The term "vitamine" was coined from the words vital + amine, since the earlier identified ones had amino groups. Later work showed that most of them did not contain amino groups, so the last letter ‘e’ was dropped in the modern term of vitamin.
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 and in experimental animals. Vitamins are essential food factors, which are required for the proper utilization of the proximate principles of food like carbohydrates, lipids and proteins.
The vitamins are mainly classified into two:

1. **Water soluble vitamins** are named as **B complex** and C.
2. **Fat soluble vitamins** are A, D, E and K. The major differences between these two groups of vitamins are:

<table>
<thead>
<tr>
<th></th>
<th>Fat soluble vitamins</th>
<th>Water soluble vitamins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solubility in fat</td>
<td>Soluble</td>
<td>Not soluble</td>
</tr>
<tr>
<td>Water solubility</td>
<td>Not soluble</td>
<td>Soluble</td>
</tr>
<tr>
<td>Absorption</td>
<td>Along with lipids</td>
<td>*Absorption simple</td>
</tr>
<tr>
<td></td>
<td>Requires bile salts</td>
<td></td>
</tr>
<tr>
<td>Carrier proteins</td>
<td>Present</td>
<td>*No carrier proteins</td>
</tr>
<tr>
<td>Storage</td>
<td>Stored in liver</td>
<td>*No storage</td>
</tr>
<tr>
<td>Excretion</td>
<td>Not excreted</td>
<td>Excreted</td>
</tr>
<tr>
<td>Deficiency</td>
<td>Manifests only when stores are depleted</td>
<td>*Manifests rapidly as there is no storage</td>
</tr>
<tr>
<td>Toxicity</td>
<td>Hypervitaminosis may result</td>
<td>Unlikely, since excess is excreted</td>
</tr>
<tr>
<td>Treatment of deficiency</td>
<td>Single large doses may prevent deficiency</td>
<td>Regular dietary supply is required</td>
</tr>
<tr>
<td>Major vitamins</td>
<td>A, D, E and K</td>
<td>B and C</td>
</tr>
</tbody>
</table>
Water soluble vitamins

1. Thiamine (Vitamin B1)
2. Riboflavin (Vitamin B2) and FAD
3. Niacin, NAD+ and NADP+
4. Pyridoxine (Vitamin B6)
5. Pantothenic acid and Co-enzyme A
6. Biotin
7. Folic acid
8. Vitamin B12
9. Ascorbic acid (Vitamin C)
THIAMINE (VITAMIN B1)

Structure

Thiamine

Active form

Thiamine pyrophosphate
Sources:
Seeds, Nuts, Wheat, Leguminous plants (rich source) & lean meat.

RDA: Minimum requirement 1.0mg for adults, infants and children 0.4-1.3mg

Physiological Role: Co-enzyme of some enzymes such as pyruvate dehydrogenase, Alpha ketoglutarate dehydrogenase, and Transketolase

Deficiency:
Beriberi: The early symptoms are anorexia, dyspepsia, heaviness and weakness. Subjects feel weak and get easily exhausted.
RIBOFLAVIN (VITAMIN B2)
Source: Meats, Nuts, Legumes, Milk, fish, egg.

RDA: 1.5-2.5mg for adults, infants 0.6mg, children 1.0-1.8mg

Deficiency: Non fatal syndrome of inflammation of the corner of mouth (angular stomatitis), painful glossitis of tongue (Purple) and Scaly dermatitis.
Physiological Role
A. FAD Accepts Hydrogen
B. FMN-dependent Enzymes (NADH dehydrogenase)
\[ \text{NAD}^+ \rightarrow \text{FMN} \rightarrow \text{CoQ} \]
C. FAD-dependent Enzymes
1. Succinate dehydrogenase
2. Xanthine oxidase.
3. Pyruvate dehydrogenase
4. Alpha ketoglutarate dehydrogenase
Niacin

Source: Milk, Lean meat, Unrefined grains, cereals and from Metabolism of Tryptophan.

RDA: Adults 17-21mg, infants 6mg. The requirement increases with increased intake of calories, illness, severe injury, infection, burns, high corn (maize) diet, pregnancy and lactation.

