Water and Minerals: The Ocean Within

BIOL 103, Chapter 8

Water: Crucial to Life

- Water is the most essential nutrient
  - 45–75% body weight
  - Body water
    - 2/3 Intracellular
    - 1/3 Extracellular

Water: Crucial to Life

- Electrolytes and water
  - When minerals or salts dissolve in water → form ions:
    - Cations
    - Anions
  - Osmosis
Intake Recommendations

- How much water is enough?
  - Men = 3.7 liters/day AI
  - Women = 2.7 liters/day AI
  - Pregnancy = 3.0 liters/day AI
  - Lactation = 3.8 liters/day
  - Increased needs for activity and sweating

Sources
- 75-80% from Beverages
- 20-25% from Foods
- Small amount from metabolic reactions (250-350mL/day)

Water Excretion: Where Does the Water Go?
1. **Insensible water losses**: the continuous loss of body water by evaporation from the lungs and diffusion through skin.
   - ¼-½ of daily fluid loss
2. Urine (~1-2 liters per day)
3. Illness
4. External factors that contribute to water losses
Intake Recommendations

- Water Balance
  - Bodies carefully maintain water balance
  1. Hormonal effects
    - Antidiuretic hormone (ADH)
    - Aldosterone
  2. Thirst
  3. Alcohol, caffeine, and common medications affect fluid balance

Water Balance – How do kidneys know how to conserve water?

1. Spinal cells in brain sense rising sodium levels in the body → signals pituitary gland to release ADH → signals kidneys to conserve water → water reabsorption dilutes sodium levels
2. Sensors in the kidneys detect a drop in blood pressure → adrenal glands release aldosterone → kidneys retain sodium → water follows sodium → water reabsorption

Intake Recommendations

- Dehydration
  - Early signs: Fatigue, headache, and dark urine with strong odor
  - Water loss of 20% can cause coma and death
  - Seniors and infants especially vulnerable
  - Treatment: water consumption (with electrolytes) or IV (moderate to severe cases)
Water Intoxication

- **Water intoxication:**
  - Can occur in people who drink too much water
  - Over-hydration can also occur in people with untreated glandular disorders that cause excessive water retention
  - Deionized water (without minerals/electrolytes)
  - Causes low blood sodium → headaches → seizures → coma → death

Understanding Minerals

- **Minerals**
  - Inorganic
  - Not destroyed by heat, light, acidity, alkalinity
  - Micronutrients (needed in small amounts)
  - Grouped as:
    1. **Major minerals** (>100 mg/day)
    2. **Trace minerals** (<100 mg/day)

Minerals in Foods

- Found in plant (soil) and animal (diet) foods
- Found in drinking water: sodium, magnesium, fluoride
- Mineral absorption limited by several factors:
  1. GI tract
  2. Competing minerals (ex. megadose)
  3. High-fiber diet contain phytates (iron, zinc, manganese, calcium)
  4. Oxalate (calcium)
Major Minerals and Health

- Mineral status significantly affects health
- Play critical parts in **hypertension** and **osteoporosis**

Sodium

- Functions:
  1. Fluid balance, blood pressure, and pH
  2. Nerve impulse transmission
- Food sources
  - Processed and convenience foods
  - Added (table) salt

Potassium

- Functions:
  1. Muscle contraction
  2. Nerve impulse transmission
  3. Regulates blood pressure and heartbeat
- Food sources:
  - People who eat low-sodium, high potassium diets often have lower blood pressure
  - Vegetables and fruits such as potatoes, spinach, melons, bananas
  - Meat, poultry, fish, dairy products
Potassium

- Dietary Recommendations
  - AI: 4,700 mg/day
- Deficiency
  - Likely factor in hypertension risk
  - Can disrupt acid-base balance
- Toxicity
  - Rare
  - High levels can slow heart

Chloride

- Functions:
  1. Fluid balance (blood, sweat, tears)
  2. Hydrochloric Acid (stomach acid)
- Food sources:
  - Table salt (NaCl – sodium chloride)
- Deficiency:
  - Excessive vomiting (ex. Bulimia nervosa)

