Vitamins and Microelements
Introduction

Definition

organic substances, essential in the diet in small amounts that are involved in fundamental functions of the body

Classification

lipid-soluble vitamin
water-soluble vitamin
14 Essential Vitamins For Human Being

- vitamins
  - water-soluble
    - Vit C
  - lipid-soluble
    - A, D, E, K
    - B1, B2, B6, B12, PP, pantothenic acid, folic acid, biotin, lipoic acid
Section I
Lipid-soluble Vitamins

Common features

- nonpolar (hydrophobic) isoprene derivative
- poorly soluble in water, but good in fat and fat solvents
- existing with the lipids in food products and absorbing with the lipids
- specifically binding to lipoprotein and certain binding-protein in blood and transportation

Classification:
VitA, VitD, VitE, VitK
Vitamin A

Chemical nature and properties

* natural form: \( A_1 \) (retinol)
  \( A_2 \) (3-dehydro-retinol)

* active form: retinol, retinal, retinoic acid

* pro-vitamin A: \( \beta \)-carotene

* storage and transportation: liver, RBP+PA
  CRBP
Chemical structure of vitamin A1 and vitamin A2
oxidação de caroteno para retinal no intestino e conversão para retinol e ácido retinóico
biochemical function and deficiency

biochemical function

* Photographic substances in visual cell

* participating synthesis of glycoprotein and maintaining differentiation of epithelial cells

* other function, e.g. affecting cell differentiation

Deficiency

night blindness, dry eyes, dry skin, etc
Synthesis and decomposition of Rhodopsin and relation to retinal

11-11-cis retinal → All trans retinal

11-cis retinol → All trans retinol

Retinal isomerase

Retinal reductase

Opsin

Rhodopsin

darkness

light

(retina)

(liver)

11-cis retinal

All trans retinal
Vitamin D

Chemical nature and properties

*types : VitD$_2$ (Ergocalciferol)

VitD$_3$ (Cholecalciferol)

*pro-VitD$_2$ : Ergosterol

Pro-VitD$_3$ : 7-hydro-cholesterol

Ergosterol $\rightarrow$ VitD$_2$

cholesterol $\rightarrow$ 7-hydro cholesterol $\rightarrow$ VitD$_3$

*active form of VitD$_3$ : 1, 25-(OH)$_2$-VitD$_3$

transportation: DBP
Chemical structure and formation of vitamin D2 and D3
Conversion in the body

**vitamin D₃**

(Cholecalciferol) → Liver 25-hydroxylase → 25-OH-vitamin D₃

(25-OH-cholecalciferol)

1α-hydroxylase in kidney, bone, placental

1, 25- (OH)₂-VitD₃

(1, 25-(OH)₂-Cholecalciferol)

24-hydroxylase in kidney, bone, placental and cartilage

24, 25- (OH)₂-VitD₃

(24, 25- (OH)₂-Cholecalciferol)
biochemical function and deficiency

Biochemical function

- Targeting on intestinal mucous, kidney and adrenal tubular,
- Promoting absorbance of calcium and phosphor,
- Being beneficial to formation and calcification of new bone

Deficiency

- children—— rickets
- adults—— osteomalacia
Vitamin E
( Tocopherol )

Chemical nature and properties

*types: Tocopherol, Tocotrienols
*easy to be oxidized; protector of other substances
Chemical structure of $\alpha$-tocopherol
biochemical function and deficiency

- anti-oxidation

Vitamin E: antioxidant

$$\text{ROO} \cdot + \text{RH} \rightarrow \text{ROOH} + \text{R} \cdot$$

( Peroxide free radical ) ( polyunsaturated fatty acids ) ( organic peroxide ) ( organic free radical )

$$\text{R} \cdot + \text{O}_2 \rightarrow \text{ROO} \cdot$$

$$\text{ROO} \cdot + \text{Vit E-OH} \rightarrow \text{ROOH} + \text{Vit E-O} \cdot$$

