.
- Tetrahydrofolate (THF) is needed to transfer one carbon units in the biosynthetic reactions.

Absorption and storage

Folates are absorbed in the small intestine. The body can store a small amount in liver. The excess is removed from liver via bile.

Deficiency

Folate deficiency signs include anemia (megaloblastic anemia) and dysfunction of the gastrointestinal tract. The anemia is caused by the abnormal blood cell division resulting in fewer and larger red blood cells.

Lack of folate in the diet can cause neural tube defects in an embryo of a pregnant woman. These can cause fatal birth defects.

viii. Pantothenic acid (Vitamin B5):

Pantothenic acid is found in every living cell including plant, animal and microbes. It is a part of coenzyme A which is an essential coenzyme involved in the catabolism of carbohydrates, proteins and fat.

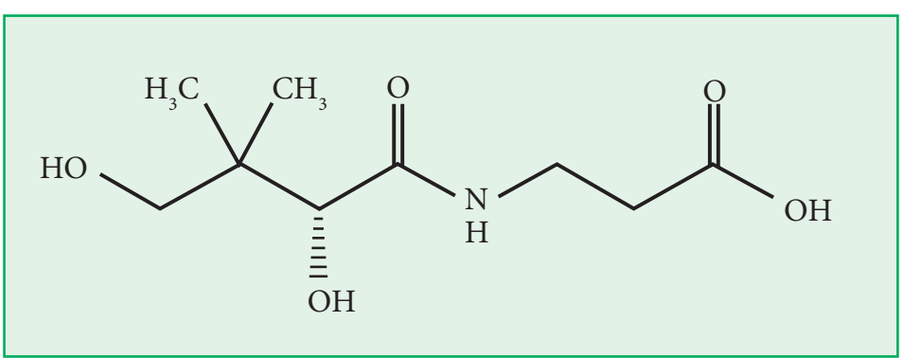

Fig. 8.28 Structure of pantothenic acid

Sources

Pantothenic acid is present in dried mushrooms, avocado, dried egg yolks and sunflower seeds in high amounts. Outer layer of whole grains contains the vitamin, but milling removes much of the pantothenic acid.

Function

- Pantothenic acid forms a part of coenzyme A which is an essential coenzyme for metabolising carbohydrates, fat and proteins.
- It is necessary to synthesise vitamin D, steroid hormones and red blood cells
- It also helps to boost the immunity

Absorption and storage

Free pantothenic acid is absorbed into intestinal cells via a saturable, sodium-dependent active transport system. However, in foods, most pantothenic acid is in the form of CoA or bound to acyl carrier protein (ACP). Since the intestinal cells can only absorb this vitamin in free pantathenic acid, it is converted into free panthothenic acid in intestine.

Deficiency

Pantothenic acid deficiency is very rare and seen only in cases of severe malnutrition. Pantothenic acid is found in many common foods and average diets are thought to have an adequate amount of it.

8.3 Vitamin C

Vitamin C is called as ascorbic acid. Ascorbic acid is an enediol-lactone of an acid with configuration similar to that of the sugar L-glucose.

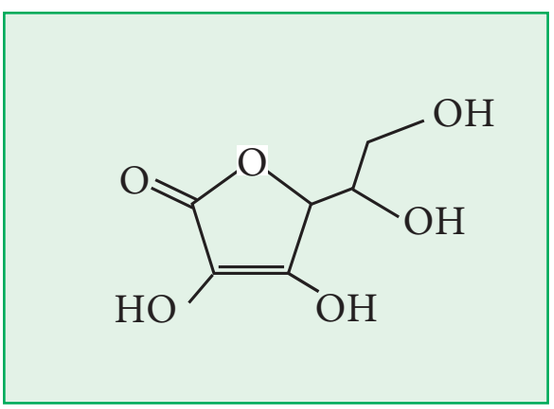

Fig. 8.29 Structure of vitamin C

Sources:

Citrus fruits like orange, lemon are especially rich in vitamin C. Water melons, tomatoes, grape and leafy vegetables are also good sources.