Calcium

- Functions
  - Bone structure
    - Hydroxyapatite
    - Bone cells
      - Osteoblasts
      - Osteoclasts
    - Reserve of calcium and phosphorus
  - Muscles and metabolism
    - Flow of calcium causes muscles to contract or relax
  - Other functions
    - Blood clotting
    - Nerve impulse transmission
Calcium

- Regulation of blood calcium levels
  - Calcitriol/Vitamin D
  - Parathyroid hormone
  - Calcitonin

- Dietary Recommendations
  - RDA: 1,300 mg/day (children 9-18)
  - RDA: 1,000 mg/day (men 19-70; women 19-50)
  - RDA: 1,200 mg/day (men 70+; women 51+)

Regulation of Blood Calcium

- Food Sources
  - Dairy products, green vegetables, processed and fortified foods
  - Oxalate
  - Calcium supplementation

Calcium

- Regulation of blood calcium levels by three hormones:
  - To prevent dips in blood calcium levels, your body will demineralize bone
  - If low blood calcium levels → calcitriol increases intestinal absorption of calcium, and parathyroid hormone (PTH) activates osteoclasts to release bone calcium
  - If high blood calcium levels → thyroid glands release calcitonin to reduce blood calcium

Calcium

- Food Sources
  - Dairy products, green vegetables, processed and fortified foods
  - Oxalate
  - Calcium supplementation
**Phosphorus**

- Functions
  - Bone structure
  - Component of ATP, DNA, RNA, and phospholipids
- Food sources
  - Milk, eggs, beans, lentils
  - Processed foods
- Phosphate balance
  - Diets that are too high in phosphorus and too low in calcium → increased bone loss

**Magnesium**

- Function
  - Participates in more than 300 types of enzyme-driven reactions such as energy metabolism
  - Cardiac and nerve function
- Main Storage: Bones

**Magnesium**

- Food sources
  - Whole grains and vegetables, chocolates
- Deficiency:
  - At risk for deficiency: chronic diarrhea, heavy alcohol use, poor diet
  - Magnesium deficiency by itself is unusual
- Toxicity:
  - Rare, but UL: 350 mg/day

**Sulfur**

- Function:
  - Primarily a component of organic nutrient, including other vitamins/amino acids
  - Helps with liver’s detoxification process
  - Help proteins maintain their functional shapes
- Food sources:
  - Typical diets contain ample sulfur
- Deficiency:
  - Unknown
Trace Minerals

- Trace Minerals:
  - Iron, Zinc, Selenium, Iodine, Copper, Manganese, Fluoride, Chromium, Molybdenum
- Cofactors for enzymes
- Components of hormones
- Participate in many chemical reaction
- Essential for:
  - Growth
  - Immune System

Iron

- Functions
  - Oxygen transport as part of hemoglobin and myoglobin
  - Cofactor for enzymes involved in energy production, immune function, and normal brain/nervous system function

Iron and Hemoglobin
Iron

- Iron absorption
  - Dietary Factors Enhancing Iron Absorption
    • Vitamin C
  - Dietary Factors Inhibiting Iron Absorption
    • Phytate & oxalates bind to non-heme iron
    • Calcium, zinc, and iron compete for absorption

- Iron Transport and Storage
  - **Transferrin** ferries iron through blood
  - Most iron stored as **ferritin** in body

Iron

- Iron Absorption
  - Effect of Iron Status
    • Absorption varies
  - Effect of GI Function
    • Depends on stomach acid/HCl
  - Effect of the Amount and Form of Iron in Food
    • Plant sources: non-heme iron
    • Animal sources: heme-iron and non-heme iron.
Iron
• Iron Turnover and Losses
  – Routine destruction of old red blood cells releases iron → recycled to build new red blood cells
  – Lose iron in feces, sweat, skin cells, and menstruation
  – Dietary iron especially important in times of rapid growth and blood expansion (infant → young children)
  – Digestive disorders/blood loss increase iron losses

Iron
• Food sources:
  – Red meat, oyster, legumes, tofu, whole grains
• Deficiency:
  – Iron-deficiency anemia
• Toxicity:
  – Adult doses can cause poisoning in children
  – Hereditary hemochromatosis – a genetic disorder in which excessive absorption of iron results in abnormal iron deposits in the liver and other tissues.