- Maintaining reproduction
- Promoting metabolism of Hb

($\delta$- amino-$\gamma$- levulinate synthase ALA)
Vitamin K

Chemical nature and properties

**Natural form**: $K_1$, $K_2$(2-methyl-1-4-naphthoquinone)

**Artificial synthesis**: $K_3$, $K_4$

transportation: lipoprotein, liver storage
Chemical structure of vitamin K

- Vitamin K₁
- 2-methyl-1-4-naphthoquinone (K₂)
- Vitamin K₃

CH₃

O

CH₂-CH=C-CH₂-(CH₂-CH₂-CH-CH₂)₃H

O

CH₃

CH₂-CH=C-CH₂-(CH₂-CH₂-CH-CH₂)₃H

(CH₂-CH=C-CH₂)ₙH (n = 6, 7 or 8)

O

O

CH₃

CH₃

O

O

CH₃

CH₃

CH₃

(CH₂-CH=C-CH₂)ₙH (n = 6, 7 or 8)
biochemical function and deficiency

biochemical function

Maintaining the normal levels of coagulation factor II、Ⅶ、IX and X
cofactor of the carboxylase:

deficiency: hemorrhagic disease
### Summary

<table>
<thead>
<tr>
<th>Chemical structure</th>
<th>A</th>
<th>D</th>
<th>E</th>
<th>K</th>
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<tr>
<td>20碳含B白芷酮环的多烯烃一元醇</td>
<td>类固醇衍生物</td>
<td>苯并二氢砒喃衍生物</td>
<td>异戊烯侧链奈醌化合物</td>
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<tr>
<th>Active form</th>
<th>retinal, 3-dehydro-retinol, retinoic acid</th>
<th>1, 25-(OH)₂-D₃</th>
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<tr>
<th>Physiological function</th>
<th>Photographic substances in visual cell, normal growth of epithelial cells antitumor, antioxidation</th>
<th>Regulation of metabolism of calcium and phosphor</th>
<th>Reproduction Anti-oxidation And aging</th>
<th>Co-enzyme of r-carboxylase</th>
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</thead>
</table>
Section Ⅱ
Water-soluble Vitamins

Common features:
• water soluble, easy to be discharged through urine
• not easy to be stored in the body, requiring diet inception

Classification
  Vitamin B family
  Vitamin C
Vitamin B1
(thiamine)

Chemical nature and properties

- vitamin B₁: thiamine
- active form: Thiamine pyrophosphate (TPP):
Chemical structure of thiamine (vitamin B1)

Thiamine pyrophosphate (TPP)
chemical structure of TPP and TPP with "active" acetyl-
biochemical function and deficiency

biochemical function

* TPP: co-enzyme of oxidative decarboxylation of α–keto acids and transketolase
  * with effects in the nerve conduction, inhibiting the cholinesterase activity

deficiency

* beriberi, peripheral Neuritis
The Process of Aerobic Oxidation of Carbohydrates

Stage 1: glycolysis pathway

Stage 2: oxidative decarboxylation of pyruvate

Stage 3: TAC cycle

Stage 4: oxidative phosphorylation
oxidative decarboxylation of pyruvate

\[
\text{pyruvate} \rightarrow \text{NAD}^+, \text{HSCoA} \rightarrow \text{CO}_2, \text{NADH} + \text{H}^+ \rightarrow \text{acetyl CoA}
\]

Pyruvate Dehydrogenase complex
Components of Pyruvate Dehydrogenase complex

**enzyme**

\[ E_1 : \text{Pyruvate Dehydrogenase} \]
\[ E_2 : \text{Dehydrolipoyl Transacetylase} \]
\[ E_3 : \text{Dehydrolipoyl Dehydrogenase} \]

