Chapter 8: Water & Minerals

Brian J. Skerry/NG Image Collection

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Student learning outcomes: At the end of this chapter, you should be able to:

- Describe the roles of water and minerals in health and disease
- Plan a diet to meet water and mineral recommendations
THINK about this – then share within a PAIR – then SHARE with the class

- What do you know about the supply of water?

- What do you know about the roles of water in the body?
Water in the body

- 60% of body weight

- 2/3 intracellular (within cells), 1/3 extracellular

- Cell membranes are permeable to water // Water crosses the membrane by osmosis to dilute dissolved solutes

- Blood pressure is generated by the heart to move water through blood vessels and into tissues
Water in the body

Osmosis causes water to move into and out of the cells in response to the concentration of dissolved substances inside and outside the cell.

Higher pressure at the arterial end of the capillaries forces water from the blood into the tissues.

Lower blood pressure and differences in solute concentration at the venous end draw water back into the capillaries by osmosis.
Think critically

If the concentration of dissolved substances in the blood plasma was higher than in the fluid surrounding the blood vessel. What would happen to water?

a) It would move into the blood vessels
b) It would move out of the blood vessels
c) It would move into the blood cells
d) The amount in the blood would not change
Water balance

- Water is not stored

- Water in must equal water out
  - In: consumption of water, fluids, foods and production during cellular respiration
  - Out: excretion in urine and feces, evaporation from the skin and lungs, and sweating
Water balance

Water intake
(2950ml = 12.5 cups)
- Drink 2200 ml
- Food 500 ml
- Metabolism 250 ml

Water output
(2950ml = 12.5 cups)
- Feces 200 ml
- Urine 1650 ml
- Evaporation and sweat 1100 ml
THINK about this – then share within a PAIR – then SHARE with the class

- What causes increases in water loss?
Increased water loss stimulates thirst

- ↓ Blood volume
- ↑ Solute concentration

- ↓ Saliva secretion
- Dry mouth
- Stimulates thirst center

- Thirst
- Person takes a drink

- ↑ Blood volume
- ↓ Solute concentration
Kidneys regulate body water

- Kidneys act as a filter
  - Water moves from the blood into kidney tubules
  - Blood cells and proteins are too large and remain in the blood
- Needed substances are reabsorbed back into the blood
- Un-needed substances are excreted in urine
Application

If you drink a lot of water, what would you expect to happen to:

- reabsorption?
- excretion?
- urine volume?
Antidiuretic hormone (ADH)

- If more water is lost than taken in, then the concentration of solutes in the blood increases.

- This stimulates thirst and secretion of antidiuretic hormone (ADH) from the brain.

- ADH stimulates the kidneys to reabsorb water (to keep the blood from becoming more concentrated).
Antidiuretic hormone (ADH)

Increased blood sodium → ADH secretion → Water reabsorption → Decreased blood sodium
Kidneys regulate body water
Application

Alcohol inhibits antidiuretic hormone.

What would you expect to happen?

a) Increased reabsorption and excretion
b) Decreased reabsorption and excretion
c) Increased reabsorption and decreased excretion
d) Decreased reabsorption and increased excretion
Water functions

- Acts as a solvent: solutes (for example: glucose, proteins, minerals) dissolve in water
- Participates in chemical reactions
- Transports nutrients, oxygen, waste materials, hormones, etc. as the main component of blood
- Protects and cushions body structures
- Regulates pH and temperature
Water functions

Blood carries heat from the body's core to the capillaries near the surface of the skin.

Heat is released from the skin to the environment.

Water in sweat evaporates from the skin, causing heat to be lost.

Evaporation cools the skin and the blood at the skin's surface.

Cooled blood returns to the body core.

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Dehydration

- Water loss is greater than water intake

- Reduces blood volume which reduces blood pressure
Application

In a person with severe dehydration, what would you expect to happen to:

- delivery of nutrients and oxygen?
- secretion of antidiuretic hormone?
- reabsorption and excretion of water?

Why does alcohol consumption result in dehydration?
Dehydration

Well hydrated

Mild dehydration

Dehydration
Water intoxication (over hydration)

- Water intake is greater than water loss

- Sodium in blood is diluted causing hyponatremia

  - Hypo means low, Na is the chemical symbol for sodium, emia means in the blood

  - Water moves by osmosis from the blood into the tissues to try to dilute the higher concentration of solutes causing tissue swelling, or edema
Meeting water needs

- AI: men = 3.7 liters/day, women = 2.7 liters/day

- Need increased intake with:
  - Increased activity
  - Increased temperature
  - Decreased humidity
  - Low-calorie diet
  - High-salt diet
  - High-fiber diet
  - Alcohol intake
Debate

Is bottled water better?

