Minerals

Inorganic elemental atoms that are essential nutrients.

Not changed by digestion or metabolism.

Functions of Minerals

- Some participate with enzymes in metabolic processes (cofactors)
- Some have structural functions (Ca, P in bone; S in keratin)
- Acid-base and water balance (Na, K, Cl)
- Nerve & muscle function (Ca, Na, K)
- Unique functions (e.g., heme, B_{12}, thyroid hormones)

The Major Minerals: an Overview

- Macrominerals
- Humans need >100 mg/d
  - Calcium
  - Phosphorus
  - Magnesium
  - Sodium
  - Chloride
  - Potassium

Bioavailability, & Regulation of Major Minerals

- Bioavailability
  - Influenced by genetics, aging, nutritional status & other food compounds
- Absorption
  - Small intestine & large intestine
- Regulation
  - Kidneys & small intestine

Classification

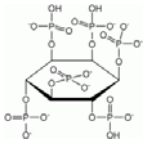
- Macro or Major minerals
  - Sodium, potassium, magnesium, calcium, phosphorus, sulfur, chloride
- Present in body tissues at concentrations >50 mg/kg (50 ppm)
- Micro or Trace minerals (body needs relatively less)
  - Chromium, manganese, iron, cobalt, molybdenum, copper, zinc, fluoride, iodine, selenium, silicon, tin, arsenic, nickel...
- Present in body tissues at concentrations <50 mg/kg (50 ppm)

Nutritionally Important Minerals

Macro		Trace	
Element	g/kg	Element	mg/kg
Ca	15	Fe	20-50
P	10	Zn	10-50
K	2	Cu	1-5
Na	1.6	Mo	1-4
Cl	1.1	Se	1-2
S	1.5	I	0.3-0.6
Mg	0.4	Mn	0.2-0.5
		Co	0.02-0.1

Minerals in Foods

Oxalate 

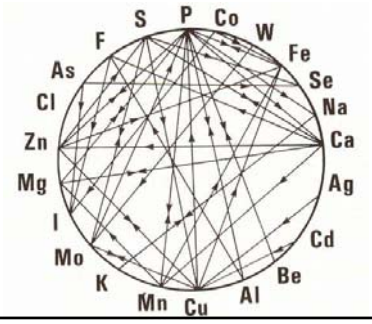
Phytate 

- Found in all food groups.
- More reliably found in animal products.
- Often other substances in foods decrease absorption (bioavailability) of minerals
  - *Oxalate*, found in spinach, prevents absorption of most calcium in spinach.
  - *Phytate,* form of phosphorous in most plants makes it poorly available

Factors Affecting Requirements

- Physiological state/level of production
- Interactions with other minerals

Mineral Interactions



Factors Affecting Requirements

- Physiological state/level of production
- Interactions with other minerals
- Tissue storage
  - Bone, Liver
  - Specific proteins to hold and transport
- Form fed
  - inorganic vs organic forms
    - Na selenite vs Na selenate vs selenomethionine

Deficiencies and Excesses

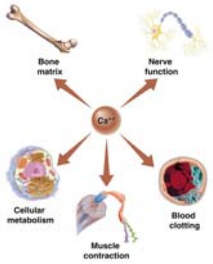
- Most minerals have an optimal range
  - Below leads to deficiency symptoms
  - Above leads to toxicity symptoms
- Mineral content of soils dictates mineral status of plants (i.e., feeds)
- May take many months to develop
  - Time impacted by body stores

Requirements and Toxicities

Element	Species	Requirement, mg/kg	Toxic level, mg/kg
Cu	Cattle	5-8	115
	Swine	6	250
Co	Cattle	0.06	60
I	Livestock	0.1	?
Se	Cattle	0.1	3-4
	Horses	0.1	5-40

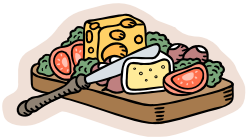
Calcium

- Most abundant mineral in animal tissues
  - 99% Ca in skeleton
  - Present in:
    - Blood & other tissues
- Lots of functions
  - Bone structure
  - Nerve function
  - Blood clotting
  - Muscle contraction
  - Cellular metabolism



Food Sources

- Milk and dairy products
  - High amounts
  - High bioavailability (fortified with vitamin D)
- Green leafy vegetables
  - Poor absorption
- Fish with bones?
- Fortified juice/cereal



Calcium

- Both Ca and P are required for bone formation and other non-skeletal functions
  - Dietary ratio of 1:1 to 2:1 is good for most animals (exception is laying hen, 13:1; Ca:nonphytate phosphorous)

Calcium Absorption

- Dependent on Vitamin D
  - Ca binding protein in intestinal epithelial cell
- Absorption depends on need
  - Particularly high during growth, pregnancy and lactation
- Bioavailability decreased by
  - Phytates (grains)
  - Oxalates
  - Wheat bran
  - Low estrogen levels (postmenopausal women)