Amla – 600-700mg/100g

Guava- 200-300mg/100g

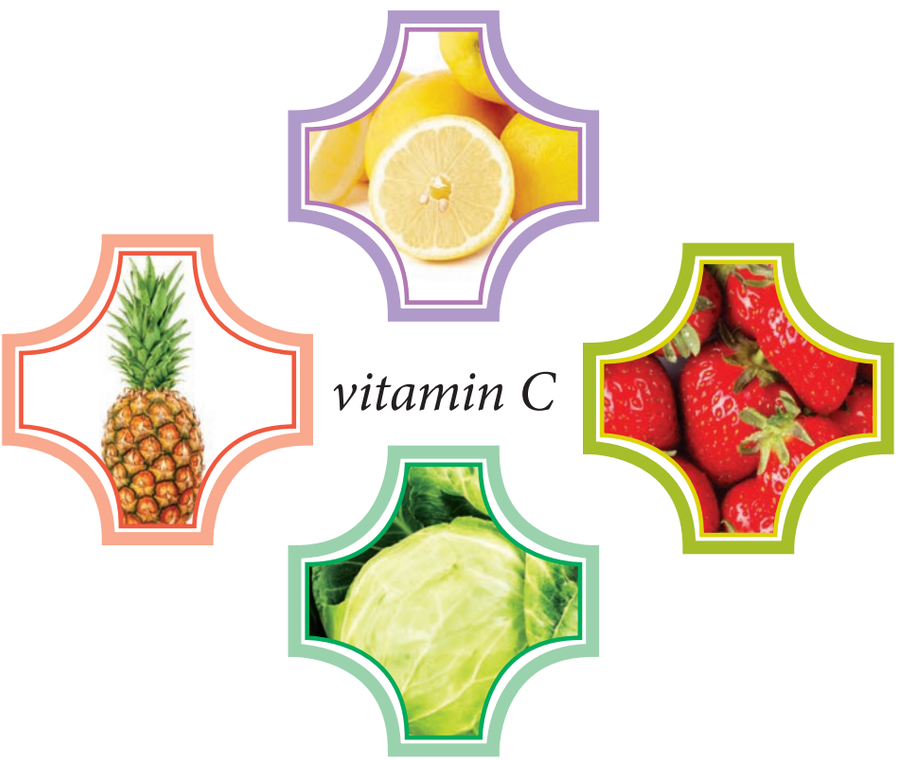

Fig. 8.30 Sources of vitamin C

Functions:

Vitamin C is involved in cellular oxidation-reduction reactions inside the cell as hydrogen carrier.

Ascorbic acid (Reduced form) ⟶ **Dehydro ascorbic acid (Oxidized form)**

- Vitamin C is essential for building collagen, the connective tissue protein which cements the cells and tissues together.
- It regulates carbohydrate metabolism.

- Vitamin C is required as coenzyme for the enzyme dopamine hydroxylase which catalyzes the conversion of dopamine to nor-epinephrine.
- It is involved in the maturation of red blood cells.
- The absorption of iron is significantly enhanced by the presence of vitamin C.
- It has a general antioxidant role , especially in the regeneration of oxidized vitamin E in membranes.

