Biochemistry of Nutrition – Micronutrients & anti-nutrients

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Unit 4

- Vitamins
- Minerals
- Antinutrients
- Alternative sweeteners

Vitamins

- Organic molecule
- Essential
- Organisms need in small quantities
- Proper functioning of metabolism
- Cannot synthesize, either at all or in sufficient quantities
- Obtain through diet
- Promote and regulate – growth, reproduction & maintenance of health
- Symptoms - visible & cured

Vitamins

Water-soluble		Fat-soluble
B vitamins		Vitamin A
B1	Thiamine	Vitamin D
B2	Riboflavin	Vitamin E
B3	Niacin	Vitamin K
B5	Pantothenic acid	
B6	pyridoxine	
B7	Biotin	
B9	Folic acid	
B12	Cobalamin	
Vitamin C		
Choline		
Carnitine		

- Water soluble vitamins: Coenzymes in energy metabolism
- Fat-soluble vitamins: Needed for cell growth, reproduction and gene regulation

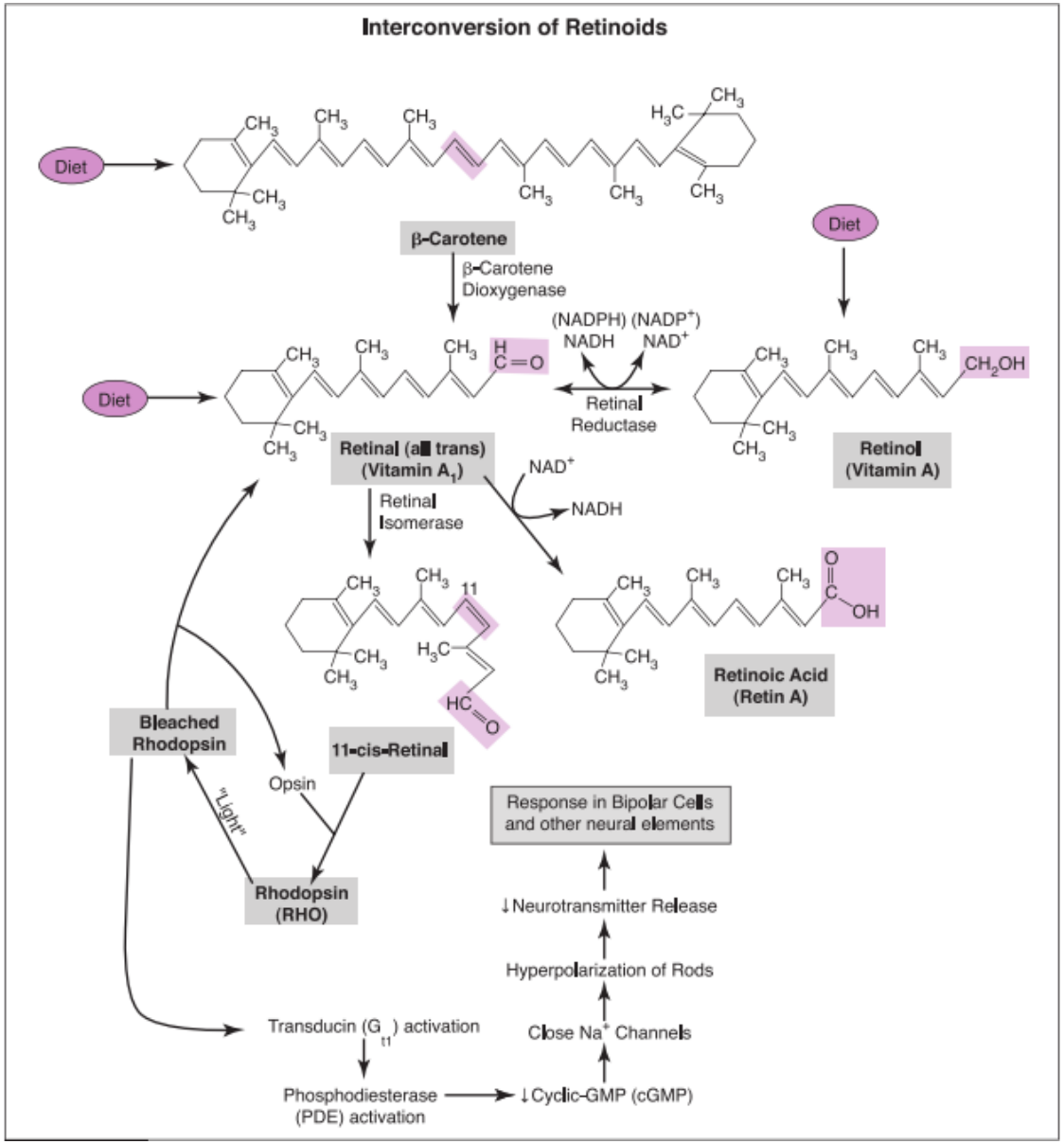
Vitamins – Properties, absorption & excretion

