Water and the Minerals: An Overview

Chapters 12-13

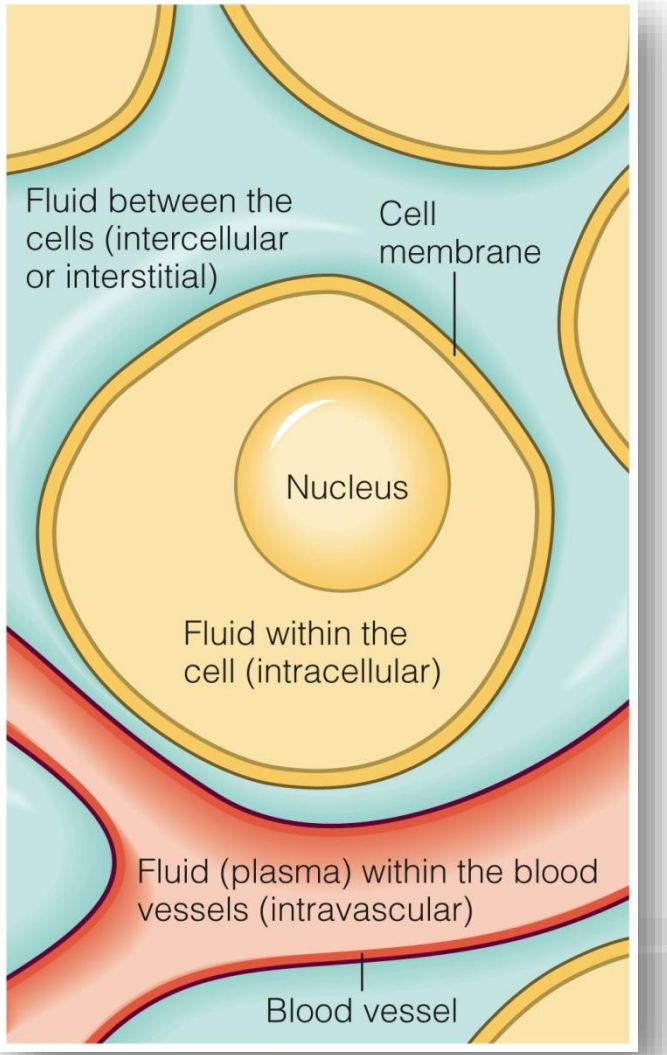
Water and the Body Fluids

- Water constitutes majority of body weight: 60%
  - Body composition
    - Lean tissue: 75% of weight = water
    - Fat: 25% of weight = water
    - Amount of lean mass directly influences water's proportion of body weight
      - Females, obese people, elderly people: smaller proportion of lean tissue so small proportion of body weight is water

Water and the Body Fluids

- Carries nutrients and waste products
- Maintains structure of large molecules (proteins, glycogen)
- Serves as a solvent: minerals, vitamins, amino acids, glucose, many other small molecules
- Acts as a lubricant and cushion: joints, eyes, spinal cord, and womb
- Aids in regulation of body temperature (sweat evaporation)
- Maintains blood volume
- Participates in metabolic reactions

Distribution and Movement of Body Fluids



- Cell fluids
  - Different compositions
  - Intracellular fluid: inside cells
  - Extracellular fluid: outside cells
    - Interstitial fluid: surrounds each cell
    - Intravascular fluid: within blood vessels
  - Body fluid: 2/3 inside cells, 1/3 outside cells

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Fluid and Electrolyte Balance

- Electrolytes: salts that *dissociate* in water and separate into charged ions
  - Ions dissolved in water conduct electricity
  - Cation: positively charged
  - Anion: negatively charged
  - *Example: sodium chloride (NaCl) dissociates into:*
    - *Sodium (Na^+)*
    - *Chloride (Cl^-)*
  - Fluids containing electrolytes = electrolyte solutions

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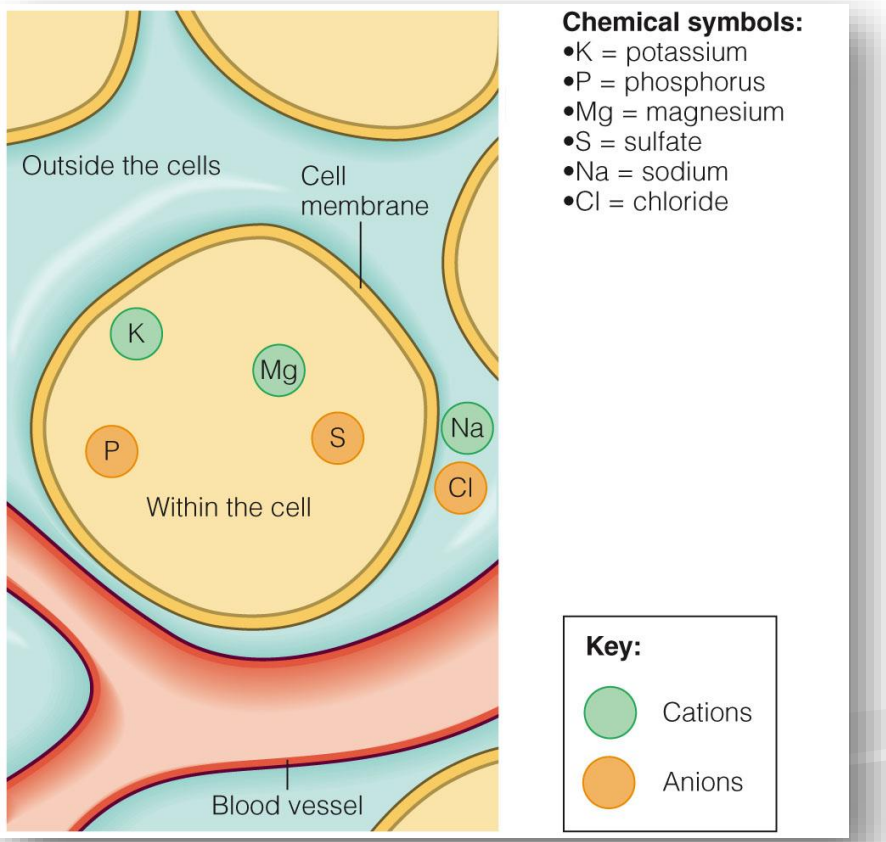
A Cell and Its Electrolytes

- Electrolyte solutions
  - Inside *and* outside of cells, equal balance of anions (negative charge) and cations (positive charge)
    - Numbers and proportions differ, but charges are balanced
    - Electrolytes predominately outside cell:
      - Sodium, chloride, calcium
    - Electrolytes predominately inside cell:
      - Potassium, magnesium, phosphate, sulfate



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A Cell and Its Electrolytes

TABLE 12-1 Important Body Electrolytes

Electrolytes	Intracellular (inside cells) Concentration (mEq/L)	Extracellular (outside cells) Concentration (mEq/L)
Cations (positively charged ions)		
Sodium (Na^+)	10	142
Potassium (K^+)	150	5
Calcium (Ca^{++})	2	5
Magnesium (Mg^{++})	40	3
	202	155
Anions (negatively charged ions)		
Chloride (Cl^-)	2	103
Bicarbonate (HCO_3^-)	10	27
Phosphate ($HPO_4^=$)	103	2
Sulfate ($SO_4^=$)	20	1
Organic acids (lactate, pyruvate)	10	6
Proteins	57	16
	202	155

NOTE: The numbers of positive and negative charges in a given fluid are the same. For example, in extracellular fluid, the cations and anions both equal 155 milliequivalents per liter (mEq/L). Of the cations, sodium ions make up 142 mEq/L; and potassium, calcium, and magnesium ions make up the remainder. Of the anions, chloride ions number 103 mEq/L; bicarbonate ions number 27; and the rest are provided by phosphate ions, sulfate ions, organic acids, and protein.

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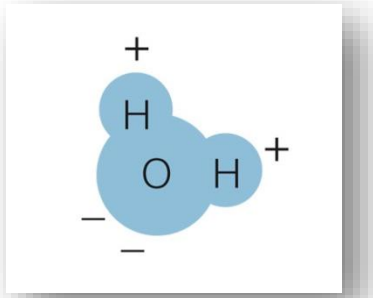
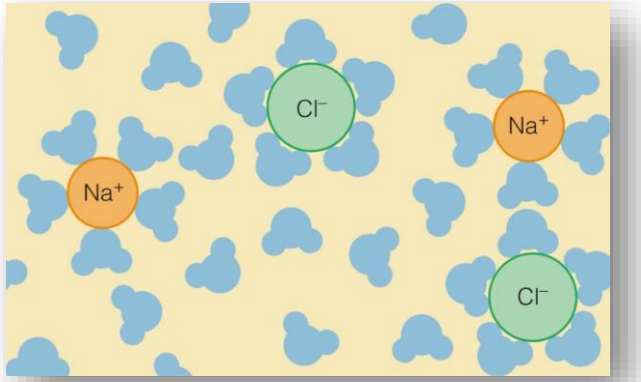
Fluid and Electrolyte Balance

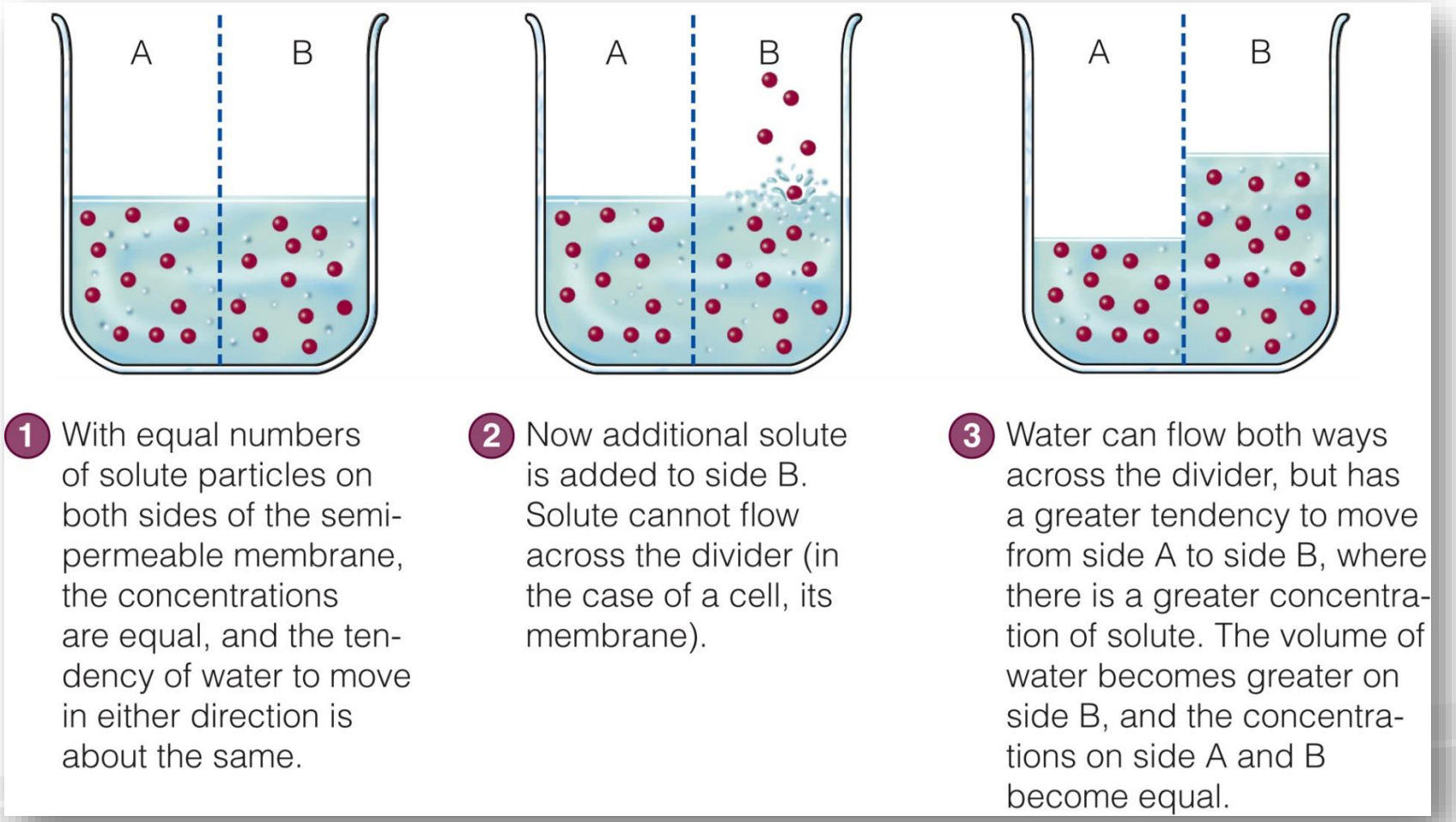


- Electrolytes attract water
  - Water molecules net charge of zero
  - Hydrogen = slightly positive; Oxygen = slightly negative
  - Water follows electrolytes across selectively permeable cell membranes