Calcium Regulation

- Plasma Ca is regulated variable
  - Normal plasma concentration is 8-12 mg/dl

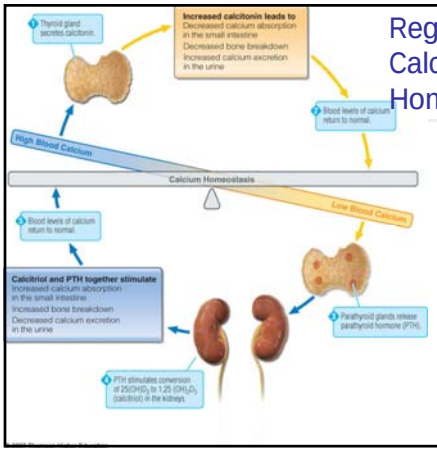
Calcium Regulation

- Three hormones involved in regulation
  - Vitamin D_3
    - from kidney
  - Parathyroid hormone (PTH)
    - from parathyroid gland
  - Calcitonin
    - from thyroid gland
- PTH and Vitamin D_3 act to increase plasma Ca, while calcitonin acts to decrease plasma Ca

Responses to Low Blood Calcium

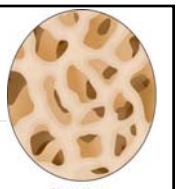
- Parathyroid hormone (PTH) released
  - Stimulates conversion of inactive form of vitamin D to calcitrol
  - Increases in blood calcium
    - Small intestine
    - Resorption at kidneys & blood

Regulation of Calcium Homeostasis



Calcium Deficiencies

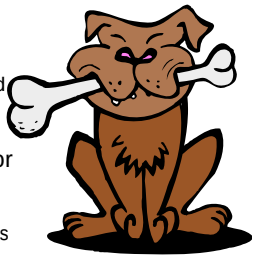
- Rickets
  - in growing animals
- Osteomalacia (osteoporosis)
  - in adult animals
- Milk fever (parturient paresis)
  - in lactating animals


Normal bone


Osteoporotic bone

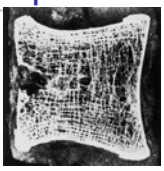
Calcium and Bone Health

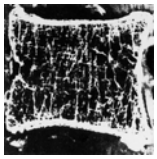
- Bone growth is greatest during "linear growth"
  - Peaks out at around age 30
- Calcium in bones used as reservoir for other needs.
  - Maintains blood calcium homeostasis

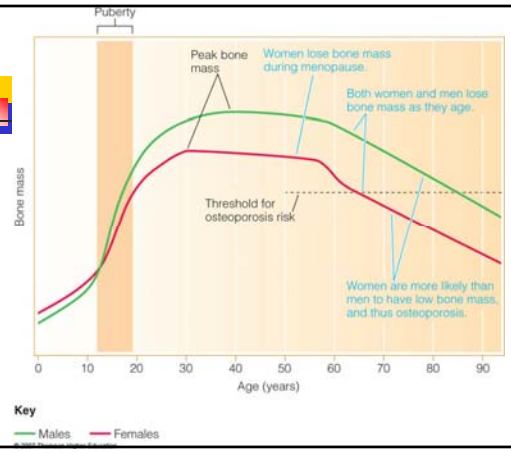


Calcium and Osteoporosis

- Around age 40, bone breakdown exceeds formation.
- Ideally, want very high bone mass when this begins.
- By age 65, some women have lost 50% of bone mass.

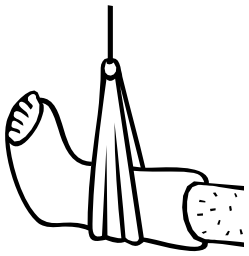






Prevention is the Key

- Maintain adequate calcium and vitamin D intake—many recommend supplements?
  - Most are absorbed similarly
  - Costs vary widely
  - What's wrong with dairy products?
- Perform weight-bearing exercise
- Take estrogen supplements?



Structural Functions of Calcium: Bones & Teeth

- Bones
  - Osteoblasts
    - Bone formation
  - Osteoclasts
    - Breakdown of older bone
- Hydroxyapatite
  - Large crystal-like molecule

Regulatory Functions of Calcium

- Stimulates blood clotting
- Muscle contractions
- Transmission of nerve impulses
- Vision
- Regulation of blood glucose
- Cell differentiation
- Cofactor for energy metabolism

Focus on Foods: Milk, Calcium, & Chronic Disease

- Associations of reduced risk of chronic disease:
- Degenerative diseases
- Heart disease
  - Lowers blood pressure
- Cancer
  - Breast, prostate, colon
- Obesity

Calcium Toxicity

- Deposition in soft tissue
- Impaired kidney function
- Interference of other nutrient absorption
  - Iron & zinc

Phosphorous

- Functions
  - Similar to calcium
  - Vitally important in energy metabolism
    - ATP
    - sugar phosphates
  - Phosphoproteins
- Deficiencies include
  - Rickets or osteomalacia
  - Pica (depraved appetite) – chewing of wood, bones
  - Low fertility and poor milk production or growth?