![Bar graph showing bottled water consumption per country (Mexico, United States, United Arab Emirates, Italy, Lebanon). Each country has a bar indicating their consumption in gallons per person per year.](image)
Concept check

- How does osmosis affect the distribution of water in the body?
- What is the role of antidiuretic hormone?
- How does water help cool the body?
- Why do water needs increase when you exercise more?
THINK about this – then share within a PAIR – then SHARE with the class

- What do you know about minerals?
Minerals

- 20 needed by the body in small amounts
- Maintain structure and regulate chemical reactions and body processes
- **Major mineral**: need >100 milligrams/day
  - sodium, potassium, chloride, calcium, phosphorus, magnesium, and sulfur
- **Trace mineral**: need <100 milligrams/day
  - iron, copper, zinc, selenium, iodine, chromium, fluoride, manganese, molybdenum, and others
Minerals

Grains: Iron, Zinc, Selenium, Copper, Magnesium, Chromium, Sulfur, Manganese, Sodium, Potassium, Phosphorus

Vegetables: Iron, Calcium, Potassium, Magnesium, Molybdenum

Fruits: Iron, Potassium

Dairy: Calcium, Zinc, Phosphorus, Potassium, Iodine, Molybdenum

Protein: Iron, Zinc, Magnesium, Potassium, Chromium, Sulfur, Iodine, Selenium, Phosphorus, Copper, Manganese, Fluoride
Minerals from food

- From plant and animal sources

- Affected by:
  - Amount in soil
  - Processing // Added (for example, during fortification) or // Removed (for example, by cooking or removing skins, bran, or germ)
  - Absorption and bioavailability // Inhibited by substances in plants, other minerals, or amount in body
Minerals from food

Oxalates, found in spinach, rhubarb, beet greens, and chocolate, have been found to interfere with the absorption of calcium and iron.

Tannins, found in tea and some grains, can interfere with the absorption of iron.

Phytates, found in whole grains, bran, and soy products, bind calcium, zinc, iron, and magnesium, limiting the absorption of these minerals. Phytates can be broken down by yeast, so the bioavailability of minerals is higher in yeast-leavened foods such as breads.

Charles D. Winters
Mineral functions

- Contribute to body structures
- Regulate body processes
- Regulate water balance
- Regulate energy metabolism
- Affect growth and development through their role in the expression of certain genes
- Act as cofactors needed for enzyme activity
Mineral functions
Mineral functions – as a cofactors
Concept check

- How do minerals and vitamins differ?
- How do phytates, oxalates, and tannins decrease mineral bioavailability?
- What is the function of a cofactor?
THINK about this – then share within a PAIR – then SHARE with the class

- What do you know about electrolytes?
**Electrolytes**

- **Ions** = charged atoms
  - charge: gained a negative *electron* (anion)
  + charge: lost a negative *electron* (cation)

- Fluid balance maintenance, nerve impulse conduction, cellular signaling
Electrolytes

- **Sodium**
  - + charge: lost a negative electron
  - extracellular: outside of cells

- **Potassium**
  - + charge: lost a negative electron
  - intracellular: inside of cells

- **Chloride**
  - – charge: gained a negative electron
  - extracellular: outside of cells
Electrolyte functions

- A high salt intake increases the amount of sodium in the body.
- High blood sodium stimulates thirst to dilute the sodium.
Electrolyte functions

Low blood pressure → Kidneys → Renin helps form angiotensin II

- Release of aldosterone → Kidneys retain sodium and water
- Blood vessels constrict

→ Normal blood pressure

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Hypertension

- **Blood pressure** consistently at or above 140/90 mm mercury

- **Caused by:** increased contractions of the heart, increased blood volume, or decreased radius of blood vessels

- **Results in:** atherosclerosis, heart attacks, strokes, death

- **Treated with:** diet, exercise, and medication

- **Risks:** genetics, race, age, obesity, diet, activity
Hypertension and diet
Hypertension and diet

