VITAMINS

ILLUSTRATED BIOCHEMISTRY

Schemes, formulas, terms and algorithm of preparation

The manual for making notes of lectures and preparation for classes

Tver, 2018
**Vitamins are**
- Organic
- Low-molecular
- Irreplaceable
- Required in small quantities
- Biologically active
- The substances participating in the active catalyses

**The most typical signs of vitamins:**
- They are not included in the structure of tissue
- They are not used as an energy source
- They more often carry out the role of a coferment in the structure of enzymes

**Sources of vitamins for man:**
- Foodstuff
- Synthesis by intestines microflora (K, B1, B3, B6, H, B9, B12)

**provitamins** (precursors of vitamins)

![Chemical structure of a provitamin](image)
Call provitamins according to the formulas ($\beta$ carotin, 7-dehydrocholesterol)

Explain, how given provitamins transform into vitamins in an organism

Antivitamins

They are:

1. structural analogues of vitamins
   - *dicoumarol* the analogue of vitamin K, reduces coagulability of blood;
   - *sulphanilamides derivatives* - analogues of p-aminobenzoic acids (PABA). Antivitamins substitute it in the folic acid structure systems in microorganisms, and block the function of folic acid coenzymes, i.e. inhibiting ultimately proliferation of sulphanilamide-sensitive microorganisms. The concept of antivitamins was proposed in 1940 by Wood due to his discovery of the ability of p-aminobenzoic acid to counteract the bacteriostatic effect of sulphanilide;

2. substances which connect vitamins and prevent the formation of active enzyme;

3. enzymes which destroy vitamins (*thaminase, ascorbooxidase*)

Formulas of antivitamins

The reasons of hypo-and avitaminosises

1. Exogenic:
- Insufficient intake of vitamins with food;
- Destruction of vitamins at food preparation (t °, conservation etc.);
- Change of normal microflora of intestines (action of antibiotics and other bacteriostatic substances);
- Influence of antivitamins.

2. Endogenic:
- Increased requirement of vitamins at some physiological and pathological conditions (pregnancy, diseases);
- Increased disintegration of vitamins and coferments in tissues;
- Disorder of the vitamins absorption;
- Disorder of the transportation of vitamins with the blood;
- Disorder of the transformation of vitamins into active forms (coferments);
- Disorder of the interaction between coferments and proteins;
- Disorder of the synthesis of an albuminous part of enzymes.

The reasons of hypervitaminosis

(are characteristic for fat-soluble vitamins)
- Excessive intake of vitamins with food;
- Excessive amount of vitamins at the treatment of hypovitaminoses

Classification of Vitamins

I – Fat-soluble vitamins
II – Water-soluble vitamins
III – Substances similar to vitamins (are synthesized from intermediate products of an exchange and carry out functions similar to vitamins)

Fat-soluble vitamins
- A (antixerophthalmic), retinol
- D (antirachitic), calciferols
- K (antihemorrhagic), napththoquinones
- E (vitamin of duplication,antisterile), tocoferols
- F (linolic,linolenic, arachidonic,oleic acids)

Water-soluble vitamins
- B₁ (antineurtic), thiamine
- B₂ (growth vitamin), riboflavin
- B₃ (antidermatitic), folic acid
- B₅ (PP - antipelagreric), niacin
- B₆ (antidermaitic), pyridoxine
- B₉ (antianemic), folic acid
- B₁₂ (antianemic), cyanocobalamin
- H (antiseborrhoeic), biotin
- C (antiscorbutic), ascorbic acid
- P (vasoformative), bioflavonoids

Vitaminoiods:(substances similar to vitamins)
- B₄ (choline)
Fat-soluble vitamins

Vitamins of groups А

Retinol (antixerophthalmic)

Chemical structure of vitamin A

Provitamin A (β-carotene)

Biological role

1. It participates in light and color perception.
   Photosensitive cells of the eye retina (rods and cones) contain the pigment rodopsin—a complex protein consisting of protein (opsin) and vitamin A (cis-retinal).