Phosphorous

- Impact on environment has scientists revisiting nutritional requirements
  - Requirements are being lowered without any negative effects on reproduction or milk production
- Bioavailability could be improved if phytate P can be reduced
  - Main source of P in grain

Phosphorus (P)

- Component of cell membranes & walls
- Found in all foods
- Structural & functional roles in body
- Energy metabolism

Metabolism & Regulation of Phosphorus in the Body

- Small intestine
  - Vitamin D-dependent active transport
  - Simple diffusion
- Concentrations controlled by:
  - Calcitriol, PTH, calcitonin

Functions of Phosphorus

- Phospholipids
- Component of:
  - DNA & RNA
  - ATP
- Protein synthesis
- Energy metabolism
- Maintenance of blood pH
- Forms hydroxyapatite

Phosphorus Toxicity

- Mineralization of soft tissues

Sodium

- Absolutely an essential nutrient, but has been "demonized" like cholesterol.
- Typical intakes way higher than what is needed in humans; added to livestock diets.
- Body usually gets rid of excess quite easily.
- Functions
  - Acid-base and osmotic balance of body fluids
  - Major cation of extracellular fluid
    - Nerve transmission
    - Transport and absorption of sugars and amino acids

Sodium and Health

- High blood sodium is associated with high blood pressure and risk of heart disease
- However, high blood sodium rarely due to dietary excess.
- Again, genetics and other factors are involved.

Sodium & Chloride

- Commonly found together in foods
- Join via ionic bonds to form salt
- Added freely to foods during:
  - Processing
  - Cooking
  - A meal

Did you know...

- *Salt free* means:
  - Less than 5 mg sodium/serving
- *Very low salt* means:
  - Less than 35 mg sodium/serving
- *Low salt*
  - Less than 140 mg sodium/serving

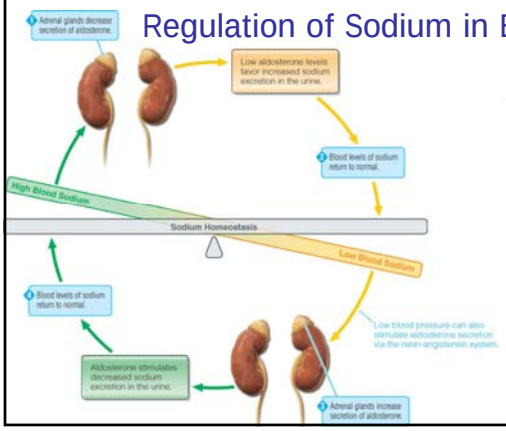
Dietary Sources & Bioavailability

- Table salt
- Monosodium glutamate
- Highly processed foods
- Condiments
- Some meats, dairy products, poultry & seafood
- Bioavailability
  - Affected by malabsorption

Regulation of Sodium & Chloride in the Body

- Small intestine
  - Sodium absorbed first
  - Chloride second
- Sodium
  - Absorbed with glucose
  - Also actively absorbed in colon
    - Water absorption

Regulation of Sodium in Blood



Functions of Sodium & Chloride

- Electrolytes
- Fluid balance
- Sodium
  - Nerve function
  - Muscle contraction
- Chloride
  - HCl production
  - Removal of carbon dioxide
  - Immune function

Sodium & Chloride Deficiencies

- Infants & children
  - Diarrhea and vomiting
- Athletes
  - Endurance sports
- Symptoms
  - Nausea, dizziness, muscle cramps, coma

Overconsumption of Sodium Chloride

- Increased blood pressure
- Susceptible individuals
  - Elderly
  - African Americans
  - Those with:
    - Hypertension
    - Diabetes
    - Chronic kidney disease

Focus on Food – Salt: Is It Really So Bad?

