



OLLI 401 - Nutrition: Essential Concepts to
Promote Healthful Living
Part 5 – Vitamins and Minerals

Albert Cheh

October 21, 2020



Outline of Part 5

- Elements of the periodic table; **abundance, availability and function**; life optimizes to these environmental factors
- Concepts of **deficiency, adequacy, excess and toxicity**
- **Vitamins and minerals – cofactors** to proteins and enzymes; structural and regulatory roles; operational niches/functions
- Given the large number of vitamins and minerals, see the textbook for specific requirements, deficiency symptoms and individual best sources; our **focus** will be on **functions** and **special situations** that might lead to **deficiency or toxicity**

PERIODIC TABLE OF ELEMENTS

Most used nonmetal building blocks

Most used metals (as metal ions)

PubChem

1 Atomic Number
H Symbol
Hydrogen Name
Nonmetal Chemical Group Block

1 H Hydrogen																	2 He Helium Noble Gas	
3 Li Lithium Alkali Metal	4 Be Beryllium Alkaline Earth Metal																	10 Ne Neon Noble Gas
11 Na Sodium Alkali Metal	12 Mg Magnesium Alkaline Earth Metal	21 Sc Scandium Transition Metal	22 Ti Titanium Transition Metal	23 V Vanadium Transition Metal	24 Cr Chromium Transition Metal	25 Mn Manganese Transition Metal	26 Fe Iron Transition Metal	27 Co Cobalt Transition Metal	28 Ni Nickel Transition Metal	29 Cu Copper Transition Metal	30 Zn Zinc Transition Metal	31 Ga Gallium Metalloid	32 Ge Germanium Metalloid	33 As Arsenic Metalloid	34 Se Selenium Nonmetal	35 Br Bromine Halogen	18 Ar Argon Noble Gas	
19 K Potassium Alkali Metal	20 Ca Calcium Alkaline Earth Metal	39 Y Yttrium Transition Metal	40 Zr Zirconium Transition Metal	41 Nb Niobium Transition Metal	42 Mo Molybdenum Transition Metal	43 Tc Technetium Transition Metal	44 Ru Ruthenium Transition Metal	45 Rh Rhodium Transition Metal	46 Pd Palladium Transition Metal	47 Ag Silver Transition Metal	48 Cd Cadmium Transition Metal	49 In Indium Post-Transition Metal	50 Sn Tin Post-Transition Metal	51 Sb Antimony Metalloid	52 Te Tellurium Metalloid	53 I Iodine Halogen	36 Kr Krypton Noble Gas	
37 Rb Rubidium Alkali Metal	38 Sr Strontium Alkaline Earth Metal	*	72 Hf Hafnium Transition Metal	73 Ta Tantalum Transition Metal	74 W Tungsten Transition Metal	75 Re Rhenium Transition Metal	76 Os Osmium Transition Metal	77 Ir Iridium Transition Metal	78 Pt Platinum Transition Metal	79 Au Gold Transition Metal	80 Hg Mercury Transition Metal	81 Tl Thallium Post-Transition Metal	82 Pb Lead Post-Transition Metal	83 Bi Bismuth Post-Transition Metal	84 Po Polonium Metalloid	85 At Astatine Halogen	54 Xe Xenon Noble Gas	
55 Cs Cesium Alkali Metal	56 Ba Barium Alkaline Earth Metal	**	104 Rf Rutherfordium Transition Metal	105 Db Dubnium Transition Metal	106 Sg Seaborgium Transition Metal	107 Bh Bohrium Transition Metal	108 Hs Hassium Transition Metal	109 Mt Meitnerium Transition Metal	110 Ds Darmstadtium Transition Metal	111 Rg Roentgenium Transition Metal	112 Cn Copernicium Transition Metal	113 Nh Nihonium Post-Transition Metal	114 Fl Flerovium Post-Transition Metal	115 Mc Moscovium Post-Transition Metal	116 Lv Livermorium Post-Transition Metal	117 Ts Tennessine Halogen	86 Rn Radon Noble Gas	
87 Fr Francium Alkali Metal	88 Ra Radium Alkaline Earth Metal	**	104 Rf Rutherfordium Transition Metal	105 Db Dubnium Transition Metal	106 Sg Seaborgium Transition Metal	107 Bh Bohrium Transition Metal	108 Hs Hassium Transition Metal	109 Mt Meitnerium Transition Metal	110 Ds Darmstadtium Transition Metal	111 Rg Roentgenium Transition Metal	112 Cn Copernicium Transition Metal	113 Nh Nihonium Post-Transition Metal	114 Fl Flerovium Post-Transition Metal	115 Mc Moscovium Post-Transition Metal	116 Lv Livermorium Post-Transition Metal	117 Ts Tennessine Halogen	118 Og Oganesson Noble Gas	
		*	57 La Lanthanum Lanthanide	58 Ce Cerium Lanthanide	59 Pr Praseodymium Lanthanide	60 Nd Neodymium Lanthanide	61 Pm Promethium Lanthanide	62 Sm Samarium Lanthanide	63 Eu Europium Lanthanide	64 Gd Gadolinium Lanthanide	65 Tb Terbium Lanthanide	66 Dy Dysprosium Lanthanide	67 Ho Holmium Lanthanide	68 Er Erbium Lanthanide	69 Tm Thulium Lanthanide	70 Yb Ytterbium Lanthanide	71 Lu Lutetium Lanthanide	
		**	89 Ac Actinium Actinide	90 Th Thorium Actinide	91 Pa Protactinium Actinide	92 U Uranium Actinide	93 Np Neptunium Actinide	94 Pu Plutonium Actinide	95 Am Americium Actinide	96 Cm Curium Actinide	97 Bk Berkelium Actinide	98 Cf Californium Actinide	99 Es Einsteinium Actinide	100 Fm Fermium Actinide	101 Md Mendelevium Actinide	102 No Nobelium Actinide	103 Lr Lawrencium Actinide	