In the visual act: At photochemical absorption of light rodopsin changes the conformation:

\[ \text{cis-retinal} \rightarrow \text{trans-retinal} \]
Thus there is a nervous pulse (visual perception).

2. It participates in oxidation-reduction reactions
3. It participates in the synthesis of glycoproteides (components of membranes) and to regulating the barrier function of mucous membranes and skin.
4. It participates in FAFC synthesis, that is in the formation of chondrotinsulphate - components of connecting structures (cartilages, bones, etc.).

**Symptoms, characteristic for hypovitaminosis**

- hemeraloplia (disorder of twilight vision)
- defects in (epithelium) skin and mucous membranes (hyperkeratosis)
- Affection of eyes:
  - xerophthalmia (dryness of the cornea and conjunctiva)
  - keratomalacia (opacification of the cornea and its softening)
  - Symptoms of hypervitaminosis A

- inflammation of eyes
- loss of hair
- dyspepsia phenomena

**Daily requirement:** 1-3 mg

**Products rich in vitamins and provitamin A:**
- Cod-liver oil
- An egg yolk
- Butter
- Liver
- Carrots (carotin)

**Vitamins of group D**

**calciferols (antirachitic)**

**Chemical structure of vitamins D₂ and D₃ and their precursors**

D₂ – ergocalciferol and his precursors – ergosterol
D₃ – cholecalciferol and his representative-7-dehydrocholesterol

- Transformation of the provitamin 7-dehydrocholesterol into vitamin D₃

![Chemical structure diagram](image)

- Rupture of the bond in ring B

Active forms of Vitamin D₃

Transformation of the vitamin into a substance similar to:

I 1, 25-(OH)₂D₃ (1, 25-dioxycholecalficiferol, calcitriol)
Biological role of $1,25$ (OH)$_2$D$_3$ and $24,25$-(IT)$_2$D$_3$.

- Regulation of Ca and P exchange in an organism (increase their contents):
  - stimulates the synthesis of the proteins, participating in transport of Ca and P. It results in:
    a) increasing the absorption of Ca and P through the cells of a mucous membrane of intestines;
    b) increasing the reabsorption of Ca and P through the tubules of the kidneys;
    c) increasing the absorption from intestines and deposition of a citric acid in bones.
  - participates in the synthesis of collagen and osteocalcin (the main incollagenic fiber of a bone).
  - $1,25$ (OH)$_2$D$_3$ increases resorption, $24,25$ (OH)$_2$D$_3$ - remodeling a bone tissue

Symptoms of D$_3$ - hypovitaminosis

- rickets (in children)
- curvature of legs (x and ð-shaped legs)
- chicken breast
- big head
- enlarged abdomen
- delay of teeth eruption and formation of dentin
- osteomalacia (in adults)

Daily requirement for children: 10-25 mkg
Products rich in vitamin D:
- Cod-liver oil
- An egg yolk
- Butter
- Liver
- Vegetable oil

**Vitamin E**

(α-, β-, γ-, δ-tocopherols: vitamin of duplication, antisterile)

Chemical structure of vitamin E (α-tocopherol).

![Chemical structure of vitamin E](image)

1. **It is antioxidative**, inhibits free radicals, stops peroxidation of lipids in cellular membranes keeping their integrity.
2. Increases the activity of vitamin A protecting a nonsaturated lateral chain from hydrogen peroxide.
3. Activates the synthesis of heme (hemoglobin, catalyses, peroxidase, cytochrome).
4. Participates in the mechanism of breath (regulates the synthesis of coenzyme A).

