EPFL

FOOD CHEMISTRY

Chapter 6 : Essential nutrients

6.1 ESSENTIAL NUTRITIONAL REQUIREMENTS

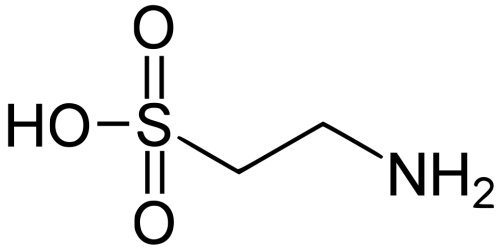
An overview

Essential nutrients : chemical species that are needed to maintain life, and that cannot be synthesized by the body.

Amino acids	Isoleucine, Leucine, Lysine, Methionine + Cysteine, Phenylalanine + Tyrosine, Threonine, Tryptophan, Valine
Fatty acids	Linoleic acid (ω-6), α-linolenic acid (ω-3)
Water-soluble vitamins	Ascorbic acid, biotin, cobalamin, folic acid, niacin, pantothenic acid, pyridoxine, riboflavin, thiamine
Fat-soluble vitamins	Carotenes (A), calciferols (D), tocopherols (E)
Major elements	Ca, Mg, P, K, Na, Cl
Trace elements	Cr, Cu, Fe, I, Mn, Mo, Ni, S, Se, Zn
Small molecules	Water
Energy	Fat + sugars + proteins

6.1 ESSENTIAL NUTRITIONAL REQUIREMENTS

Species dependance of essential nutrients



Taurine

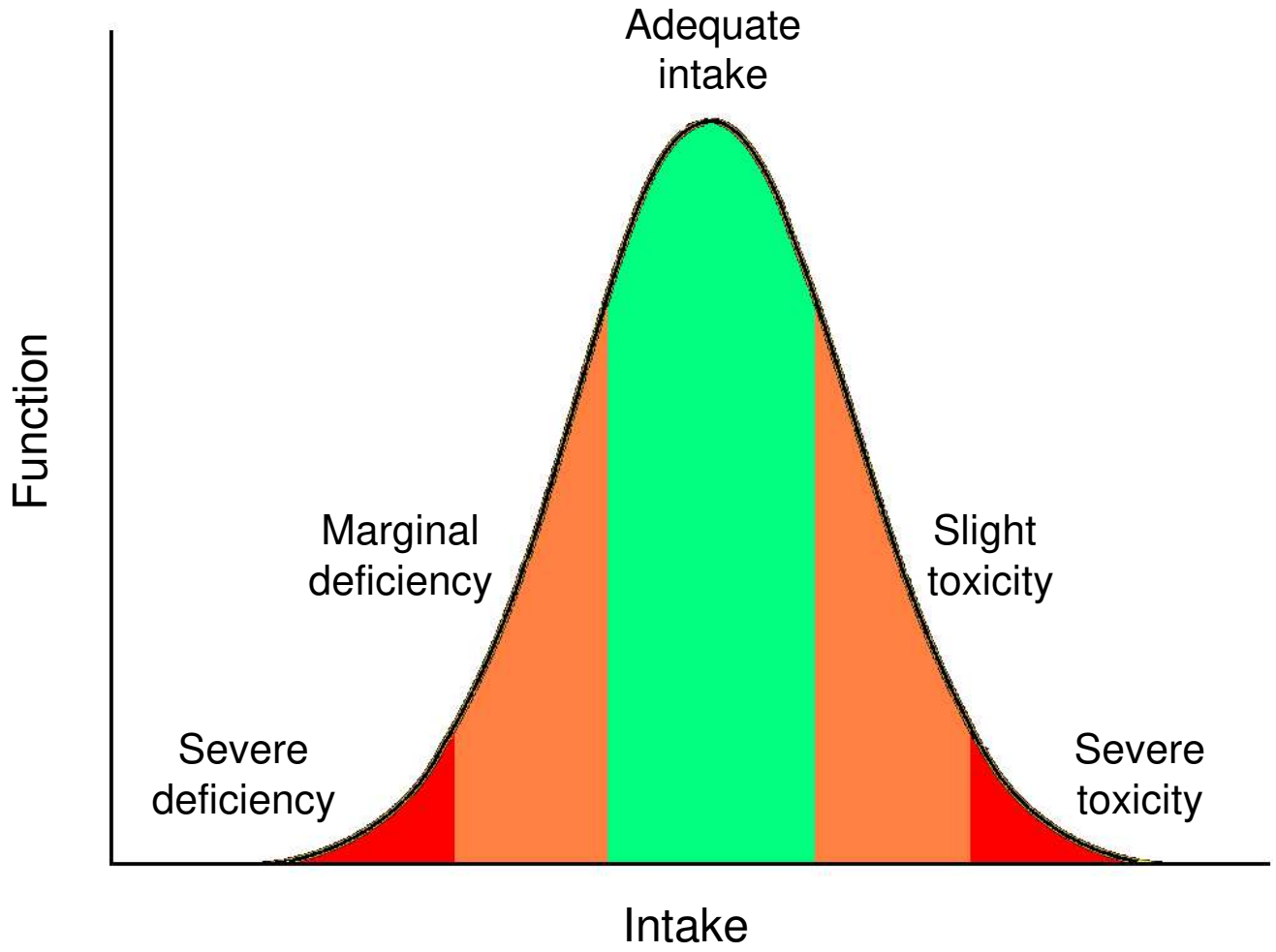
Taurine is an important molecule in people and animals. It accounts for about 0.1% of total human body weight.

It is a major component of bile and is used to moderate calcium signaling, osmoregulation, and proper muscle function.

Human can synthesize taurine from the amino acid cysteine. However, cats and other carnivores cannot, so they have to obtain it from their diet.

6.1 ESSENTIAL NUTRITIONAL REQUIREMENTS

Dose-response relationship



6.1 ESSENTIAL NUTRITIONAL REQUIREMENTS
Nutritional recommendations

The Recommended Dietary Allowance (RDA) was developed in the USA during World War II by a committee established to investigate issues of nutrition that might « affect national defense ».

- ESTIMATED AVERAGE REQUIREMENT (EAR), expected to satisfy the needs of 50% of the people.

