Vitamins

- Vitamins are a group of organic nutrients required in small quantities for a variety of biochemical functions.

- Generally, cannot be synthesized by the body and must therefore be supplied in the diet except vitamin D and niacin.

- Vitamins does not Structural roles.
Enzyme cofactors

- Vitamins and their derivatives often serve as cofactors for enzymes.

- Vitamin cofactors are referred to as coenzyme.

\[
\text{Apoenzyme} + \text{cofactor} = \text{Holoenzyme}
\]

- Cofactors that remain tightly bound to the enzyme are called \textit{prosthetic groups}.
Deficiency of vitamins

▲ Inadequate dietary intake & absorption
▲ Inadequate use
▲ Increased requirements & excretion
▲ Drug-induced deficiency

Vitamins are include

Two main Groups:

1- Soluble in Lipids: A, E, K, D
2- Soluble in Water: B Group & C
The roles of Group 1

▲ Their digestion & absorption is depend to Fats metabolism
▲ Blood transfer by Chylomicron, LDL or VLDL
▲ Tissue deposit in Liver & Adipose tissue
▲ Bile Excretion & Poisoning
Vitamin A

- Store in Liver
- Transfer by binding to RBP
- Roles:
  As hormone in development & Tissue differentiation
  Vision, Hematopoiesis & as Antioxidant

- Shortage: blindness, skin dry, infection, development disorder & infertility

- Poisoning: abdominal pain, nausea, vomiting, headache & dizziness
Vitamin E (Tocopherol)

- Store in adipose & liver
- Roles:
  As hemoglobin synthesis, Cell respiration & as Antioxidant

- Shortage: in premature infant led to RBC membrane Vulnerability & Hemolytic anemia

- Poisoning: Free radical production & Atherosclerosis
Interaction between antioxidants in the lipid phase (cell membranes) and the aqueous phase (cytosol). (R•, free radical; PUFA-OO•, peroxyl radical of polyunsaturated fatty acid in membrane phospholipid; PUFA-OOH, hydroxyperoxy polyunsaturated fatty acid in membrane phospholipid, released into the cytosol as hydroxyperoxy polyunsaturated fatty acid by the action of phospholipase A₂; PUFA-OH, hydroxy polyunsaturated fatty acid; Toc-OH vitamin E (α-tocopherol); TocO•, tocopheroxyl radical; Se, selenium; SSH, reduced glutathione; GS-SG, oxidized glutathione, which is reduced to GSH after reaction with NADPH, catalyzed by glutathione reductase; PUFA-H, polyunsaturated fatty acid).
Vitamin K

- Store in Liver
- Transfer by binding to Chylomicron, LDL & VLDL

Roles:
- In $\gamma$-carboxylation for coagulation & osteogenesis

Shortage:
- Due to malnutrition, antibiotics, liver Disease & lipid malabsorption led to coagulation disorder

Poisoning:
- hemolytic anemia which led to kernicterus
The role of vitamin K in the synthesis of γ-carboxyglutamate.
Vitamin D (Cholecalciferol)

7-Dehydrocholesterol $\xrightarrow{\text{LIGHT}}$ Previtamin D $\xrightarrow{\text{Thermal isomerization}}$ Cholecalciferol (calcioi; vitamin D$_3$)

The body itself makes vitamin D when it is exposed to the sun.

Cheese, butter, margarine, fortified milk, fish and fortified cereals are food sources of vitamin D.
**Vitamin D Activation**

- **Liver**
  - **Transfer by binding to VitD BP**
  - **Roles:**
    - In **Ca regulation** by: increasing of intestinal absorption, decreasing of Ca excretion & bone Ca uptake. **Gene expression**

- **Kidney**

- **Shortage:**
  - Led to **Rickets, Osteomalacia & Osteoporesis**
The roles of Group 2

- There are includes **B groups & Vitamin C**
- They are **soluble in Water & Easy absorption**
- Free in Blood & not deposited & **Plant source**
- Excessive amount is **excrete to Urine** → They aren't Toxic

Except that:
- **Vitamin B12**
- Intrinsic Factor mediated for absorption
- Transcobalamin transfers B12
- Store in Liver
- Bacterial synthesis & **Animal source**

Main Roles:
- **As coenzyme in Energy metabolism** (B1, B2, B3, B5, B6, B)
- **As single carbonated compound transfering** (B9 & B12)
Thiamin (Vitamin B$_1$)

