Mineral (nutrient)

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A **mineral** is a chemical element required as an essential nutrient by organisms to perform functions necessary for life.[1][2] Minerals originate in the earth and cannot be made by living organisms.[3] Plants get minerals from soil.[3] Most of the minerals in a human diet come from eating plants and animals or from drinking water.[3] As a group, *minerals* is one of the four groups of essential nutrients, the others of which are vitamins, essential fatty acids, and essential amino acids.[4]

The five major minerals in the human body are calcium, phosphorus, potassium, sodium, and magnesium.[1] All of the remaining functional elements in a human body are called "trace elements", which include iron, cobalt, copper, zinc, manganese, molybdenum, iodine, and selenium.[5]

Most chemical elements that are ingested by organisms are in the form of simple compounds. Plants absorb dissolved elements in soils, which are subsequently ingested by the herbivores that eat them, and the elements move up the food chain. Larger organisms may also consume soil (geophagia) or use mineral resources, such as salt licks, to obtain limited minerals unavailable through other dietary sources.

Bacteria and fungi play an essential role in the weathering of primary elements that results in the release of nutrients for their own nutrition and for the nutrition of other species in the ecological food chain. One element, cobalt, is available for use by animals only after having been processed into complex molecules (e.g., vitamin B12) by bacteria. Minerals are used by animals and microorganisms for the process of mineralizing structures, called "biomineralization", used to construct bones, seashells, eggshells, exoskeletons and mollusc shells.[6]

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Essential chemical elements for humans

At least twenty chemical elements are known to be *required* to support human biochemical processes by serving structural and functional roles as well as electrolytes.[7] However, as many as twenty-nine elements in total (including hydrogen, carbon, nitrogen and oxygen) are suggested to be used by mammals, as inferred by biochemical and uptake studies.[8] Among the five major minerals, an adult female has 920-1000 g of calcium while an adult male has ~1.22 kg,[1] with 99% of it contained in bones and teeth, and the other 1% in extracellular fluids, intracellular structures and cell membranes.[1] Phosphorus makes up about 1% of a person's body weight.[9] The last four major minerals (potassium, sodium, chlorine and magnesium) make up only about 0.85% of the weight of the body. Together these eleven chemical elements make up 99.85% of the body.

Most of the known and suggested mineral nutrients are of relatively low atomic weight, and are reasonably common on land, or, at least, common in the ocean (iodine, sodium):

Nutritional elements in the periodic table

H																		He
Li	Be												B	C	N	O	F	Ne
Na	Mg												Al	Si	P	S	Cl	Ar
K	Ca	Sc		Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y		Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og
			*	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
			**	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	

- The four organic basic elements
- Quantity elements
- Essential trace elements
- Suggested function from deprivation effects or active metabolic handling, but no clearly-identified biochemical function in humans
- Limited circumstantial evidence for trace benefits or biological action in mammals
- No evidence for biological action in mammals, but essential in some lower organisms.

(In the case of lanthanum, the definition of an essential nutrient as being indispensible and irreplaceable is not completely applicable due to the extreme similarity of the lanthanides. Thus Ce, Pr, and Nd may be substituted for La without ill effects for organisms using La, and the smaller Sm, Eu, and Gd may also be similarly substituted but cause slower growth.)

The following play important roles in biological processes:

DV = Daily Value (formerly Recommended Daily Allowance); **UL** = Tolerable Upper Intake Level (figures shown are for adults age 31-50, male or female neither pregnant nor lactating)

Dietary element	DV [mg][10]	UL [mg][11][12]	Amount	Category	High nutrient density dietary sources	Insufficiency	Excess
Potassium	3500	NE	Quantity	A systemic electrolyte and is essential in coregulating ATP with sodium	Sweet potato, tomato, potato, beans, lentils, dairy products, seafood, banana, prune, carrot, orange[13]	hypokalemia	hyperkalemia
Chlorine	3400	3600	Quantity	Needed for production of hydrochloric acid in the stomach and in cellular pump functions	Table salt (sodium chloride) is the main dietary source.	hypochloremia	hyperchloremia
Sodium	2400	2300	Quantity	A systemic electrolyte and is essential in coregulating ATP with potassium	Table salt (sodium chloride, the main source), sea vegetables, milk, and spinach.	hyponatremia	hypernatremia
Calcium	1000	2500	Quantity	Needed for muscle, heart and digestive system health, builds bone, supports synthesis and function of blood cells	Dairy products, eggs, canned fish with bones (salmon, sardines), green leafy vegetables, nuts, seeds, tofu, thyme, oregano, dill, cinnamon.[14]	hypocalcaemia	hypercalcaemia
Phosphorus	1000	4000	Quantity	A component of bones (see apatite), cells, in energy processing, in DNA and ATP (as phosphate) and many other functions	Red meat, dairy foods, fish, poultry, bread, rice, oats.[15][16] In biological contexts, usually seen as phosphate [17]	hypophosphatemia	hyperphosphatemia
Magnesium	400	350	Quantity		Spinach, legumes,		hypermagnesemia