**co-enzyme**

- TPP
- Lipoic acid
- HSCoA
- FAD, NAD^+
1. α-羟乙基-TPP的生成

2. 乙酰硫辛酰胺的生成

3. 乙酰CoA的生成

4. 硫辛酰胺的生成

5. NADH+H⁺的生成
Vitamin $B_2$  
(riboflavin)

Chemical nature and properties

- vitamin $B_2$: riboflavin
- active form: mononucleotide (FMN)
  
  flavin adenine dinucleotide (FAD):
chemical structure of riboflavin
chemical structure of FAD

chemical structure of FMN

hydrogen transmission of FMN and FAD
FMN:

6, 7-dimethyl-isoalloxazine

ribotol

Phosphoric acid
FAD

6, 7-dimethyl-isoalloxazine

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<th>adenine</th>
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<td>ribotol</td>
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<td></td>
<td>ribose</td>
</tr>
<tr>
<td>Phosphoric acid</td>
<td>Phosphoric acid</td>
</tr>
</tbody>
</table>
biochemical function and deficiency

biochemical function:
FMN and FAD are the prosthetic group of oxidoreductases with function of transmitting hydrogen.

deficiency: cheilosis, glossitis, scrotitis etc.
Vitamin B₃
(nicotin acid, nicotinamid, Vitamin PP)

Chemical nature and properties

*vitamin PP:

nicotinic acid
nicotinamide

*active form

Nicotinamide adenine dinucleotide (NAD⁺)

Nicotinamide adenine dinucleotide phosphate (NADP⁺)
chemical structure of nicotinic acid and nicotinamide
\[
\text{NAD}^+, \text{R: H} \\
\text{NADP}^+, \text{R: } \begin{array}{c}
\text{P} \\
\text{O}
\end{array}
\]
NAD\(^+\) and NADP\(^+\)

nicotinamide      adenine

ribose           ribose- (Phosphoric acid)

Phosphoric acid     Phosphoric acid
biochemical function and deficiency

biochemical function

*NAD\(^+\) and NADP\(^+\): coenzyme of dehydrogenases (Malate dehydrogenase, lactate dehydrogenase), transfer of hydrogen.

deficiency

*pellagra
The coenzyme structure formed by nicotinamide

Dehydrogenation catalyzed by dehydrogenase with NAD as co-enzyme
Vitamin $B_6$
(pyridine derivatives)

Chemical nature and properties

*vitamin $B_6$:* pyridoxine
  - pyridoxal
  - pyridoxamine

*active form:*
  - Pyridoxal-Phosphate
  - Pyridoxamine-Phosphate
Pyridoxine

Pyridoxal

Pyridoxamine

Pyridoxal-Phosphate

Pyridoxamine-Phosphate
Glutamic acid + Oxaloacetate $\rightleftharpoons \alpha$ Ketoglutaric acid + Aspartate

Total reaction: glutamic acid + Oxaloacetate $\rightleftharpoons \alpha$ Ketoglutaric acid + Aspartate

Transamination
biochemical function and deficiency

*Pyridoxal-Phosphate

Coenzyme of amino acid aminotransferase, decarboxylase, and δ- amino-γ- levulinate synthase （ALA synthase）
Vitamin B$_5$ (pantothenic acid)

Chemical nature and properties

- pantothenic acid
- active form: CoA

4-phosphopantetheinyl: acyl carrier protein (ACP)

Biochemical function and deficiency

- CoA and 4-phosphopantetheinyl are coenzyme of acyl transferase, transfer of acyl
Chemical structure of CoA

pyruvic acid dehydrogenase

\[
\text{CH}_3\text{COCOO}^- + \text{NAD}^+ + \text{CoASH} + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{COSCoA} + \text{HCO}_3^- + \text{NADH} + \text{H}^+
\]

Acetyl Coenzyme A

formation of acetyl CoA

\[
\text{CH}_2\text{C-S-CoA} + \text{CH}_2\text{C} = \text{O} + \text{H}_2\text{O} \rightarrow \text{HO-C-COO}^- + \text{CoA-SH}
\]

acetyl CoA

oxaloacetate

citric acid synthase

utilization of acetyl CoA

function of CoA in acetyl transfer reaction
Biotin

Chemical structure of biotin

α biotin

β biotin
Biochemical function

Biotin: co-enzyme of carboxylase (pyruvate carboxylase)