- Thiazole + Pyrimidine
- TPP is active form
- Roles:
  Decarboxylation of Pyruvate

- Source: Cereals, Meat, Liver, Heart, Kidney

- Shortage: High consumption of Tea, coffee & Alcohol led to Beriberi Disease
Pyruvate $\rightarrow$ CoA-SH $\rightarrow$ NAD$^+$ $\rightarrow$ TPP, lipoate, FAD $\rightarrow$ NADH$+$H$^+$ $\rightarrow$ pyruvate dehydrogenase complex ($E_1 + E_2 + E_3$) $\rightarrow$ CO$_2$ $+$ Acetyl-CoA
Riboflavin (Vitamin B\textsubscript{2})

- Flavin + Ribitol
- Active forms: FMN & FAD
- Roles:
  Oxidation-Reduction reactions
- Source: Meat, Egg, Vegetables, Milk
- Shortage:
  In alcoholism
Niacin (Vitamin B₃)

- Pyridine ring
- Active forms: NAD or NADP
- Roles:
  Oxidation-Reduction reactions
- Source: Meat, Nut, Vegetables, Milk
And from Trp at present of B₆
- Shortage:
  In alcoholism, B6 deficiency & Carcinoid Syndrome which led to Pellagra
- High doses is useful for Hyperlipidemia
Pantothenic Acid (Vitamin B₅)

Active forms: In AcCoA & ACP form with –SH agent

Roles:
- Acyl group activation & Fatty Acid synthesis

*** Pyruvate Dehydrogenase Complex
- Source: Egg, Kidney, Liver, Yeast

![Chemical structure of pyruvate dehydrogenase complex](image)
Vitamin B6 (Pyridoxine)

- Pyridine derivatives
- Active forms: Pyridoxal, PLP
- Roles:
  Aminoacid, carbohydrate & lipid metabolism, transamination, decarboxylation and heme synthesis
- Source: Meat, Egg, Fish, Nuts
- Shortage: malnutrition, Antibiotics e.g. Isoniazid
- Symptoms:
  Dermatitis, Convulsion, Anemia and even Cancer
Interconversion of the vitamin B₆ vitamers.
\[
\alpha-\text{AA}_1 + \alpha-\text{KA}_2 \rightleftharpoons \alpha-\text{KA}_1 + \alpha-\text{AA}_2
\]

Pyridoxine

Pyridoxamine

Pyridoxal

Pyridoxal Phosphate

\[
\text{α-Ketoglutarate} + \text{H}_{3}\text{N}-\text{C}+\text{H} \rightleftharpoons \text{Glutamate} + \text{COO}^{-}
\]
آلاتین ترانسآمیناز (ALT) تبدیل متقابل آلاتین و پیروزات را کاتالیز می‌کند:

\[
\begin{align*}
\text{COO}^- & \quad \text{COO}^- \\
\text{C} = \text{O} & \quad \text{C} = \text{O} \\
\text{CH}_2 & \quad \text{H}_3\text{N} - \text{C} - \text{H} \\
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\end{align*}
\]
Vitamin H (Biotin)

- Imidazole and thiophene ring
- Active forms: covalent binding to Carboxylase enzyme
- Roles:
  Carboxylation & Single carbon groups metabolism
- Source: Nut, Egg, Mushroom...
- Shortage:
  Antibiotics & Avidin in raw Egg
- Deficiency Symptoms: Nausea, Vomit and inflammation
Vitamin B₉ (Acid Folic)

- Glu + PABA + Petridine ring
- Active forms: in dihydrofolate Reductase (DHP) & -C- Metabolism

Roles:
- Carboxylation & Single carbon groups metabolism
- The antagonists for DHP are Trimethoprim & Methotrexate

- Source: Vegetable, Fruits, Bread, Meat...

- Shortage:
- Led to cell division disorder & Megaloblastic Anemia
Vitamin B12
- Corrin tetrapyrrole ring + Cobalt
- Active forms: in dihydrofolate

Single carbon groups metabolism

- Roles:
  Carboxylation & Single carbon groups metabolism
- B6, B9 & B12:
  have a protective role against Myocardial Infarction or Homocysteine (Hcy)

- Source: Egg, Liver, Milk, Meat...