Water-soluble	Fat-soluble
Soluble in water	Soluble in fat
Attached to proteins in the food	Typically found in fatty portions of the food
Need digestion	Very little digestion
Mostly absorbed in the small intestines and, to lesser extent, the stomach	Absorption requires the presence of dietary lipids as well as the action of bile. • Occurs mostly in small intestines • Requires incorporation into micelles and the action of bile • Once transported into the intestinal cell, vitamins and packaged with other lipids into chylomicrons
Circulated directly to the liver in the blood	Circulated away from the small intestine in the lymph *via* chylomicrons before eventually entering the blood either as components of lipoproteins or bound to transport properties.
Body does not actively store water-soluble vitamins. No toxicity.	Body can store most of the fat-soluble vitamins. Consuming large amounts of them (especially in supplement form) can results in toxicities.

Vitamin A

- Vitamin A exists as a provitamin in vegetables (i.e., b-carotene).
- Vitamin A exists in three oxidation states; retinal, retinol, and retinoic acid (retin A).

Actions of Vitamin A
Retinol and Retinal
Vision
Rhodopsin synthesis (rods)
Porphyropsin synthesis (cones)
Retinoic Acid
Growth and differentiation of epithelial cells
Glycoprotein synthesis
Expression/production of growth hormone
Mucus production
Bone remodeling
Reproduction
Spermatogenesis
Placental development
Maintain corpus luteum function
Lung surfactant (phospholipid) production
Stimulate myeloid cell differentiation to granular leukocytes
Induce transglutaminases
Crosslinking of proteins (which is necessary for macrophage function, blood clotting, and cell adhesion)