<https://pubchem.ncbi.nlm.nih.gov/periodic-table/>

Abundance

More

Availability -

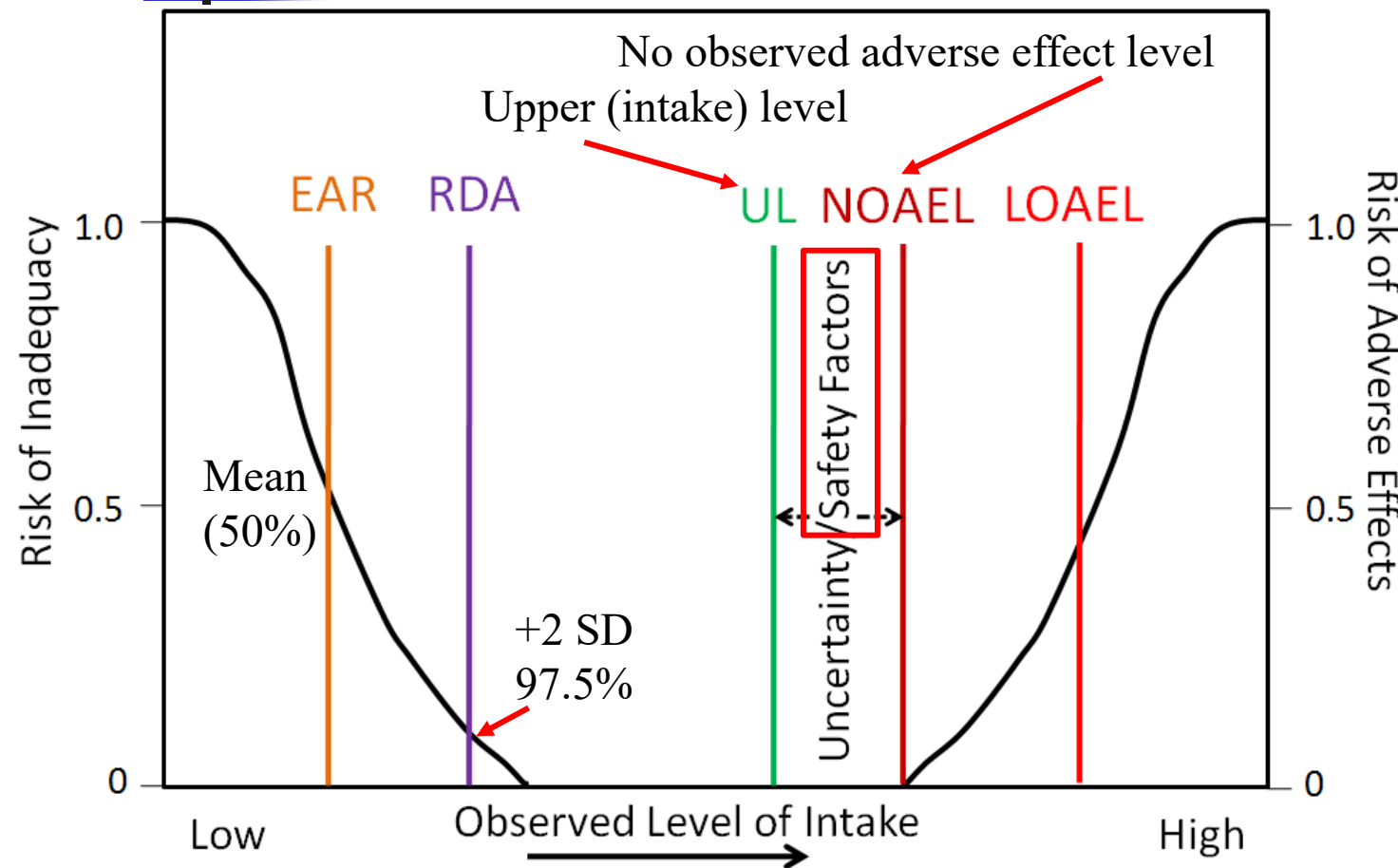
Aluminum and titanium oxides are very insoluble, so not available