- Shortage:
  Also B₁₂ deficiency led's to Neurological disorders.
  Intrinsic Factor is required for B₁₂ absorption. Its deficiency led to Pernicious Anemia.
Or Methylmalonyl-CoA Mutase
Sources and utilization of one-carbon substituted folates.
Vitamin C (Ascorbic acid)

- Carbohydrate derivative (Ascorbic Acid)
- It has a reduction power in reactions (as Antioxidant)
- Roles:
  - Collagen synthesis, cathecolamine and steroid hormone metabolism, WBC activity & Fe absorption
- Source: Vegetables & Fresh Fruits
- Shortage:
  - Led to Scurvy (Adults)
  - & Barlow (Childs)
<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Functions</th>
<th>Deficiency Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Retinol, β-carotene</td>
<td>Visual pigments in the retina; regulation of gene expression and cell differentiation; β-carotene is an antioxidant</td>
</tr>
<tr>
<td>D</td>
<td>Calciferol</td>
<td>Maintenance of calcium balance; enhances intestinal absorption of Ca²⁺ and mobilizes bone mineral</td>
</tr>
<tr>
<td>E</td>
<td>Tocopherols, tocotrienols</td>
<td>Antioxidant, especially in cell membranes</td>
</tr>
<tr>
<td>K</td>
<td>Phylloquinone, menaquinones</td>
<td>Coenzyme in formation of γ-carboxyglutamate in enzymes of blood clotting and bone matrix</td>
</tr>
<tr>
<td>B₁</td>
<td>Thiamin</td>
<td>Coenzyme in pyruvate and α-ketoglutarate, dehydrogenases, and transketolase; poorly defined function in nerve conduction</td>
</tr>
<tr>
<td>B₂</td>
<td>Riboflavin</td>
<td>Coenzyme in oxidation and reduction reactions; prosthetic group of flavoproteins</td>
</tr>
<tr>
<td>Niacin</td>
<td>Nicotinic acid, nicotinamide</td>
<td>Coenzyme in oxidation and reduction reactions, functional part of NAD and NADP</td>
</tr>
<tr>
<td>B₆</td>
<td>Pyridoxine, pyridoxal, pyridoxamine</td>
<td>Coenzyme in transamination and decarboxylation of amino acids and glycogen phosphorylase; role in steroid hormone action</td>
</tr>
<tr>
<td>Folic acid</td>
<td>Coenzyme in transfer of one-carbon fragments</td>
<td>Megaloblastic anemia</td>
</tr>
<tr>
<td>B₁₂</td>
<td>Cobalamin</td>
<td>Coenzyme in transfer of one-carbon fragments and metabolism of folic acid</td>
</tr>
<tr>
<td></td>
<td>Pantothenic acid</td>
<td>Functional part of CoA and acyl carrier protein: fatty acid synthesis and metabolism</td>
</tr>
<tr>
<td>H</td>
<td>Biotin</td>
<td>Coenzyme in carboxylation reactions in gluconeogenesis and fatty acid synthesis</td>
</tr>
<tr>
<td>C</td>
<td>Ascorbic acid</td>
<td>Coenzyme in hydroxylation of proline and lysine in collagen synthesis; antioxidant; enhances absorption of iron</td>
</tr>
</tbody>
</table>
Minerals Are Required for Both Physiologic & Biochemical Functions

Table 44–2. Classification of Minerals According to Their Function.

<table>
<thead>
<tr>
<th>Function</th>
<th>Mineral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural function</td>
<td>Calcium, magnesium, phosphate</td>
</tr>
<tr>
<td>Involved in membrane function</td>
<td>Sodium, potassium</td>
</tr>
<tr>
<td>Function as prosthetic groups in enzymes</td>
<td>Cobalt, copper, iron, molybdenum, selenium, zinc</td>
</tr>
<tr>
<td>Regulatory role or role in hormone action</td>
<td>Calcium, chromium, iodine, magnesium, manganese, sodium, potassium</td>
</tr>
<tr>
<td>Known to be essential, but function unknown</td>
<td>Silicon, vanadium, nickel, tin</td>
</tr>
<tr>
<td>Have effects in the body, but essentiality is not established</td>
<td>Fluoride, lithium</td>
</tr>
<tr>
<td>May occur in foods and known to be toxic in excess</td>
<td>Aluminum, arsenic, antimony, boron, bromine, cadmium, cesium, germanium, lead, mercury, silver, strontium</td>
</tr>
</tbody>
</table>