- Solution: solute dissolved in fluid
  - Concentration of solution = amount of solute : fluid
  - Osmosis = water moves across membrane toward more concentrated solutes
  - Proteins attract water and regulate fluid
    - Transport proteins regulate passage of ions across cell membranes

Osmosis



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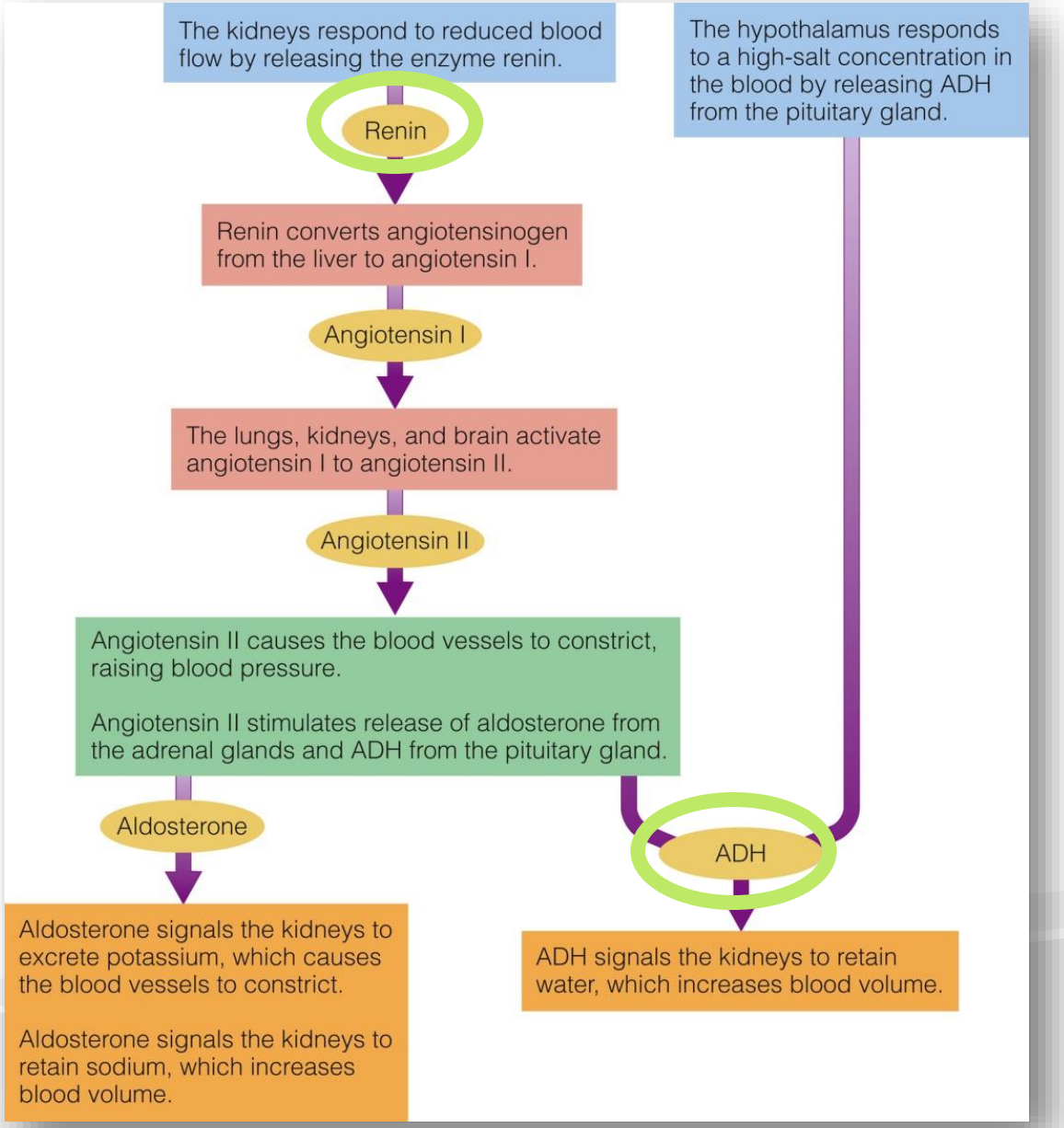
Regulation of Blood Volume and Blood Pressure

- Kidneys: site of blood volume and blood pressure regulation
  - Constantly reabsorb substances/water and excrete wastes/water
  - Instructions for retaining/releasing substances come from complex series of reactions triggered by:
    - **Antidiuretic Hormone (ADH):** water-conserving hormone
    - **Renin:** water-conserving enzyme



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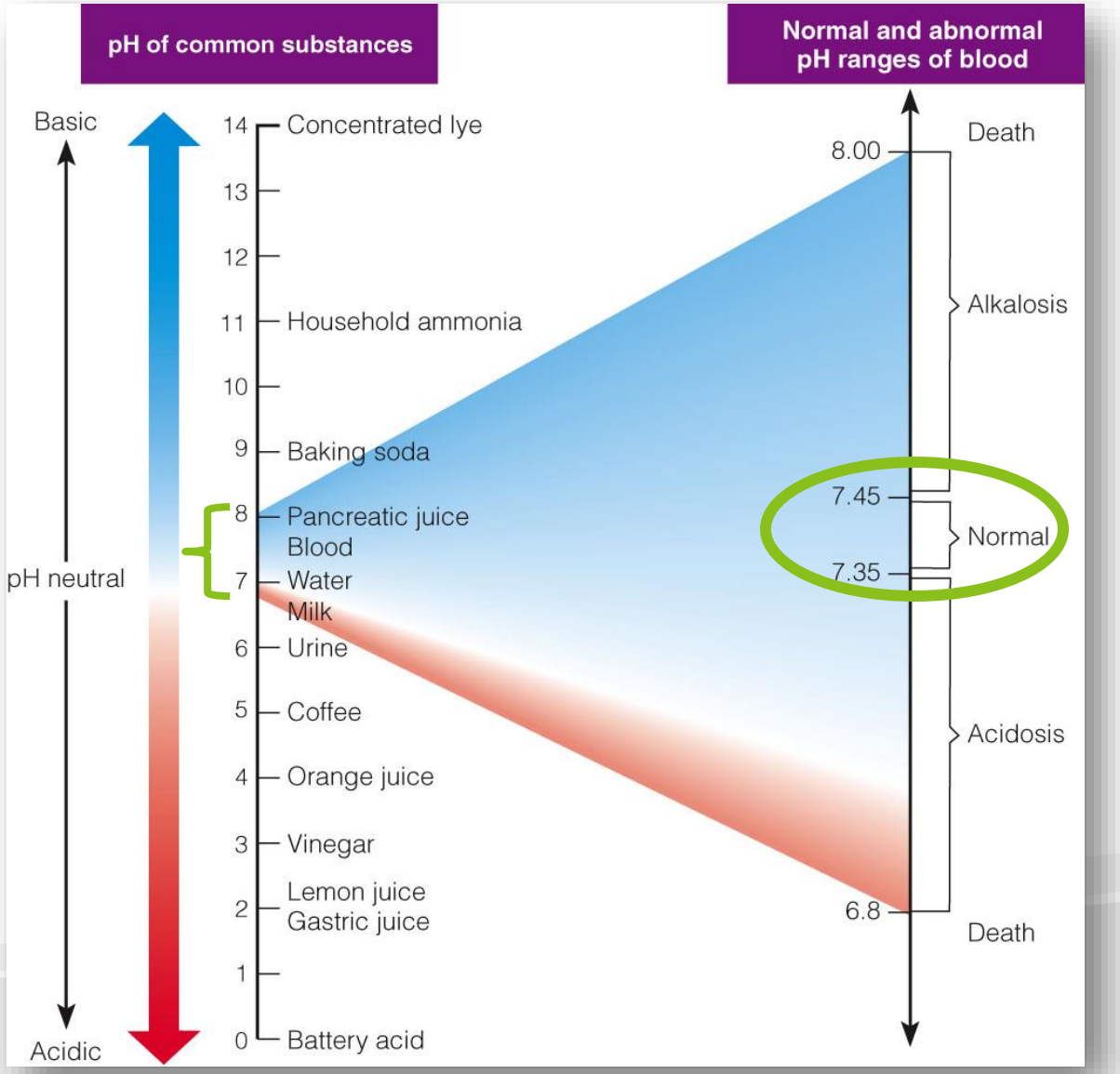
Fluid and Electrolyte Imbalance

- Body defends itself against normal imbalance
  - Normal imbalances: sweating, minor GI issues
  - Normal replacements: plain water and regular foods
- Causes of severe imbalance
  - Prolonged vomiting or diarrhea; heavy sweating; burns; traumatic wounds; some medications
  - Water alone isn't enough to rehydrate body
  - Requires medical intervention: replacement of fluids + electrolytes (*which* electrolytes depend on cause of imbalance)

Acid-Base Balance

- Ions help regulate body fluid acidity
- Narrow pH range to avoid life-threatening consequences: 7.35 – 7.45
- Concentration of hydrogen ions (H^+) determines acidity
  - High hydrogen concentration = acidic
  - Low hydrogen concentration = basic



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Acid-Base Balance

- Body's defense against pH fluctuation:
  - Buffers in blood
    - Carbonic acid (from CO_2)
    - Bicarbonate (from carbonic acid)
  - Respiration in lungs
    - Controls carbonic acid concentration via respiration rate
    - Too much carbonic acid → increased respiration (more CO_2 exhaled instead of forming carbonic acid)
    - Too much bicarbonate → slowed respiration (more CO_2 retained forms carbonic acid to neutralize bicarbonate)
  - Excretion in kidneys
    - Controls bicarbonate concentration via excretion or reabsorption
    - Body remains balanced, acidity of urine fluctuates

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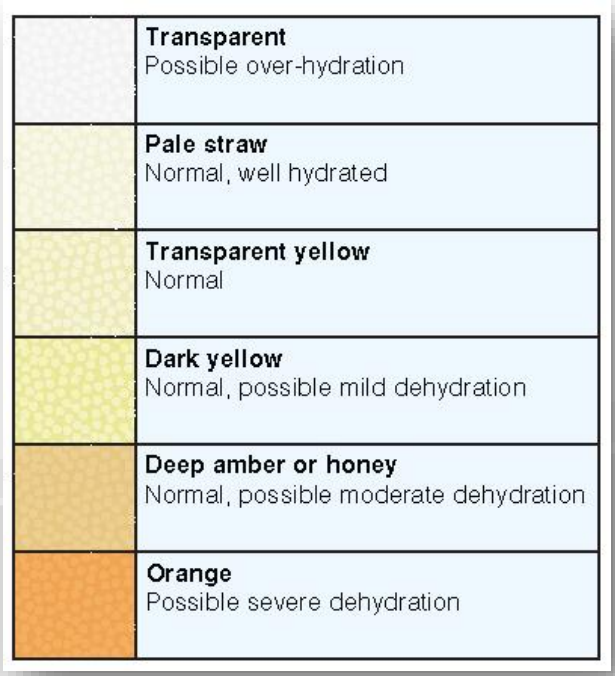
Water Balance and Recommended Intake

- Thirst and satiety: sensed by mouth, hypothalamus, and nerves
- Sources
  - Beverages: beware of added sugar!
  - Foods: fruits and veggies >90% water
  - Metabolic water: generated in condensation reactions and oxidation of energy-yielding nutrients
- Recommended intake:
  - Varies by diet, activity level, and environment
  - ½ cup per 100 kcalories expended: 2000 kcalories = 8-12 cups/day (most US adults consume enough)