Function – iron oxide very insoluble, but iron is very useful, so we use it, but may encounter shortages

Less

Life based on gold would constantly starve

Nutritional Adequacy and Homeostasis



If there are adequate or lavish dietary sources (no deficiency), the body maintains **homeostasis** (constant correct concentration) either by doing **uptake only if needed**, or by **excreting excess**, or **both**.

Toxicity results if too high a concentration builds up. **Water solubility** is an important factor for vitamins and minerals



Recommended Daily Allowances to Avoid Deficiency

- **Recommended Daily Allowance (RDA)** is calculated from the Estimated Average Requirement (EAR) plus two standard deviations for a normal distribution (previous slide)
- **Adequate Intakes (AI)** are used when data are less certain, cannot do a statistically calculated RDA
- **USDA provides a calculator** that allows you to input gender, age, height and weight and activity level to get a closer list of RDAs for you:
 - <https://www.nal.usda.gov/fnic/dri-calculator/>

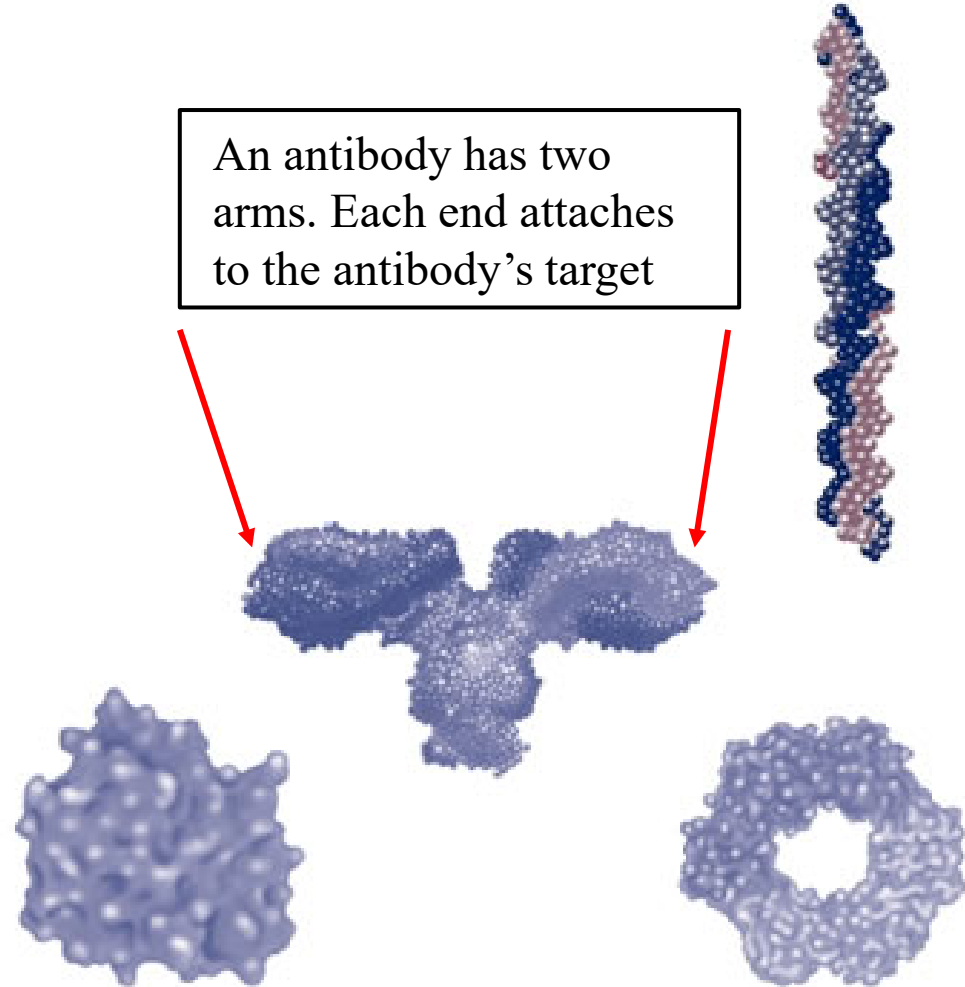


Basic Human Biochemistry

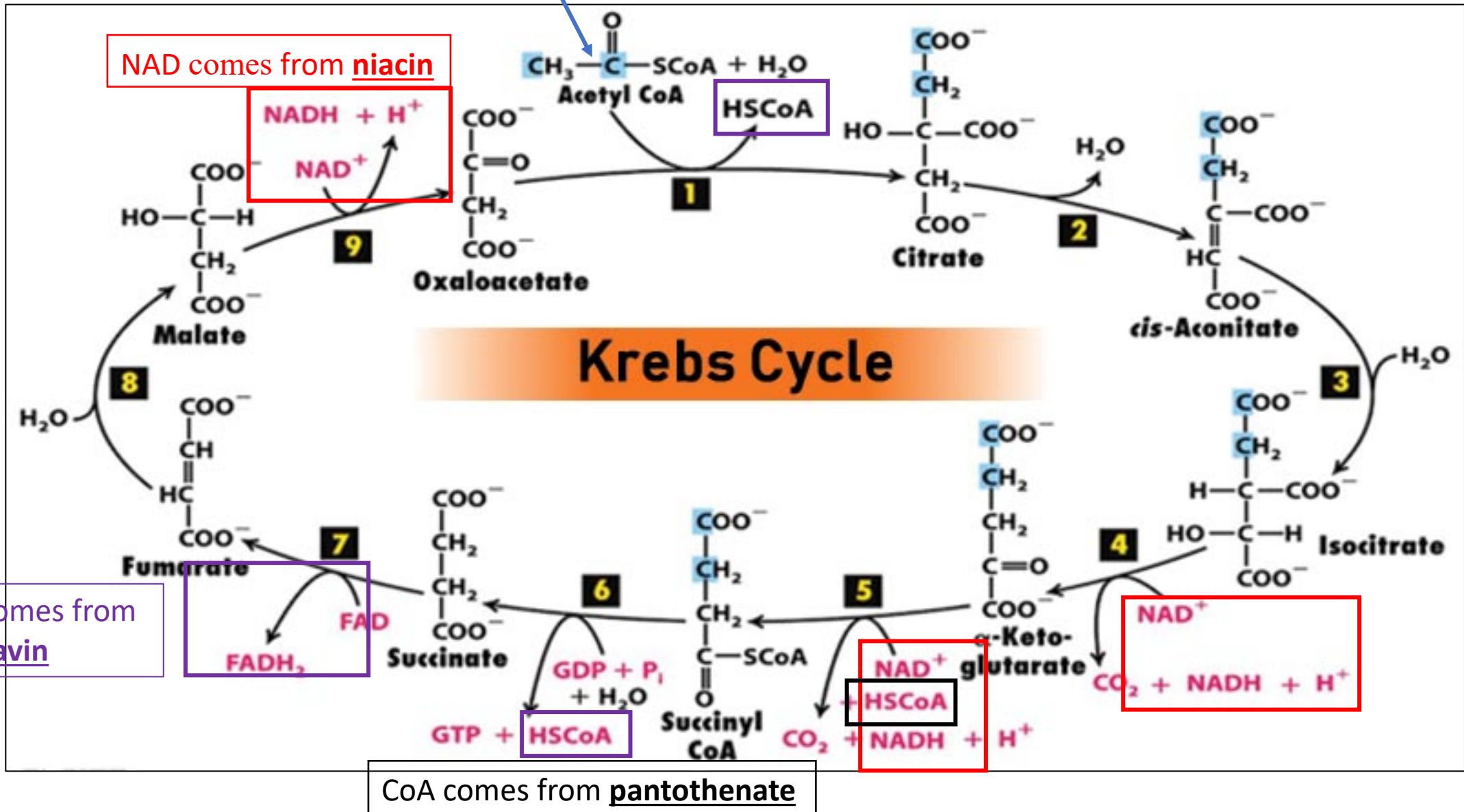
- **Water** environment
- **DNA, RNA** – information
- **Carbohydrates** – largely energy and energy storage
- **Lipids (fats)** – cell and subcellular membranes, energy and storage
- **Proteins** – structure and movement, transporters, regulators and builders; as enzymes, make chemical reactions happen
 - Constructed from 21 amino acids (includes selenocysteine), which create a wide variety of structures, but may need help to do their jobs
 - This is where vitamins and minerals come in

