Vitamins: general characteristic

• Vitamins – essential nutrients that must be included in every day diet.
• Water soluble vitamins cannot be stored in human tissues. Their excess is excreted with urine.
• Significant amounts of fat soluble vitamins can be stored in adipose tissue and the liver.
Vitamins

Water soluble vitamins: classification
Classification of vitamins

- **Water-soluble**
  - Non-B-complex
    - Ascorbic acid (vitamin C)
  - B-complex
    - Energy-releasing
      - Thiamine (vitamin B₁)
      - Riboflavin (vitamin B₂)
      - Niacin (vitamin B₃)
      - Biotin
      - Pantothenic acid
    - Hematopoietic
      - Folic acid
      - Vitamin B₁₂
    - Other
      - Pyridoxine (vitamin B₆)
      - Pyridoxal
      - Pyridoxamine

- **Fat-soluble**
  - Vitamin A (retinol, β-carotenes)
  - Vitamin D (cholecalciferol)
  - Vitamin K (phylloquinones)
  - Vitamin E (tocopherols)
Vitamin B1, Thiamine

- Coenzymes: Thiamine pyrophosphate
- A coenzyme of lyases
- Takes part in CO2 removal from keto-acids.
- Sources: Cereal, grains, bread, corn.
- Recommended daily allowance (RDA): 1-3 mg.
- Deficiency: anorexia, wekness. In severe cases, lesions of nerve system and cardiomuscular system. Beri-beri disease and Wernicke-Korsakoff syndrome.

![Thiamine molecule]

![Thiamine phosphate molecule]
Food courses of thiamin

- Meats: 0.4-1mg/85g of pork or ham
- Cereals and grain products: 0.3-0.9 mg/cup of ready-to-eat cereals; 0.15mg/a half of cup noodles or pasta; 0.1 mg/a half of cup of cooked rice.
- Legumes: 0.2mg/a half of cup of black beans, green peas.
- Fruits: 0.3 mg/1cup of orange juice; 0.3 mg/168 g of grapefruit juice
Vitamin B2, Riboflavin

- Coenzymes: FAD, FMN
- Coenzymes of oxidoreductases (dehydrogenases)
- Takes part H removal from substrates (FADH$_2$ is a reduced form).
- Sources: cereal, germ, lean meat, liver, kidney, milk.
- RDA: 1-3 mg.
- Deficiency: fractures at the corners of lips, cheilitis, stomatitis.
Food sources of riboflavin

- Dairy products: 0.5mg/225g of yogurt; 0.45mg/cup of milk; 0.2mg/a half of cup of cottage cheese.
- Cereals and grain products: 0.4-1 mg/cup of ready-to-eat cereal.
- Meats and eggs: 0.3mg/85g of pork; 0.25mg/egg
- Vegetables
- 0.15mg/a half of cup of spinach or mushrooms or soybeans
Vitamin B3, niacin

- Coenzymes: $\text{NAD}^+$, $\text{NADP}^+$
- Coenzymes of oxidoreductases; $\text{NAD}^+$ is a coenzyme of dehydrogenases ($\text{NADH} – \text{reduced form}$); $\text{NADPH}$ is a coenzyme of reductases
- Sources: grains, cereals, yeast, milk, leafy vegetables, meats
- RDA: 25 mg
- Deficiency: dermatitis, diarrhoea, dementia (is known as pellagra ("rough skin") or 3D disease)
Food sources of niacin

- Meats: 14 mg of niacin/85 g of beef liver; 10 to 11 mg/85 g of tuna; 2-6 mg/85 g of beef, lamb, poultry, other fish.
- Cereal and grain products: 2-10 mg/1 cup of ready-to-eat cereal; 1 mg/a half of cup of noodles; 1.5 mg/a half of cup of cooked rice.
- Vegetables 2 mg/a half of cup of canned tomato product; 1.5 mg/a half of cup of mushrooms; 1 mg/a half of cup of corn or potatoes.
- Other 4 mg/28 g of peanuts
Vitamin B5, pantothenic acid

• Coenzymes: CoA, 4-phosphopantethein
• CoA is a coenzyme of transferases involved in transferring of acyl- and acetyl-units. CoA is essential in metabolism of fatty acids and sugars.
• 4-phosphopantethein is involved in fatty acid synthesis.
• Sources: Whole-grains, cereals, legumes, animal tissues.
• RDA: 25 mg.
• Deficiency is unlikely because of wide distribution in foods.
Food sources of B5

- Fish and poultry: 0.7-1.0mg/65g fish, turkey or chicken; 0.7mg/large egg.
- Milk: 0.9mg/1 cup of milk.
- Legumes and seeds: 0.6mg/a half of cup of cooked slit peas; 2mg/1/4 cup sunflower seed kernels.
- Other vegetables: 0.5-1.7 mg/a half of cup of mushrooms; 0.4mg/ a half of cup of potatoes; 0.7mg/a half of cup of sweet corn.
Vitamin B6, pyridoxin

- Coenzymes: pyridoxal phosphate (Pyr.P)
- Pyr. P is a coenzyme of:
  - transferases (transfers amino \{-NH_2\} group);
  - lyases (removes amino and carboxy groups from amino acids)
  - isomerases.
- Sources: seeds, grains, milk, eggs.
- RDA: 2-3 mg
- Deficiency: nervousness and disturbances of CNC functions.
Food sources high in B6

- Cereals and grains: 0.3-1mg/1 cup of ready-to-eat cereal; 0.3 mg/a half of cup of enriched cooked rice; 0.15 mg/a half of cup of brown rice.