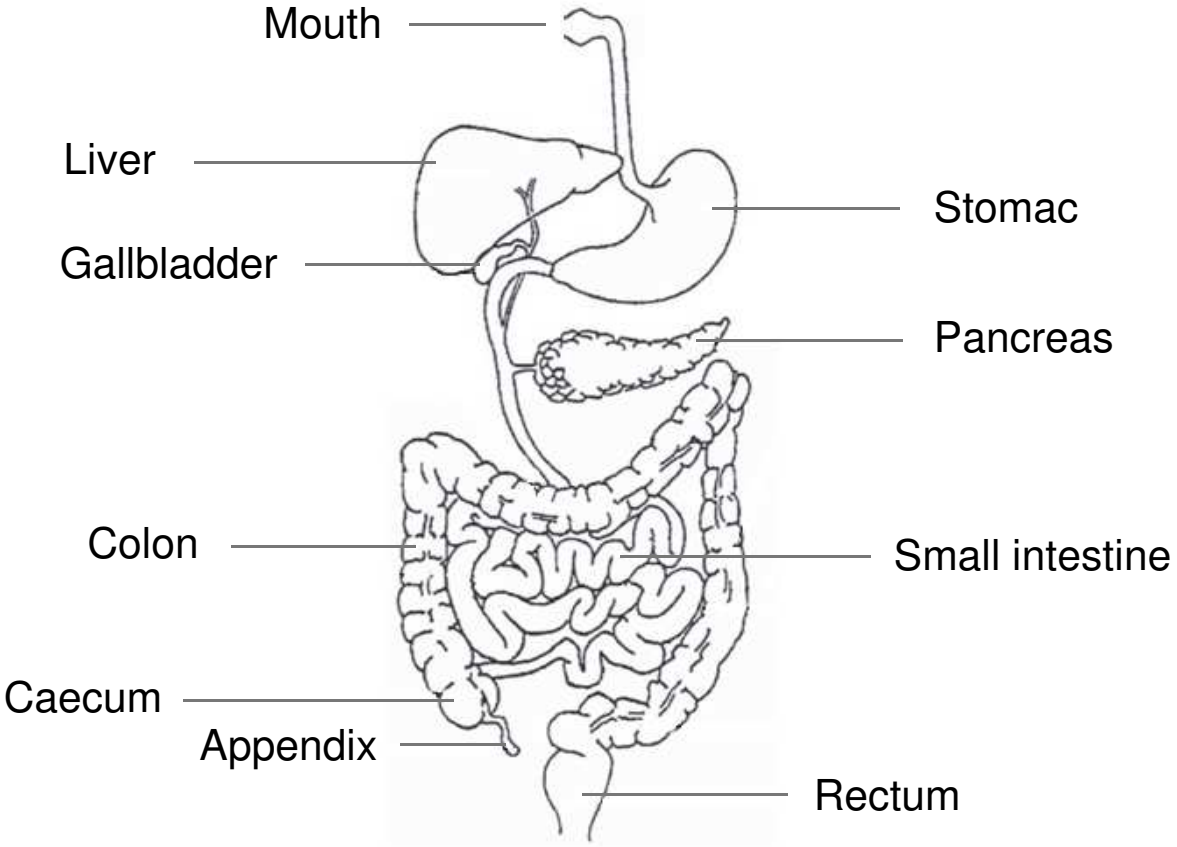
- RECOMMENDED DAILY ALLOWANCES (RDA), the daily dietary intake level of a nutrient considered sufficient to meet the requirements of nearly all (97–98%) healthy individuals in each life-stage and gender group .

- ADEQUATE INTAKE (AI), where no RDA has been established, but the amount established is believed to be adequate.

- TOLERABLE UPPER INTAKE LEVELS (UL), to caution against excessive intake of nutrients (like vitamin A) that can be harmful in large amounts.

6.2 INTAKE OF NUTRIENTS

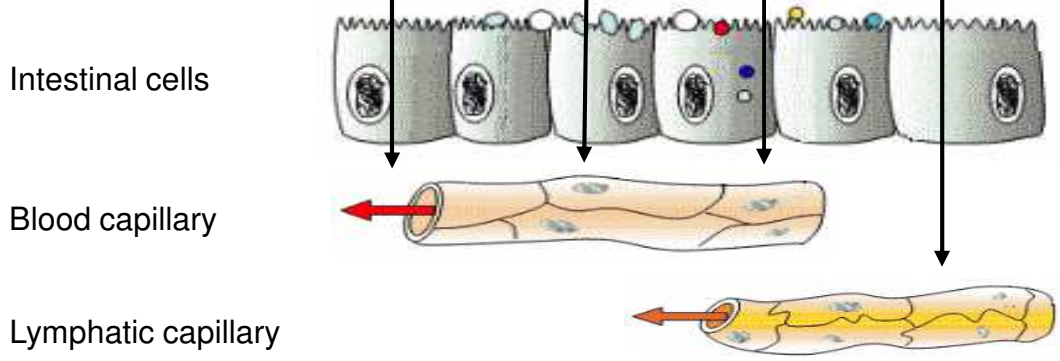
The gastro-intestinal tract



6.2 INTAKE OF NUTRIENTS

Absorption of essential elements

Medium	Enzymes	pH	Production	Water Salts Vitamins	Carbo-hydrates	Lipids	Proteins
Saliva	Amylase	6.9	1.5 l/day				
Gastric juice	Pepsin	1 - 3	2.5 l/day				
Bile	No enzyme	7 – 9	0.7 l/day				Emulsion
Pancreatic juice	Amylase Lipase Protease	7 - 9	1 – 4 l/day				
Intestinal juice	Various enzymes						