Structural Biology - Different Protein Shapes

An antibody has two arms. Each end attaches to the antibody's target



Glucose is converted to **Acetyl CoA**. The last step, which yields acetyl CoA uses **thiamine** (and lipoic acid)



One illustrative metabolic pathway found on the MCAT; **enzymes** do the reactions

<https://microbenotes.com/tca-cycle-citric-acid-cycle-or-krebs-cycle/>



Vitamin Functions - 1

- Retinol (**A**) is also produced from beta carotene (golden rice) - vision, general wound healing, immune system function
- Thiamin (**B1**), Riboflavin (**B2**), Niacin (**B3**), Pantothenate (**B5**), and Biotin (**B7, H**) – energy generation from sugars (see previous) and fatty acids. **B3** and **B2** act as electron carriers in mitochondrial ATP production (as NAD and FAD respectively).
- Pyridoxine (**B6**) – amine metabolism, including amino acids and certain neurotransmitters (neurological health)



Vitamin Functions - 2

- Cobalamin (**B12**) and folate (**B9**, which incorporates p-aminobenzoic acid, PABA) – methyl transfer reactions, blood cell formation and neurological health
- Ascorbate (**C**) – collagen maintenance (scurvy), antioxidant, immune response. Pauling – hominid ancestors ate lots of fruit
- **D** complex – calcium homeostasis with phosphate, bone health. Related to sunlight level; skin color, deficiency today?
- Tocopherol (**E**) – antioxidant
- **K** – coagulation; need healthy microbiome



Need for Vitamin and Mineral Supplements

- **Michael Pollan – Eat food, not too much, mostly plants.**
- **Avoid too many highly refined foods;** fruits and vegetables are good and may be sufficient. Note genomics says we adapted to meat; B12 deficiency in vegans
- Focus on special deficiency cases for individual vitamins and minerals. **Foodstuff supplementation** indicates commonly recognized shortages – refined **wheat flour** is enriched with thiamine, riboflavin, niacin, reduced iron (Fe⁺²) and after 1998, folate (spina bifida); **milk** with vitamin D