**Symptoms of E hypovitaminosis (in experiment)**

- Disorder of reproductive function (an atrophy of testes, resorption of a fetus at pregnancy);
- Muscular dystrophy;
- Infiltration of fatty acid in the liver;
- Affection of nervous system

**Daily need (requirement)**: 5-30 mg

**Products rich in vitamin E**:
- Vegetable oils

**vitamin K**

(antihemorrhagic, phyloquinone)

$K_1$ – phyloquinone
**Biological role**

1. It activates biosynthesis of blood clotting factors (prothrombin (II), proconvertin (VII), Christmas factor (IX), Stuart-Prower factor (X))
2. It activates $\gamma$-carboxylation of glutamate in the structure of above mentioned factors of clotting:
   - additional COO - groups appear which participate in the linkage of Ca ++. Through Ca ++ prothrombin connects with phospholipid membranes and splits with the formation of thrombin: then the system of blood clotting starts with the formation of a fibrinous clot

Synthetic analogues of vitamin K (they stimulate blood clotting).
Antivitamins K (anticoagulant, they prevent blood clotting)

Symptoms of E hypovitaminosis:
- Spontaneous of parenchyma and capillary bleeding.
- Increased bleeding in traumas.

Daily need (requirement) up to 2 mg

Products rich in vitamin:
- Cabbage
- Spinach
- Pumpkin
- Ashberries
**Vitamin F**
(essential fatty acids, polyunsaturated high fatty acid)

**Chemical structure of vitamin F**

Linolenic acid (18:2)
α-linolenolic acid (18:3)
arachidonic acid (20:4)

**Biological role of vitamin F**

1. It joins the composition of phospholipids membranes.
2. Fulfillment of energetic function.
4. Arachidonic acid - the precursor of prostagladins, thromboxanes and leukotrienes.

**Daily need (requirement):** 20-25 g.

**Products rich in vitamin F:**
- Liquid vegetable oils

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**Coenzyme Q (ubiquinone)**

**Chemical structure of coenzyme Q** (contains a benzoquinone ring and isoprene chain in the sixth position).

\[
\begin{align*}
H_3CO & \quad CH_3 \\
H_3CO & \quad \underbrace{(CH_2-CH=C(CH_3)-CH_2)_nH}_{\text{isoprene}} \\
& \quad n = 6-10 \ (Q_{6,7-10})
\end{align*}
\]

**Biological role of coenzyme Q**

The component of biological oxidation chain participates in transfer electrons and hydrogen along a respiratory chain.
- Name participants of a respiratory chain from which 2H come to ubiquinone.
- Name participants of a respiratory chain on which ubiquinone gives 2H.

**Products rich in vitamin Q**
It is present in the majority of food stuffs, and also it can be synthesized in tissues from the melaconic acid.

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**WATER SOLUBLE VITAMIN**

**Vitamin B₁**
(thiamin, antinueritic)

Chemical structure of vitamin B₁ (pyrimidine, thiazole ring).

![Chemical structure of vitamin B₁](image)

**Biological role**
TDP (thiamindiphosphate) is formed in an organism from Vitamin B₁ it serves as a coenzyme, oxidative decarboxylation of α-keto acids.

![Biological role](image)

TDP is a part of the composition of:

1. pyruvatedehydrogenase complex (glycolysis, stageII), carrying out the decarboxylation of pyruvate:

   $$\text{pyruvate} \rightarrow \text{acetyl} - \text{S CoA} + \text{NADH} + \text{CO}_2$$

   Respiratory chain in mitochondria

   ![Respiratory chain in mitochondria](image)
2. $\alpha$-Ketoglutarate dehydrogenase complex (CTC) carrying out the decarboxylation of $\alpha$-ketoglutaric acid

$$\alpha$-KG $\rightarrow$ succinyl $\sim$ S CoA + CO$_2$$$

$$\downarrow$$

ATP

3. Transaldolase, transketolase reaction (PPP)

$$\text{Glucose} \rightarrow \text{NADHH}_2 + \text{ribose} \rightarrow \text{glucose}$$

$$\downarrow$$

highly fatty acid, cholestrol DNA, RNA

Symptoms B1 of hypovitaminosis

- lack of thiamin causes beriberi;
- polyneuritis, encephalopathy (Wernicke’s syndrome);
- impairment of cardiovascular system functions (syndrome Weysa);
- atrophy of the muscular tissue;
- impairment of digestive functions (motor and secretive functions).