Deficiency: Deficiency leads to Pellagra, a disease involving GIT and CNS intense irritation and inflammation of the mucous membranes of the mouth and other parts of the GIT, leading to gastrointestinal hemorrhage, Dermatitis, Dementia & Diarrhea.
Niacin deficiency

Co-enzyme Forms of Niacin

 ![Diagram showing the chemical structures of Niacin and its co-enzyme forms](image-url)
NAD+ Dependent Enzymes such as: Lactate dehydrogenase, Glyceraldehyde-3-phosphate dehydrogenase, Pyruvate dehydrogenase, and Alpha ketoglutarate dehydrogenase

NADPH Dependent Reactions
Keto acyl ACP dehydrogenase, HMG CoA reductase, Folate reductase, and Phenyl alanine hydroxylase
VITAMIN B6 (Pyridoxine)  
a family of 3 related pyridine derivatives;  
pyridoxine (alcohol), pyridoxal (aldehyde) and  
pyridoxamine.  
**Active form** of pyridoxine is **pyridoxal phosphate (PLP)**

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**Functions of Pyridoxal Phosphate**

1- Amino acid metabolism such as Transamination and Decarboxylation.

2- Heme Synthesis.

3- Glycogenolysis.
Sources: Wheat, corn, egg yolk, Liver and muscle meat

RDA: 1.4-2.2 mg for Adults, children 0.3-0.4 mg. Patients with anti-tubercular treatment needs more Vitamin B6.

Deficiency: usually is not common, but may result due to intake of drugs like Isoniazid and contraceptives. Alcoholics also suffer from such deficiency. Isoniazid binds to pyridoxine and makes it unavailable as a vitamin, causing peripheral neuropathy. Oral contraceptives stimulate the synthesis of the enzyme which require this vitamin, thus causing deficiency.
PANTOTHENIC ACID (Vit B 5) Coenzyme A.

Structure
The Greek word “pantos” means everywhere. As the name suggests, it is widely distributed in nature. Pantothenic acid contains beta alanine and D-pantoic acid in amide linkage.
Structure of Co-enzyme A (CoA) derived from pantothenic acid

[Diagram showing the structure of CoA, with key components and reactions involved in its formation.]
Co-enzyme Activities of Pantothenic Acid

1- Transfer the **sulfhydryl** (-SH) group.
2- transfer acyl groups to other acceptors, for example:

\[
\text{Acetyl CoA} + \text{Choline} \rightarrow \text{Acetyl choline} + \text{CoA} \\
\text{Pyruvate} + \text{CoA} + \text{NAD}^+ \rightarrow \text{AcetylCoA} + \text{CO}_2 + \text{NADH}
\]

(enzyme is acetyl choline synthase)

(Enzyme is pyruvate dehydrogenase).

3- Co-enzyme A is an important component of fatty acid synthase complex
Sources: Eggs, Liver, Animal tissue, Whole grain cereals, Yeast and Legumes

RDA: 4-7mg/day

Deficiency: rare due to its wide distribution
The burning foot syndrome in prisoners which is associated with reduced capacity for acetylation is ascribed to pantothenic acid deficiency.
BIOTIN (anti-egg white injury factor)

Source: Normally synthesized by intestinal bacteria. Found in all foods particularly: Liver, egg, peanuts & milk

RDA: 100-200μg/day. Requirement increase in pregnancy and lactation. Patients on oral antibiotics for a long period of time require more of this vitamin.

Deficiency:
Rare, but Avidin, a glycoprotein in egg white binds tightly to biotin and makes it unavailable for the necessary carboxylation reactions. The symptoms in this case are: Dermatitis, Glossitis, Muscle pain, depression, alopecia (Loss of hair), Loss of appetite and Nausea.
Co-enzyme Activity of Biotin
Biotin acts as co-enzyme for carboxylation reactions.
1. Acetyl CoA carboxylase
2. Propionyl CoA carboxylase
3. Pyruvate carboxylase
FOLIC ACID
The active form of folic acid is Tetra hydro folate (THF)
Folic acid

THFA
Source: The vitamin is abundant in leafy green vegetables such as spinach, so is named folic acid, from the same root as foliage, whole grain cereals and Liver.

RDA: 100μg/day (The RDA during Lactation & pregnancy are 500 - 800μg/day)

Deficiency
1. Reduced DNA synthesis
2. Macrocytic Anemia
3. Homocysteinemia
4. Birth Defects
5. Cancer
Vit B12 (Cobalamin).
Source: Synthesized by Microorganisms (Vitamin B12 is not present in vegetables. Liver is the richest source. Curd is a good source, because lactobacillus can synthesize B12)

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

Deficiency of both B12 and folic acid produce similar signs and symptoms and Anemias.
ASCORBIC ACID (VITAMIN C)
Functions:
• Collagen biosynthesis
• Degradation of Tyrosine
• Absorption of Iron
• Steroidogenesis
• Adrenaline synthesis
• Bile acid formation
• Bone mineral metabolism
• Potent anti oxidant

WBC’s are rich in vit C and plays an important role in Immunity.