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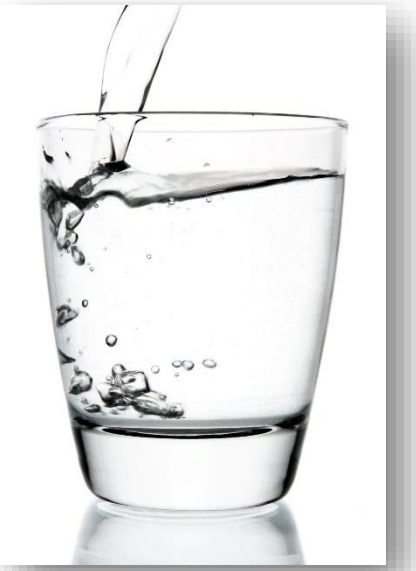
Water Balance and Recommended Intake



- Health effects of water
  - Physical and mental performance: concentration, alertness, short-term memory
  - Optimal functioning of: GI tract (prevents constipation); kidneys (protect against kidney stones); heart; and more!
  - Different types of tap water:
    - Soft water: high sodium and potassium
    - Hard water: high calcium and magnesium

Water Balance and Recommended Intake

- Water losses
  - Obligatory water excretion: urine carries away waste products generated during metabolic processes (~2 cups/day)
  - Additional losses: vapor, sweat, feces
  - Total daily losses ~10 ½ cups/day

Water Balance			
Water Sources	**Amount (mL)**	**Water Losses**	**Amount (mL)**
Beverages	550-1500	Kidneys (urine)	500-1400
Foods	700-1000	Skin (sweat)	450-900
Metabolism (condensation)	200-300	Lungs (breath)	350
		GI tract (feces)	150
Total	**1450-2800**	**Total**	**1450-2800**

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Signs of Dehydration

TABLE 12-1 Signs of Dehydration

Body Weight Lost (%)	Symptoms
1–2	Thirst, fatigue, weakness, vague discomfort, loss of appetite
3–4	Impaired physical performance, dry mouth, reduction in urine, flushed skin, impatience, apathy
5–6	Difficulty concentrating, headache, irritability, sleepiness, impaired temperature regulation, increased respiratory rate
7–10	Dizziness, spastic muscles, loss of balance, delirium, exhaustion, collapse

NOTE: The onset and severity of symptoms at various percentages of body weight lost depend on the activity, fitness level, degree of acclimation, temperature, and humidity. If not corrected, dehydration can lead to death.

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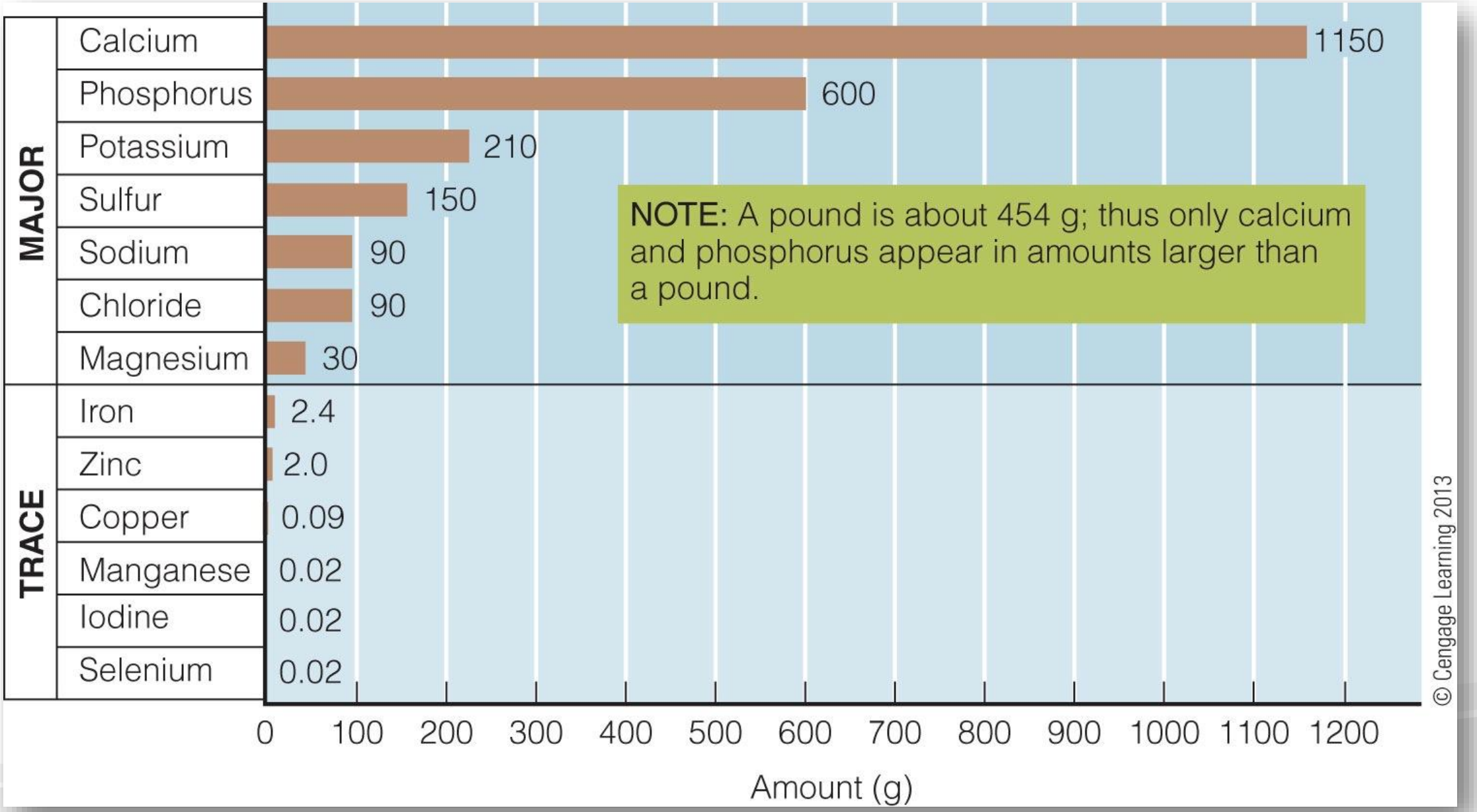
Water Balance and Recommended Intake

- Excess water intake
  - Sodium = essential for maintaining intracellular and extracellular water balance
  - Water intoxication (excessive intake): rare
    - Diluted sodium concentration in blood
    - Symptoms: confusion, convulsions, death
  - Hyponatremia (very excessive intake): rare
    - Very low sodium concentration in the blood
    - Can result from:
      - Rapid and excessive fluid intake
      - Low salt diet (rare)
      - Excessive sweating (exacerbated by high fluid intake)

Overview of Minerals

- Major minerals: present in body in larger amounts, needed by body in larger amounts
- Trace minerals: present in body in smaller amounts, needed by body in smaller amounts
- *All* minerals are vital
  - Micronutrients: similar to vitamins
  - Chemical nature differs from vitamins


MAJOR
Calcium
Phosphorus
Potassium
Sulfur
Sodium
Chloride
Magnesium
1150
600
210
150
90
90
30
NOTE: A pound is about 454 g; thus only calcium and phosphorus appear in amounts larger than a pound.
TRACE
Iron
Zinc
Copper
Manganese
Iodine
Selenium
2.4
2.0
0.09
0.02
0.02
0.02
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Amount (g)
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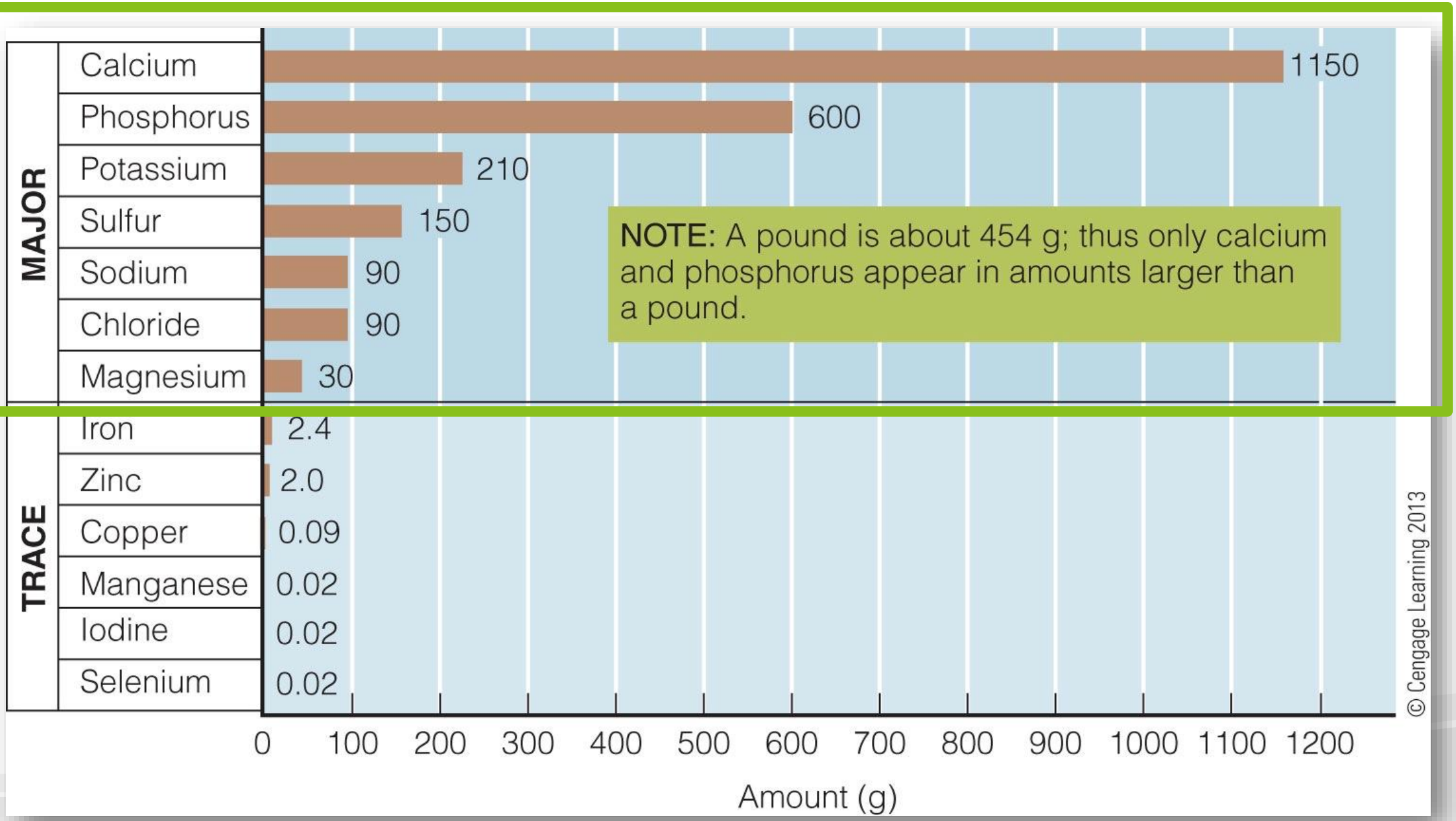
Overview of Minerals

- Inorganic elements (do NOT contain carbon)
  - Always retain chemical identity
  - Remain in body until excreted
  - Cannot be changed or destroyed by heat, air, acid, or mixing
    - Ashes on food contain original minerals
    - Leached into cooking water and discarded = lost from food
- Absorption and transport
  - Some minerals (e.g. potassium): easily absorbed, transported freely, readily excreted
  - Other minerals (e.g. calcium): need carriers to be absorbed and transported
- Excess intake can be toxic