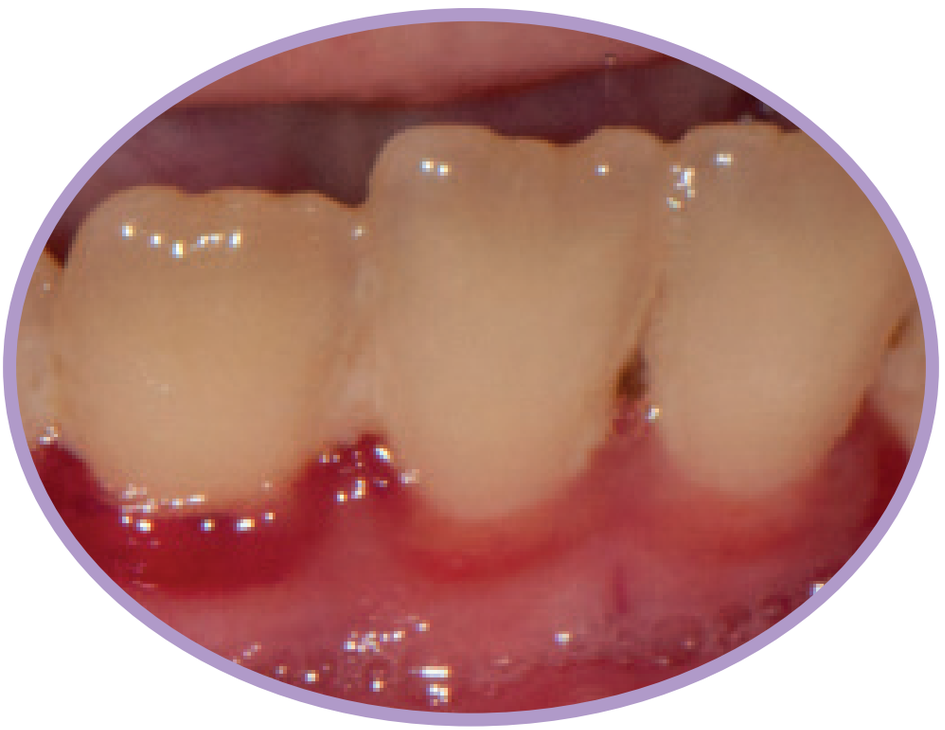

Fig. 8.31 Deficiency due to vitamin C

Absorption and storage

Ascorbic acid is rapidly absorbed from the intestines and passed on through the portal vein to the general circulation. Vitamin C is found in highest concentrations in the adrenals, the pituitary and retina than in circulation. Excessive intake of the vitamin do not increase beyond the optimal levels.

Deficiency:

Scurvy is the classical syndrome of vitamin C deficiency. It is related to defective collagen synthesis which is indicated by fragile skin, muscle weakness, bleeding of the gums, loose teeth and delayed wound healing.

Table 8.1. Recommended Daily Allowances(RDA) of fat and water soluble vitamins for Adults

VITAMINS	RDA
Vitamin A	5000 IU
Vitamin D	10 mg
Vitamin E	25-30 mg
Vitamin K	2 mg
Thiamine (B_1)	1.5 - 2.0 mg
Riboflavin (B_2)	1.6 - 2.0 mg
Niacin (B_3)	17 - 20 mg
Pyridoxine (B_6)	2 - 3 mg
Folic acid (B_9)	500 µg
Cobalamin (B_{12})	3 µg
Pantothenic acid (B_5)	5 - 12 mg
Biotin (B_7)	25 - 50 µg
Vitamin C	75 mg