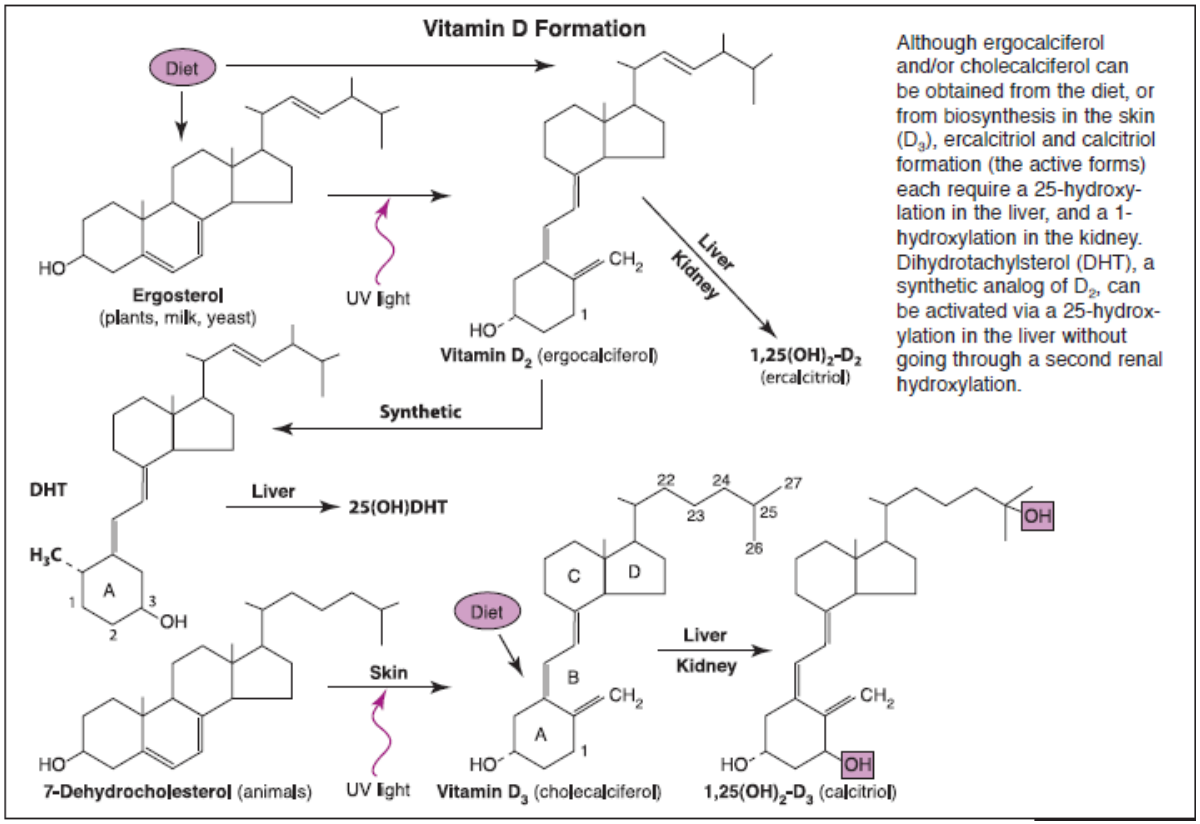
Vitamin A

- Although the primary signs and symptoms of vitamin A deficiency are usually noted in the visual system, hypovitaminosis A also leads to a reduction in mucus-secreting cells and replacement of columnar epithelial cells by thick layers of horny, stratified epithelium in several parts of the organism.
- Retinoic acid – not stored in the body
- Large quantities of fat-soluble vitamins can be stored in the liver and in adipose tissue and toxicity can result following excessive intake of vitamin A.

cod liver oil	30000
liver turkey	8058
liver beef, pork, fish	6500
liver chicken	3296
ghee	3069
sweet potato	961
carrot	835
broccoli leaf	800
butter	684

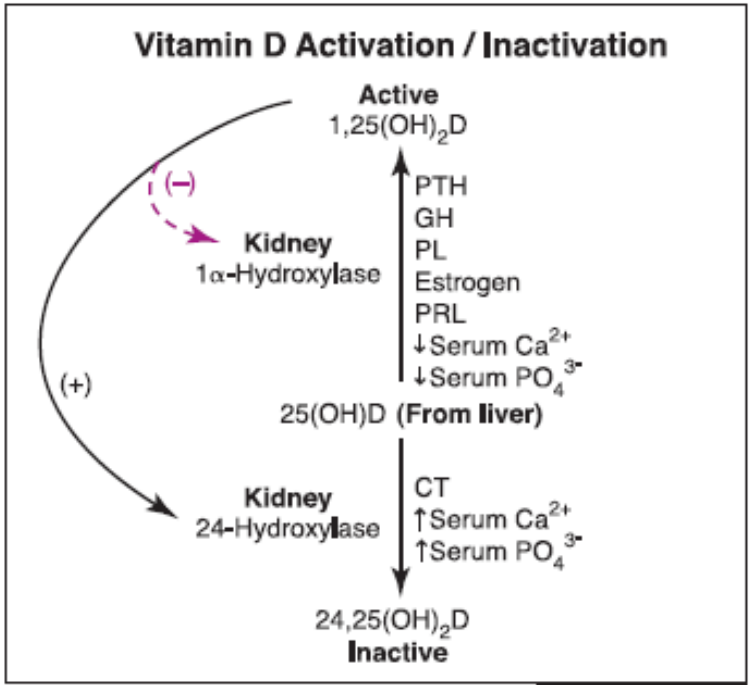
Vitamin D

- Vitamin D conforms to the definition of both a hormone and a vitamin
- Not essential
- Can be synthesized in the skin
- Several forms (vitamers) of vitamin D exist. The two major forms are vitamin D2 or ergocalciferol, and vitamin D3 or cholecalciferol
- Ergosterol, which occurs in plants, is a vitamin D precursor



Vitamin D

- The active form of vitamin D serves to enhance serium Ca2+ levels through facilitating intestinal Ca2+ absorption
- It also promotes the action of parathyroid hormone (PTH) on bone and the kidneys.
- Since most of the actions of vitamin D and PTH are similar, vitamin D is frequently used to treat patients with PTH deficiency.