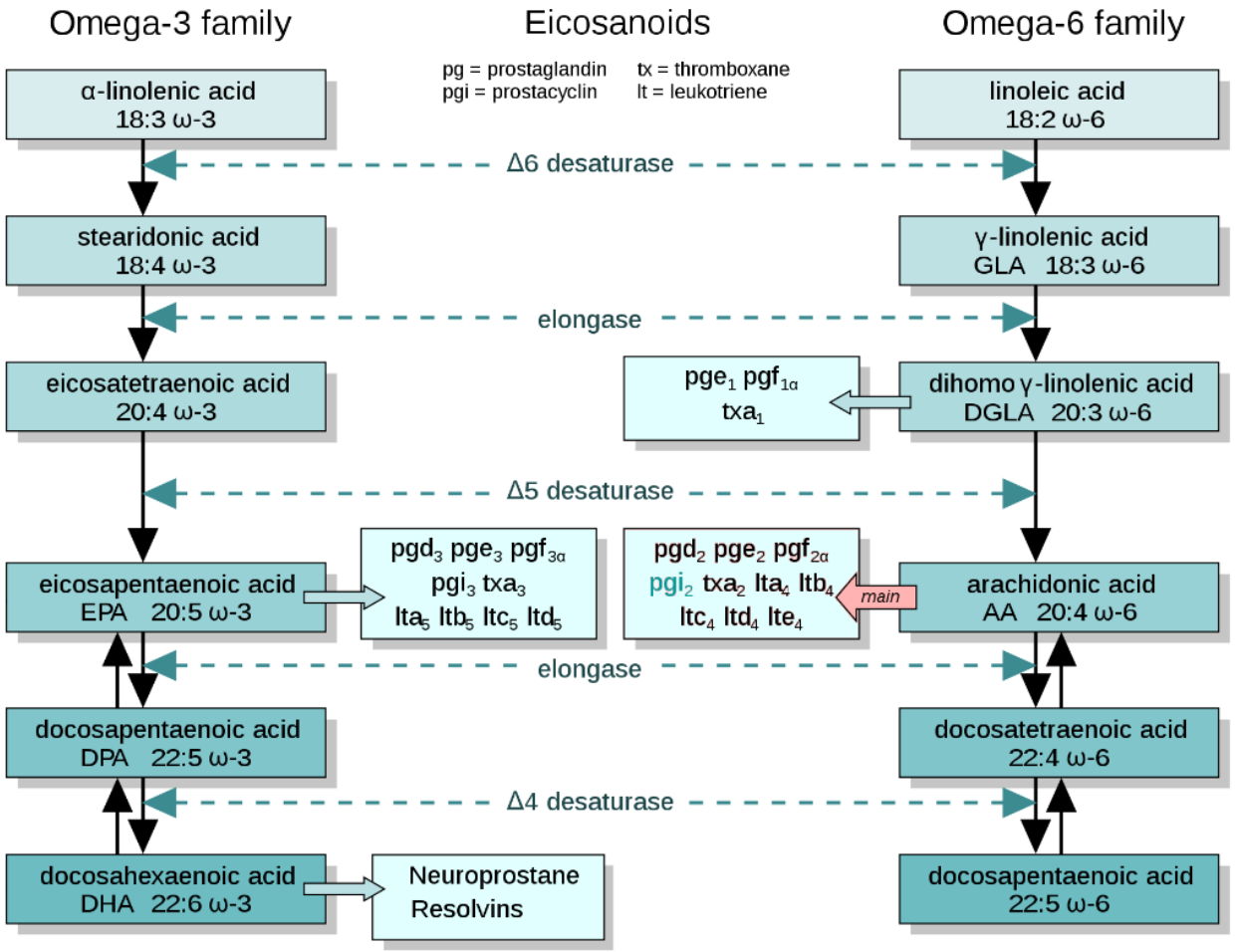
6.3 ESSENTIAL FATTY ACIDS AND AMINO ACIDS

Role and disorders due to nutrient deficiencies

Essential nutrient	***Role***	***Disorder due to insufficient intake***
18:2 (n-6) 18:3 (n-3)	Precursors of leukotrienes (signalling molecules, inflammatory response), prostaglandins (non-hormonal messengers), thromboxanes (vaso-constrictors, help platelets aggregation)	Neural disorders, hemostasis disorders
Met Leu Val Lys Ile Phe Trp His Thr Arg	Protein synthesis, hormone precursors	Edema, kwashiorkor, marasmus

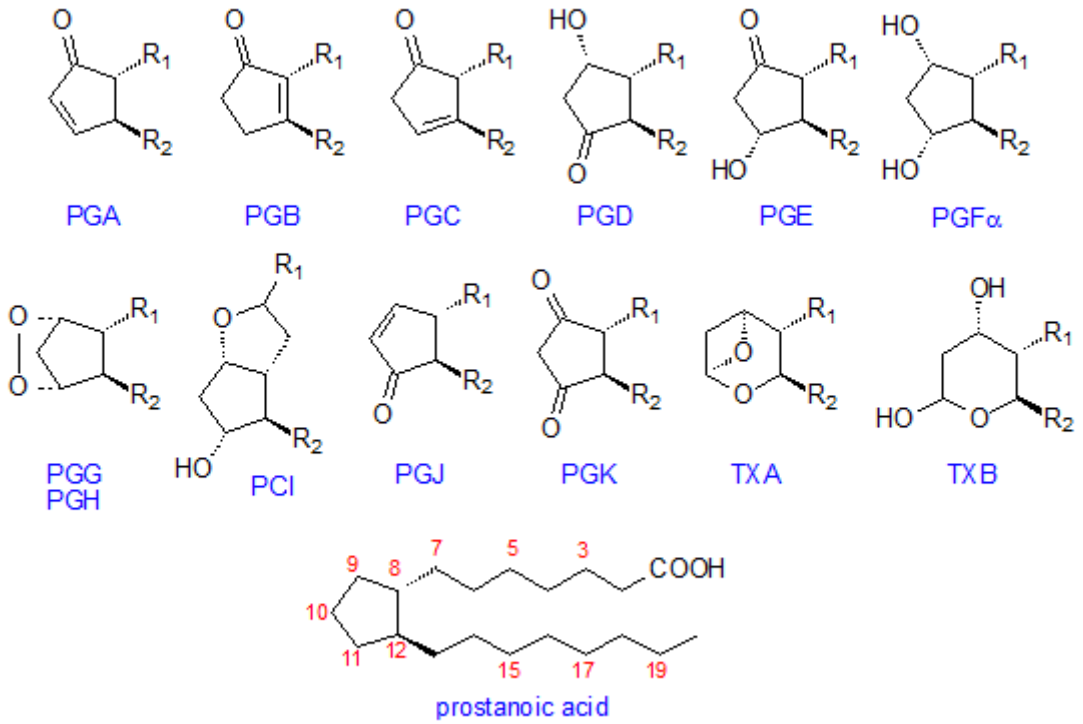
6.3 ESSENTIAL FATTY ACIDS AND AMINO ACIDS

Eicosanoids production



6.3 ESSENTIAL FATTY ACIDS AND AMINO ACIDS

Eicosanoids nomenclature



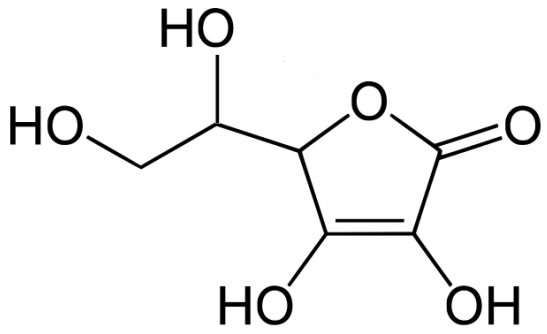
6.4 VITAMINS

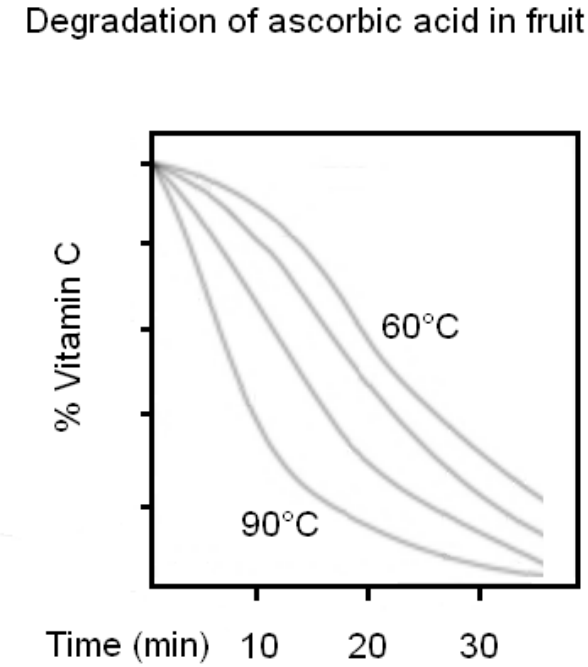
Approximate intake of vitamins in Switzerland