- Salt sensitivity affected by:
  - Genetics
  - Exercise
  - Responsiveness of renin-angiotensin-aldosterone system

Chlorine

- Functions
  - Acid-base and osmotic regulation
  - HCl and chloride salts in gastric secretions
- Deficiencies
  - Metabolic alkalosis
    - Increased bicarbonate compensates for decreased Cl
  - Growth retardation

Sulfur

- Component of amino acids
  - cystine, cysteine, and methionine for bioactive and structural proteins
    - wool contains about 4% sulfur
- Chondroitin sulfate is a constituent of cartilage
- Deficiency is related to protein deficiency

Magnesium

- Functions
  - Associated with Ca and P
  - 70% of Mg in skeleton
  - Enzyme activation (e.g., pyruvate dehydrogenase)
- Deficiency
  - Hypomagnesemic tetany (grass tetany)
    - early lactating cows on grass
    - poor nervous and muscular control

Magnesium (Mg): Dietary Sources & Bioavailability

- Green leafy vegetables, seafood, legumes, nuts, dairy products, chocolate, brown rice, whole grains
- Bioavailability influenced by:
  - Calcium
  - Phosphorus

Metabolism & Regulation of Magnesium in the Body

- Stabilizes enzymes
- Neutralizes negatively charged ions
- Energy metabolism
- Cofactor for over 300 enzymes
  - DNA & RNA metabolism
- Nerve & muscle function

Magnesium Deficiency & Toxicity

- Deficiencies
  - Alcoholics
  - Abnormal nerve & muscle function
  - ? increase risk for CVD & type 2 diabetes
- Toxicity
  - Large dose supplements
  - Intestinal distress, alterations in heart beat

Potassium

- Functions
  - Regulation of osmotic and acid-base balance
  - Major cation of intracellular fluid
    - nerve and muscle excitability
  - Cofactor for several reactions in carbohydrate metabolism
- Major salt in ruminant sweat
  - Increases requirement in heat stress
- Typically high in forages

Potassium (K): Dietary Sources & Bioavailability

- Legumes, potatoes, seafood, dairy products, meat, fruits/veg
- Bioavailability
  - High

Regulation & Functions of Potassium in the Body

- Absorption in small intestine & colon
- Blood potassium regulated by:
  - Kidneys
  - Aldosterone increases excretion
- Electrolyte
- Maintains fluid balance
- Muscle function
- Nerve function
- Energy metabolism

Potassium Deficiency & Toxicity

- Deficiency
  - Diarrhea & vomiting
  - Diuretics
  - Hypokalemia
- Symptoms
  - Muscle weakness, constipation, irritability, confusion, ? insulin resistance, irregular heart function, decreased blood pressure, difficulty breathing
- Toxicity
  - Supplementation

The Trace Minerals: An Overview

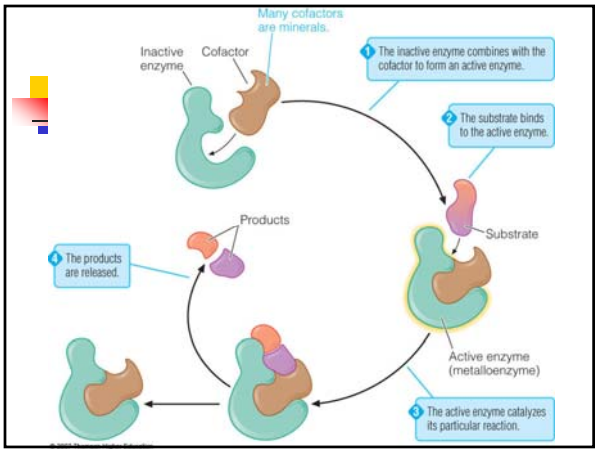
- Inorganic atoms or molecules
- Microminerals or trace elements
- < 100 mg/day needed

Bioavailability & Regulation of Trace Minerals

- Bioavailability influenced by:
  - Genetics
  - Nutritional status
  - Nutrient interactions
  - Aging
- Absorbed in small intestine
- Circulated in blood
- Deficiencies & toxicities rare
  - Except genetic disorders & environmental exposure

Functions of Trace Minerals in the Body

- Cofactors
  - Metalloenzyme
- Components of nonenzymatic molecules
- Provide structure to mineralized tissues

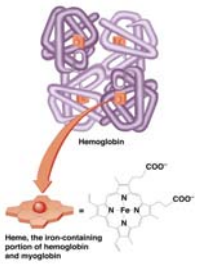


Trace Elements (minerals)

- Need small amounts of these.
- Found in plants and animals.
- Content in plant foods depends on soil content (where plant was grown).
- They are difficult to quantify biochemically.
- Bioavailability often influenced by other dietary factors (especially other minerals)

Iron

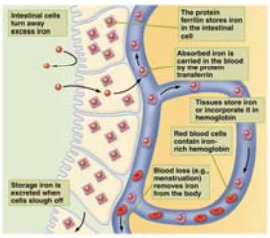
- Most common nutrient deficiency in the world.
- Functions
  - Oxygen transport via hemoglobin
    - Thus, necessary for ATP production!
  - Essential component of many enzymes
  - Immune function
  - Brain function
    - Iron deficiency/toxicity thought to slow mental development in kids.



Iron in the Body

- 70% of iron in body is functional; found in enzymes and other molecules
  - >80% of this found in red blood cells
- 30% of iron is in storage depots or transport proteins
- Iron absorption, transport, storage and loss is highly regulated.