DASH recommendations for a 2000-Calorie diet

- **Grains**: 7–8 ounces
- **Vegetables**: 2–2 1/2 cups
- **Fruits**: 2–2 1/2 cups
- **Oils**: 2–3 teaspoons
- **Dairy**: 2–3 cups low-fat dairy
- **Protein**: 3–6 ounces lean meat, fish, and poultry
  - 1–2 ounces beans, nuts, and seeds

MyPlate recommendations for 2000-Calorie diet

- **Grains**: 6 ounces
- **Vegetables**: 2 1/2 cups
- **Fruits**: 2 cups
- **Oils**: 6 teaspoons
- **Dairy**: 3 cups
- **Protein**: 5 1/2 ounces

choosemyplate.gov

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Hypertension and diet

A blood pressure measurement is two numbers: systolic over diastolic 120/80

Systolic is the maximum pressure in the arteries

Diastolic is the minimum pressure in the arteries

- Typical American diet
- DASH diet

[Systolic blood pressure (mm mercury)]

Dietary sodium level (mg/day)

[Diastolic blood pressure (mm mercury)]
Hypertension & diet

Based on this graph, if someone switched from a typical American diet pattern containing 2400 mg of sodium, to a DASH pattern with 1500 mg of sodium, by how much will systolic blood pressure decrease?

a) 5 mm of mercury  
b) 7 mm of mercury  
c) 3 mm of mercury  
d) 10 mm of mercury
Electrolyte imbalance

- **Deficiency:**

  - **Results in:** acid–base imbalance, poor appetite, muscle cramps, confusion, apathy, constipation, irregular heartbeat, death

  - **Caused by:** heavy/persistent sweating, chronic diarrhea or vomiting, kidney disorders, or medications
Electrolyte imbalance

- **Excess:**
  - Excess potassium from supplements can cause the heart to stop
  - Excess sodium from consumption or dehydration
Electrolyte recommendations

- Sodium:
  - UL: 2300 mg/day
  - Over 51 years old, African American or with medical conditions = 1500 mg/day
  - Typical consumption = 3400 mg/day

- Potassium:
  - DRI = 4700 mg/day
  - DV = 3500 mg/day
  - Typical consumption = 2000-3000 mg/day
Sodium in processed foods

- Home cooking: 5%
- Salt shaker at the table: 6%
- Naturally present in foods: 12%
- Added to processed food: 77%
Sodium in processed foods

Less processed

More processed

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Sodium in processed foods

For a typical American, which of the following will result in the greatest reduction in sodium intake?

a) taking away the salt shaker during meals

b) reducing the amount of salt added during meal preparation

c) consuming fewer processed foods
# Water & electrolyte summary

## A summary of water and the electrolytes  
**Table 8.1**

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Sources</th>
<th>Recommended intake for adults</th>
<th>Major functions</th>
<th>Deficiency diseases and symptoms</th>
<th>Groups at risk of deficiency</th>
<th>Toxicity</th>
<th>UL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>Drinking water, other beverages, and food</td>
<td>2.7-3.7 L/day</td>
<td>Solvent, reactant, protector, transporter, regulator of temperature and pH</td>
<td>Thirst, dark-colored urine, weakness, poor endurance, confusion, disorientation</td>
<td>Infants, people with fever and diarrhea, elderly individuals, athletes</td>
<td>Confusion, coma, convulsions</td>
<td>ND</td>
</tr>
<tr>
<td>Sodium</td>
<td>Table salt, processed foods</td>
<td>&lt;2300 mg; ideally 1500 mg/day</td>
<td>Major positive extracellular ion, nerve transmission, muscle contraction, fluid balance</td>
<td>Muscle cramps</td>
<td>People consuming a severely sodium-restricted diet, those who sweat excessively</td>
<td>High blood pressure in sensitive people</td>
<td>2300 mg/day</td>
</tr>
<tr>
<td>Potassium</td>
<td>Fresh fruits and vegetables, legumes, whole grains, milk, meat</td>
<td>4700 mg/day or more</td>
<td>Major positive intracellular ion, nerve transmission, muscle contraction, fluid balance</td>
<td>Irregular heartbeat, fatigue, muscle cramps</td>
<td>People consuming poor diets high in processed foods, those taking thiazide diuretics</td>
<td>Abnormal heartbeat</td>
<td>ND</td>
</tr>
<tr>
<td>Chloride</td>
<td>Table salt, processed foods</td>
<td>&lt;3600 mg/day; ideally 2300 mg/day</td>
<td>Major negative extracellular ion, fluid balance</td>
<td>Unlikely</td>
<td>None</td>
<td>None likely</td>
<td>3600 mg/day</td>
</tr>
</tbody>
</table>