Overview of Minerals

- Variable bioavailability
  - Food binders: chemically combine with minerals to prevent absorption; minerals are excreted with other wastes
    - Example: phytates in legumes and grains; oxalates in rhubarb and spinach
- Nutrient interactions
  - Presence of other minerals can influence:
    - Absorption, metabolism, and excretion
    - Example: sodium and calcium interact so both are excreted when sodium levels are high
    - Excesses of one causes inadequacy of another: supplements
- Varied roles in body: fluid balance, growth, health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0.02
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Amount (g)
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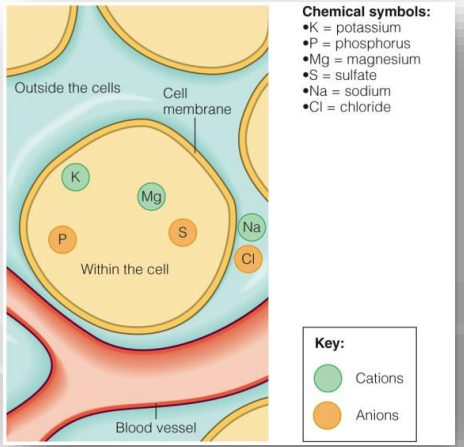
Sodium

- Salt tastes good!
  - Use in cooking to enhance other flavors, change the way foods cook
- Roles in body
  - Principal cation of extracellular fluid
  - Primary regulator of fluid volume
  - Maintains body's acid-base balance
  - Essential to nerve impulse transmission and muscle contraction
- Readily absorbed in GI tract; travels freely in blood; kidneys filter out and return blood to necessary levels
  - Amount excreted = amount ingested
  - Sodium rises → thirst; kidneys excrete excess sodium + fluid



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Sodium

- Recommendations
  - Diets rarely lack sodium: main form in diet is sodium chloride (table salt)
  - UL for adults: 2300 mg sodium (1 teaspoon of salt)
    - 90% of US population exceeds UL
- Excess sodium (salt)
  - Hypertension, heart disease
  - DASH eating pattern (Dietary Approaches to Stop Hypertension)
    - Low in sodium
    - High in potassium-rich fruits and vegetables
    - High in calcium-rich low fat milk
    - Effective at lowering blood pressure

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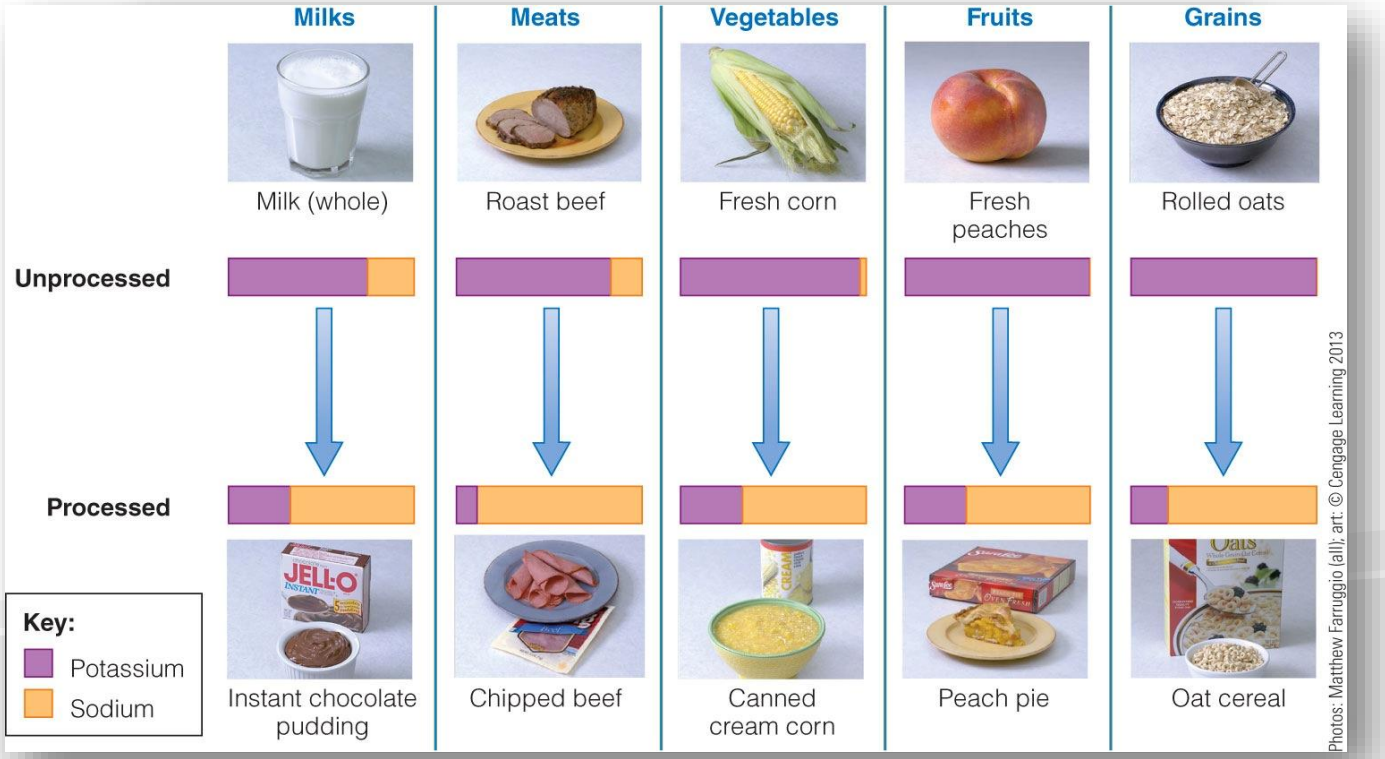
Sodium

- Food sources
  - Highest in processed foods (more than home cooking)
  - More sodium, less potassium = blood pressure double whammy



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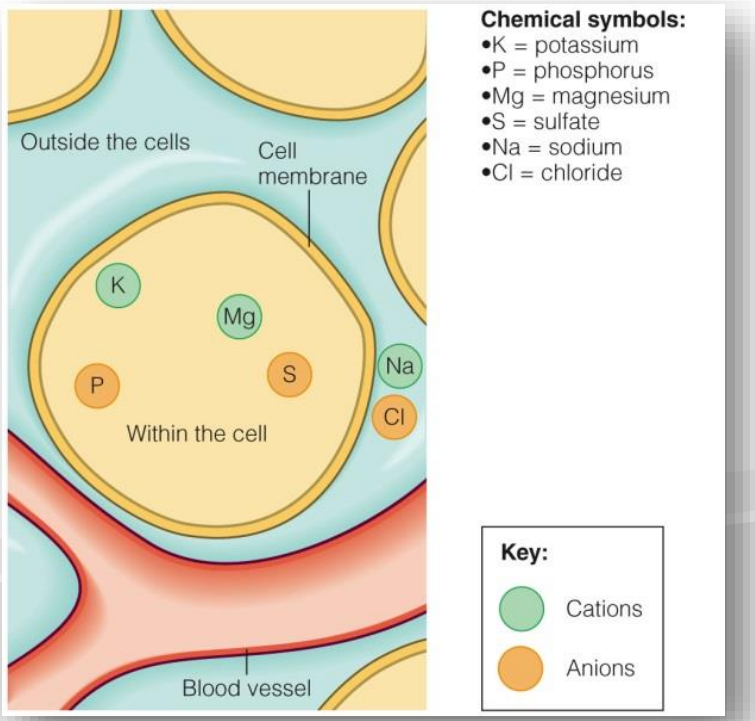
Sodium

- Deficiency
  - Not caused by inadequate dietary intake, but by excessive losses
    - Vomiting, diarrhea, heavy sweating, excessive water intake (hyponatremia) lowers blood concentration
    - Headache, confusion, stupor, seizures, coma
- Toxicity
  - Acute: edema, elevated blood pressure
  - Chronic: hypertension
  - Damages blood vessels, kidneys, brain, and heart

Chloride

- Essential nutrient: required in the diet
- Roles in the body
  - Principal anion of extracellular fluid
    - Associates with sodium (NaCl)
  - Helps maintain fluid and electrolyte balance
  - Part of hydrochloric acid in stomach
    - Maintains body's acid-base balance



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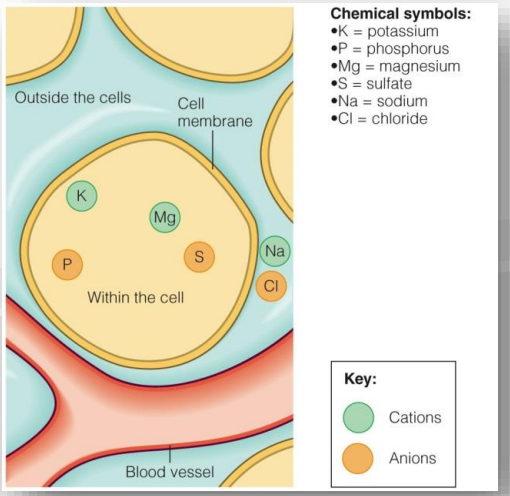
Chloride

- Recommendations
  - Abundant in processed foods: part of sodium chloride and other salts
  - Recommendations similar to sodium
    - ~3/4 tsp table salt = some sodium, more chloride
- Deficiency and toxicity
  - Diets rarely lack chloride
  - Deficiencies caused by excessive losses
    - Vomiting, diarrhea, heavy sweating
  - Toxicity: dehydration due to water deficiency

Potassium

- Roles in the body
  - Principal cation of intracellular fluid
  - Helps maintain fluid and electrolyte balance
  - Helps maintain cell integrity
  - Essential to nerve impulse transmission and muscle contraction
- Recommendations and intakes
  - Fresh foods = richest sources
  - AI for potassium = 4700 mg/day
    - Most people need to increase fruit and vegetable consumption



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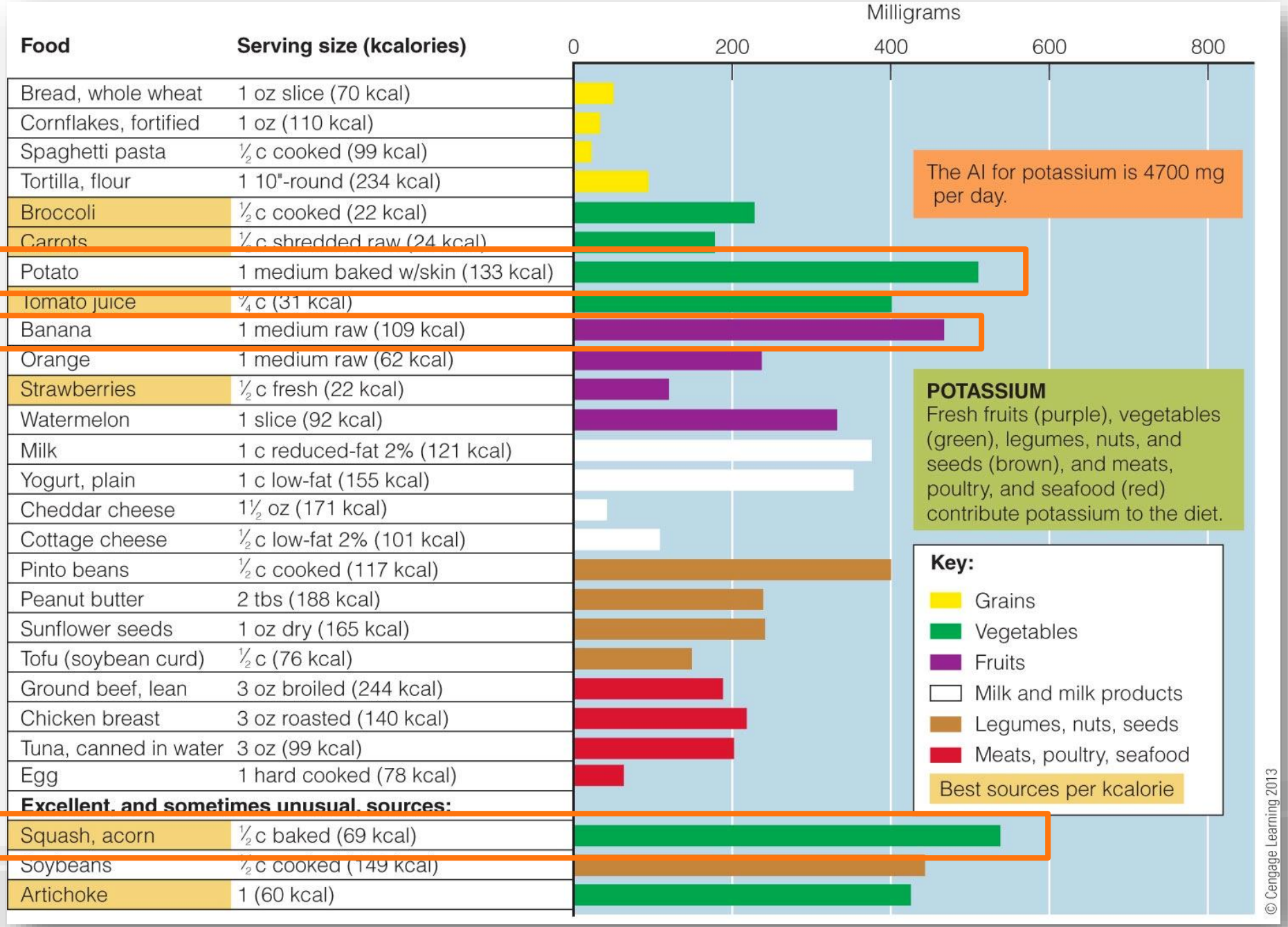