Vitamin	Unit	2007 - 2008	2001 - 2002	RDA
A (retinol)	mg	1.3	1.6	0.9
Carotene	mg	3.6	3.5	-
D (ergocalciferol)	µg	3.1	2.5	5.9
E (tocopherol)	mg	17.2	15.3	12.2
B1 (thiamine)	mg	1.3	1.3	1.1
B2 (riboflavine)	mg	1.8	1.9	1.2
Niacine	mg	15.8	15.0	13.8
B6 (pyridoxal)	mg	1.9	1.9	1.3
B9 (folic acid)	µg	305.0	294.0	388.0
B12 (cobalamine)	µg	6.2	6.3	2.8
B5 (pantothenic acid)	mg	6.4	6.0	5.8
C (ascorbic acid)	mg	106.0	121.0	97.0

6.4 WATER-SOLUBLE VITAMINS

Ascorbic acid (Vitamin C)





Antioxydant, collagen biosynthesis

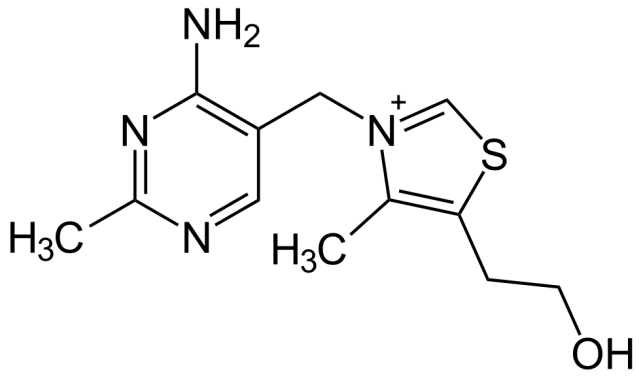
Deficiency : scurvy

Main sources : fresh fruits and vegetables

RDA : 120 mg

6.4 WATER-SOLUBLE VITAMINS

Thiamine (Vitamin B1)



Very important in case of chronic alcoholism : its deficiency produces neurologic disorders and cognitive impairment.

Alcoholics may suffer from thiamine deficiency due to:
* Inadequate nutritional intake
* Decreased uptake of thiamine from the GI tract
* Thiamine stores are reduced due to hepatic steatosis
* Impaired thiamine utilization due to lack of Mg
* Inhibition of thiamine transport due to ethanol

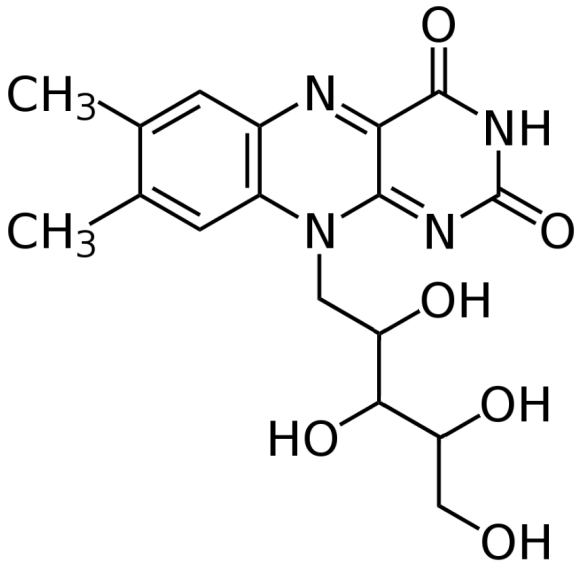
- ► Cofactor of the transformation of glucides into energy
- ► Necessary to the normal function of muscles and nervous system

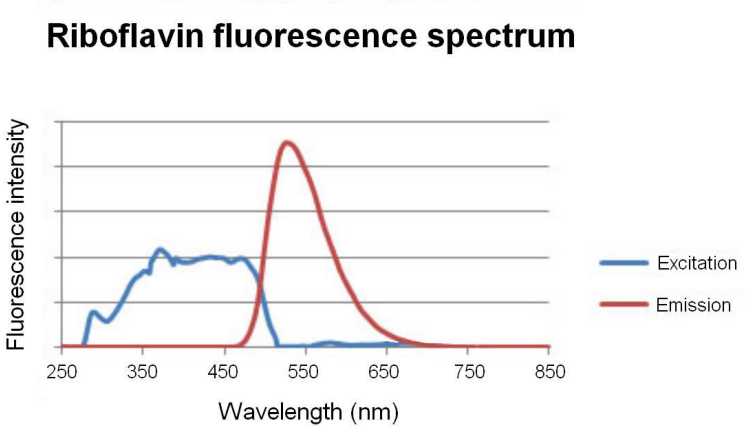
Main sources : bakers yeast, whole grains, pork meat

Deficiency : beri-beri RDA : 1.4 mg

6.4 WATER-SOLUBLE VITAMINS

Riboflavin (Vitamin B2)$_{E101}$





Main sources : bakers yeast, eggs, meat, milk

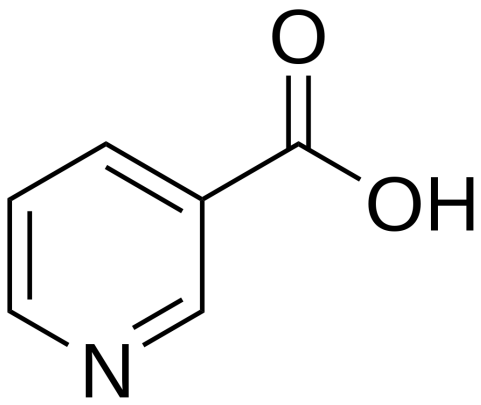
RDA : 1.6 mg

Deficiency : mouth ulcers, dermatitis, photophobia

Central component of the cofactors FAD and FMN, required by all flavoproteins

6.4 WATER-SOLUBLE VITAMINS

Niacin (Vitamin B3 or PP)



Bowl of nixtamal
(lime treated corn)

Main sources : milk, eggs, leafy vegetables

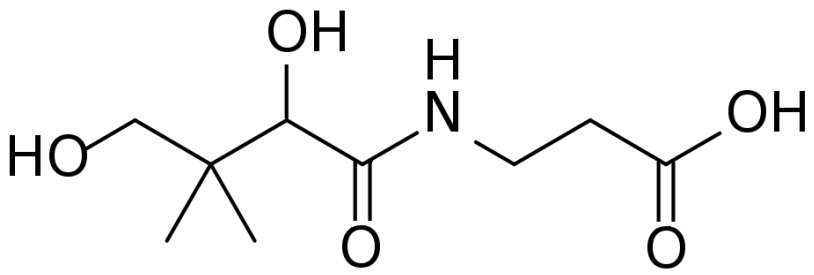
Source of NAD+ / NADP+, cofactor of numerous enzymatic reactions