Macroelement Functions

Mostly Metallic Elements in the Periodic Table; Act as Ions

- **Sodium** (Na^+), **Potassium** (K^+) and **Chloride** (Cl^-) – electrolyte balance and neural transmission, blood pressure
- **Calcium** (Ca^{+2}) + **Phosphate** ($\text{H}_{1,2}\text{PO}_4^{-1}$ or -2) as crystalline hydroxyapatite – bone, teeth, **note osteoporosis**; $\text{Ca} (+2)$ also involved in metabolic control – calcium channels, calmodulin
- **Magnesium** (Mg^{+2}) – chemically similar to calcium; cellular metabolic function, associated with proteins, DNA and RNA
- C, H, O, N and S are found combined with other elements, not independently, so are not covered here

Micro-(trace)element Functions

First Transition Metal Row from Cr to Zn

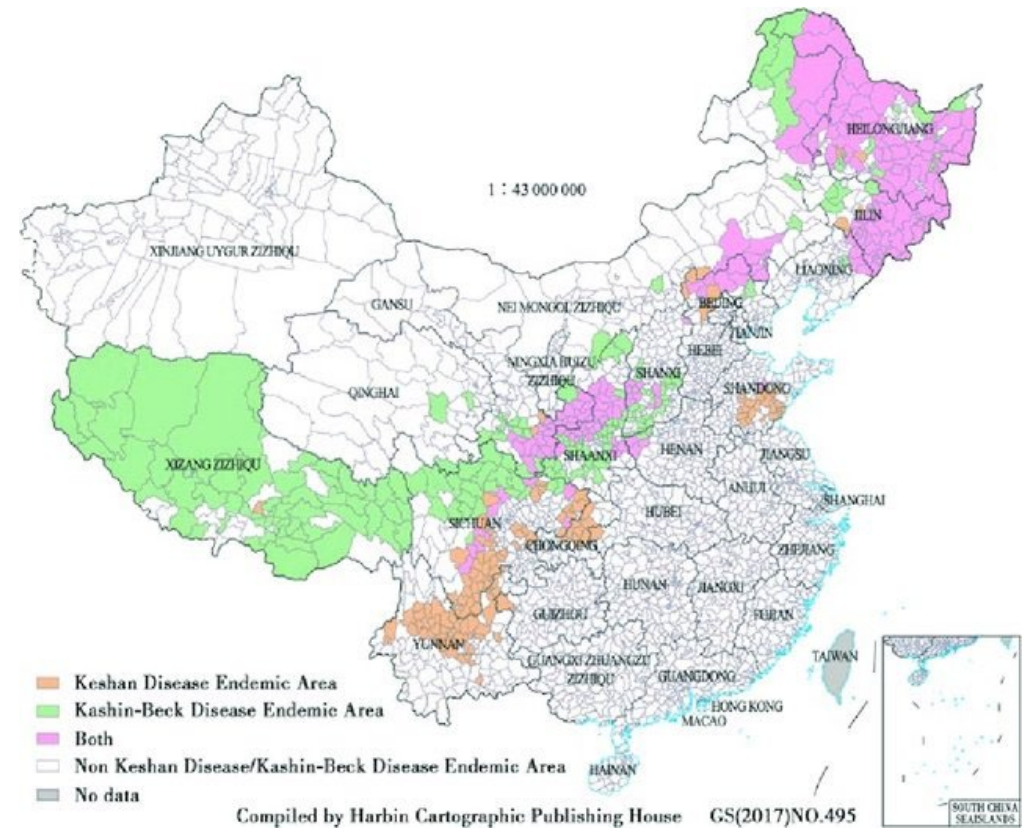
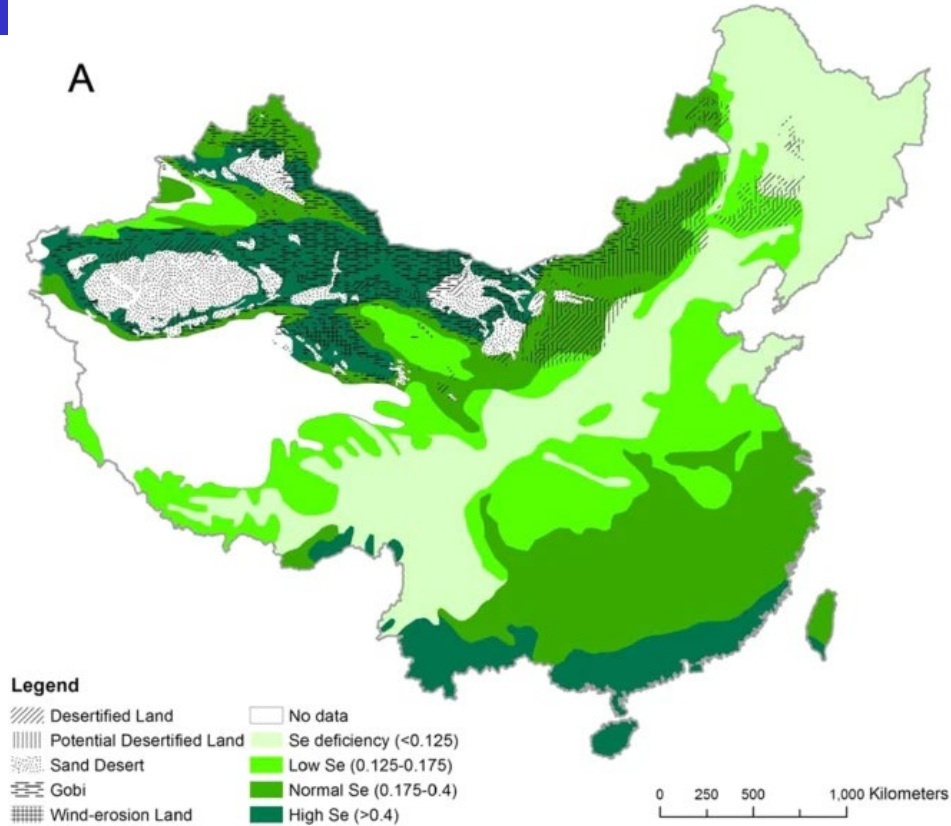
- **Chromium** (Cr^{+3}) – glucose tolerance, diabetes prevention
- **Manganese** (Mn^{+2}) – enzyme cofactor, including SOD
- **Iron** ($\text{Fe}^{+2/+3}$) – oxygen and electron transport, enzyme cofactor where oxidation-reduction occurs
- (Cobalt (Co^{+2}) – found in vitamin B12, not independently)
- (Nickel (Ni^{+2}) – oddity, essential or not? Cancer, dermatitis)
- **Copper** (Cu^{+2} and $+1$) enzyme cofactor; antioxidant SOD
- **Zinc** (Zn^{+2}) – enzyme cofactor, especially DNA, RNA