Food	Serving size (kcalories)
Bread, whole wheat	1 oz slice (70 kcal)
Cornflakes, fortified	1 oz (110 kcal)
Spaghetti pasta	½ c cooked (99 kcal)
Tortilla, flour	1 10"-round (234 kcal)
Broccoli	½ c cooked (22 kcal)
Carrots	½ c shredded raw (24 kcal)
Potato	1 medium baked w/skin (133 kcal)
Tomato juice	¾ c (31 kcal)
Banana	1 medium raw (109 kcal)
Orange	1 medium raw (62 kcal)
Strawberries	½ c fresh (22 kcal)
Watermelon	1 slice (92 kcal)
Milk	1 c reduced-fat 2% (121 kcal)
Yogurt, plain	1 c low-fat (155 kcal)
Cheddar cheese	1½ oz (171 kcal)
Cottage cheese	½ c low-fat 2% (101 kcal)
Pinto beans	½ c cooked (117 kcal)
Peanut butter	2 tbs (188 kcal)
Sunflower seeds	1 oz dry (165 kcal)
Tofu (soybean curd)	½ c (76 kcal)
Ground beef, lean	3 oz broiled (244 kcal)
Chicken breast	3 oz roasted (140 kcal)
Tuna, canned in water	3 oz (99 kcal)
Egg	1 hard cooked (78 kcal)
Excellent, and sometimes unusual, sources:	
Squash, acorn	½ c baked (69 kcal)
Soybeans	½ c cooked (149 kcal)
Artichoke	1 (60 kcal)

Potassium

- Relationship with hypertension
  - Diets low in potassium increase risk
    - Especially when combined with high sodium intake
  - Diets high in potassium reduce risk
    - Also reduce risk of heart disease and stroke
  - DASH eating patterns can help
- Deficiency
  - Increased blood pressure, kidney stones, bone turnover
  - Acute: irregular heartbeat, muscle weakness, glucose intolerance
- Toxicity
  - Excess = kidneys accelerate excretion
  - Result of supplements or potassium salts (not dietary intake)

Calcium

- Most abundant mineral in the body
- 99% of body's calcium = bones and teeth
  - Bone structure, site of muscle attachment
  - Calcium bank ready to compensate for blood calcium losses
- Adequate intake
  - Grows a healthy skeleton in early life
  - Helps minimize bone loss in later life

Calcium

- Bone formation
  - Calcium salts form crystals on collagen matrix
  - Mineralization: strength and rigidity of maturing bones
  - Bone remodeling: ongoing process of mineral gains and losses
- Teeth formation
  - Fluoride stabilizes calcium crystals in teeth
- Body fluids (only 1%)
  - Maintains blood pressure; participates in blood clotting; binds to proteins in cells, activates them, leads to:
    - Regulation of muscle contraction
    - Transmission of nerve impulses
    - Secretion of hormones
    - Activation of some enzyme reactions

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Calcium

- Calcium balance in blood
  - Vitamin D, parathyroid hormone, and calcitonin work together to maintain homeostasis
    - Feedback loops involving: intestines, bones, and kidneys
  - *Blood* calcium remains normal despite:
    - Dietary inadequacy
    - Diminishing bone calcium
  - Blood calcium changes only if regulatory controls are abnormal
    - Calcium rigor: blood calcium above normal, muscles contract but can't relax
    - Calcium tetany: blood calcium below normal, uncontrolled muscle contractions

Blood Calcium Regulation: Feedback Loops

FIGURE 12-13

Low blood calcium

Signals the parathyroid glands to secrete parathyroid hormone into the blood

Thyroid gland with parathyroid glands embedded

High blood calcium

Signals the thyroid gland to secrete calcitonin

Vitamin D

Stimulates calcium reabsorption from the kidneys into the blood

Parathyroid hormone

Stimulates the activation of vitamin D

Stimulates calcium reabsorption from the kidneys into the blood

Kidneys

Calcitonin

Inhibits the activation of vitamin D

Prevents calcium reabsorption in the kidneys

Enhances calcium absorption in the intestines

Intestines

Limits calcium absorption in the intestines

Stimulates osteoclast cells to break down bone, releasing calcium into the blood

Stimulates osteoclast cells to break down bone, releasing calcium into the blood

Bones

Inhibits osteoclast cells from breaking down bone, preventing the release of calcium

End results

Raised blood calcium

Raised blood calcium

Parathyroid hormone secretion inhibited

End results

Lower blood calcium

Calcitonin secretion inhibited

NOTE: Calcitonin plays a major role in defending infants and young children against the dangers of rising blood calcium that can occur when regular feedings of milk deliver large quantities of calcium to a small body. In contrast, calcitonin plays a relatively minor role in adults because their absorption of calcium is less efficient and their bodies are larger, making elevated blood calcium unlikely.

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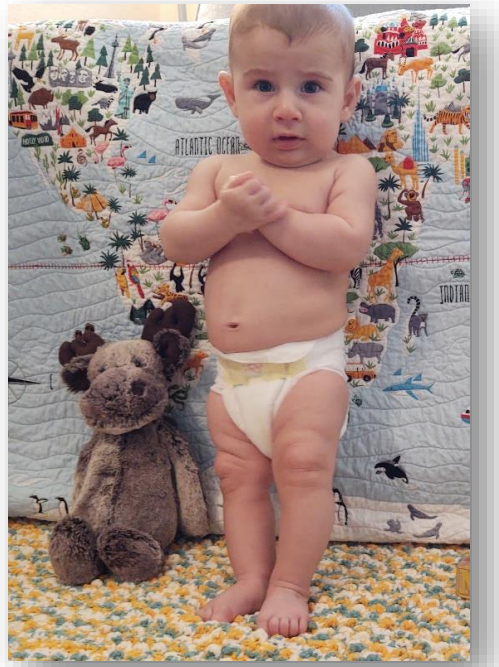
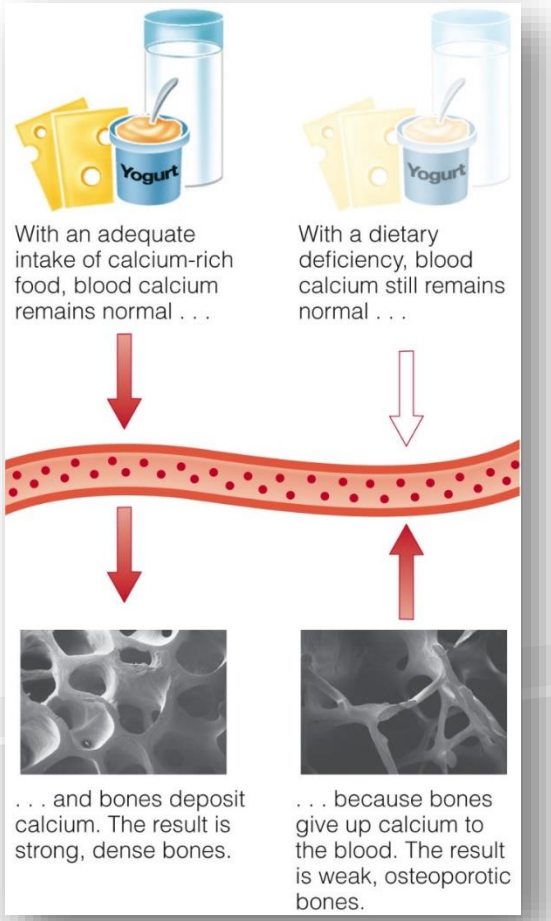
Calcium



- Absorption
  - Vitamin D: enhances absorption
  - Fiber, oxalates, phytates: inhibits absorption
  - When calcium is needed, body increases absorption
  - Rates of absorption:
    - Adults: ~30%
    - Growing people (children, teens, and pregnant women): 50% or more
    - Infants: 55-60%

Calcium

- Recommendations
  - Hight intake: bones benefit; low intake: bones suffer
  - Based on amount needed to retain the most calcium in bones
  - Set high enough to accommodate 30% absorption rate (adults)
    - RDI varies by age and sex
  - ~50% of Americans do NOT meet current recommendations
  - UL has been established
    - Adverse effects from supplements: kidney stones



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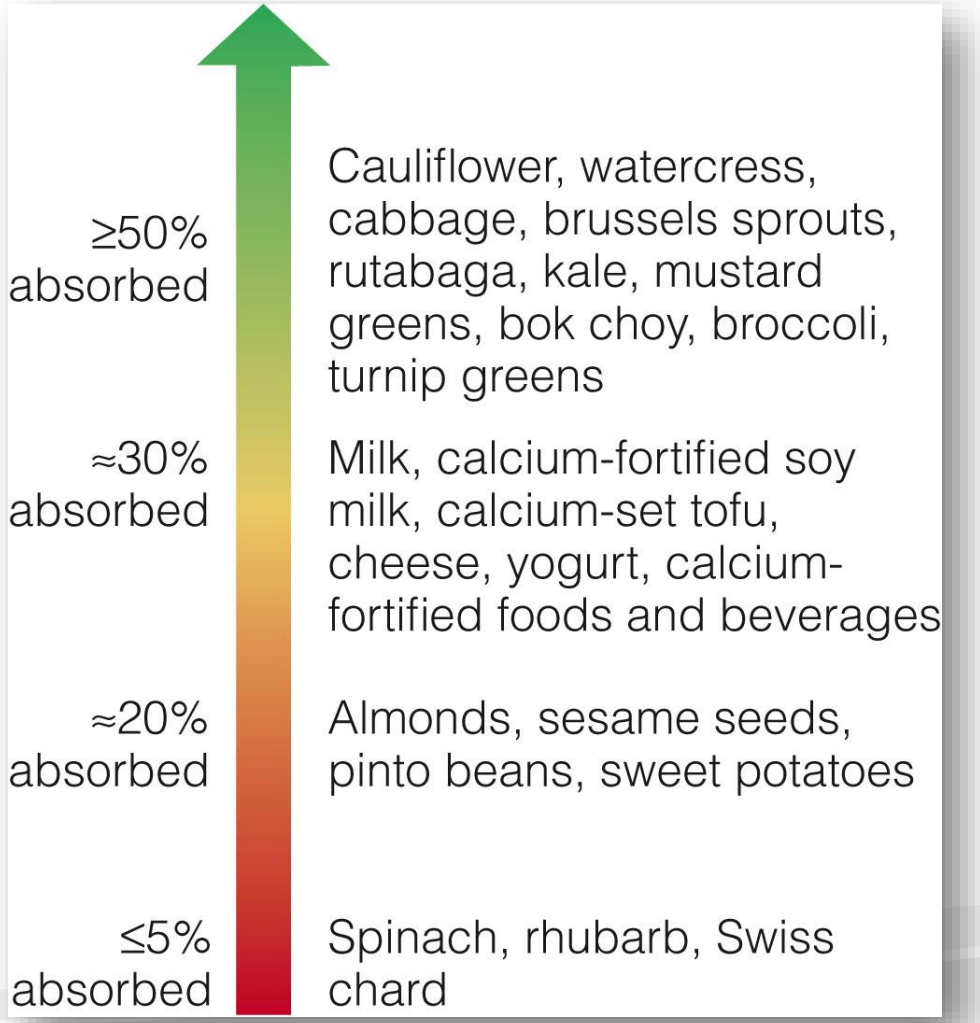
Calcium

