Water and Minerals: The Ocean Within

BIOL 103, Chapter 10

Today’s Topic

- Water: Crucial to Life
- Intake Recommendations: how much water is enough?
- Minerals Overview
- Major Minerals: Sodium, Potassium, Chloride, Calcium, Phosphorous, Magnesium, Sulfur
- Trace Minerals

Water: Crucial to Life

- Water is the most essential nutrient
  - 45-75% of body’s weight
  - 2/3 of body water is intracellular: inside the cell
  - 1/3 of body water is extracellular: water between cells and in (blood) plasma

Water: Crucial to Life

- Electrolytes and water
  - When minerals or salts dissolve in water, they form ions (electrolytes)
    - Cations
    - Anions
  - In your body cells: your body controls and balances the concentration of electrolytes, both within and outside of each cell.
    - Osmosis
      - Diluted side to concentrated side
Intake Recommendations

- Intake recommendations: How much water is enough?
  - Men = 3.7 liters/day
  - Women = 2.7 liters/day
  - Pregnancy and lactation = 3.0–3.8 liters/day
  - Increased needs for activity and sweating
- Sources:
  - Drinking water
  - Beverages
  - Water in food
  - Metabolic reactions (250-350 mL/day)

Water Excretion: Where Does the Water Go?

1. Insensible water losses: the continuous loss of body water by evaporation from the ______ and diffusion through ______.
   - ¼-½ of daily fluid loss
2. Urine (~1-2 liters per day)
3. Illness
4. External factors that contribute to water losses:
   - Low humidity
   - High altitude
   - High protein/salt foods

Water Balance

- How does your body regulate water balance?
  1. Thirst: reminds us to drink more water, but it is unreliable during hot weather or heavy ______
  2. Hormonal effects:
     - Antidiuretic hormone (ADH)/Vasopressin
     - Aldosterone

Fig 10.4 Functions of Water
Water Balance – How do kidneys know how to conserve water?

1. Special cells in brain sense rising sodium levels in the body → signals ______ 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 → ______ gland release aldosterone → kidneys retain sodium → water follows sodium → water reabsorption

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Dehydration

- Dehydration
  - Any condition that causes rapid water loss is dangerous to the body
  - Can be caused by diarrhea, vomiting, heavy sweating
  - Signs: fatigue, dry mucous membranes, headache, dark urine with strong odor
  - Water loss of 20% of body weight can cause coma or death
  - Treatment: water consumption (with electrolytes) or IV (moderate to severe cases)

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Water Intoxication

- Water intoxication:
  - Can occur in people who drink too much water
  - Overhydration 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**:
    2. **Trace minerals** (AKA *microminerals*)

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 (e.g. megadose)
  3. High-fiber diet contain **phytates** (iron, zinc, manganese, calcium)
  4. **Oxalate** (calcium)

Major Minerals and Health

• Hypertension: persistent high blood pressure
  – Affects ¼ of American adults
  – Systolic BP is the higher number
    • pressure during contraction
  – Diastolic BP is the lower number
    • pressure resting phase
  – Normal BP: __________ mmHg
    • If persistent systolic above 140 or diastolic BP above 90
      usually requires treatment

Sodium

• Functions:
  1. Fluid balance, blood pressure, 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

### Chloride

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

### Calcium

- **Functions:**
  1. 99% of calcium found in bones and teeth
     - Made up of **Hydroxyapatite**: a crystalline mineral compound of calcium and phosphorous.
     - Reservoir to supply calcium and phosphorous to blood and soft tissues
  2. 1% in other functions: muscle contraction, blood clotting, nerve impulse transmission, cell metabolism

- **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
**Regulation of Blood Calcium**

- **Calcitonin**
  - If calcium level rises above set point
- Thyroid gland releases calcitonin
- Blood calcium level falls
- Parathyroid glands release parathyroid hormone (PTH)
- Blood calcium level rises below set point

**Function:**
- Activate/deactivate enzymes during the final steps of energy metabolism (carbs, fats, and proteins)
- Component of ATP and phospholipids

**Food sources:**
- Protein-rich foods such as meat, milk, and eggs
- Processed meats, soft drinks

**Phosphate balance:**
- Deficiency is rare

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**Calcium**

- **Food sources:**
  - Dairy products, green vegetables, Chinese cabbage, and tofu
  - Fortified products (breakfast cereal, soy milk, fruit juice)
  - **Oxalate:** binds calcium → less calcium absorbed
  - Calcium supplementation will not interfere with absorption of other minerals, but can interfere with the absorption of some medications

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**Phosphorous**

- **Functions:**
  - Activate/deactivate enzymes during the final steps of energy metabolism (carbs, fats, and proteins)
  - Component of ATP and phospholipids

- **Food sources:**
  - Protein-rich foods such as meat, milk, and eggs
  - Processed meats, soft drinks

**Phosphate balance:**
- Deficiency is rare

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**Magnesium**

- **Function:**
  - Participates in more than 300 types of enzyme-driven reactions, including energy metabolism, blood clotting, muscle contraction, DNA and protein synthesis

- **Food sources:**
  - Whole grains, vegetables, legumes, tofu, seafood, and chocolate

- **Magnesium balance:**
  - We absorb ~50% of dietary magnesium
  - At risk for deficiency: chronic diarrhea, poor diet, and heavy alcohol use.
Sulfur