**Note:** UL, Tolerable Upper Intake Level; ND, not determined.
Concept check

- Why does eating a salty meal cause your weight to increase temporarily?
- Why is hypertension called “the silent killer”?
- What is the DASH diet?
- Which types of foods contribute the most sodium to the American diet?
THINK about this – then share within a PAIR – then SHARE with the class

■ What do you know about calcium and bones?
Strong bones

- Protein matrix: mostly collagen
- Hardened by minerals: mostly calcium, phosphorus, also magnesium, sodium, fluoride, other minerals
- Require:
  - Protein and vitamin C to maintain collagen
  - Calcium and other minerals to ensure solidity
  - Vitamin D to maintain calcium and phosphorus levels
Bones

- Living tissue
- Support weight and participate in movement
- Constantly broken down and re-formed during bone remodeling
- Peak bone mass: maximum bone density attained life, usually in young adulthood
- Osteoporosis: more bone loss than formation resulting in fractures
Bones

Both men and women lose bone mass slowly after about age 35.

In growing children, total bone mass increases as the bones grow larger.

Men achieve a higher peak bone mass than do women.

In women, bone loss is accelerated for a span of 5 to 10 years surrounding menopause.

During puberty, bone mass increases rapidly, and sex differences in bone mass appear.

Bone weakened by osteoporosis

Normal bone
Bones

When weakened by osteoporosis, the front edge of the vertebrae collapses more than the back edge, so the spine bends forward.
Osteoporosis

- More bone loss than formation

- **Results in:** fractures

- **Risks:** level of *peak bone mass* and rate at which bone is lost; affected by genetics, gender, age, hormones, low body weight, and lifestyle (smoking, alcohol, exercise, diet)

  - Women have more **age-related bone loss** than men when estrogen levels decrease after menopause
## Osteoporosis

### Factors affecting the risk of osteoporosis  Table 8.2

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>How it affects risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Fractures due to osteoporosis are about twice as common in women as in men. Men are larger and heavier than women and therefore have a greater peak bone mass. Women lose more bone than men due to postmenopausal bone loss.</td>
</tr>
<tr>
<td>Age</td>
<td>Bone loss is a normal part of aging, and risk increases with age.</td>
</tr>
<tr>
<td>Race</td>
<td>African Americans have denser bones than do Caucasians and Southeast Asians, so their risk of osteoporosis is lower.</td>
</tr>
<tr>
<td>Family history</td>
<td>Having a family member with osteoporosis increases risk.</td>
</tr>
<tr>
<td>Body size</td>
<td>Individuals who are thin and light have an increased risk because they have less bone mass.</td>
</tr>
<tr>
<td>Smoking</td>
<td>Tobacco use weakens bones.</td>
</tr>
<tr>
<td>Exercise</td>
<td>Weight-bearing exercise, such as walking and jogging, throughout life strengthens bone, and increasing weight-bearing exercise at any age can increase your bone density.</td>
</tr>
<tr>
<td>Alcohol abuse</td>
<td>Long-term alcohol abuse reduces bone formation and interferes with the body’s ability to absorb calcium.</td>
</tr>
<tr>
<td>Diet</td>
<td>A diet that is lacking in calcium and vitamin D plays a major role in the development of osteoporosis. Low calcium intake during the years of bone formation results in a lower peak bone mass, and low calcium intake in adulthood can accelerate bone loss.</td>
</tr>
</tbody>
</table>
## Soda verses milk

<table>
<thead>
<tr>
<th></th>
<th>Low-fat milk</th>
<th>Cola soft drink</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serving size (oz)</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Energy (Cal)</td>
<td>153</td>
<td>150</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>Calcium (mg)</td>
<td>450</td>
<td>0</td>
</tr>
<tr>
<td>Phosphorus (mg)</td>
<td>588</td>
<td>45</td>
</tr>
<tr>
<td>Riboflavin (mg)</td>
<td>0.6</td>
<td>0</td>
</tr>
<tr>
<td>Vitamin A (µg)</td>
<td>216</td>
<td>0</td>
</tr>
<tr>
<td>Vitamin D (µg)</td>
<td>3.8</td>
<td>0</td>
</tr>
<tr>
<td>Caffeine (mg)</td>
<td>0</td>
<td>40</td>
</tr>
</tbody>
</table>