- Milk products: most abundant source
  - Alternative options:
    - Conceal milk products in foods
    - Carefully choose other dietary sources: tofu, almonds, bread, some vegetables, fortified juices and other foods
    - Beware: spinach and Swiss chard = low bioavailability
- Deficiency
  - Osteopenia and osteoporosis
    - Silent disease, develops without warning (blood samples offer no clues)
    - Especially women over 50



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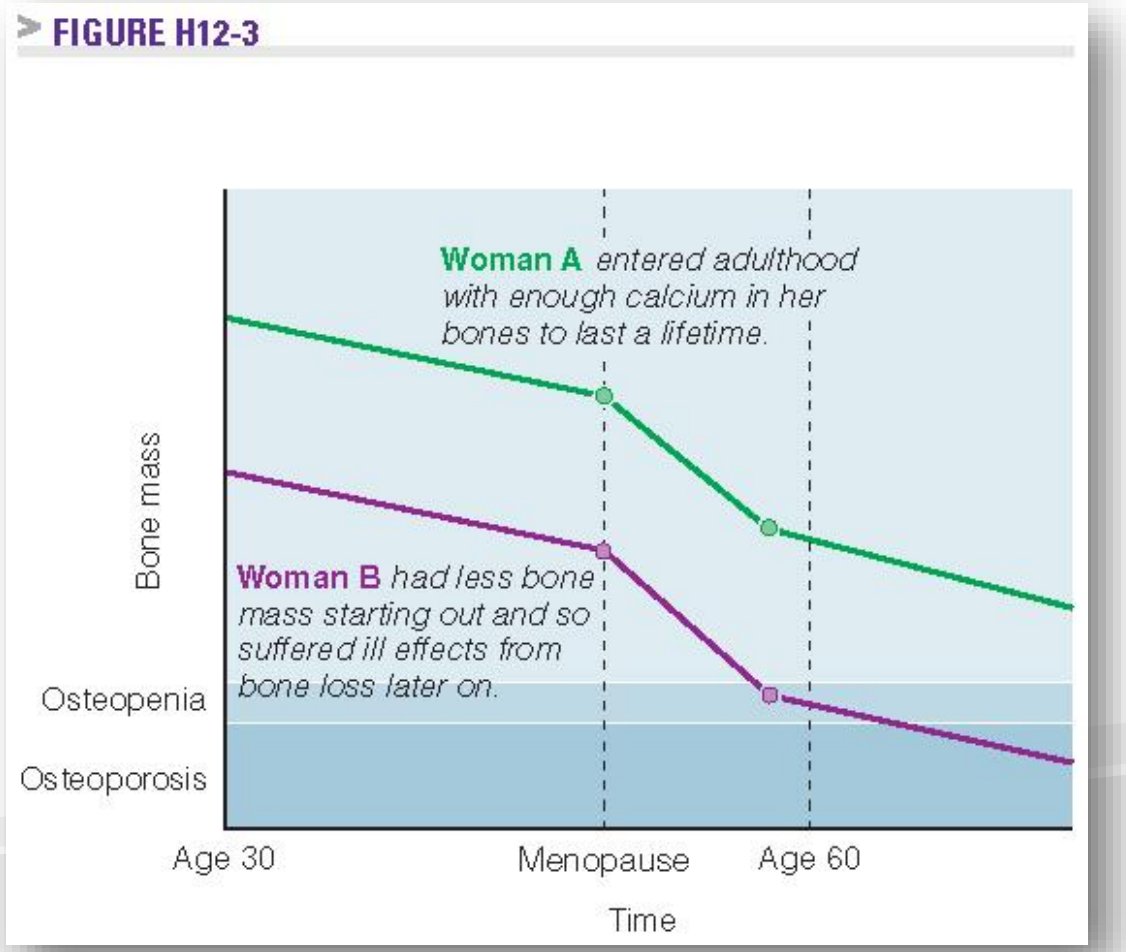
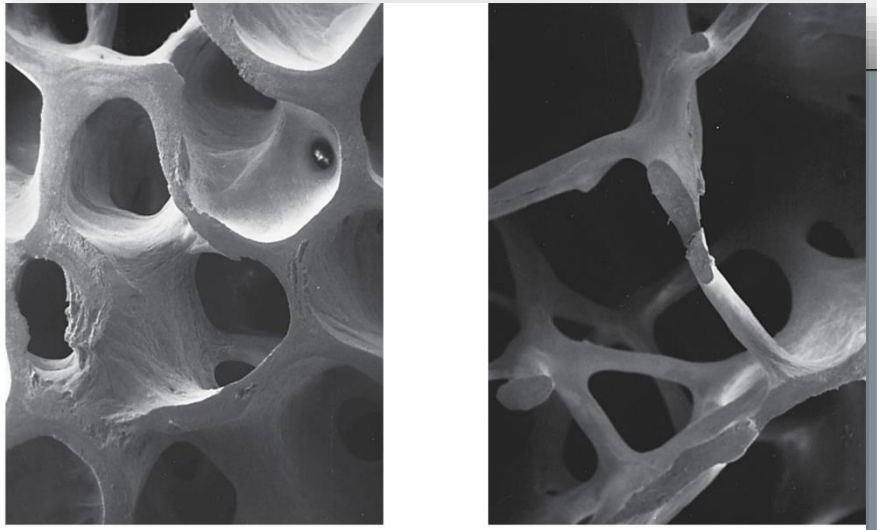
Bone Calcium

- Two major stages of life for bones:
  - Childhood and adolescence: bone-acquiring stage (late 20's = peak bone mass – size and density)
    - Maximizing bone mass: adequate dietary intake before age 30
  - Late adulthood: bone-losing decades



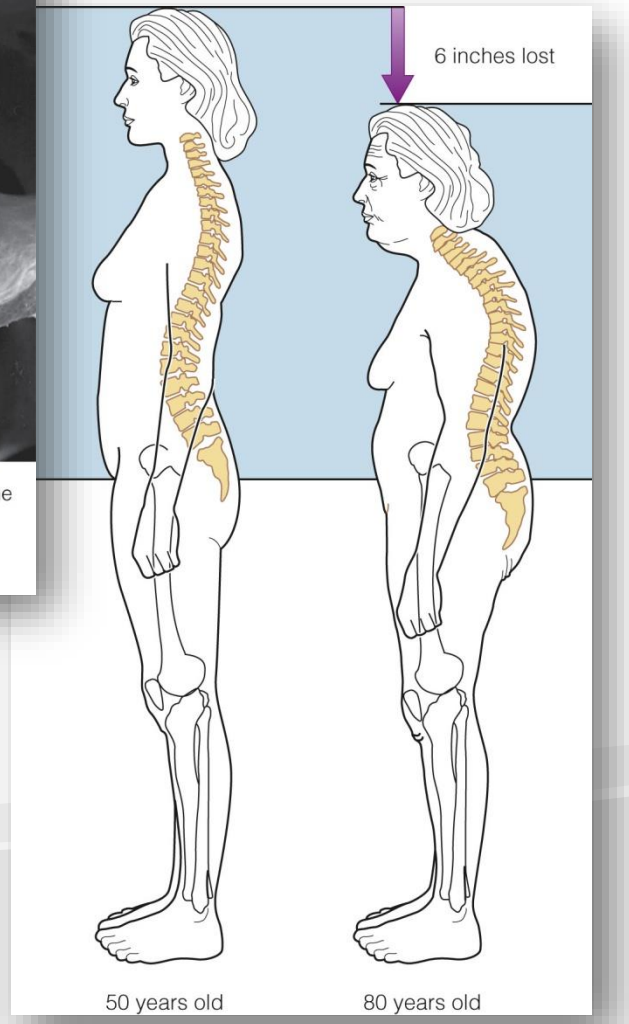
Calcium: Bone Development and Disintegration

- Bone density declines
  - Body weight overburdens bones (e.g. spine, hips)
- Risk factors:
  - Modifiable: diet, physical activity, body weight, smoking, alcohol use
  - Nonmodifiable: age, sex, genetics



Electron micrograph of healthy trabecular bone.

Electron micrograph of trabecular bone affected by osteoporosis.



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Calcium Loss: Sex and Hormones

- Sex = second strongest predictor
- Men = greater bone density
- Women = less bone density → greater bone losses
  - Menopause: dwindling estrogen → increased bone loss
    - Can lose up to 20% of bone mass in 6-8 years following menopause
    - Estrogen therapy or soy
  - Women must be especially vigilant regarding bone health!

Phosphorus

- Second most abundant mineral in body
  - 85% of body's phosphorus: hydroxyapatite crystals (bones and teeth)
- Roles in body
  - Part of major buffer system in cells
  - Part of DNA and RNA
  - Assists in energy metabolism (ATP compound)
  - Activate enzymes and B vitamins
  - Helps transport lipids in the blood
  - Structural component of cell membranes

Phosphorus

- Recommendations and intakes
  - Best sources: foods rich in proteins
    - Meat, poultry, fish, milk and cheese
  - Deficiencies are unlikely
  - Processed foods = phosphate-based additives
    - Phosphorus intake has increased
  - Toxicity is rare
  - UL established
    - Excessive intakes (processed foods): disrupts kidney function and bone metabolism

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Magnesium

- Body locations
  - >50% of body's magnesium: bones
    - Reservoir to regulate blood concentration (similar to calcium)
- Roles in body
  - Maintains bone health
  - Part of protein making machinery
  - Necessary for energy metabolism
  - Supports normal function of immune system
  - With calcium, involved with muscle contraction and blood clotting

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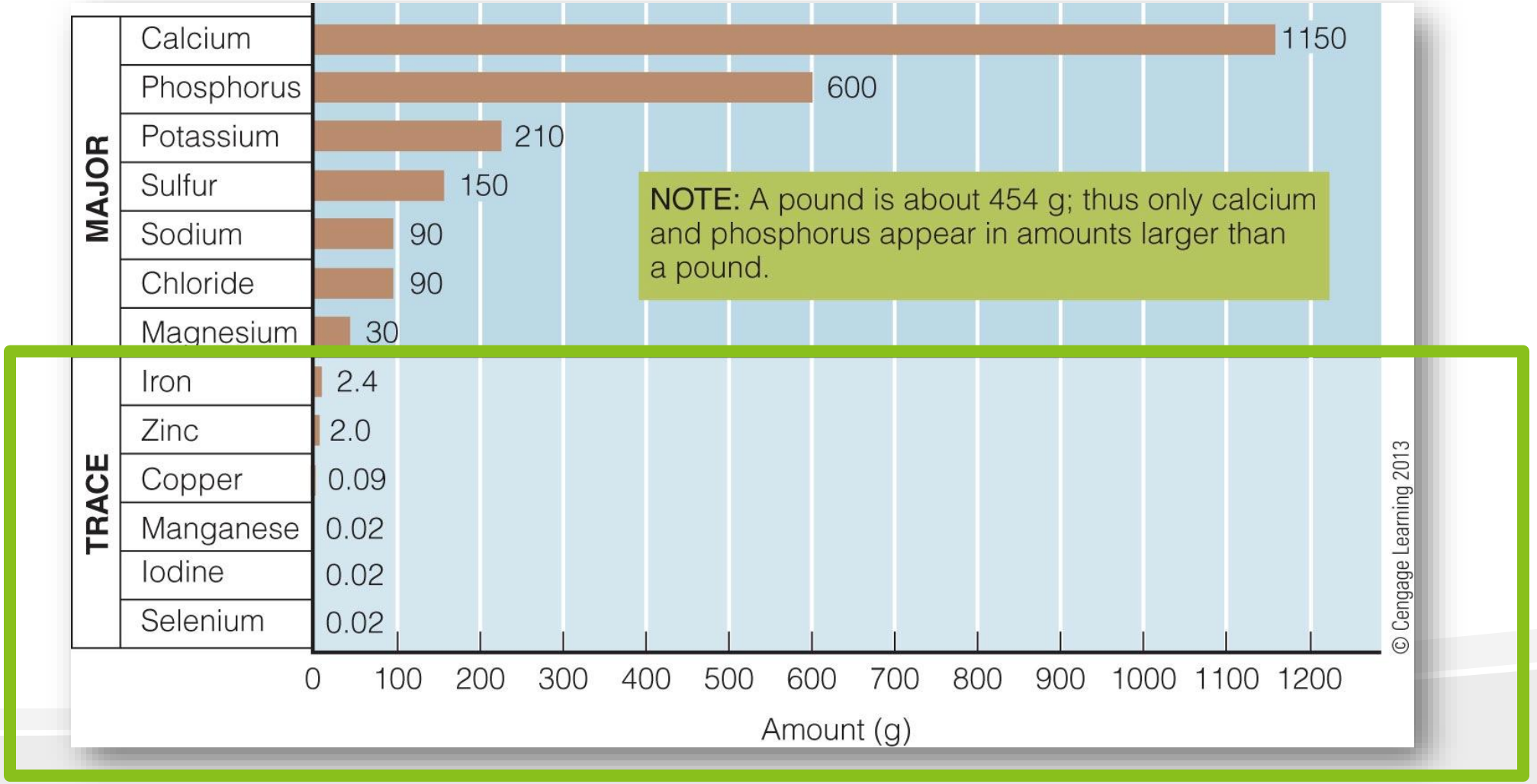
Magnesium