Iron Absorption

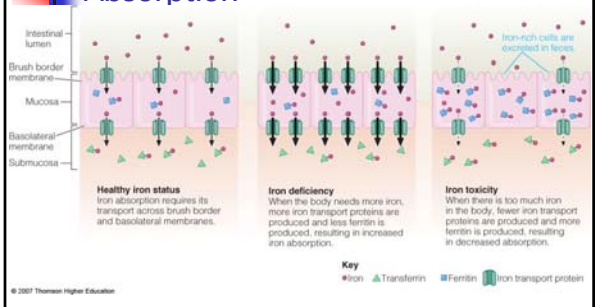


- Primary regulator of iron homeostasis
  - 1-50% of iron is absorbed.
- If body needs more iron, it increases amount of "transferrin" an iron carrying protein.
- Iron can also be stored in another protein called "ferritin"

Iron Absorption

- Transport across
  - Brush border
  - Basolateral membrane
- Heme iron
  - Chemical modification not needed
- Nonheme iron
  - Reduced to ferrous form
- Ferritin

Effect of Iron Status on Iron Absorption

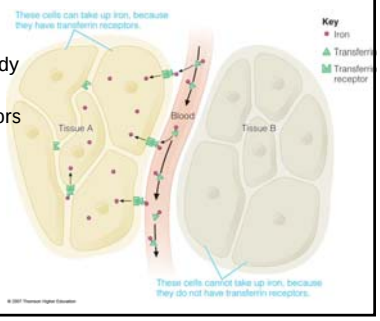


Effect of Iron Status on Iron Absorption

- Iron deficiency
  - Increases production of transport proteins
  - Decreases ferritin production
- Adequate or excess iron
  - Decreases production of transport proteins

Iron Circulation, Uptake Into Cells, & Storage

- Transferrin
  - Delivers iron to body cells
  - Transferrin receptors



Iron Circulation, Uptake Into Cells, & Storage

- Iron storage compounds
  - Ferritin
    - Main storage form
  - Hemosiderin
    - Long-term storage

Absorption, cont.

- Iron from animal sources much better absorbed than that from plant sources
- Absorption of iron from plant sources increased by
  - Vitamin C
  - Meat in diet
- Absorption is decreased by
  - Phytates (grain products)
  - Polyphenols (tea, coffee)
  - Other minerals (calcium, zinc)

Iron Deficiency Anemia

- Public health concern in U.S. and around the world.
- Infants, children, pregnant and lactating women most at risk.
- Symptoms
  - ↓ hemoglobin concentration of blood
  - ↓ red blood cell size
  - Cognitive problems, poor growth, decreased exercise tolerance.

Iron (Fe): Dietary Sources

- Heme iron
  - Bound to a heme group
  - Shellfish, beef, poultry, organ meats
  - Makes up
    - Hemoglobin, myoglobin, cytochromes
- Nonheme iron
  - Green leafy vegetables, mushrooms, legumes, enriched grains
  - ~85% of dietary iron

Bioavailability of Iron

Influenced by:

- Form
  - Heme
  - Ferric
  - Ferrous
- Iron status
- Presence/absence of other dietary components

Enhancers of Nonheme Iron Bioavailability

- Vitamin C & stomach acid
  - Convert ferric to ferrous iron
- Meat factor
  - Compound in meat, poultry, seafood
  - Meat + nonheme iron

Inhibitors of Nonheme Iron Bioavailability

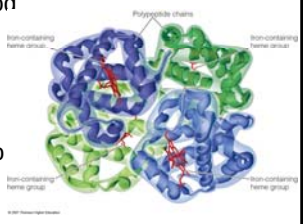
- Chelators
  - Phytates
    - In vegetables, grains, seeds
  - Polyphenols
    - Some vegetables, tea, coffee, red wine

Functions of Iron

- Oxygen transport: hemoglobin
- Iron reservoir: myoglobin
- Cellular energy metabolism

Oxygen Transport: Hemoglobin

- Most abundant protein in red blood cells
- 4 protein subunits 4 iron-containing heme groups
- Delivers oxygen to cells
- Picks up carbon dioxide



Iron Reservoir: Myoglobin

- Found in muscle cells
- Heme group + protein subunit
- Releases oxygen to cells when needed for:
  - ATP production
  - Muscle contraction

Cellular Energy Metabolism

- Cytochromes
  - Heme-containing complexes
  - Function in electron transport chain
  - Allow conversion of ADP to ATP
- Iron as cofactor
  - Electron transport chain
  - Citric acid cycle
  - Gluconeogensis

Other Roles of Iron

- Cytochrome P450 enzymes
- Cofactor for antioxidant enzymes
  - Protects DNA, cell membranes, proteins
- Cofactor for enzyme to make DNA