Binding to carboxyl to Form Carboxyl biotin

Binding to ε-amino residue of lysine to form biocytin
Folic acid

Chemical nature and properties

*folic acid: Pteroylglutamic acid

*active form: tetrahydrofolate \((\text{FH}_4)\)
Pteroylglutamic acid

Chemical structure of folic acid
Folic acid $\xrightarrow{\text{FH2 reductase}}$ FH2

$\text{NADPH} + \text{H}^+ \xrightarrow{} \text{NADP}^+$

FH2 $\xrightarrow{\text{FH2 reductase}}$ FH4

$\text{NADPH} + \text{H}^+ \xrightarrow{} \text{NADP}^+$

5, 6, 7, 8-FH4
biochemical function and deficiency

biochemical function: FH4: co-enzyme of transferase of one carbon unit

deficiency: Megaloblastic anemia

clinical application: Antitumor drug
Vitamin $\text{B}_{12}$
(coobalamin)

Chemical nature and properties

*vitamin $\text{B}_{12}$*: coholamine

*active form*: coholamine

$5\text{-deoxyadenosylcobalamin}$
$R : -CH_3$

coholamine

$R : 5'\text{-deoxyadenosine}$

$5'\text{- deoxyadenosylcobalamin}$
biochemical function and deficiency

*biochemical function : methyl transfer
*deficiency : Megaloblastic anemia, nerve disease, High blood level of homocysteine
Vitamin C
(ascorbic acid)

Chemical nature and properties

*vitamin C: ascorbic acid
Vitamin C $\leftrightarrow$ Dehydro-vitamin C

\[ \text{HO} - \text{C} - \text{C} - \text{O} \rightleftharpoons \text{O} - \text{C} - \text{C} - \text{O} \]

\[ \text{HO} - \text{C} - \text{CH} \rightleftharpoons \text{O} - \text{C} - \text{CH} \]

\[ \text{H}_2\text{C} - \text{OH} \rightleftharpoons \text{H}_2\text{C} - \text{OH} \]

\[ \text{£-2H} \quad \text{£«2H} \]
biochemical function and deficiency

*biochemical function*: redox reaction, hydroxylation, synthesis of collagen protein, absorbance of ferralia

*deficiency*: scurvy
α-Lipoic acid

Oxidize type

Reduce type
biochemical function and deficiency

cooparating with TPP to participate oxidative decarboxylation of pyruvic acid, α–keto acid; coenzyme of lipoic acid acetyl transferase
<table>
<thead>
<tr>
<th>Name</th>
<th>Form of coenzyme</th>
<th>Function</th>
<th>Deficiency</th>
</tr>
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<tbody>
<tr>
<td>vitamin B1</td>
<td>TPP</td>
<td>co-enzyme of oxidative decarboxylation of α-keto acids and transketolase</td>
<td>beriberi</td>
</tr>
<tr>
<td>thiamine</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Vitamin B2,</td>
<td>FAD</td>
<td>coenzyme of flavin dehydrogenase</td>
<td>Cheilosis</td>
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<tr>
<td>riboflavin</td>
<td>FMN</td>
<td></td>
<td>glossitis</td>
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<tr>
<td>Vitamin PP</td>
<td>NAD</td>
<td>Coenzyme of dehydrogenase, transfer of hydrogen</td>
<td>pellagra</td>
</tr>
<tr>
<td></td>
<td>NADP</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>Form of coenzyme</td>
<td>Function</td>
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</tr>
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<tr>
<td>Vitamin B6</td>
<td>Pyridoxal-Phosphate</td>
<td>Coenzyme of aminotransferase, amino carrier amino</td>
<td>/</td>
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<tr>
<td>pantothenic acid</td>
<td>CoA</td>
<td>Acetyl transfer</td>
<td>/</td>
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<tr>
<td>biotin</td>
<td></td>
<td>co-enzyme of carboxylase, carrier of CO₂</td>
<td>Antibiotin protein</td>
</tr>
<tr>
<td>name</td>
<td>Form of coenzyme</td>
<td>Function</td>
<td>Deficiency</td>
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<tr>
<td>--------------</td>
<td>---------------------------------------------------------------------------------</td>
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<tr>
<td>Folic acid</td>
<td>(FH4)</td>
<td>Carrier of one carbon unit</td>
<td>Megaloblastic anemia</td>
</tr>
<tr>
<td>Vitamin B12</td>
<td>Coholamine (5\text{-deoxyadenosylcobalamin})</td>
<td>methyl transfer</td>
<td>Megaloblastic anemia</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>ascorbic acid (reduce)</td>
<td>hydroxylation</td>
<td>scurvy</td>
</tr>
<tr>
<td>(\alpha)-Lipoic acid</td>
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</tbody>
</table>
SUMMARY