Daily need (requirement) 1 - 3 mg.

Products rich in vitamin B$_1$: yeast, crude rice, flour (torment) of a rough grinding, the liver.

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**vitamin B$_2$**  
**(riboflavin)**

Chemical structure of vitamin B$_2$ (isoalloxazine, sugar alcohol, ribitol)

\[ \text{CH} - \text{CH(OH)} - \text{CH(OH)} - \text{CH(OH)} - \text{CH}_2(\text{OH}) \]

Biological role of vitamin B$_2$

- It participates in the formation of coferments:
  - *flavin mononucleotide* (FMN)
  - Enzymes: cytochromoxidaes, monochromoxidase, L-amino acid oxidase
  - *flavinadeninedinucleotide* (FAD) enzymes of respiratory tissue, succinate dehydrogenase (CTA), D-amino acid oxidase, pyruvatedehydrogenase
The place of connection of protons (H⁺) and electrons to coenzymes

Chemical structure of vitamin B₃

2,4-dioxi-3,3-dimethylbuteric acid β-alanin

Biological role

Is a part of coenzyme A

Thioethenolamin Pantothenic acid 3'-phosphoadenosin-5-diphosphate
The mechanism of action

![Chemical reaction]

They are carried out with the help of Co A - SH:
- Oxidizing decarboxylation of pyruvate and α-ketoglutarate
- Oxidation and synthesis of highly fatty acids
- Reactions in Krebs cycles
- Synthesis of TG (triglycerides) and PL (phospholipids)
  — Exchange of ketones bodies
  — Synthesis of cholesterol
  — Maintenance of normal structure of tissue membranes (a mucous membrane of intestines, tissue of a myocardium, the liver, kidneys)

Symptoms of B₃-hypovitaminosis (in experiment)

- dermatitis
- affection of mucous membranes
- dystrophic changes in glands of internal secretion
- disoders of nervous system
- affection of GIT
- depigmentation of hair, wool, allopagia

Daily need (requirement): 3 - 5 mg.
Products rich in vitamin B₃: liver, yeast, an egg yolk, green parts of plants.

«Vitamin» B₄ (cholin)

Chemical structure (aminoethanol)

\[(\text{CH}_3)_3 \equiv \text{N}^+\text{–CH}_2\text{–CH}_2\text{OH}\]

Biological role
1. It is a component of acetylcholin-mediator parasympthetic nervous system.
2. It is a part of lecithin of the basic phospholipids of cells membranes.
3. It is a donor of CH₃ - groups in the reaction of tranamethylation at biosynthesis of methionin, ptherine and pyrimidine nucleotides, phospholipids.
4. It plays the role of a lipotrophic factor. Owing to the competition between ways of synthesis of phospholipids and triglycerides for the common substrata, all substances (cholin, inozitol, serine, methionine, vitamins B₆, B₁₂ and B₁₅, a folic acid), promoting the synthesis of phospholipids, inhibit the formation of triglycerides in tissues (adiposity)

Symptoms of B₄-hypovitaminosis
- infiltration of fatty acid in the liver
- hemorrhagic dystrophy of kidneys
- Disorder of blood clotting process (disorder of V factor of blood clotting synthesis—accelerant)

Products rich in choline: liver, kidneys, meat, fish products, cabbage.

**vitamin B₅ (PP)**
(niacin, antipellargic)

Chemical structure of vitamin B₅
(amide of the nicotinic acid).

![Chemical structure of vitamin B₅](image)

**Biological role of vitamin B₅**

1. It participates in the formation of *nicotiamadenindinuclotide* (NAD) *nicotinamidenindinuclotidphosphate* (NADP) – coferments of dehydrogenesis

![Chemical structure of vitamin B₅](image)

- The place of a proton connection
- The place of an electron connection

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The mechanism of action
1. NAD and NADP-dependent dehydrogenases carry out dehydrogenesis (oxidation) of substrates, and are carriers of hydrogen in oxidation-regenerative reactions, including a circuit of biological oxidation in mitochondria.
2. NADPH₂ participates in the synthesis of HFA.