Vitamin D

Deficiency

- Vitamin D deficiency symptoms include abnormal bone mineralization and deformities (i.e., rickets in young animals, and osteomalacia in adults), hypocalcemia and high circulating titers of PTH.
- Since, vitamin D receptors are present on hair follicles, vitamin D deficiency can promote hair loss.

Toxicity

- Hypercalcemia and hyperphosphatemia, deposition of Ca^{2+} in soft tissues (especially the kidneys, heart, lung and vasculature), hypercalciuria and kidney stones.

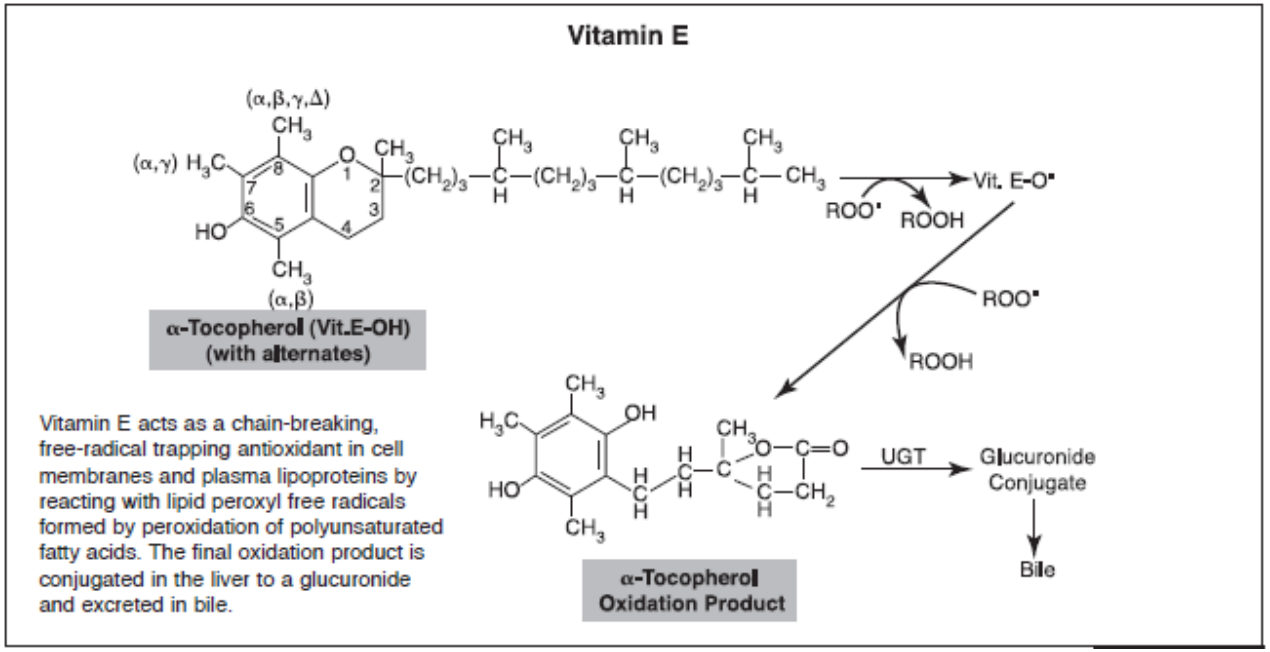
Remedy

- Glucocorticoids and thyrocalcitonin administred to reverse the symptoms of toxicity.