1. Vitamins are all organic nutrients with various essential metabolic functions, required in small amounts in the diet because they cannot be synthesized by the body.

2. Apart from vitamin C, the water-soluble vitamins are all members of the B complex and act as enzyme cofactors.

3. Thiamin is a cofactor in oxidative decarboxylation of α-keto acids and of an important enzyme the pentose phosphate pathway, transketolase.
4. Riboflavin and niacin are each important cofactors in oxidoreduction reactions. Riboflavin is present as prosthetic groups in flavoprotein enzymes flavin mononucleotide and flavin adenine dinucleotide, whereas niacin is present in the NAD and NADP cofactors of many dehydrogenase enzymes.

5. Pantothenic acid is present in coenzyme A and acyl carrier protein, which act as carriers for a groups in many important reactions, whereas pydoxal phosphate is the coenzyme for several enzyme of amino acid metabolism including the transaminases.
6. Biotin is the coenzyme for several carboxylase enzymes, including acetyl-CoA carboxylase, the rate controlling enzyme in lipogenesis, and pyruvate carboxylase, important in gluconeogenesis.

7. As well as having separate functions, vitamin B12 and folic acid take part in providing one-carbon residues for nucleic acid synthesis.

8. Ascorbic acid is a water-soluble antioxidant that maintains many metal cofactors in the reduced state.
9. Absence of the water-soluble vitamins from the diet provokes multiple deficiency states. Absence a single vitamin leads to a characteristic deficiency syndrome.

10. The lipid-soluble vitamins have the common features of being apolar, hydrophobic molecules and also of being isoprene derivatives. They all require normal fat absorption to be occurring for efficient absorption, and if this mechanism is defective, deficiency symptoms are likely to occur.
11. Vitamin A (retinol) is represented not only as such in the diet but also by the provitamin (P-carotene) in plants. Retinol and retinoic acid are considered to act by controlling gene expression, whereas retinal is utilized in vision and has a role in glycoprotein synthesis.

12. Vitamin D is a steroid prohormone whose activity is carried out by its hormone derivative. It is utilized in the regulation of calcium and phosphate metabolism, and its omission from the diet leads to rickets and osteomalacia.
13. Vitamin E (tocopherol) is the most important antioxidant in the body, acting in the lipid phase of membranes throughout the cell. It protects the effects of toxic radicals such as the peroxyl radical, mainly as a breaker of free-radical chain reactions.