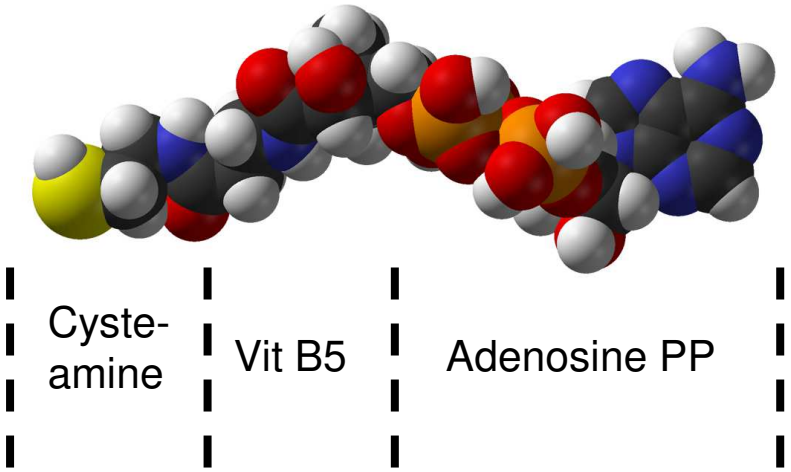
Deficiency : pellagra (diarrhea, dermatitis, dementia)

RDA : 18 mg

6.4 WATER-SOLUBLE VITAMINS

Pantothenic acid (Vitamin B5)





Coenzyme A

Constituent of CoA, major source of carbon transport in the cell

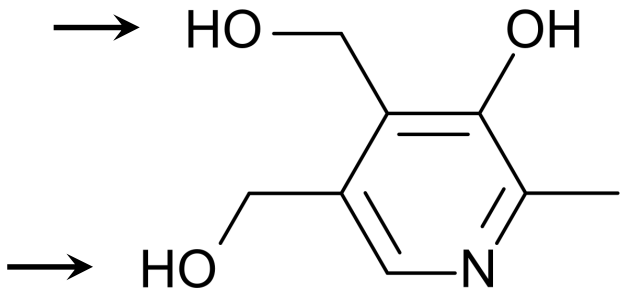
Deficiency (very rare) : apathy, neurological disorders muscle cramps, hypoglycemia

RDA : 7 mg

Main sources : meat, eggs, whole grain cereals, legumes

6.4 WATER-SOLUBLE VITAMINS

Pyridoxine (Vitamin B6)



- pyridoxine (PN)
- pyridoxine phosphate (PNP)
- pyridoxal (PL)
- pyridoxal phosphate (PLP)
- pyridoxamine (PM)
- pyridoxamine phosphate(PMP)

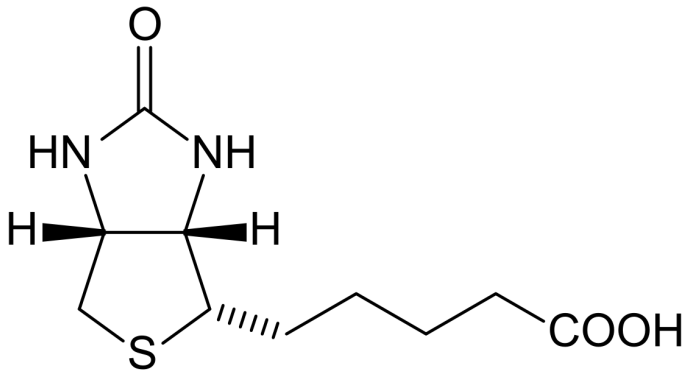
Main sources : brewer's yeast, carrots, chicken, eggs, fish, meat, peas

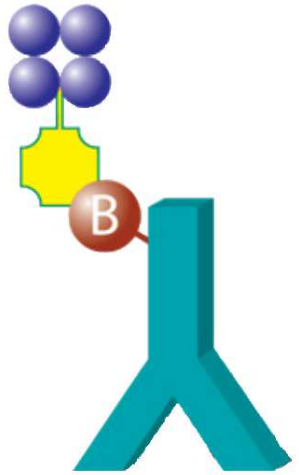
Active in numerous biochemical pathways involving red blood cells, the immune system, central nervous system function, protein metabolism, production of energy, synthesis of DNA and RNA.

Deficiency (rare) : dermatitis, neuropathy, confusion RDA : 2 mg

6.4 WATER-SOLUBLE VITAMINS

Biotin (Vitamin B7)





Avidin – biotin complex

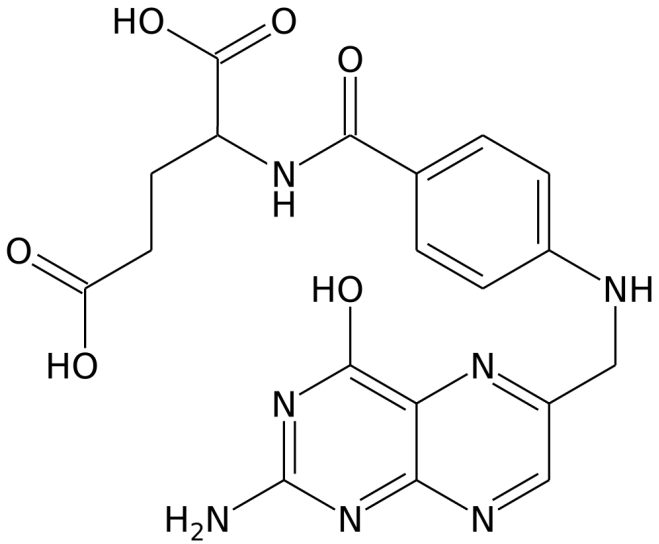
Cofactor of numerous metabolic reactions
Biosynthesis of fats and amino-acids
CO_2 transfer reaction

Symptoms of biotin deficiency include hair loss, conjunctivitis, dermatitis (“biotin deficient face”), neurological disorders.

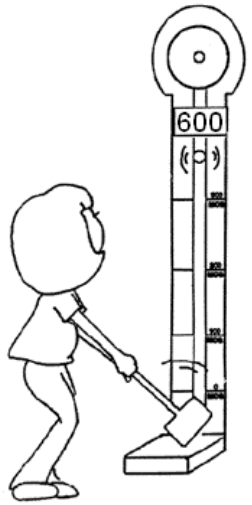
RDA : 0.035 mg

6.4 WATER-SOLUBLE VITAMINS

Folic acid (Vitamin B9)



Synthesis of DNA and RNA, cofactor of biological reactions.
Important in rapid cell division, such as in infancy and pregnancy, but also in proliferation of cancerous cells.