Symptoms of B₃ hypovitaminosis (pellagra)
- dermatitis
- diarrhea
- depression (psychoses)

Daily need (requirement): 18 mg.
Products rich vitamin B₃: rice, bread, potato, yeast, the liver, bran, etc.

**Vitamin B₆**
(pyridoxine, antidermatal)

Chemical structure of vitamin B₆

Biological role of vitamin B₆

1. It participates in the formation of coferments: pyrodoxal phosphate and pyridoxamine phosphate which are main parts of enzymes:

   - Transaminase of amino acids (provides the transfer of amino groups)
   - decarboxylase amino acids (provide the formation of biogenic amines of ethanolamine from the serine as a lipotropic factor);
Symptoms of B<sub>6</sub> hypovitominosis - dermatitis which are not cured by vitamin B<sub>5</sub>; - Disorders of nervous system (attacks of the type of epilepsy); - Disturbance of tryptophan exchange
Daily need(requirement): about 2 mg.

Products rich in vitamin B<sub>6</sub>: yeast, grain and leguminous products, liver.
The antagonist of vitamin B<sub>6</sub> - isoniazid which is used for the treatment of tuberculosis.

**"Vitamin" B<sub>8</sub>**

(inositol)

Chemical structure of vitamin B<sub>8</sub> (six-nuclear cyclic alcohol)

![Chemical structure](image)

**Biological role of vitamin B<sub>8</sub>**

It participates in biosynthesis of - phospholipids - in the formation of secondary intermediaries (messenger) of endocellular signals. - it plays the role of a lipotropic factor

Symptoms of B<sub>8</sub> hypovitominosis (in experiment) - The arrest of growth - Loss of wool - Infiltration of fatty acid in the liver with the accumulation of cholesterol.

Daily need (requirement): 1,0-1,5g.
Products rich in inositol: liver, meat, milk, flour (torment) of a rough grinding, vegetables, fruit.

**Vitamin B<sub>9</sub>**

(a folic acid, antianemic)

Chemical structure of vitamin B<sub>9</sub>
(a derivative of pteridine, paraaminobenzoic and glutamic acids)
Biological role of vitamin B<sub>9</sub>

Tetrahydrofolic Acid (THFA) is formed from vitamin B<sub>9</sub>:

\[
\text{folic acid} \quad + \quad 4 \text{H} \quad \rightarrow \quad \text{tetrahydrofolic acid (THFA – coferments)}
\]

THFA is a part of some transferase enzymes and participates in transport, methionine, choline, tryptophan and other molecules of one-carbon groups from serine:
- formyl (-CO-I)
- methyl (-CH3)
- methenyl (-CH2-
- methylene (-CH=)
- oxymethyl (-CH2OH)
- formimino (-CH=NH)

1. THFA participates in biosynthesis of purine and pyrimidine mononucleotides, and also some replaceable amino acids (serine, glycine).
2. Fast dividing cells of hematogenic tissue use THFA for the formation of precursors of DNA – purine nucleotides and thymidinemononucleotides, and then nucleic acids.

Symptoms of B<sub>9</sub>-hypovitaminosis
- Megaloblastic (macrocytes) anemia
- Affection of GIT (diarrhea)

Daily need (requirement): 1-2 mg.

Products rich in vitamin B<sub>9</sub>: yeast, green leaves of plants, liver, kidneys, meat.

The antagonist of folic acid (B<sub>9</sub>) - 4-aminopterine inhibits nucleic acids synthesis and also is used in oncology (leukose) as an antineoplastic preparation.
**Vitamin B₁₂**
(cobalamin, antianemic)

Chemical structure of vitamin B₁₂
(It consists of a porphyrin ring (corrin ring) nucleus with an atom of cobalt, nucleotide ligand and other groups of atoms).