- Vegetables: 0.1 mg/a half of cup of kidney beans or chickpeas; 0.15-2.0mg/a half of cup of brussels sprouts, spinach, sweet red peppers, broccoli; 0.25mg/a half of cup of carrot juice.

- Meat, poultry, fish: 0.4mg/28g of beef or fish
Folic acid

- Coenzymes: tetrahydrofolic acid (THFA)
- THFA is a coenzyme of transferases which transfer one C atom containing units (methyl, methylene, methenyl, etc.)
- Sources: plants
- RDA: 0.4 mg
- Deficiency: anemia
Food sources high in folate

- Cereals and grains: 650µg/a half of cup of Kellog’s cereal; 150-400µg/1 cup of ready-to-eat cereal; 75-100µg/a half of cup of cooked rice.
- Legumes: 110-150µg/a half of cup of black, navy, kidney beans; 60-80µg/a half of cup of split peas.
- Vegetables: 120-130µg/a half of cup of spinach or asparagus; 80-85µg/per a half of cup of broccoli, brussels sprouts.
**Vitamin B12, cobalamine**

- The only vitamin containing trace-elements cobalt.
- Coenzymes: 5’-deoxyadenosyl cobalamin and methyl-cobalamin.
- 5’-deoxyadenosyl cobalamin is a coenzyme of isomerase, which catalyses H-atom shift in the molecule

![Intramolecular rearrangements](image)

- Methyl-cobalamin is a coenzyme of transferases
- RDA: 3 microgramms
- Sources: meat, liver
- Deficiency: megaloblastic anaemia, degradation of spinal cord.
Food sources high in B12

• Fish: 8µg/85g of sardines; 5µg/85 g canned salmon.
• Meats: 1.4-2.5µg/85 g of beef.
• Dairy: 1-1.3µg/1cup of milk/yogurt; 0.6µg/a half of cup of cottage cheese; 0.6µg/28g of mozzarella cheese.
Vitamin C, ascorbic acid

- Coenzymes: unknown
- Acts as a coenzyme of oxidoreductases (e.g. those involved in hydroxylation of Lys and Pro under collagen syntheses.
- Vit.C acts as an antioxidant, which collects electrons from free radicals in body fluids (blood, extracellular fluid).
- RDA: 50 mg – 100 mg, up to 1g.
- Sources: citrus fruits, berries, tomato, leaves of green vegetables
- Deficiency: impaired resistance to infections, gum bleeding, scurvy
Food sources high in C

- 70 mg/1 medium kiwi fruit; 45-55mg/a half of cup of fresh or frozen strawberries or fresh orange sections.
- Juices: 90 mg/3/4 cup fresh orange juice; 70 mg/3/4 cup fresh grapefruit juice or grape juice.
- Vegetables: 120-140mg/a half of cup of sweet red pepper; 35-60mg/a half of cup of broccoli or brussels sprouts; 15-35 mg/a half of cup of cauliflower, red cabbage, sweet potato.
Biotin

- Coenzymes: Biocytin, the vitamin covalently linked to Lys residue in the AS of enzymes.
- A coenzyme of ligases, involved in CO2 binding to substrates (ATP is required).
- Sources: all kinds of foods.
- RDA: 150-200 mg.
- Deficiency: unlikely because of synthesis in large quantities by intestinal bacteria
Fat soluble vitamins
Vitamin A, retinol

- Active forms: retinol, retinal, retinoic acid.
- Stored as esters of retinol in the liver.
- Sources: β-carotenes (plant pigments) and fish oil (contains esters of retinol).

- Retinal and retinoic acids are products of retinol oxidation.
- Retinal is an essential component of visual pigment rhodopsin in rod cells of retina.
Retinal

- Involved in monochromatic vision.
- 11-cis retinal binds to protein opsin, yielding visual pigment rhodopsin.
- Under illumination 11-cis retinal is converted to all-trans retinal, which dissociates from rodopsin.
- The action potential is generated in rod cells as a result of all-trans retinal formation.
Visual cycle

\[ \Delta^{11}\text{-cis-Retinal} \rightarrow \text{opsin} \rightarrow \text{Rhodopsin} \rightarrow \text{trans-Retinal} \rightarrow \text{nerve impulse} \rightarrow \text{opsin} \]
Retinol and retinoic acid act as hormones

- Retinoic acid controls cell differentiation.
- Retinoic acid initiates a sequence of events which arrest cell-cycle.
- Retinoic acid is efficient in treatment of leukemias.
- Precursor of retinol β-carotene and retinol has mild antioxidant activity.
• Vit. E is a group of compounds known as tocopherols, which differ in number of methyl groups in molecules. Tocopherols are identified by Greek letters: α-, β-, γ-, δ-. α-tocopherol is the major one.

• Vit. E molecule has isoprene chain attached.

• Vit. E acts as antioxidant in lipids (blood lipoproteins, membranes). It binds free radicals and stops formation of lipid peroxides.

• Deficiency in Vit. E causes oxidative stress related to membrane damage.

• Vit. E supplements are efficient in prevention of atherosclerosis, senescence and even malignant transformations.

• Deficiency rare.

• Sources: seed oil.
Vitamin D

- Ergocalciferol in plants; cholecalciferol in animals.
- Vit. D is converted into 1,25-dihydroxyvitamin D (hormone calcitriol).
- Essential for Ca ions absorption from intestinal lumen and from urine into blood.
- Calcitriol is the most powerful regulator of Ca ions concentration in humans.
Vitamin K

- derivative of naphtoquinones.
- Act as a coenzyme of enzymes (carboxylaseas) which add carboxyl group to carboxylic acids present in blood clotting enzymes, known as blood clotting factors.
- Analogs of vit. K are anticoagulants.