- In general, vitamin D2 is found in fungi and vitamin D3 is found in animals
- Fish liver oils, such as cod liver oil (100 IU/g)

Vitamin E

- There are several naturally occurring forms of vitamin E (tocopherol).
- α-Tocopherol has the widest natural distribution and greatest physiologic activity



Vitamin E

- Function: Vitamin E is the first line of defense against peroxidation of lipids contained in the cell membranes.
  - Defense against peroxidation of unsaturated fatty acids (UFAs) contained in cell membrane phospholipids. Cholesterol and phospholipids in the plasma membrane, as well as those in subcellular membranes (e.g., mitochondria, endoplasmic reticulum, etc.,), posess high affinities for α-Tocopherol.
  - This works against injury to cell membranes, as in red blood cells fragility and the muscular degeneration of animals.
  - It also aids in the normal functioning of the seminiferous epithelium (and therefore sperm production) and assist with implantation (thus sustaining the fetus in the uterus).

Vitamin E

- **Deficiency**
  - Excessive lipid peroxidation of membranes and other sites of fat accumulation accounts for most of the symptoms associated with Vitamin E deficiency.
  - **Erythrocyte fragility:** The most clear cut example is enhanced erythrocyte fragility, where RBCs exhibit a marked change in morphology and become easily destroyed.
  - **Muscular degeneration:** Vitamin E is also essential for the development and maintenance of normal nerve and muscle cell activity. Either vitamin E or selenium deficiency can results in a massive influx of Ca2+ into cells; mitochondria become loaded with this element, and reduce their ATP output. This mineral influx results in muscular degeneration, and gives muscle a characteristic white appearance i.e. white muscle.
  - **Steatitis:** Fatty tissue inflammation
  - **Retinopathy:** Retinopathy is any damage to the retina of the eyes, which may cause vision impairment. This can occur in vitamin E deficiency upon exposure to high oxygen tensions.
  - **Reproductive failure:** In males, Deficiency results first in sperm immotility, then in degeneration of the seminiferous epithelium, and then cessation of sperm production. In females there is a failure of uterine function in vitamin E deficiency, with a lack of development of the vasculature that would allow the conceptus to implant in the uterine wall.

Vitamin E

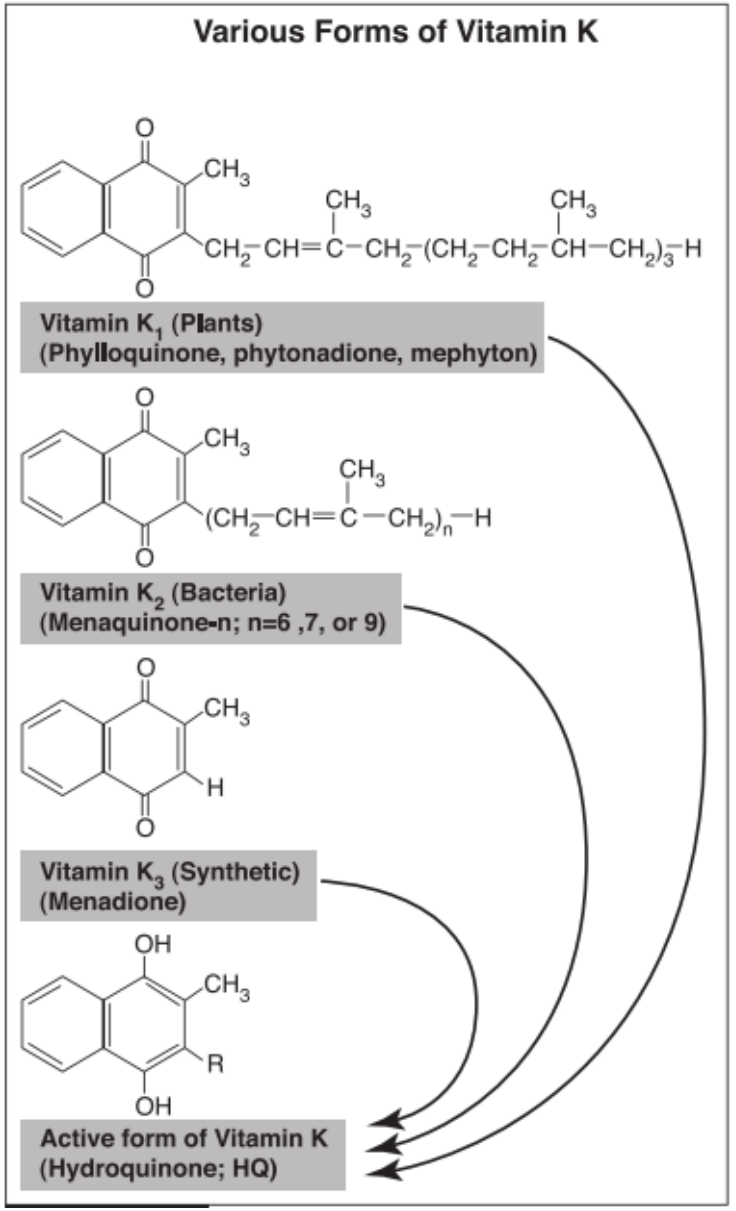
- No risks in high doses but can act as an anticoagulant, therefore hypervitaminosis E may increase the risk of bleeding.