Iron Deficiency

- Most common nutritional deficiency
- At-risk groups
  - Infants, growing children, pregnant women
- Pica

Mild Iron Deficiency

- Signs
  - Fatigue
  - Impaired physical work performance
  - Behavioral abnormalities
  - Impaired intellectual abilities in children
  - Body temperature regulation
  - Influences immune system

Severe Iron Deficiency: Iron-Deficiency Anemia

- Microcytic hypochromic anemia
  - Small, pale red blood cells
  - Inability to produce enough heme
  - Decreased ability to carry oxygen
  - Decreased ATP synthesis

Focus on Clinical Applications: Measuring Iron Status

- Serum ferritin concentration
  - < 12 micrograms/L
- Total iron-binding capacity
  - > 400 micrograms/dL
- Serum transferrin saturation
  - < 16%
- Hemoglobin concentration
  - Men < 130 g/L Women < 120 g/L
- Hematocrit
  - Men < 39% Women <36%

Basics of Iron Supplementation

- Ferrous Iron
  - Best absorbed
  - Other terms:
    - Ferrous fumarte
    - Ferrous sulfate
    - Ferrous gluconate
- Ferric Iron

Iron Toxicity

- Medicinal or supplemental iron
- Most common cause of childhood poisoning
- Symptoms
  - Vomiting, diarrhea, constipation, black stools
  - Death
- Excess deposited in liver, heart, muscles

Special Recommendations for Vegetarians & Endurance Athletes

- Vegans
  - Needs are 80% higher
  - Iron supplements
  - Heme + nonheme iron foods
- Endurance athletes
  - Increased blood loss in feces/urine
  - Chronic rupture of red blood cells in feet
  - Needs are 70% higher

Copper (Cu): Dietary Sources & Bioavailability

- Forms
  - Cupric
  - Cuprous
- Organ meats, shellfish, whole-grain products, mushrooms, nuts, legumes
- Bioavailability decreases with
  - Antacids
  - Iron

Absorption, Metabolism, & Regulation of Copper

- Absorbed in small intestine & stomach
- Influenced by Cu status
- Ceruloplasmin
- Excess incorporated into bile & eliminated in feces

Functions of Copper

- Cofactor for metalloenzymes in redox reactions:
  - ATP production
    - Cytochrome c oxidase
  - Iron metabolism
  - Neural function
  - Antioxidant function
    - Superoxide dismutase
  - Connective tissue synthesis

Copper Deficiency & Toxicity

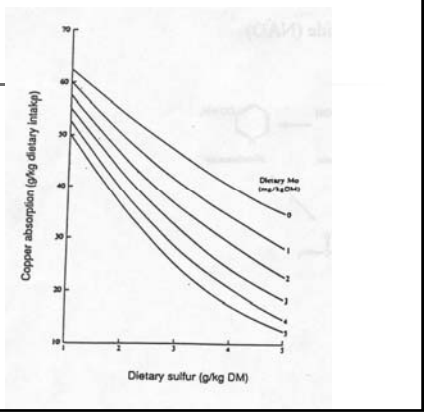
- Deficiency
  - Hospitalized patients & preterm infants
  - Antacids
- Signs & Symptoms
  - Defective connective tissue, anemia, neural problems
- Toxicity
  - Rare

Copper

- Functions
  - Essential for normal absorption, transport and mobilization of iron and hemoglobin synthesis
  - Integral component of many enzymes (e.g., cytochrome oxidase)
- Stored in most tissues, especially liver

Copper Deficiency

- Anemia
- Depigmentation of hair or wool
  - Black sheep are sometimes kept as indicators of marginal Cu deficiency
- Loss of wool crimp (“steely” wool)
- Bone disorders
- Central nervous lesions with muscular incoordination



Induced Copper Deficiency

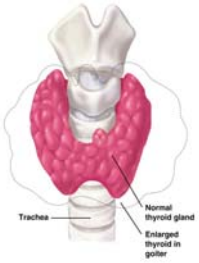
- Caused by relatively high levels of Mo and/or S
- Site of interaction is in the rumen
  - Formation of insoluble Cu salts including sulfides and thiomolybdates
- Net effect is decreased Cu absorption

Induced Copper Toxicity

- Occurs with “normal” dietary levels of Cu and “low” levels of Mo and S
- Accumulates in liver
- Sheep are more susceptible than cattle or pigs

Iodine

- Function
  - Essential component of thyroid hormones
    - Important for regulation of body temperature, basal metabolic rate, reproduction and growth.
- Regulation in body
  - Almost all is absorbed.
  - Excess removed in urine.