Source: Citrus fruits, Potato, tomato & green vegetables

RDA: 60mg/day

A symptom of extreme vitamin C deficiency, called scurvy, is the weakening of collagen fibers caused by the failure to hydroxylate proline and lysine.
VITAMIN A (RETINOL, RETINAL, RETINOIC ACID)

Vitamin A is fat soluble. The active form is present only in animal tissues. The pro-vitamin, beta-carotene is present in plant tissues.
All trans-retinal

11-cis-retinal

Site of cleavage

Beta-carotene
Source: A rich source is Liver, but leafy vegetables and some fruits provide the largest amount of β-carotene. Liver, egg yolk, butter and milk are good sources of β-carotene.

Functions
β-carotene has an antioxidant role and prevents the development of diseases in which the action of free radicals is implicated. It plays a protective role against Cancer and cardiovascular disease. As the normal proliferation of epithelial cell growth and differentiation depends on retinoids.
Rhodopsin mechanism
(RDA) for
i. Children = 400-600 microg/day.
ii. Men = 750-1000 microg/day
iii. Women = 750 microg/day
iv. Pregnancy = 1000 microg/day

One international unit = 0.3 mg of retinol. One retinol equivalent = 1 microgram of retinol or 6 microgram of beta carotene.

Excessive intake can lead to toxicity since the vitamin is stored
Vit A deficiency

Low plasma [Vitamin A] has been shown to be associated with:

• increased risk of developing cancer.
• Failure of bone formation (Thick, solid bones).
• Abnormal Keratin forms in the mucosal cells, cause keratomalecia in the eye.
• dryness and roughness of skin
VITAMIN D (CHOLECALCIFEROL)

Requirement of Vitamin D
i. Children = 10 microgram (400 IU)/day
ii. Adults = 5 microgram (200 IU)/day
iii. Pregnancy, lactation = 10 microgram/day
iv. Above the age of 60 = 600 IU per day.
Deficiency of Vitamin D
The deficiency diseases are rickets in children and osteomalacia in adults. Hence vitamin D is known as antirachitic vitamin.

Sources of Vitamin D
Exposure to sunlight produces cholecalciferol. Moreover fish liver oil, fish and egg yolk are good sources of the vitamin. Milk contains moderate quantity of the vitamin.

Doses above 1500 units per day for very long periods may cause toxicity. Symptoms include weakness, polyuria, intense thirst, difficulty in speaking, hypertension and weight loss.
VITAMIN E tocopherols

Sources of Vitamin E
Vegetable oils are rich sources of vitamin E; e.g. wheat germ oil, sunflower oil, cotton seed oil.

Recommended Daily Allowance
Males 10 mg per day
Pregnancy 10 mg/day
15 mg of vitamin E is equivalent to 33 international units.

Pharmacological dose is 200-400 IU per day.
Role of Vitamin E

Most powerful natural antioxidant protects RBC from **hemolysis**
boosts immune response.
reduces the risk of atherosclerosis by reducing oxidation of LDL

**Deficiency**

Human deficiency has not been reported. But in volunteers, vitamin E deficiency has been shown to produce increased fragility of RBCs, muscular weakness and creatinuria.

At doses above 1000 IU per day, it may cause tendency to hemorrhage, as it is a mild anticoagulant.
Vit. K

R = 20C in (Phylloquinone) in K₁
R = 30C in (Menaquinone) in K₂
R = H in Menadione

Henrik Dam  
NP 1943  
1895-1976

Edward Doisy  
NP 1943  
1893-1986
Daily Requirement of Vitamin K
Recommended daily allowance is 50-100 mg/day. This is usually available in a normal diet.

Sources of Vitamin K
Green leafy vegetables
Even if the diet does not contain the vitamin, intestinal bacterial synthesis will meet the daily requirements, as long as absorption is normal.

Hypervitaminosis K
Hemolysis, hyperbilirubinemia, kernicterus and brain damage are the manifestations of toxicity. Administration of large quantities of menadione may result in toxicity. This should be kept in mind in treating premature babies.
Role of Vitamin K
Vitamin K is necessary for coagulation

Deficiency
i. Hemorrhagic disease of the newborn.
ii. Prolongation of prothrombin time and delayed clotting time are characteristic of vitamin K deficiency.