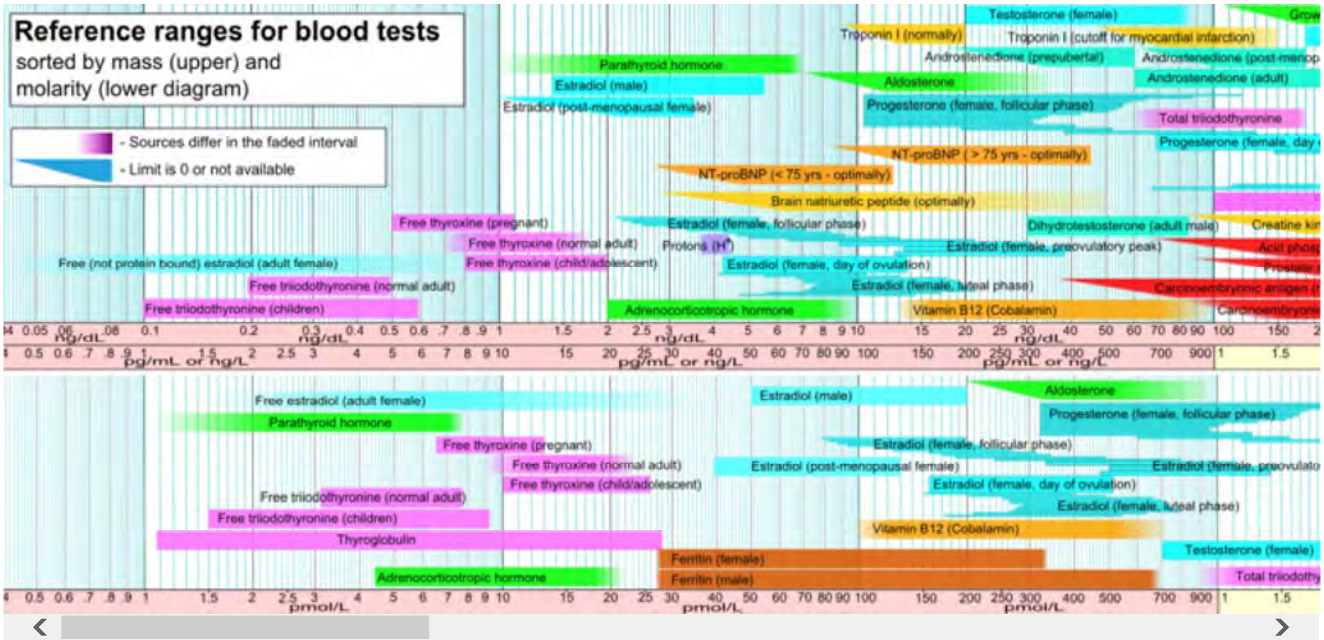
Dietary element	DV [mg] [10]	UL [mg] [11][12]	Amount	Category	High nutrient density dietary sources	Insufficiency	Excess
				Required for processing ATP and for bones	nuts, seeds, whole grains, peanut butter, avocado[18]	hypomagnesemia, magnesium deficiency	
Iron	18	45	Trace	Required for many proteins and enzymes, notably hemoglobin to prevent anemia	Meat, seafood, nuts, beans, dark chocolate[19]	iron deficiency	iron overload disorder
Zinc	15	40	Trace	Pervasive and required for several enzymes such as carboxypeptidase, liver alcohol dehydrogenase, and carbonic anhydrase	Oysters*, red meat, poultry, nuts, whole grains, dairy products[20]	zinc deficiency	zinc toxicity
Manganese	2	350	Trace	A cofactor in enzyme functions	Grains, legumes, seeds, nuts, leafy vegetables, tea, coffee[21]	manganese deficiency	manganism
Copper	2	11	Trace	Required component of many redox enzymes, including cytochrome c oxidase	Liver, seafood, oysters, nuts, seeds; some: whole grains, legumes[21]	copper deficiency	copper toxicity
Iodine	0.150	1.1	Trace	Required for synthesis of thyroid hormones, thyroxine and triiodothyronine and to prevent goiter: ▪ Iodine in biology	Seaweed (kelp or kombu)*, grains, eggs, iodized salt [22]	iodine deficiency	iodism Hyperthyroidism [23]
Chromium	0.120	NE	Trace	Involved in glucose and lipid metabolism, although its mechanisms of action in the body and the amounts	Broccoli, grape juice (especially red), meat, whole grain products[26]	Chromium deficiency	Chromium toxicity