Other Trace Elements

- **Fluoride** (F-) – deficiency associated with tooth decay; excess with fluorosis, mottled teeth, brittle bones
- **Selenium** (selenocysteine, the 21st amino acid); anti-lipid peroxidation; Keshan disease – cardiomyopathy and congestive heart failure in China
- **Molybdenum** (Mo+6) – xanthine oxidase, purine, uric acid metabolism; also aldehyde oxidase (blocked by Antabuse)
- **Iodine** (I-) – exception to rule of essential elements are at the top of periodic table, thyroid function and goiter

Keshan Disease China (Selenium Deficiency)



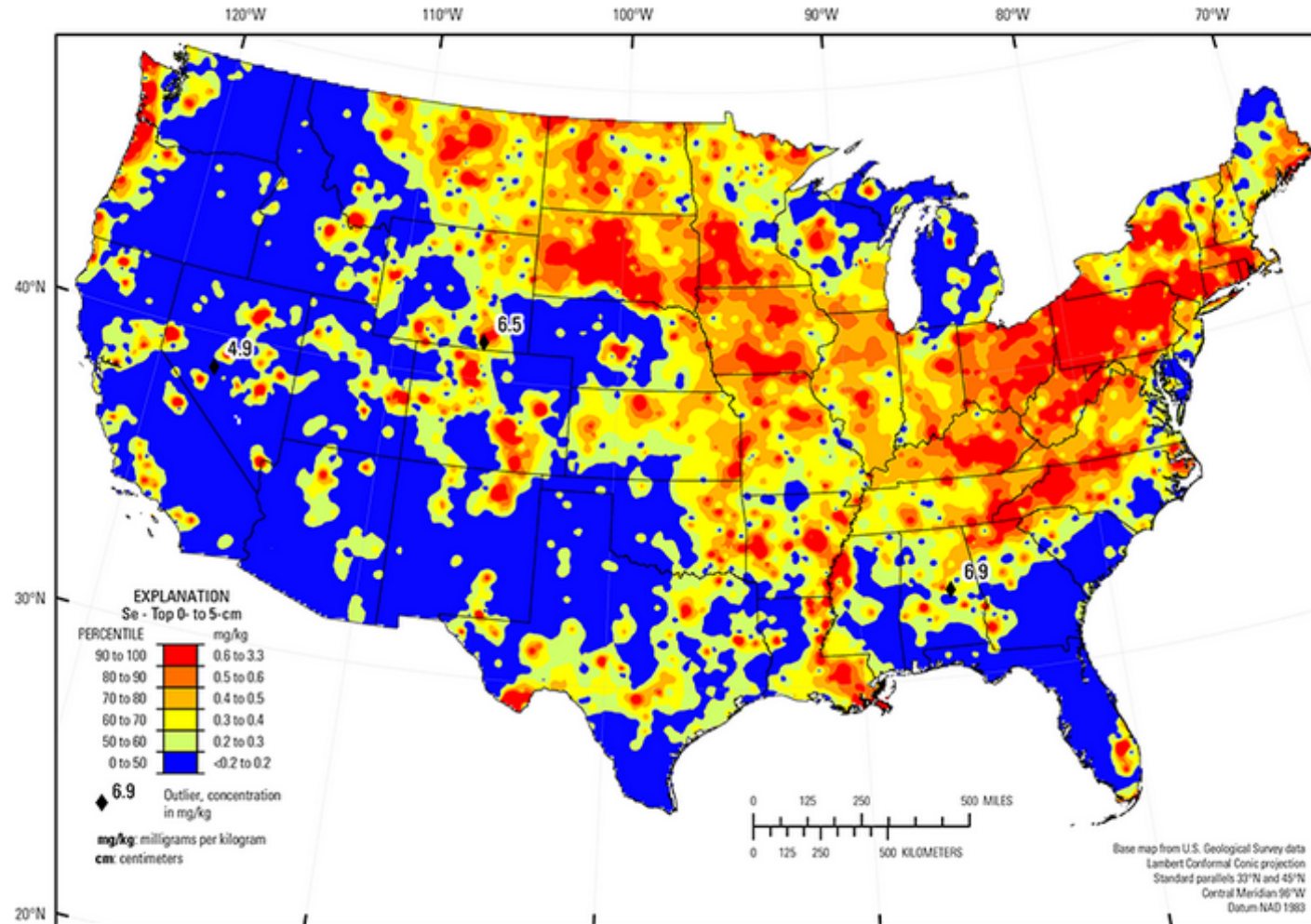
Soil selenium levels; pale green = deficiency

<https://www.nature.com/articles/srep20953>

Keshan disease regions (purple)

https://www.researchgate.net/publication/339031516_Endemic_Disease_in_China/figures?lo=1

Selenium



https://pubs.usgs.gov/sir/2017/5118/sir20175118_element.php?el=34

Climate change expected to aggravate selenium deficiency in soils:

<http://food-forminerals.cypressingredients.com/blog/selenium-deficiency-predicted-from-climate-change>



Trace Element Deficiencies and Ways to Counter Them

- **Nutrient deficiencies common with old age:** calcium (women especially, but also men), vitamin D, and to a lesser extent, magnesium, B12 and folate, potassium, zinc
- Avoid diets low in concentration
- Find foods high in concentration
- Consider supplements – chemical form – solubility, chelation
- (Soil deficiencies)



Toxic Elements

- **Iron** (hemochromatosis) and **Copper** (Wilson's disease) with two oxidation states can produce oxygen radicals, so are kept under tight control; **avoid excess intake**
- Elements toward the bottom of the periodic table are rare; don't see much, may not take much to be too much; Paracelsus
- **Lead** (Pb^{+2}) and **Mercury** (Hg^{+2} and methylmercury) are neurotoxic; **Cadmium** (Cd^{+2} mimics Zn^{+2}) and **Arsenic** (As as arsenate, AsO_4 mimics phosphate, PO_4) are carcinogenic and generally toxic; **Thallium** (Tl) is a general poison; Be