If you can get pregnant, take folic acid !

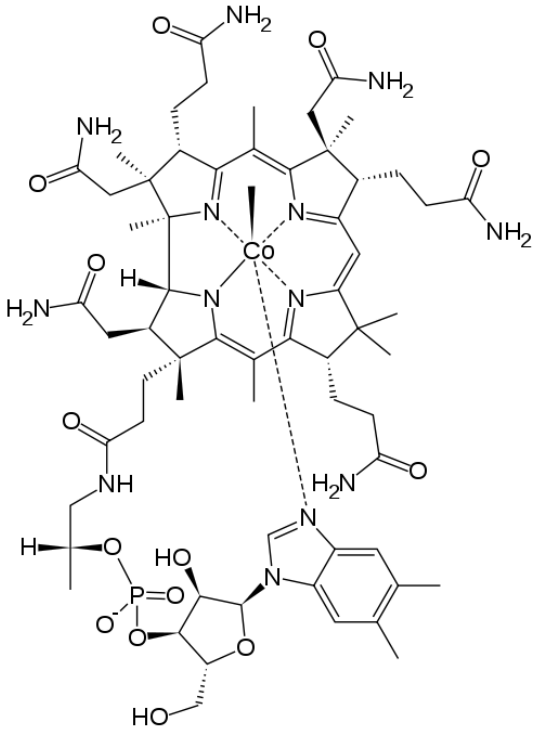
Sources : vegetables, egg yolk

RDA : 0.6 mg

Deficiency : neural tube defects in developing embryos .

6.4 WATER-SOLUBLE VITAMINS

Cobalamin (Vitamin B12)



Plays a role in methylation reactions

Deficiency : anemia, neuropathy
(strict vegetarian diet)

RDA : 0.003 mg

Has been at the origin of 4 Nobel prizes :

1934 Whipple, Minot, Murphy

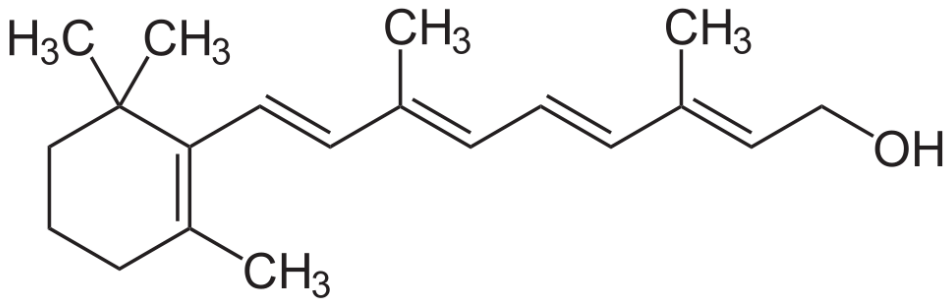
1964 Dorothy Crawford Hodgkin

1965 Bob Woodward

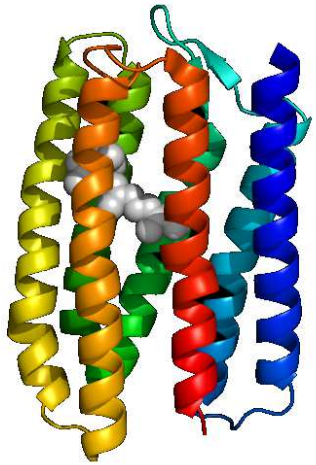
1981 Kenishi Fukui, Roald Hoffmann

6.5 FAT-SOLUBLE VITAMINS

Retinol (Vitamin A)



Retinal, retinoïc acid
Provitamin A : β-carotene



If eaten in one meal, 30 to 90 grams of polar bear liver is enough to kill a human being.

Major sources : liver, butter, eggs, carotene containing vegetables.

RDA : 1.3 mg

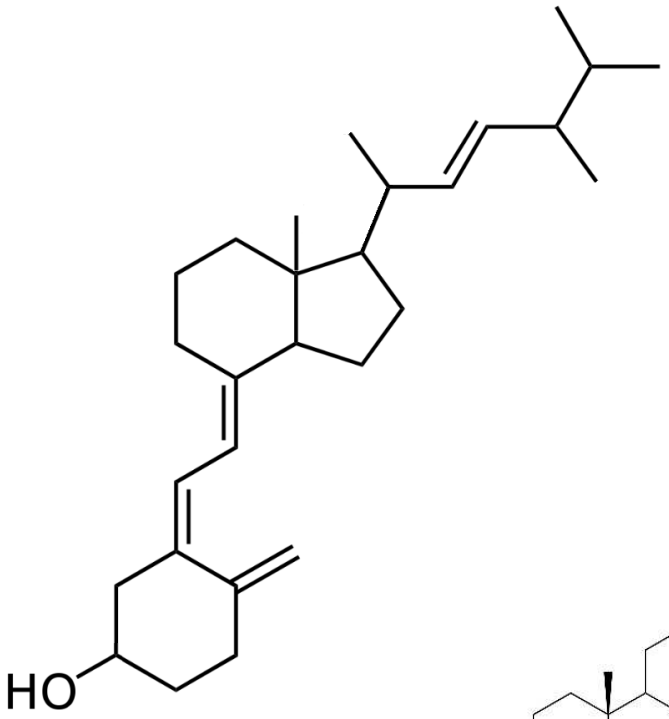
Rhodopsin : active constituent of photosensitive cells

Photon : retinene all trans ⟶ all cis

Sensitivity : 10^{-14} W (a candle at 16 km !)

6.5 FAT-SOLUBLE VITAMINS

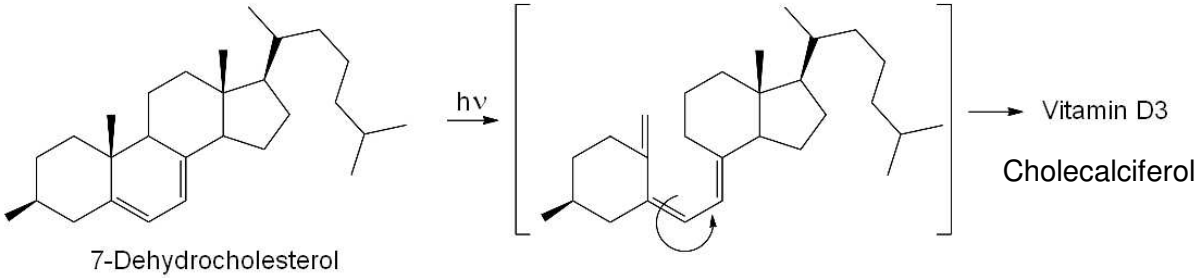
Ergocalciferol (Vitamin D steroid hormone)



Vitamin D can be photosynthesized by humans and is therefore not a vitamin except for people who lack sufficient UV light exposure.