**Biological role of vitamin B₁₂**

Cobalt coferments are formed from vitamin B₁₂:

- Methylcobalamin (CH₃ – B₁₂), participates in the reaction of transfer of CH₃ i.e. trans-methylation (together with THFA):

  \[ \text{ethenolamin} \xrightarrow{\text{CH₃--B₁₂}} \text{cholin} \]

- Deoxyadenosylcobalamin participates in the reaction of isomerization:

  \[ \text{HFA} \xrightarrow{\beta-oxidation} \text{methylmalonin-CoA} \xrightarrow{\text{deoxyadenosyl-B₁₂}} \text{succinyl-CoA} \xrightarrow{} \text{CTA} \]

**Symptoms of B₁₂-hypovitominosis.**
- Malignant, macrocytes, megablastic anemia.
- Disorders of nervous system (spinal cord).
- Decrease(reduction) of gastric juice acidity.
- Castl factors (external - B₁₂, internal - gastromykoproteides, formed in mucous membrane of stomach, provides the transport of the vitamin from intestines into blood).

**Daily requirement:** 2-5 mkg.
Products rich in vitamin B₁₂: liver, fish, meat, milk, eggs. It is synthesized also by the microflora of intestines.

**Vitamin** B₁₃ (orotic acid)

chemical structure of the orotic acid

![Chemical structure of orotic acid](image)

**Biological role of the orotic acid**

- It is a precursor of pyrimidine bases (uracil, thimin, cytosine), hence:
  - stimulates biosynthesis of nucleic acids (DNA, PNA),
  - stimulates synthesis of tissue,
  - increases the processes of hemogenesis.

Vitamin B₁₅ (pangamic acid)

Chemical structure of the pangamic acid
(It is a derivative of the gluconic acid and dimethylglycine).

![Chemical structure of pangamic acid](image)

**Biological role of the pangamic acids**

It is the donor of methyl groups and can participate in biosynthesis:
- choline,
- methionine,
- creatine. It is a lipotropic factor, i.e. prevents the development of a fatty dystrophy of the liver.

**Products rich in vitamin B₁₅:** liver, seeds of plants, yeast, etc.

**Vitamin B₁₅**
(carnitine)

Chemical structure of carnitine
(γ-trimethylamino-β-oxybutrate).

\[(\text{CH}_3)_3\text{N}^+-\text{CH}_2-\text{CH(OH)}-\text{CH}_2-\text{COOH}\]

Biological role of carnitine
It is used as a coferment in enzymes, providing the transfer of HFA and Acetyl-CoA through mitochondria membrane.

daily requirement: about 0.5 g.
**Products rich in vitamin B₁₅:** meat products.

**Vitamin H**
(biotin, antiseborrhetic)

chemical structure of vitamin H
(a derivative of urea, thiophen and the valearic acid).

<table>
<thead>
<tr>
<th>H</th>
<th>H</th>
<th>H₂</th>
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<tbody>
<tr>
<td>O=C</td>
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<tr>
<td>N</td>
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<td>S</td>
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<tr>
<td>(CH₂)₄-</td>
<td>COOH</td>
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Biological role
It is a coferment of enzymes of carboxylation, transcarboxylation (i.e it takes part in the activation and transfer of CO₂) at:

changing acetal CoA into malonyl CoA (biosynthesis of HFA),
converting pyruvate into oxaloacetate (gluconeogenesis).
Symptoms of H-hypovitaminosis.

- dermatitis
- affection of nails
- loss of hair
- pains in muscles
- anemia

Daily requirement: 0.25 mg.
Products, rich in biotin: liver, kidneys, milk, eggs yolk, vegetative products: potato, rice, onion, tomato, spinach. It is synthesized by microflora of intestines.

**Vitamin C**  
(ascorbic acid, antiscorubtic)

Chemical structure of vitamin C  
(lactonic acid, similar in structure to L-glucose).