Plant source	Amount (mg / 100g)
Wheat germ oil	150
Hazelnut oil	47
Canola/rapeseed oil	44
Sunflower oil	41.1
Safflower oil	34.1

Animal source	Amount (mg / 100g)
Fish	1.0-2.8
Oysters	1.7
Butter	1.6
Cheese	0.6-0.7
Eggs	1.1
Chicken	0.3

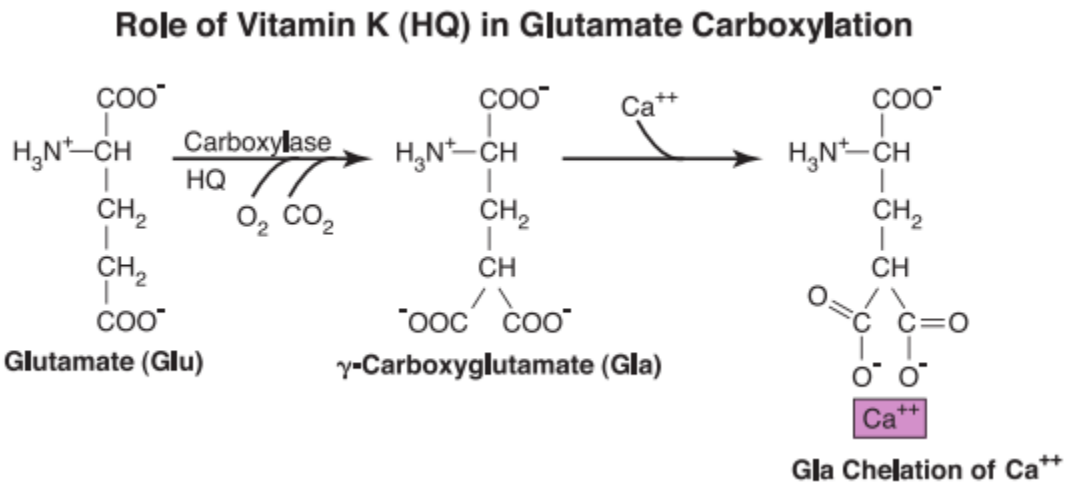
Vitamin K

- Vitamin K, which is needed for blood clotting, can be derived from plants, bacteria, and animal tissues.
- A water-soluble form of vitamin K can be converted to the active derivative, hydroquinone.
- The biologic half-life of vitamin K is shorter than the other fat-soluble vitamins.
- The liver is the main repository of vitamin K.



Vitamin K

- **Vitamin K is required for the hepatic postsynthetic transformation of several protein clotting factors.** clotting factors II (prothrombin), VII (proconvertin), IX (plasma thromboplastic component, Christmas factor, or antihemophilic factor B), and X (StuartPrower factor); as well as anti-coagulation proteins C, and S (which facilitates the inactivation of factors Va and VIII by facilitating the action of activated protein C).
- Vitamin K helps to facilitate the g-carboxylation of glutamate residues, which in turn chelate Ca^{++}
- An important therapeutic use of vitamin K is as an antidote in poisoning by dicoumarol or warfarin.
- Vitamin K plays a role in bone metabolism, as well as in the renal reabsorption of Ca^{++}