Dietary Sources

- Seafoods
- Milk/dairy products
- Iodized salt

Iodine Deficiency

- Goiter (less severe)
  - Enlarged thyroid gland due to body's attempt to increase thyroid hormone production
- Cretinism (more severe)
  - Severe iodine deficiency during pregnancy→serious problems in baby
    - Stunted growth, deaf, mute, mentally retarded.

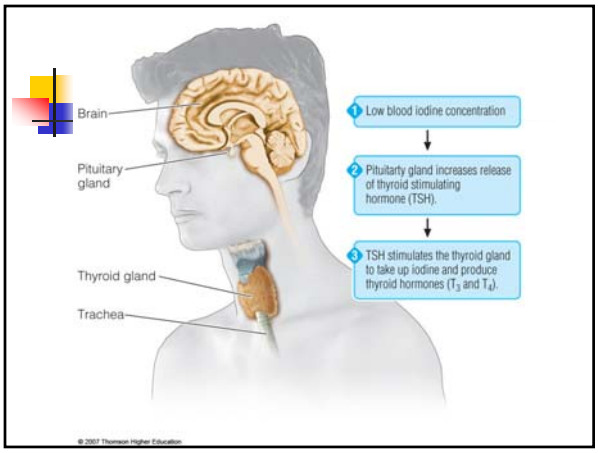
Iodine Deficiency Disorders

- Cretinism

- Goiter

Absorption, Metabolism, & Regulation of Iodine

- Absorbed in small intestine & stomach
- Taken up by thyroid gland
- Thyroid-stimulating hormone regulates uptake



Functions of Iodine

- Component of:
  - Thyroxine (T_4)
  - Triiodothyronine (T_3)
- Regulates energy metabolism, growth, development
- Signs of deficiency
  - Severe fatigue
  - Lethargy

Focus on Food: Iodine Deficiency & Iodine Fortification of Salt

- 1920s – “Goiter Belt”
- Statewide campaigns
- Started providing iodized salt to children
- Goiter almost eliminated
- Current – Public Health working to eradicate goiter internationally

Iodine Toxicity

- Hypothyroidism
- Hyperthyroidism
- Formation of goiters

Absorption, Metabolism, & Regulation of Selenium

- Most Se enters blood
- Incorporated into selenomethionine
- Makes selenoproteins
- Stored in muscles
- Maintenance of Se through excretion in urine

Functions of Selenium

- Component of glutathione peroxidase
  - catalyzes removal of hydrogen peroxide

$$GSH + H_2O_2 \longrightarrow GSSG + H_2O$$

GSH = reduced glutathione
GSSG = oxidized glutathione

- Component of iodothyronine-5'- deiodinase
  - Converts T_4 to T_3
- Improves killing ability of neutrophils
  - Reduces the prevalence and severity of mastitis

Selenium

- Protects cells from autooxidative damage
- Shares this role with vitamin E
  - Important antioxidant
- Deficiencies
  - White muscle disease in lambs and calves
    - Skeletal and cardiac myopathies
  - Exudative diathesis (hemorrhagic disease) in chicks

Selenium Content of Soils

Selenium

- Toxicity
  - Blind staggers or alkali disease
- Range between minimum requirement and maximum tolerable level is narrow
  - Supplementation must be done with care!
- FDA regulations allow two forms of inorganic Se (Na selenite and Na selenate) to be used
  - 0.3 mg of supplemental Se/kg of DM is maximum
  - Organic form available

Selenium Deficiency & Toxicity

- Deficiency
  - Keshan disease
- Toxicity
  - Garlic-like odor of breath
  - Nausea
  - Vomiting
  - Diarrhea
  - Brittleness of teeth & fingernails

Chromium (Cr): Dietary Sources, Bioavailability, & Regulation

- Food content depends on soil
- Whole grains, fruits/veg, processed meats, beer, wine
- Bioavailability affected by:
  - Vitamin C
  - Acidic medications
  - Antacids
- Transported in blood to liver
- Excess excreted in urine & feces

Functions of Chromium

- Regulates insulin
- Growth & development
- Lab animals
  - Increases lean mass
  - Decreases fat mass
- Ergogenic aid
  - Chromium picolinate

Chromium Deficiency & Toxicity

- Deficiency
  - Hospitalized patients
    - Elevated blood glucose
    - Decreased insulin sensitivity
    - Weight loss
- Toxicity
  - Rare
  - Industrially released chromium

Manganese (Mn): Dietary Sources & Regulation

- Whole grains, pineapples, nuts, legumes, dark green leafy vegetables, water
- <10% absorbed
- Excess incorporated into bile & excreted in feces

Functions of Manganese

- Cofactor for metalloenzymes
  - Gluconeogenesis
  - Bone formation
- Energy metabolism
- Cofactor for superoxide dismutase

Manganese Deficiency & Toxicity

- Deficiency
  - Rare
  - Scaly skin, poor bone formation, growth faltering
- Toxicity
  - Rare
    - Mining
    - Liver disease
    - High water levels