14. Vitamin K is needed for the synthesis of blood clotting factors (e.g., II, VII, IX, and X), as a cofactor to a carboxylase that acts on the residues of clotting factor precursor enabling them to chelate calcium. Vitamin K regeneration cycle by dicumarol pounds is the basis for their anticoagulant properties.
Section III
Microelement

Concept

The elements in one human body that amounts required for each day is less than 100 mg

Classification

ion、iodine、copper、zinc、manganese、selenium、fluorin、molybdenum、cobalt、chrome, etc.
选择题练习

维生素
没有五元环结构的维生素是(  )

A. 硫胺素  
B. 生物素  
C. 叶酸  
D. 维生素D  
E. 钴胺素
2. 参与固定CO₂的是（ ）

A. 硫胺素
B. 生物素
C. 维生素C
D. 维生素D
E. 维生素A
3. 维生素D的生化作用是(  )

A. 促进钙、磷吸收
B. 促进钙、磷排泄
C. 降低钙、磷吸收
D. 降低钙、磷排泄
E. 促进胃对钙、磷吸收
4. 在体内无抗氧化作用的维生素是(  )

A. 维生素A  
B. 维生素E  
C. 维生素C  
D. 维生素K  
E. 硫辛酸
5. 缺乏维生素K时，可引起(  )

A. 凝血因子合成不受影响
B. 凝血因子合成增加
C. 凝血时间正常
D. 凝血时间延长
E. 凝血时间缩短
6. Which one doesn’t contain vitamine?

A. FMN
B. FAD
C. CoQ
D. CoASH
E. NAD⁺
下列哪种维生素缺乏会引起坏血病？

A. 硫胺素  B. 核黄素  C. 硫辛酸  D. 维生素C  E. 泛酸
与一碳单位代谢有关的维生素有（ ）

A. 维生素B₂
B. 维生素B₁₂
C. 维生素B₆
D. 生物素
E. 叶酸
9. Which vitamine join in composition of coenzyme or prosthetic group?

A. Vitamine C
B. Vitamine D
C. Vitamine B$_2$
D. Vitamine B$_6$
E. Folic acid
10. 具有维生素A活性的物质包括（ ）

A 视黄醇  
B 视黄醛  
C 视黄酸  
D β-胡萝卜素  
E 玉米黄素
11. 下列关于维生素的叙述正确的是(  )

A 维生素是构成组织细胞成分之一
B 根据化学结构和性质分类
C 全部由食物供给
D 是一类需要量很大的物质
E 有些溶于水，有些溶于脂肪
12. 自然界黄红色植物中含维生素A的前体最主要的是(  )

A  α-胡萝卜素
B  β-胡萝卜素
C  γ-胡萝卜素
D  视黄醛
E  玉米黄素
13. Night-blindness is due to lack of (  )

A  Vitamin C
B  Vitamin E
C  lactoflavin
D  vitamine A
E  vitamine D
14. The active form of vitamin D is (  )

A  1,24-(OH)₂-VD₃
B  1,25-(OH)₂-VD₃
C  24,25-(OH)₂-VD₃
D  25-(OH)-VD₃
E  24-OH-VD₃
15. 维生素D缺乏时可引起（   ）

A 痛风症
B 呆小症
C 夜盲症
D 干眼病
E 佝偻病
16. 经常晒太阳不致缺乏的维生素是(  )

A  维生素C
B  维生素A
C  维生素B₆
D  维生素B₁₂
E  维生素D
17. 下列哪种辅酶中不含核苷酸？

A  FAD  
B  CoASH
C  FH_{4} 
D  NADP^{+} 
E  FMN
18. 与生物素有关的代谢反应有（ ）

A 丙酮酸羧化生成草酰乙酸
B 氨基酸脱羧反应
C 一碳基团的转移
D 乙酰CoA转变成丙二酰CoA
19. 硫辛酸的作用( )

A. 抗脂肪肝作用  
B. 降低胆固醇作用  
C. 对巯基酶有保护作用  
D. 易进行氧化还原反应  
E. 是酰基转移酶的辅酶
20. 在体内可转变为维生素的有(  )

A  β-胡萝卜素  
B  7-脱氢胆固醇  
C  色氨酸  
D  麦角固醇  
E  古咯糖酸内酯
论述题：

试述维生素A缺乏时，为什么会患夜盲症？