Zinc
• Functions
  – Serves as cofactor for major enzymes
    • Cu-Zn SOD
  – Gene Regulation
    • Zinc fingers
  – Immune System
  – Sense of taste
  • Taste perception

Zinc
• Regulation of Zinc in the Body
  – Absorption
    • Similar to iron
    • Only about 10-35% of zinc absorbed
    • Phytate inhibits absorption
  – Transport, distribution, and excretion
    • Circulates bound to protein
  – Sources:
    • Red meat, seafood, refried beans, yogurt
Zinc

- **Deficiency**
  - Uncommon but may occur in people with illnesses that impair absorption
  - Poor growth and delayed development
  - Zinc deficiency lowers immunity; infection causes zinc loss
- **Toxicity**
  - Usually rare
  - Chronic doses may induce copper deficiency

Iodine

- **Function:** Thyroid hormone production
  - Thyroid hormone helps regulate body temperature, basal metabolic rate, reproduction, and growth
- **Food sources:**
  - Iodized salt, saltwater fish, seafood, seaweed

Iodine

- **Deficiency:**
  - **Goiter:** enlarged thyroid gland
  - **Cretinism:** mental retardation, stunted growth, deafness, muteness
    - Occurs in fetus if pregnant woman is deficient
- **Toxicity:**
  - **Goiter**

Cretinism

- Severely stunted physical and mental growth due to deficiency of thyroid hormones, usually due to maternal hypothyroidism
- Other signs: thickened skin, enlarged tongue, or protruding abdomen.
**Iodine and Thyroid Gland**

- **Functions:**
  1. Part of antioxidant enzyme (glutathione peroxidase)
  2. Thyroid metabolism: convert thyroid hormone to its most active form
- **Absorption:**
  - Enhance absorption: Vitamins A, C, E
  - Inhibits absorption: Phytates

**Selenium**

- **Functions:**
  - Part of antioxidant enzyme (glutathione peroxidase)
  - Thyroid metabolism: convert thyroid hormone to its most active form
- **Absorption:**
  - Enhance absorption: Vitamins A, C, E
  - Inhibits absorption: Phytates

- **Deficiency:**
  - Keshan disease
  - Increase cancer risk
- **Toxicity:**
  - Brittle hair and nails, garlic-like body odor

**Selenium**

- **Food sources:**
  - Organ meats, fish, seafood, meats, Brazil nuts
- **Deficiency:**
  - Keshan disease
  - Increase cancer risk
- **Toxicity:**
  - Brittle hair and nails, garlic-like body odor
Copper

- Functions
  - Melanin, collagen, and elastin production
  - Nerve function
  - Energy production
  - Iron Metabolism: ceruloplasmin

- Absorption and Storage
  - Little stored, most incorporated into ceruloplasmin
  - Interferes with absorption: Iron, Zinc

Manganese

- Functions
  - Energy production
  - Urea formation
  - Antioxidant enzyme systems/MnSOD

- Food Sources
  - Tea, nuts, cereals

- Inhibits absorption:
  - Magnesium, Calcium, Iron

Copper

- Food Sources
  - Organ meats, shellfish, nuts, and legumes

- Deficiency
  - Rare
  - Anemia, poor immune function

- Toxicity
  - Relatively nontoxic

Manganese

- Deficiency
  - Rare
  - Animal studies: impairs growth/bone abnormalities

- Toxicity
  - Incidents due to ______________ .
    • Symptoms: hallucinations, memory/motor coordination.
Fluoride

- Functions
  - Bone and tooth structure
- Food sources
  - Fluoridated water
- Balance
  - Excess can cause fluorosis
- The fluoridation debate

Chromium

- Functions:
  - __________ metabolism
    - Enhances insulin’s ability to move glucose into cells.
- Food sources:
  - Mushrooms, dark chocolate, nuts, whole grains
- Deficiency and toxicity:
  - Difficult to determine deficiency
  - No UL

Molybdenum

- Functions:
  - Enzyme cofactor that induce oxidation (e.g. sulfite oxidase)
- Food sources
  - Peas, beans, organ meats, some breakfast cereals
- Absorption:
  - Inhibit: Copper
- Deficiency/Toxicity:
  - Deficiency: Rare
  - Toxicity: Unlikely

Other Trace Minerals and Ultratrace Minerals

- Arsenic
- Boron
- Nickel
- Silicon
- Vanadium