Molybdenum (Mo): Dietary Sources

- Food content depends on soil
- Legumes, grains, nuts
- Absorbed in intestine
- Circulated to liver via blood

Functions of Molybdenum

- Redox reactions
- Cofactor for several enzymes
- Metabolism of:
  - Sulfur-containing amino acids
  - DNA & RNA
- Detoxifying drugs in liver

Molybdenum Deficiency & Toxicity

- Deficiency
  - Rare
- Toxicity
  - No known effects in humans
  - Animals – disrupts reproduction

Zinc (Zn): Dietary Sources & Bioavailability

- Bioavailability influenced by:
  - Phytates
  - Iron
  - Calcium
  - Animal sources
  - Acidic substances

Absorption, Metabolism, & Regulation of Zinc

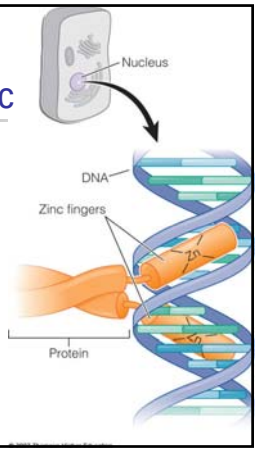
- Requires proteins to:
  - Transport zinc into enterocyte
    - Metallothionine
  - Bind zinc within cell
- Excess excreted in feces
- Genetic influences

Acrodermatitis Enteroathica

- Zinc deficiency even with adequate amounts of dietary zinc
- Supplementation
- Infants
  - Growth failure
  - Red/scaly skin
  - Diarrhea
- Human Genome Project

Functions of Zinc

- Cofactor
  - RNA synthesis
- Stabilizes proteins that regulate gene expression
  - Zinc fingers
- Antioxidant
- Stabilizes cell membranes

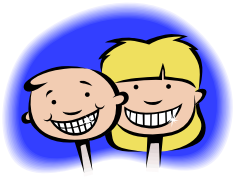


Zinc Deficiency & Toxicity

- Deficiency
  - Decreases appetite
  - Increases morbidity
  - Decreases growth
  - Skin irritations, diarrhea, delayed sexual maturation
- Toxicity
  - Supplements
  - Poor immune function
  - Depressed levels of HDL
  - Impaired copper status
  - Nausea, vomiting, loss of appetite

Fluoride

- 99% is found in bones and teeth
- Function
  - to promote mineralization of calcium and phosphate.
  - Inhibits bacterial growth in mouth→decreases cavity formation.



Fluoride (F^-): Dietary Sources, Bioavailability, & Regulation

- Not an essential nutrient
- Potatoes, tea, legumes, fish w/bones, toothpaste, added to drinking water
- American Dental Association
  - Fluoridation 1-2 ppm
- Absorbed via small intestine
- Circulates in blood to liver & then teeth & bone
- Excess excreted in urine

Functions of Fluoride

- Part of bone & teeth matrix
- Stimulates maturation of osteoblasts
- Topical application decreases bacteria in mouth
  - Fewer cavities

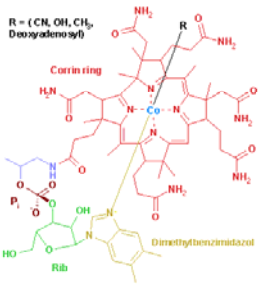
Fluoride Deficiency & Toxicity

- Deficiency
  - None known
- Toxicity
  - GI upset, excessive production of saliva, watery eyes, heart problems, coma
  - Dental fluorosis
  - Skeletal fluorosis

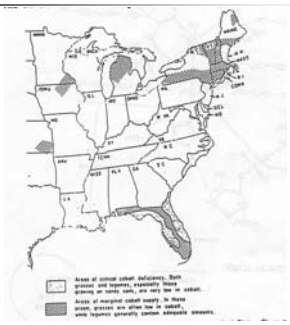
Cobalt

- Known since 1930s that a wasting disease was associated with Co deficiency in plants and soils
- Starved for glucose!
- Vitamin B_{12} was found to contain Co

Vitamin B_{12}



Cobalt Deficient Areas of the US



Cobalt and Vitamin B_{12}

- Injection of Co-deficient sheep and cattle with Vitamin B_{12} was as effective as feeding Co in curing the disease
- Injection of Co had no effect
- Microbial synthesis of Vitamin B_{12} was the key!

Functions of Cobalt and Vitamin B_{12}

- Essential coenzyme for
  - Propionate metabolism
    - methylmalonyl CoA to succinyl CoA
  - DNA synthesis
  - Bacterial synthesis of methionine

Other Trace Minerals

More research needed about:

- Nickel
- Aluminum
- Silicon
- Vanadium
- Arsenic
- Boron