EVALUATION

I. Choose the best answer:

1. Night blindness is caused by the deficiency of

   a. Vitamin A b. Vitamin D c. Vitamin E d. Vitamin K

2. Which of the following vitamin is essential for biosynthesis of co-enzyme Q?

   a. Vitamin A b. Vitamin D c. Vitamin E d. Vitamin C

3. Anti hemorrhagic vitamin is

   a. Vitamin K b. Vitamin E c. Vitamin D d. Vitamin C

4. FAD is found in

a. Cytochrome C reductase b. Xanthine oxidase

c. Acyl CoA dehydrogenase d. All of these

5. Cobalt is present in

a. Vitamin B1 b. Vitamin B_2 c. Vitamin B_6 d. Vitamin B_{12}

7. A deficiency of vitamin B_{12} causes

a. Scurvy b. Rickets c. Pernicious anemia d. Beriberi

8. Rickets is due to deficiency of

a. Vitamin D b . Vitamin A c. Vitamin C d. Vitamin B1

9. Pyridoxal phosphate is a coenzyme for the reaction, except

a. Transamination b. Deamination c. Decarboxylation d. Oxidation – reduction

10. Beriberi is caused by deficiency of

a. Thiamine b. Thymine c. Threonine d. Tyrosine

11. Pellagra occurs due to deficiency of

a. Biotin b. Niacin c. Pantothenic acid d. Folic acid

12. All the following vitamins have antioxidant property, except

a. Beta carotene b. Ascorbic acid c. Tocopherol d. Cholecalciferol

13. Increased prothrombin time is observed in the deficiency of

a. Vitamin K b. Vitamin B2 c. Vitamin A d. Vitamin B12

14. Thiamine pyrophosphate is required for the following enzymatic activity

a. Hexo kinase b. Transketolase

c.Transaldolase d. Glucose 6-phosphatase

15. Which of the following vitamin is required for collagen synthesis?

a. Ascorbic acid b. Nicotinic acid

c. Pantothenic acid d. Folic acid

16. Biologically active form of vitamin D is

a. 1, 25 dihydroxycholecalciferol b.24, 25 dihydroxycholecalciferol

c. 25 hydroxycholecalciferol d. 1, 24 dihydroxycholecalciferol

II. Give short answer for the following:

1. How will you classify vitamins?
2. Name the fat soluble vitamins.
3. What are the different forms of vitamin B6?
4. Name one important enzyme in which $NADP^+$ acts as coenzyme.
5. What is the biologically active form of thiamine?
6. What are the effects of vitamin B12 deficiency?
7. What are the types of vitamin D?
8. Name the naturally occurring sources of vitamin K?
9. Write the chemical name of vitamin E.
10. State the sources of thiamine.

III. Give short answer for the following:

1. Give the functions of vitamin D
2. Explain the antioxidant property of vitamin E
3. Write a note on deficiency of vitamin B1
4. Give an example of metabolic reactions where TPP acts as coenzyme
5. State the biochemical functions of vitamin B3.
6. What is the biologically active form of riboflavin?
7. Write short notes on niacin deficiency.
8. What are the deficiency manifestations of vitamin D?

IV. Answer the followings

1. What are the functions of vitamin A?
2. Give an account on functions and deficiency symptoms of Vitamin K
3. Explain the functions of thiamine.
4. Write the various biological functions of pyridoxine.
5. Explain the functions and deficiency of vitamin C.

SUMMARY

Vitamins are low molecular weight organic compounds that are essential for many functions of living organisms. They can be classified as water soluble and fat-soluble vitamins based on their solubility. The fat-soluble vitamins that include A, D, E and K gets readily dissolved in fat and are insoluble in water. These vitamins are present in liver and fatty tissues and the excess can be stored in human body. The water-soluble vitamins include C and B complex vitamins (B1, B2, B3, B6, B12, Biotin, Folic acid and Pantothenic acid).

Vitamin A (Retinol) plays an essential role in the visual cycle. Its deficiency causes keratomalacia. Green leaves, meat and carrots are good sources for this vitamin.

Vitamin D which exists in two forms D_2 and D_3 is essential for absorption of calcium and phosphorous and for normal growth. Its deficiency causes rickets in children and osteomalacia in adults. Fish liver oil is rich in vitamin D.

Vitamin E is an antioxidant and its deficiency cause reproductive failure and muscular dystrophy. Groundnut oil and wheat germ oil are good sources of this vitamin.

Vitamin K is essential for the biosynthesis of prothrombin a necessary substance for blood clotting. Its deficiency causes hemorrhagic condition. Green vegetables, soybean oil and spinach are good sources for vitamin K

The B-complex vitamins work together and are essential for overall growth of organism. It helps in harvesting energy from carbohydrates, fat and protein and some other important functions.

Vitamin C is involved in cellular oxidation-reduction reactions as a hydrogen carrier. Its deficiency causes scurvy syndrome. Citrus fruits like lemon and orange are rich in vitamin C.

CONCEPT MAP

CRZ4N