- **Function:**
  - Primarily a component of organic nutrient, including other vitamins/amino acids
  - Help proteins maintain their functional shapes
  - Liver detoxification
- **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:**
  1. Oxygen transport (as part of hemoglobin and myoglobin)
     - **Hemoglobin:** carries oxygen in blood
     - **Myoglobin:** moves oxygen into muscle cells
  2. Cofactor for enzymes
     - Participates in reactions involving energy production
  3. **Immune function**
  4. Brain and nervous system function
     - Nerve cell protection: iron helps produce myelin sheath
     - Nerve cell communication: iron helps produce neurotransmitters

Iron and Hemoglobin
Nerve Cells

Regulation of Iron in the body

• Iron absorption depends on:
  1. Iron status (primary factor)
  2. GI function
    • Depends on stomach acid (HCl)
  3. Amount and type of iron in food
    • 2 types of iron found in food:
      — Heme iron: found in the hemoglobin and myoglobin of animal foods
      — Non-heme iron: iron in plants and animal foods that is not part of hemoglobin or myoglobin.

Problem Set 10, Q3

• Explain the difference between heme and non-heme iron. Which is absorbed better?

  — Heme iron: found in the hemoglobin and myoglobin of ___________ foods
  — Non-heme iron: iron in plants and animal foods that is not part of hemoglobin or myoglobin.
  — ________________ is absorbed better

Iron

• Iron absorption is affected by the following dietary factors:
  — Enhance (for non-heme iron): Vitamin C
  — Inhibit:
    • Phytate and Oxalate bind to non-heme iron
    • Calcium, Zinc, and Iron compete for absorption
• Transport and storage:
  — Transporter: Transferrin
  — Storage form of iron: Ferritin (most)
• Turnover and losses:
  — Rapid growth and blood expansion (infant → young children)
  — Blood loss
  — Digestive disorder
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

• Cofactor for nearly 100 enzymes:
  – Functions fall into 3 categories: catalytic, structural, regulatory.
  – Helps proteins fold into structural shapes
  – Gene activation, cell death, nerve transmission
  – Immune system

Regulation of Zinc in the Body

• Absorption:
  – ~10-35% of zinc in diet
  – Depends on body’s needs, zinc content of the meal, and presence of competing minerals
  – Phytate and supplemental calcium inhibit absorption
• Transport, distribution, and excretion:
  – Zinc circulates in the bloodstream bound to protein, traveling to the liver and tissues.
• Food sources:
  – Red meats, seafood

Zinc

• Deficiency:
  – Uncommon, but may occur in people with illness that impair absorption
  • Poor growth and delayed development
  – Zinc deficiency lowers immunity; infection causes zinc loss
• Toxicity:
  – Usually rare
  – Can cause copper deficiency:
    • Q: Why is zinc toxicity beneficial for those with Wilson’s disease (genetic disorder that increases copper absorption)?
### Selenium

**Functions:**
1. Part of antioxidant enzyme
2. Thyroid metabolism: convert thyroid hormone to its most active form

**Absorption:**
- Enhance absorption: Vitamins A, C, E
- Inhibits absorption: Phytates

### 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

### Selenium

**Food sources:**
- Organ meats, fish, seafood, meats, plants grown in selenium-rich soil

**Deficiency:**
- Keshan disease: enlarged heart disorder in children
- Worsens hypothyroidism (low thyroid hormones → slowing of mental/physical functions)

**Toxicity:**
- Brittle hair and nails, garlic like odor

### Iodine

**Deficiency:**
- Goiter: enlarged thyroid gland
  - Low iodine → low thyroid hormone → produces more TSH → thyroid gland grows bigger
- Cretinism (during pregnancy): mental retardation, stunted growth, deafness, muteness (in baby)

**Toxicity:**
- Goiter
  - Too much iodine → inhibit thyroid hormone synthesis → stimulate thyroid growth → goiter.
Iodine and Thyroid Gland

**Problem Set 10 Question #4:**

Q: Explain two ways someone can have hypothyroidism. (Hint: which two minerals are involved?)

Copper

- **Functions:**
  - In many reactions including energy release, skin pigmentation, etc.
  - Works with ceruloplasmin, a copper-dependent enzyme required for iron transport.
- **Absorption:**
  - Absorption varies from 20% to 50%
  - Interferes with absorption: iron, zinc

Copper

- **Deficiency:**
  - Causes anemia and poor immune function
  - Because copper deficiency reduces production of red and white blood cells
- **Toxicity:**
  - Relatively non-toxic
- **Food sources:**
  - Organ meats, shellfish, nuts, legumes, peanut butter, chocolate
Manganese

• Functions:
  – Urea formation
  – Antioxidant enzyme systems/MnSOD
• Food sources:
  – Tea, nuts, cereals
• Deficiency:
  – High calcium, magnesium, iron diets can interfere with manganese absorption
• Toxicity:
  – Incidents due to air pollutants
    • Symptoms: hallucinations, memory/motor coordination.

Fluoride

• Functions:
  – Bone and tooth structure by promoting deposits of calcium and phosphorous.
• Fluoride Sources (Problem Set 10 Question# 5):
  – Fluoridated water
  – Fluoride supplements, toothpastes, mouthwash
• Toxicity:
  – Excess can cause fluorosis: discoloration and “specks on teeth; weakens teeth.
• The fluoridation debate

Chromium

• Functions:
  – Glucose 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 (e.g. ADH)
• Food sources
  – Peas, beans, organ meats, some breakfast cereals
• Absorption:
  – Inhibit: Copper
• Deficiency/Toxicity:
  – Deficiency: Rare
  – Toxicity: Unlikely