Deficiency : Rickets, osteomalacia

Major source : Fatty fish species, eggs, cheese

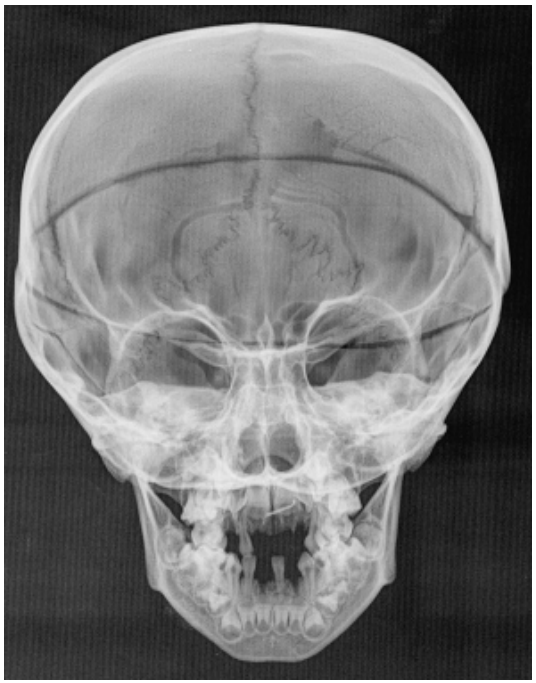


RDA : 0.02 mg

6.5 FAT-SOLUBLE VITAMINS

Vitamin D deficiency in the Medicis family

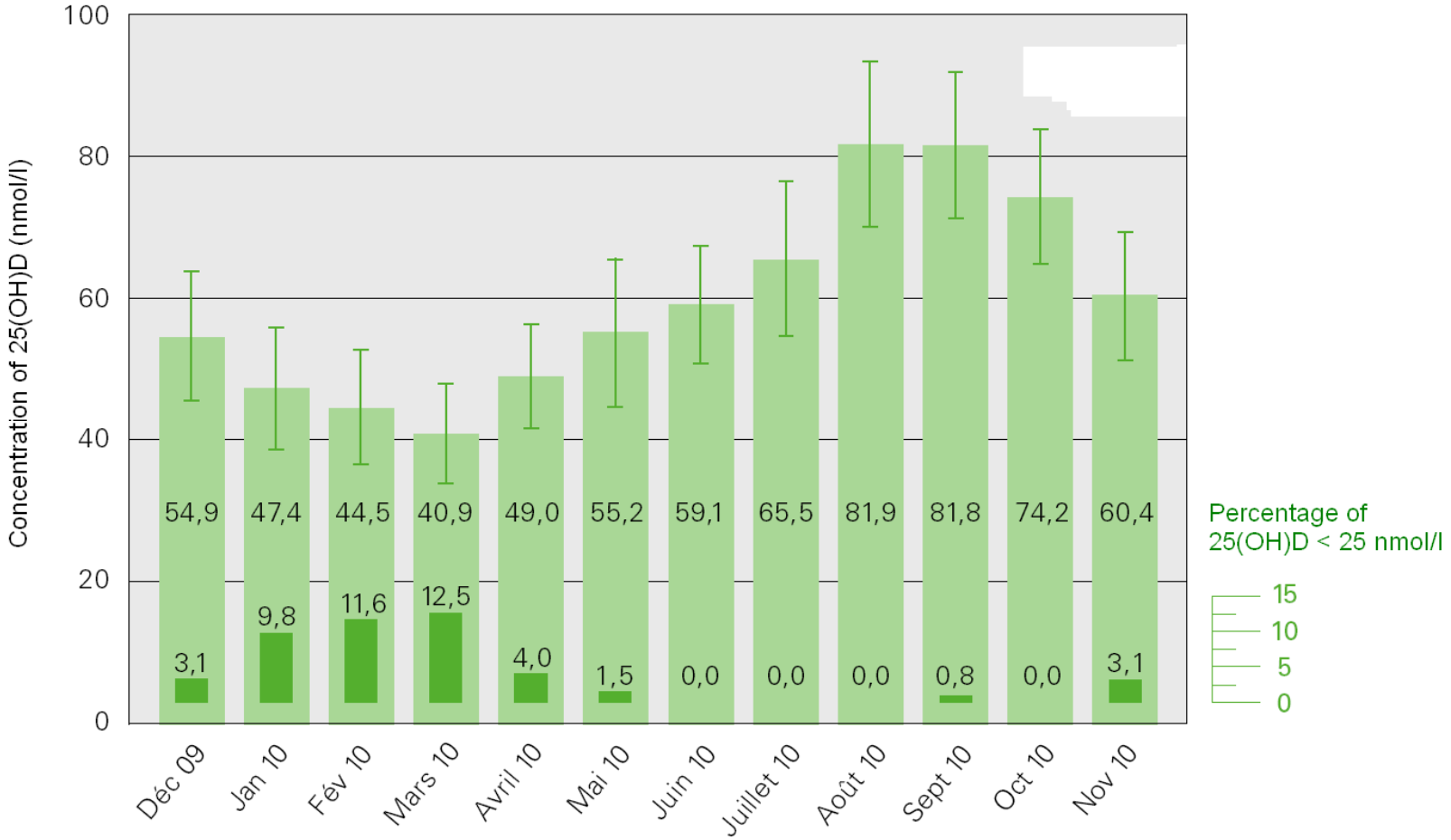
Giovanni Bizzelli - Giovanna d'Austria e suo figlio don Filippino de' Medici



Radiography of the skull of don Filippino

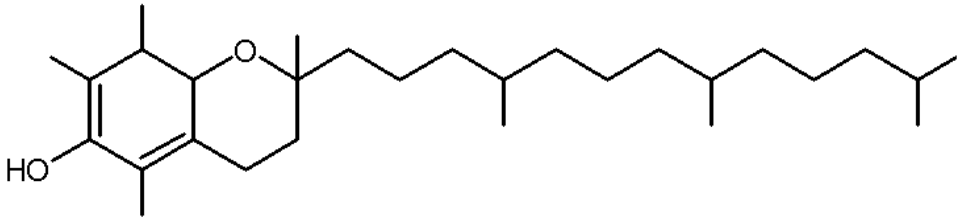
6.5 FAT-SOLUBLE VITAMINS

Concentration of vitamin D in the serum of blood donors



6.5 FAT-SOLUBLE VITAMINS

Tocopherols (Vitamin E)



Antioxydant, elimination of free radicals
The need of vitamin E is increased with a diet rich in polyunsaturated FA