![Chemical structure of vitamin C](image)

**Biological role of vitamin C**

It participates in oxidation-reduction reactions:
- **hydroxylation of proline and lysine** with the formation of the appropriate hydroxamino acid, molecules necessary for the formation of tropocollagen and strong collageneric fibres. In this connection at deficiency of vitamin C the formation of connective structures of a bone tissue (teeth decay), junction (teeth fall down), walls of blood vessels (hemorrhage from the gingivae, haemorrhage and petechin) is destroyed;
- **hydroxylation of tyrosine and tryptophan** with the formation of mediators of nervous realization (adrenaline and noradrenaline, serotonin);
- hydroxylation vitamin 

D₃ with the formation of hormonal substances -calcitriol;
- hydroxylation of intermediate products during the formation of hormones of a bark of adrenal glands from cholesterol;
- participation in transformation of the folic acid (B9) into the tetrahydrofolic acid (THFA);
- It is an antioxidizer and limits reactions of peroxides formation in tissues.

Symptoms of C-hypervitaminosis (scurvy)
- gingiva hemorrhage
- loosenings decay and loss of teeth
- fine dot haemorrhages under the skin and into it - petechiae
- haemorrhages and bleedings in internal organs
- edema of lower extremities and pains at walking.

Daily requirement: 75-100 mg.
Products rich in vitamin C: pepper, cabbage, berries of a mountain ash, black currant, citrus, hips.

**Vitamin P**
(rutin, quercetin, vitamin of premeability)

chemical structure of vitamin P
(bioflavonoids).

![Chemical structure of vitamin P](image)

**Biological role of vitamin P**
1. It increases the deposition of the ascorbic acid.
2. Together with vitamin C it supervises permeability and fragility of blood vessels.
   - Together with vitamin C it participates in the synthesis of connective collagen structures
   - it inhibits hyaluronidase (interfere the depolymerisation of hyalouronic acids).
3. It activates tissue respiration.

Symptoms of P hypovitaminosis
- Haemorrhages and bleedings and other symptoms, characteristic for C-hypovitaminosis (scurvy).

Daily requirement: 25-50 mg.
Products rich in vitamin P: hips, citron, black currant, mountain ash, black fruits of a mountain ash.
**Vitamin N**

( lipoic acid)

Chemical structure of vitamin N
(a derivative of the valeric acid).

![Chemical structure of vitamin N](image)

**Biological role of vitamin N**

As an amide of the lipoic acid is a part of enzymes:
- pyruvate dehydrogenase complex,
- α-ketoglutarate dehydrogenase complex,

They participate in oxidizing decarboxylation of α-ketoacid (pyruvate and α-ketoglutarate) and transfer the residues of these ketoacid on KoA with the formation Acetyl - KoA and succinyl-CoA.

Products, rich in vitamin N: products of an animal origin - meat, milk.

**Paraaminobenzoic acid**

(vitamin for microorganisms)

Chemical structure of PABA

![Chemical structure of PABA](image)

**Biological role of PABA**

- It is a part of the folic acid
- It is the factor of microorganisms growth
- It activates the enzyme - tyrozinase

Call structural analogues of PABA which are used in medical practice, and explain the mechanism of their action (see antivitamins).

Products rich in PABA: liver, kidneys, meat, yeast.

**Vitamin U**

(S-methylmethionine, antulcal factor)
Chemical structure of vitamin U

\[
\begin{align*}
\text{HOOC} & \text{–} \text{CH} & \text{–} & \text{CH}_2 & \text{–} & \text{CH}_2 & \text{–} & \text{S}^+ & \text{–} & \text{Cl}^- \\
\text{NH}_2 & & & & & & & \text{S– methylmethioine} & & & \\
& & & & & & & & & & \text{CH}_3
\end{align*}
\]

Biological role of vitamin U

1. As the donor of CH₃-groups, it participates in the synthesis of:
   - methionine,
   - choline,
   - creatine.
2. It works as a lipotropic factor (see choline).
3. It stimulates the restoration of injured GIT mucous membranes.

Products rich in vitamin U: fresh cabbage, greens of parsley, carrot, onions, pepper, green tea, bananas, milk, etc.