Vitamin K

- **Deficiency**
- Vitamin K deficiency can be caused by fat malabsorption, which may be associated with severe liver disease and/or biliary obstruction, pancreatic dysfunction, atrophy of the intestinal mucosa, or any cause of steatorrhea. In addition, sterilization of the large bowel by antibiotics can result in deficiency when dietary intake is limited. Vitamin K deficiency can present itself before other fat-soluble vitamin deficiencies, since the turnover of this vitamin is normally rather high.
- **Toxicity**
- Although few toxicity symptoms have been reported in animals, vitamin K (menadione), the synthetic water-soluble form of the vitamin used clinically, can apparently react with sulfhydryl groups on proteins, and therefore become toxic. Gastrointestinal disturbances and anemia have been associated with vitamin K excess.

Food	Serving size	Vitamin K_1 (µg)		Food	Serving size	Vitamin K_1 (µg)
Kale, cooked	½ cup	531		Parsley, raw	¼ cup	246
Spinach, cooked	½ cup, 77g	444		Spinach, raw	1 cup	145
Collards, cooked	½ cup	418		Collards, raw	1 cup	184
Swiss chard, cooked	½ cup	287		Swiss chard, raw	1 cup	299
Mustard g reens, cooked	½ cup	210		Mustard greens, raw	1 cup	279
Turnip gre ens, cooked	½ cup	265		Turnip greens, raw	1 cup	138
Broccoli, cooked	1 cup	220		Broccoli, raw	1 cup	89
Brussels sprouts, cooked	1 cup	219		Endive, raw	1 cup	116
Cabbage, cooked	½ cup	82		Green leaf lettuce	1 cup	71
Asparagus	4 spears	48		Romaine lettuce, raw	1 cup	57

Water-soluble vitamins & minerals
: see the rough notes

Antinutrients

- **Antinutrients are natural or synthetic compounds that interfere with the absorption of nutrients.**
  - **Protease inhibitors** (e.g., Bowman–Birk trypsin inhibitor in soybeans), which inhibit trypsin, pepsin, and other proteases in the gut, preventing digestion and absorption of proteins and amino acids
  - **Lipase inhibitors** (e.g., tetrahydrolipstatin), which interfere with enzymes, such as lipases, which catalyze hydrolysis of some lipids and fats
  - **Amylase inhibitors** in beans, which prevent the action of enzymes that break the glycosidic bonds of starches and other complex carbohydrates, preventing the release of simple sugars and absorption by the body
  - **Phytic acid** in the hulls of nuts, seeds, and grains, which has a strong binding affinity for calcium, magnesium, iron, copper, and zinc, preventing their absorption
  - Oxalic acid and oxalates, which are present in many plants, particularly members of the spinach family, bind calcium to prevent its absorption.
- **Many traditional preparation methods (e.g., fermentation)** reduce antinutrients, such as phytic acid, increase the nutritional quality of plant foods, and are widely used in societies where cereals and legumes are a significant part of the diet. For example, cassava is fermented to reduce levels of both toxins and antinutrients. **Glucosinolates (e.g., broccoli, Brussels sprouts, cabbage, and cauliflower), although widely recognized for their putative health benefits, also interfere with the uptake of iodine and flavonoids, and chelate metals (e.g., iron and zinc) thus reducing their absorption.**

Alternative sweeteners

- Alternative sweeteners are chemical substances used as a sweet alternative to replace sucrose.
- Many have been developed to provide zero-calorie or low calorie sweetening for foods and drinks.
- Based on sweetness compared to sucrose : intense (high potency sweetners) and bulk sweeteners

Relative sweetness of natural sweeteners [27]

Sugar	Relative sweetness
Sucrose	1.0
Glucose	0.6
Fructose	2.0
Maltose	0.6
Lactose	0.25
Steviol glycosides	40–300

Table 13.2 Relative sweetness of artificial sweeteners [27]

Sweetener	Relative sweetness*
Saccharine	300–500
Acesulfame-K	150–300
Cyclamate	30
Sucralose	600
Aspartame	150–200
Neotame	7000–13000
Alitame	2000
Talin	2500

*With reference to sucrose

Sources

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NOTE: BROWESE ONLINE VITAMINS AND MINERAL CHAPTERS AND PRACTICE MULTIPLE CHOICE QUESTIONS.