Major sources : vegetable oils

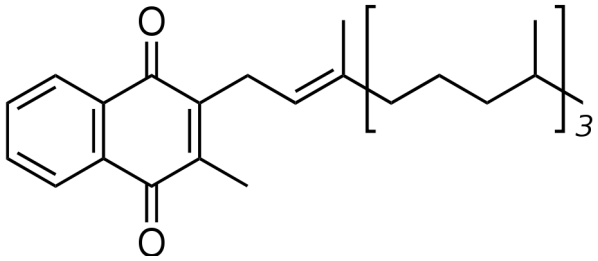
Deficiency : neuromuscular problems (myopathies), anemia

Used as an additive of bacon to prevent the formation of nitrosamines

RDA : 19 mg

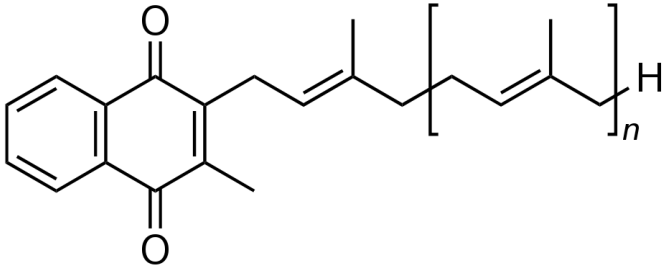
6.5 FAT-SOLUBLE VITAMINS

Phylloquinones (Vitamin K)



Phylloquinone K1

Green vegetables!



Menaquinone K2 (n = 3 – 6)

Synthesized by small intestine bacteria (inhibited by antibiotics !)

Active in blood coagulation and bone metabolism

RDA : 19 mg (bacterial vitamin K from intestine is usually suffisant)

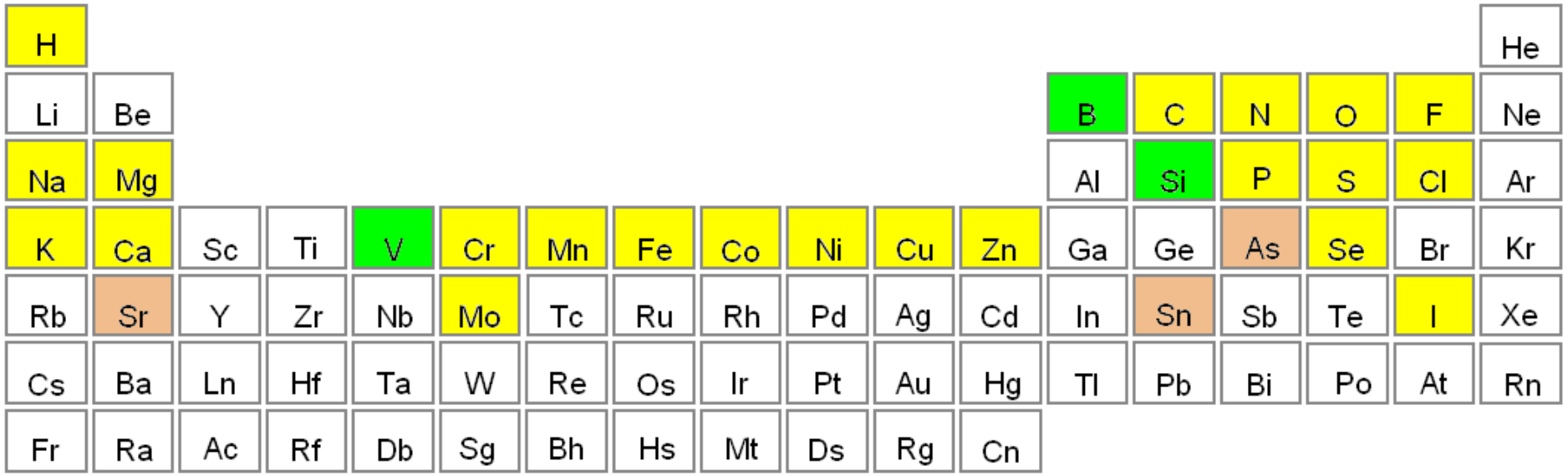
6.6 MINERALS

Main elements in the human body

Oxygen	65%	Sulphur	0.25%
Carbon	18%	Sodium	0.15%
Hydrogen	10%	Chlorine	0.15%
Nitrogen	3%	Magnesium	0.05%
Calcium	1.5%	Iron	0.006%
Phosphorus	1.0%	Fluorine	0.004%
Potassium	0.35%	Zinc	0.003%

6.6 MINERALS

Essential elements



Essential element

Essential element, no identified biological function

Probable essential element

6.6 MINERALS

Major elements

	Functions	***RDA (g)***	***Deficiency***	***Toxicity***	***Main sources***
Ca	Constituent of bones and teeth; regulates nerves and muscles	1.3	Osteomalacia, osteoporosis		Dairy products
P	Constituent of bones, teeth and nucleic acids	1.25	Osteoporosis	Hyperthyroïdism	Dairy products, nuts
Na	Regulates nerves and muscles	1.5		Hypertension	Table salt
K	Regulates nerves and muscles	4.7	Muscular weakness, paralysis	Cardiac arrest, small bowel ulcers	Legumes, tomatoes, bananas
Cl	Electrolytic balance, gastric fluid	2.3		Renal diseases	Table salt
Mg	Constituent of bones and teeth; enzymes cofactor	0.42	Cramps (can be induced by alcoholism)		Nuts, leafy vegetables

6.6 MINERALS

Trace elements

	Main functions	***RDA (mg)***	***Deficiency***
Cr	Constituent of glucose tolerant factor	0.045	
Cu	Oxydases	1.3	Anemia
I	Thyroxine, triiodotyronine	0.29	Cretinism, goiter
Fe	Heme enzymes	27	Anemia
Mn	Numerous metalloenzymes	2.6	
Mo	Oxydases	0.05	
Se	Glutathione peroxydase	0.07	
Zn	Cofactor of numerous enzymes	13	Growth failure, impaired wound healing, decreased taste and smell acuity

6.6 MINERALS

Approximate intake of elements in Switzerland

Element	Unit	2007 - 2008	2001 - 2002	RDA
Potassium	mg	3300	3200	1920
Sodium	mg	1560	1520	530
Chlorine	mg	2430	2210	800
Calcium	mg	1200	1120	990
Phosphorus	mg	1610	1450	750
Magnesium	mg	340	350	310
Iron	mg	12.5	11.8	11.5
Zinc	mg	12.7	12.0	8.0
Iodine	µg	85 (160)	101 (180)	145
Selenium	mg/l	99	93	80

6.6 MINERALS

Iron requirements

Children 0 - 8 years : 7 mg / day

Children 8 - 12 years : 8 mg / day

Teenagers : 12 mg / day boy and 14 mg / day girl

Adult men : 9 mg / d

Adult women: 16 mg / d (9 mg postmenopausal women)

Pregnant women: 25-35 mg / day for 4 to 9 months pregnancy (supplement after the first quarter)