Dietary element	DV [mg] [10]	UL [mg] [11][12]	Amount	Category	High nutrient density dietary sources	Insufficiency	Excess
				needed for optimal health are not well-defined[24][25]			
Molybdenum	0.075	2	Trace	The oxidases xanthine oxidase, aldehyde oxidase, and sulfite oxidase [27]	Legumes, whole grains, nuts [21]	molybdenum deficiency	molybdenum toxicity[28]
Selenium	0.070	0.4	Trace	Essential to activity of antioxidant enzymes like glutathione peroxidase	Brazil nuts, seafoods, organ meats, meats, grains, dairy products, eggs[29]	selenium deficiency	selenosis
Cobalt	none	NE	Trace	Required in the synthesis of vitamin B_{12}, but because bacteria are required to synthesize the vitamin, it is usually considered part of vitamin B_{12}			Cobalt poisoning

* One serving exceeds UL (tolerable upper intake level).

Blood concentrations of minerals

Minerals are present in a healthy human being's blood at certain mass and molar concentrations. The figure below presents the concentrations of each of the chemical elements discussed in this article, from center-right to the right. Depending on the concentrations, some are in upper part of the picture, while others are in the lower part. The figure includes the relative values of other constituents of blood such as hormones. In the figure, minerals are color highlighted in purple.



Reference ranges for blood tests, sorted logarithmically by mass above the scale and by molarity below.

Dietary nutrition

Dietitians may recommend that minerals are best supplied by ingesting specific foods rich with the chemical element(s) of interest. The elements may be naturally present in the food (e.g., calcium in dairy milk) or added to the food (e.g., orange juice fortified with calcium; iodized salt, salt fortified with iodine). Dietary supplements can be formulated to contain several different chemical elements (as compounds), a combination of vitamins and/or other chemical compounds, or a single element (as a compound or mixture of compounds), such as calcium (as calcium carbonate, calcium citrate, etc.) or magnesium (as magnesium oxide, etc.), chromium (usually as chromium(III) picolinate), or iron (as iron bis-glycinate).

The dietary focus on chemical elements derives from an interest in supporting the biochemical reactions of metabolism with the required elemental components.[30] Appropriate intake levels of certain chemical elements have been demonstrated to be required to maintain optimal health. Diet can meet all the body's chemical element requirements, although supplements can be used when some requirements (e.g., calcium, which is found mainly in dairy products) are not adequately met by the diet, or when chronic or acute deficiencies arise from pathology, injury, etc. Research has supported that altering inorganic mineral compounds (carbonates, oxides, etc.) by reacting them with organic ligands (amino acids, organic acids, etc.) improves the bioavailability of the supplemented mineral.[31]

Typical Maximum Nutrient Losses due to cooking [32]

Vitamin & Minerals	Freeze	Dry	Cook	Cook+Drain	Reheat
Vitamin A	5%	50%	25%	35%	10%
Vit A- Retinol Activity Equivalent	5%	50%	25%	35%	10%
Vit A- Alpha Carotene	5%	50%	25%	35%	10%
Vit A- Beta Carotene	5%	50%	25%	35%	10%
Vit A- Beta Cryptoxanthin	5%	50%	25%	35%	10%
Vit A- Lycopene	5%	50%	25%	35%	10%
Vit A- Lutein+Zeaxanthin	5%	50%	25%	35%	10%
Vitamin C	30%	80%	50%	75%	50%
Thiamin	5%	30%	55%	70%	40%
Riboflavin	0%	10%	25%	45%	5%
Niacin	0%	10%	40%	55%	5%
Vitamin B6	0%	10%	50%	65%	45%
Folate	5%	50%	70%	75%	30%
Food Folate	5%	50%	70%	75%	30%
Folic Acid	5%	50%	70%	75%	30%
Vitamin B12	0%	0%	45%	50%	45%
Calcium	5%	0%	20%	25%	0%
Iron	0%	0%	35%	40%	0%
Magnesium	0%	0%	25%	40%	0%
Phosphorus	0%	0%	25%	35%	0%
Potassium	10%	0%	30%	70%	0%
Sodium	0%	0%	25%	55%	0%
Zinc	0%	0%	25%	25%	0%
Copper	10%	0%	40%	45%	0%

Elements considered possibly essential but not confirmed

Many ultratrace elements have been suggested as essential, but such claims have usually not been confirmed. Definitive evidence for efficacy comes from the characterization of a biomolecule containing the element with an identifiable and testable function.[5] One problem with identifying efficacy is that some elements are innocuous at low concentrations and are pervasive (examples: silicon and nickel in solid and dust), so proof of efficacy is lacking because deficiencies are difficult to reproduce.[30] Ultratrace elements of some minerals such as silicon and boron are known to have a role but the exact biochemical nature is unknown, and others such as arsenic and chromium are suspected to have a role in health, but with weaker evidence.[5] Roles for trace minerals include enzyme catalysis, attracting substrate molecules, redox reactions, and structural or regulatory effects on protein binding.[5]