- Sources
  - Legumes, seeds, and nuts
  - Leafy green vegetables (part of chlorophyll molecule)
  - Mineral water
- Intakes
  - Critical to heart health; protective effect against hypertension
  - Average dietary intake for U.S. adults = below recommendations
    - Deficiencies: exacerbate inflammation; contribute to heart disease, stroke, hypertension, diabetes, and cancer
    - Severe deficiency: tetany (uncontrolled muscle contractions); impair nervous system
    - Toxicity: rare; UL for supplements and salts

Sulfate

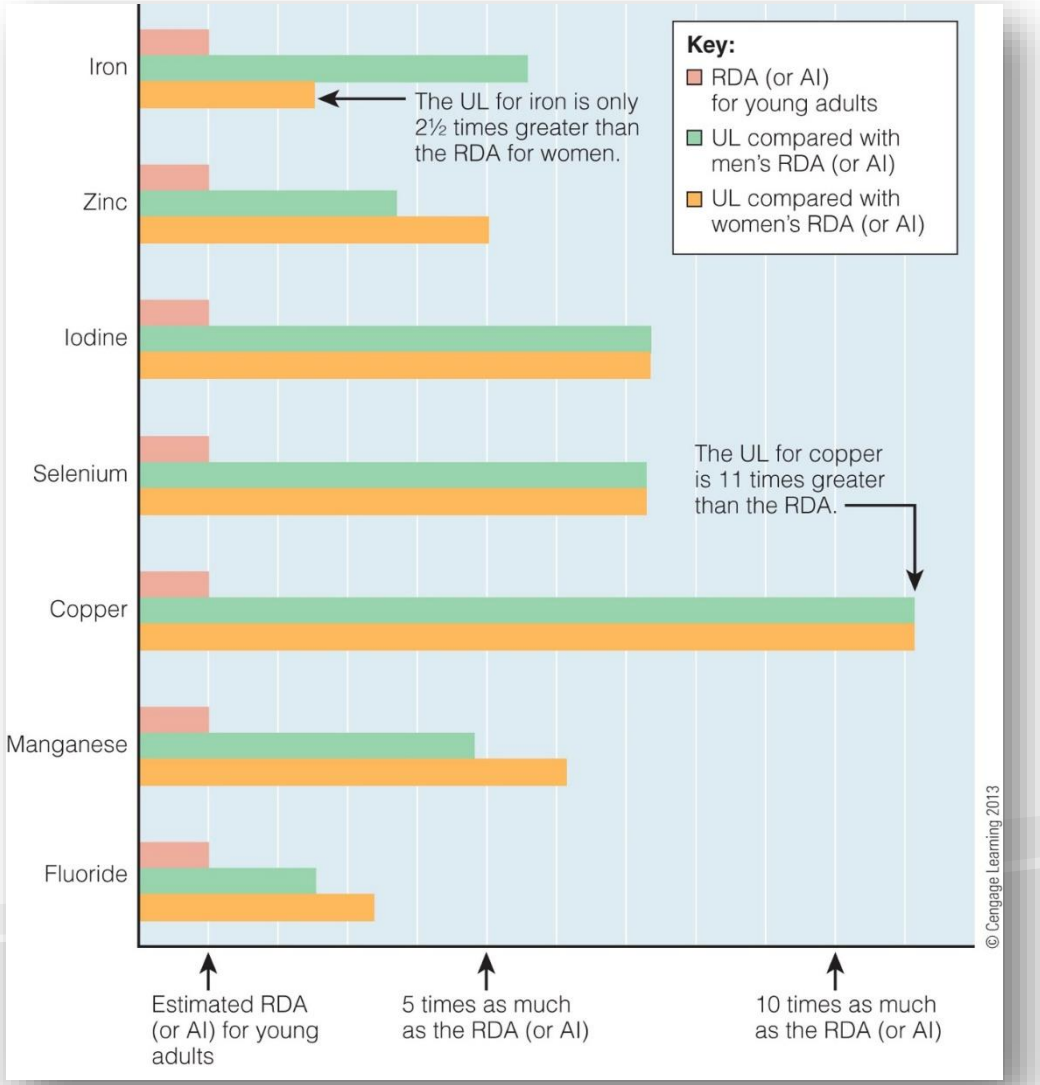
- Role in body
  - Determine contour of protein molecules; rigidity of certain proteins
- Sources of sulfate
  - Easily met by variety of food and beverages
  - Dietary proteins: methionine and cysteine (amino acids)
- No recommended intake
  - Normal protein intake will yield enough sulfate

Major vs. Trace Minerals



The Trace Minerals – An Overview

- Food sources: depend on soil and water composition
- Mild deficiencies: easy to overlook
- Toxicities
  - Can occur with as little as 2.5 times recommended intake
  - FDA regulation of supplements – no limitations on trace minerals
- RDA/AI vs UL



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The Trace Minerals – An Overview

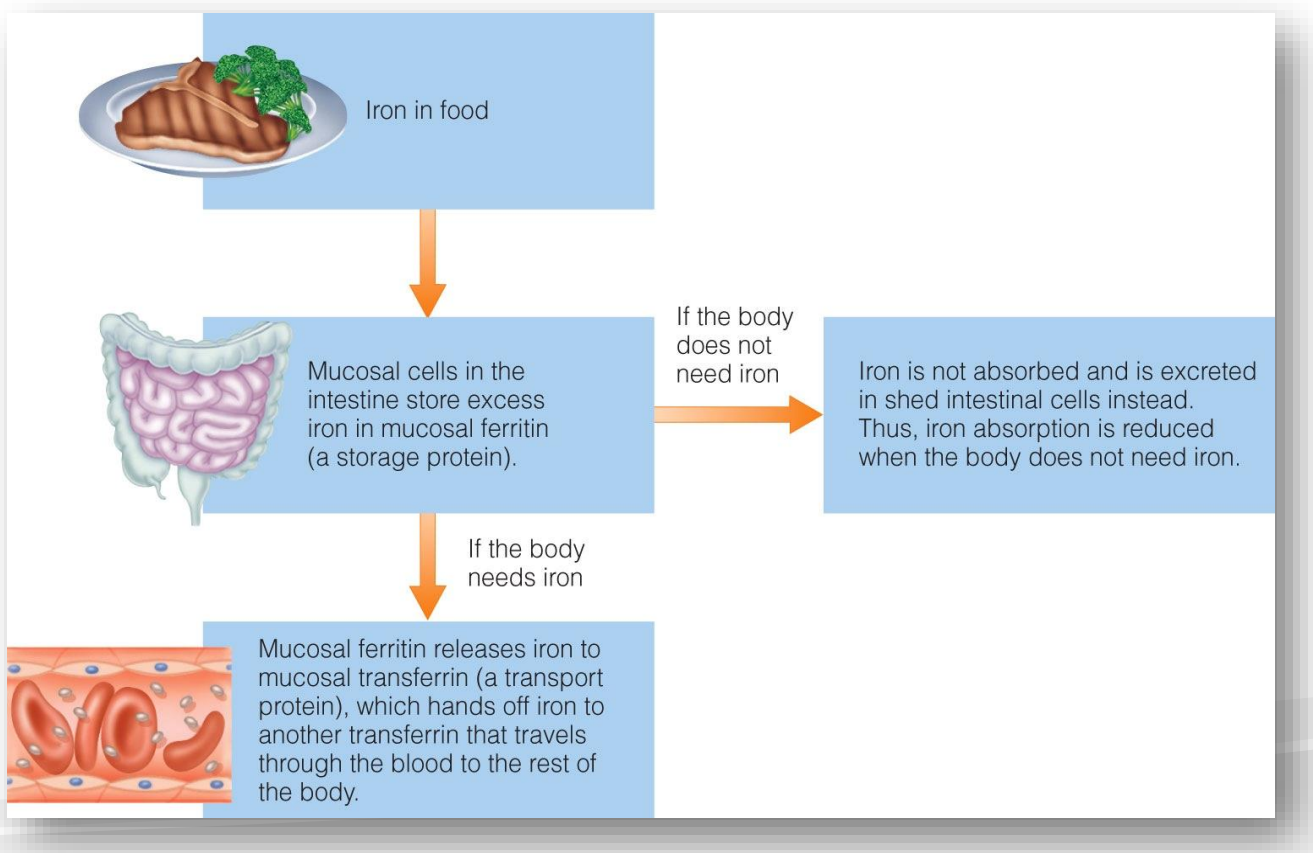
- Interactions are typically well-coordinated
  - …But sometimes lead to nutrient imbalances
    - Excess of one (manganese) → deficiency in another (iron)
    - Deficiency of one (selenium) → interfere with work of another (iodine)
    - Deficiency of one (iron) → toxic reactions from contaminant minerals (lead)
- Nonessential trace minerals
  - Nickel: cofactor for certain enzymes
  - Silicon: bone/teeth formation
  - Vanadium: bone development and reproduction
  - Cobalt: key mineral in vitamin B_{12}
  - Boron: bone and brain health, immune response

Iron: Roles in the Body

- Roles in the body
  - Cofactor to enzymes
    - Synthesis of amino acids, collagen, hormones, neurotransmitters
  - Part of electron carriers in electron transport chain
    - Transfer H and their electrons to O (forming H_2O)
  - Most is found in: hemoglobin (red blood cells) and myoglobin (muscle cells)
    - Accept, carry, and release oxygen

Iron: Absorption

- Body conserves iron (difficult to excrete)
  - Balance maintained primarily through absorption
  - Empty stores → more is absorbed
  - Full stores → less is absorbed
- Help from proteins/hormones:
  - Ferritin (protein): captures iron from food, stores in small intestine
  - Transferrin (protein): transport
  - Hepcidin (hormone in liver): controls absorption and release



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Iron: Absorption

- Absorption depends on dietary sources
  - Heme iron: animal flesh
    - ~10% of daily intake, and ~25% absorbed
    - Absorption not influenced by dietary factors
  - Nonheme iron: plant-derived, animal-derived foods
    - ~90% of daily intake, but only ~17% absorbed
    - Absorption-enhancing factors
      - MFP factor: protein found in **m**eat, **f**ish, and **p**oultry; enhances absorption from other foods eaten at same meal
      - Vitamin C enhances absorption from other foods eaten at same meal
      - Some acids (citric acid) and sugars (fructose)

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Iron: Absorption

- Absorption-inhibiting factors
  - Phytates: legumes, grains, rice
  - Vegetable proteins: legumes, nuts
  - Calcium: dairy
  - Polyphenols: tea, grains, oregano, red wine
- Individual variation in absorption
  - Health, stage in life cycle, and iron status
- Dietary factors and individual variations combined = difficult to estimate absorption

Iron: Deficiency

- Most common nutrient deficiency worldwide
- Vulnerable U.S. populations:
  - Toddlers, adolescent girls, women of childbearing age, pregnant women, adolescents
    - Rapid growth, blood losses
  - Overweight and obese people
- Deficiency develops in stages:
  - Beginning with decrease in blood iron
  - Anemia: severe depletion of iron stores
    - Impaired hemoglobin synthesis: fatigue, weakness, headache, apathy, pallor, poor resistance to cold