Element	Description	Excess
Bromine	Possibly important to basement membrane architecture and tissue development, as a needed catalyst to make collagen IV.[33]	bromism
Arsenic	Essential in rat, hamster, goat and chicken models, but no biochemical mechanism known in humans.[34]	arsenic poisoning
Nickel	Nickel is an essential component of several enzymes, including urease and hydrogenase.[35] Although not required by humans, some are thought to be required by gut bacteria, such as urease required by some varieties of Bifidobacterium.[36] In humans, nickel may be a cofactor or structural component of certain metalloenzymes involved in hydrolysis, redox rections, and gene expression. Nickel deficiency depressed growth in goats, pigs, and sheep, and diminished circulating thyroid hormone concentration in rats.[37]	Nickel toxicity
Fluorine	Fluorine (as fluoride) is not generally considered an essential element because humans do not require it for growth or to sustain life. However, if one considers the prevention of dental cavities an important criterion in determining essentiality, then fluoride might well be considered an essential trace element. However, recent research indicates that the primary action of fluoride occurs topically (at the surface).[38][39]	Fluoride poisoning
Boron	Boron is an essential plant nutrient, required primarily for maintaining the integrity of cell walls.[40][41][42] Boron has been shown to be essential to complete the life cycle in representatives of all phylogenetic kingdoms, including the model species danio rerio (zebrafish) and Xenopus laevis (African clawed frog).[35][43] In animals, supplemental boron has been shown to reduce calcium excretion and activate vitamin D.[44]	Nontoxic
Lithium	It is not known whether lithium has a physiological role in any species,[45] but nutritional studies in mammals have indicated its importance to health, leading to a suggestion that it be classed as an essential trace element.	Lithium toxicity
Strontium	Strontium has been found to be involved in the utilization of calcium in the body. It has promoting action on calcium uptake into bone at moderate dietary strontium levels, but a rachitogenic (rickets-producing) action at higher dietary levels.[46]	Rachitogenic (causing Rickets)
Other	Silicon and vanadium have established, albeit specialized, biochemical roles as structural or functional cofactors in other organisms, and are possibly, even probably, used by mammals (including humans). By contrast, tungsten, lanthanum, and cadmium have specialized biochemical uses in certain lower organisms, but these elements appear not to be utilized by humans.[8] Other elements considered to be possibly essential include aluminium, germanium, lead, rubidium, and tin.[35][47][48]	Multiple

Mineral ecology

Recent studies have shown a tight linkage between living organisms and chemical elements on this planet. This led to the redefinition of minerals as "an element or compound, amorphous or crystalline, formed through 'biogeochemical' processes. The addition of `bio' reflects a greater appreciation, although an incomplete understanding, of the processes of mineral formation by living forms."[49]:621 Biologists and geologists have only recently started to appreciate the magnitude of mineral biogeoengineering. Bacteria have contributed to the formation of minerals for billions of years and critically define the biogeochemical mineral cycles on this planet. Microorganisms can precipitate metals from solution contributing to the formation of ore deposits in addition to their ability to catalyze mineral dissolution, to respire, precipitate, and form minerals.[50][51][52]

Most minerals are inorganic in nature. Mineral nutrients refers to the smaller class of minerals that are metabolized for growth, development, and vitality of living organisms.[49][53][54] Mineral nutrients are recycled by bacteria that are freely suspended in the vast water columns of the worlds oceans. They absorb dissolved organic matter containing mineral nutrients as they scavenge through the dying individuals that fall out of large phytoplankton blooms. Flagellates are effective bacteriovores and are also commonly found in the marine water column. The flagellates are preyed upon by zooplankton while the phytoplankton concentrates on the larger particulate matter that is suspended in the water column as they are consumed by larger zooplankton, with fish as the top predator. Mineral nutrients cycle through this marine food chain, from bacteria and phytoplankton to flagellates and zooplankton which are then eaten by fish. The bacteria are important in this chain because only they have the physiological ability to absorb the dissolved mineral nutrients from the sea. These recycling principals from marine environments apply to many soil and freshwater ecosystems as well.[55][56] In terrestrial ecosystems, fungi play similar roles as bacteria: they mobilize nutritional elements composing matter that is inaccessible for other organisms and transport acquired nutrients to nutritionally scarce patches of ecosystem.[57]

See also

- Food composition
- Health food
- Macronutrient
- Micronutrient deficiency

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Further reading

- Humphry Bowen (1966) *Trace Elements in Biochemistry*. Academic Press.
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External links

- Metals in Nutrition (http://www.portfolio.mvm.ed.ac.uk/studentwebs/session2/group29/intronut.htm)
- Concept of a nutritious food: toward a nutrient density score (http://www.ajcn.org/content/82/4/721.full.pdf)

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