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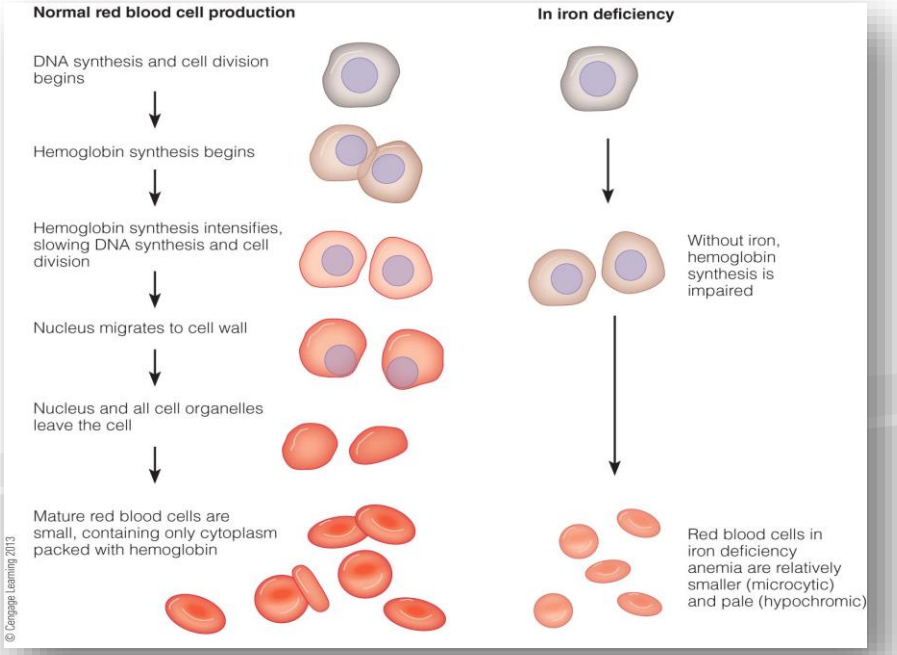

Iron: Deficiency vs Toxicity

- Deficiency behavioral symptoms (begin early)
  - Impaired energy metabolism
  - Altered neurotransmitter synthesis
    - Reduces work capacity, mental productivity
    - Appear unmotivated or apathetic
- Toxicity
  - Genetic disorder: hereditary hemochromatosis
    - Failure to prevent unneeded dietary iron from being absorbed → toxic accumulation in body
    - Symptoms: similar to deficiency (apathy, lethargy, fatigue)
  - Iron poisoning (especially among children from supplements)
    - Symptoms GI distress (constipation, nausea, vomiting, diarrhea)
  - UL established = 45 mg/day for adults

Iron: Recommendations and Sources

- RDAs
  - Women: 18mg/day (typically only get 12-13 mg)
  - Men: 8 mg/day (easily meet needs)
  - Vegetarians: 1.8 times as much
- Iron-rich foods
  - Natural: meats, fish, poultry, legumes, eggs
  - Enriched: flour and grain products
  - Typical US diet includes 7 mg iron/1000 kcals
- Maximizing absorption
  - MFP factor, vitamin C

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Zinc: Roles in the Body

- Gene expression
- Cell membranes
- Immune function
- Growth and development
- Synthesis, storage, and release of insulin
- Wound healing
- Blood clotting
- Thyroid hormone function
- Behavior and learning performance
- Visual pigment
- Taste perception
- Sperm production

Zinc: Absorption and Recycling

- Absorption rate varies depending on zinc status
  - Zinc intake increases → zinc absorption decreases
  - Zinc intake decreases → zinc absorption increases
  - Dietary factors: phytates from certain foods limit absorption
- Recycling via enteropancreatic circulation
  - Absorbed in small intestine
  - Incorporated into pancreatic juices
    - Pancreas → small intestine → pancreas
- Zinc losses: excreted via intestinal cells (feces)
  - Small losses: urine, sweat, skin, hair, menstrual fluids, semen

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Zinc: Transport and Deficiency

- Transport in bloodstream via transport proteins
- Deficiency
  - Vulnerable groups: children, vegetarians/vegans, Middle Eastern diets
  - Rich sources of zinc: meats
  - Phytates inhibit zinc absorption: legumes, whole grain foods
  - Symptoms (widespread and pervasive): stunted growth (sexual organs); impaired immune response; damage to central nervous system and brain; vitamin A deficiency symptoms

Zinc: Toxicity and Recommendations

- Toxicity
  - Symptoms: vomiting, diarrhea, headache, exhaustion
- Sources and recommendations
  - Protein-rich foods: shellfish, meats, poultry, milk, cheese
  - US diets:
    - Phytate content of grains isn't high enough to impair zinc absorption
    - Average intakes exceed recommendations slightly
- Supplementation
  - Developing countries: important for reducing disease and death due to diarrhea and pneumonia
  - Developed countries: treatment of common cold symptoms

Iodine

- Part of thyroid hormones which regulate:
  - Body temperature, metabolic rate, reproduction, growth, blood cell production, nerve and muscle function, rate at which cells use oxygen (amount of energy expended during basal metabolism)
- Deficiency
  - Thyroid hormone production declines, body attempts to absorb more iodine, goiter develops
  - Preventable brain damage (globally, 1/3 of school-age children have deficiency)
  - Cretinism: deficiency during pregnancy
    - Mental impairment, stunted growth in newborns
  - Iodized salt = successful at increasing global intake

Iodine: Toxicity and Recommendations

- Toxicity
  - Interferes with thyroid function → enlarges thyroid gland (goiter)
  - UL set
- Sources and recommendations
  - Coastal areas: seafood, kelp, water, sea mist
  - Inland: depends on iodine in soil
  - Iodized salt: fast foods, bakeries, milk
    - Processed foods = regular salt
  - Average US intakes exceed recommendations slightly

Selenium

- Roles in body
  - Antioxidant; part of some proteins; substitute for sulfur in formation of some amino acids
- Deficiency
  - Keshan disease: heart enlargement and insufficiency
- Toxicity
  - UL set: brittleness and loss of hair and nails, garlic breath odor, nervous system abnormalities
- Sources
  - Found in soil; meats, milk, eggs, brazil nuts

Copper

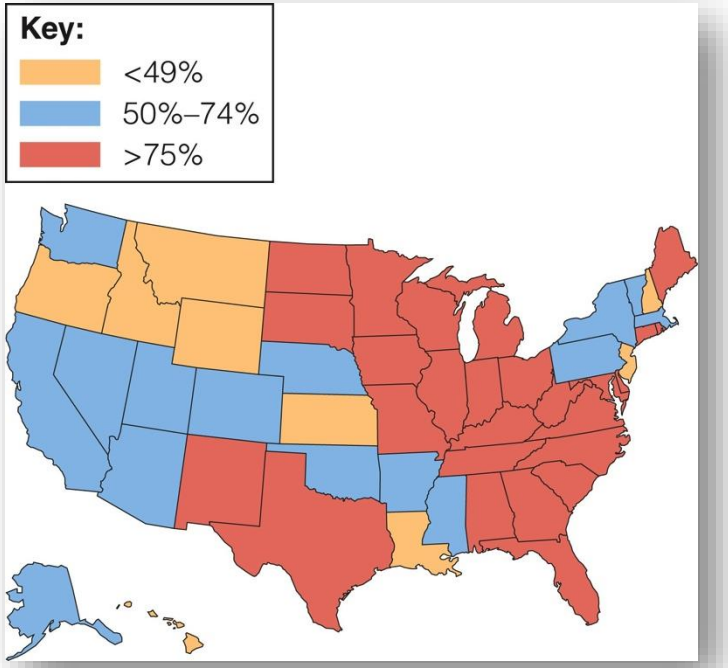
- Transport and balance depend on a system of proteins
- Roles in body
  - Part of enzymes; iron metabolism; defense against oxidative damage of free radicals; manufacture collagen; and more!
- Deficiency = rare in US
- Toxicity
  - Excessive intakes unlikely from foods
  - Excessive intakes from supplements can cause liver damage (UL set)
- Food sources (more than 50% is absorbed from foods)
  - Legumes, whole grains, nuts, shellfish, seeds, copper plumbing
- Route of elimination = bile

Manganese

- Roles in body
  - Cofactor for metabolic enzymes; assists in bone formation; conversion of pyruvate to TCA cycle compound
- Deficiency = rare
- Toxicity
  - From environmental contaminates (not diet): mining
  - UL set for dietary sources
- Recommendations and sources: AI set
  - Grain products

Fluoride

- Found in bones and teeth
  - Fluorapatite: makes teeth strong and resistant to decay
- Deficiency: dental decay
- Toxicity
  - Fluorosis: only occurs during tooth development
- Sources
  - Fluoridated drinking water
  - Tea and fish



Chromium

- Roles in the body
  - Participates in carbohydrate and lipid metabolism
  - Helps maintain glucose homeostasis by enhancing insulin activity
    - Lacking chromium: diabetes-like condition develops with elevated blood glucose and impaired responses
- Sources: unrefined (whole) foods

Molybdenum

- Role in the body: working part of several metalloenzymes
- Dietary deficiencies = unknown
  - Very small amount is needed
- Toxicity = rare
  - UL set: excess can cause kidney damage, reproductive abnormalities
- Sources
  - Legumes, breads, grain products, leafy green vegetables, milk, and liver

Contaminant Minerals

- Enter food supply in soil, water, and air pollution
- Impair body's growth, work capacity, and general health
- Heavy metals
  - Mercury
  - Cadmium
  - Lead

Closing Thoughts on the Nutrients

- Look at nutrients as a whole
  - Work cooperatively with one another
    - Actions are typically *interactions*
  - Most foods deliver multiple nutrients
- Needs based on supporting optimal health
- Nutrients should be examined in context of whole diet

Phytochemicals and Functional Foods

Highlight 13

Phytochemicals

- Found in plant-derived foods, exhibit biological activity in the body
- Physiological effects
  - Suppression of diseases
  - Adverse effects if consumed in excess
- Functional foods: provide health benefits beyond nutrient contents
  - Whole foods
  - Modified: reduced *trans* fat; fortified or enriched with nutrients
  - Long-term, regular consumption for largest benefit

Phytochemicals

- Cancer: protecting against DNA damage
  - Soybeans: phytoestrogens (antioxidant properties)
  - Tomatoes: lycopene (antioxidant properties)
- Heart disease: fruits and vegetables support heart health
  - Decreasing inflammation, protect against oxidative stress (antioxidant)
  - Flavonoids: may protect LDL against oxidation; whole grains, legumes, soy, fruit, vegetables, herbs, spices, teas, cocoa, red wine, olive oil, and nuts
  - Carotenoids: antioxidant; dark orange and dark green fruits and vegetables
  - Plant sterols and lignans: inhibit cholesterol absorption in body; soy, flaxseed
- Defense against other diseases

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TABLE H13-1 The Colors of Foods Rich in Phytochemicals

Red	White-Brown	Orange-Yellow	Blue-Purple	Green
				
Anthocyanins Lycopene	Allicin Allyl sulfides	Beta-carotene Limonene	Anthocyanins Ellagic acid Phenolics	Beta-carotene Lutein Indoles
Beets Cherries Cranberries Pink grapefruit Pomegranates Radicchio Radishes Raspberries Red apples Red peppers Red potatoes Rhubarb Strawberries Tomatoes Watermelon	Bananas Brown pears Cauliflower Chives Dates Garlic Ginger Leeks Mushrooms Onions Parsnips Shallots Turnips	Apricots Cantaloupe Carrots Lemons Mangoes Nectarines Oranges Papayas Peaches Persimmons Pineapple Pumpkin Rutabagas Squash Sweet potatoes Tangerines Yellow peppers	Black currants Blackberries Blueberries Dried plums Eggplant Elderberries Plums Purple figs Purple peppers Raisins Purple cabbage Purple grapes	Artichokes Arugula Asparagus Avocados Broccoli Brussels sprouts Cabbage Celery Cucumbers Endive Green apples Green beans Green grapes Green onions Green pears Green peppers Honeydew melon Kiwifruit Leafy greens Limes Okra Peas Snow peas Spinach Sugar snap peas Watercress Zucchini

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