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Calcium

- 99% in bones and teeth

- In body cells and fluids, needed for:
  - Muscle contraction
  - Neurotransmitter release
  - Blood pressure regulation
  - Cell communication
  - Blood clotting

- Levels regulated by hormones:
  - Too high: calcitonin “tones” it down
  - Too low: PTH and calcitriol “try” to bring it up
Calcium hormones

Decreased blood calcium

PTH & Calcitriol secretion

Stimulate intestinal absorption, kidney reabsorption & bone resorption

Inhibited blood calcium

Increased blood calcium

Calcitonin secretion

Inhibit bone resorption

Decreased blood calcium

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Calcium

- **RDA**: 19-50 years = 1000 mg/day; **UL** = 2500 mg/day

- **Sources**: dairy products, dark green vegetables, fish with bones, foods processed and fortified with calcium

- **Deficiency**: Osteoporosis

- **Excess**: caused by cancers, increased PTH, excessive calcium and/or vitamin D intake causing altered availability of iron, zinc, magnesium, phosphorus; constipation; loss of appetite, abnormal heartbeat, weight loss, fatigue, frequent urination, soft tissue calcification, kidney stones and damage
Calcium supplements

Choose supplements that contain calcium carbonate or calcium citrate. Avoid products that contain aluminum and magnesium. These may actually increase calcium loss.

Calcium is absorbed best when taken in doses of 500 mg or less.

500 mg taken twice a day provides 100% of the RDA for men ages 19 to 70 and women ages 19 to 50.

Choosing a supplement with vitamin D ensures that the vitamin will be available for calcium absorption.

Some antacids are sources of calcium. These are over-the-counter medications, so they carry a Drug Facts panel rather than a Supplement Facts panel.

**Calcium Citrate with Vitamin D**

**DIETARY SUPPLEMENT**

Suggested Use: Adults take one tablet twice daily with the meal of your choice.

**Supplement Facts**

<table>
<thead>
<tr>
<th>Amount per serving</th>
<th>% Daily Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin D₃ 400 IU</td>
<td>100%</td>
</tr>
<tr>
<td>Calcium 500 mg</td>
<td>50%</td>
</tr>
</tbody>
</table>

Other Ingredients: Cellulose, modified cellulose gum, magnesium stearate (vegetable source), magnesium silicate. Made according to US Pharmacopeia (USP) standards.

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Phosphorus

- Most found with calcium in bones and teeth

- In soft tissues, needed for:
  - Phospholipid, DNA, RNA, and ATP structures
  - Enzyme activity regulation
  - Cellular acidity maintenance // Phosphate Buffer System
Phosphorus functions

Phosphorus is important in energy metabolism because the high-energy bonds of ATP are formed between phosphate groups.

Phosphorus is a component of phospholipids, which form the structure of cell membranes.

Phosphorus is involved in regulating enzyme activity; the addition of a phosphorus-containing group to certain enzymes can activate or inactivate them.

Phosphorus is a major constituent of DNA and RNA, which orchestrate the synthesis of proteins.

Phosphorus is part of a compound that can prevent changes in acidity so that chemical reactions inside the cell can proceed normally.
Phosphorus

- **RDA**: adults = 700 mg/day; **UL** = 4000 mg/day

- **Sources**: dairy products; meat; cereal; bran; eggs; nuts; fish; and food additives used in baked goods, cheese, processed meats, and soft drinks

- **Deficiency**: rare; due to chronic diarrhea or poor absorption due to overuse of aluminum-containing antacids; causes bone loss, weakness, loss of appetite

- **Excess**: high dietary phosphorus does not appear to be harmful for healthy adults, concern with sodas
Magnesium

- 50-60% in bones

- In cells and fluids, needed for:
  - Calcium regulation
  - Blood pressure regulation
  - ATP structure stabilization which is important for:
    - Energy release from carbohydrate, fat, and protein
    - Nerve and muscle functioning
    - DNA, RNA, and protein synthesis
Magnesium

- **RDA**: men = 420 mg/day; women = 320 mg/day
- **Sources**: leafy greens, nuts, seeds, legumes, bananas, germ and bran of whole grains
- **Deficiency**: rare; causes osteoporosis, nausea, muscle weakness and cramping, irritability, mental derangement, blood pressure, heartbeat changes
- **Excess**: no effects from foods; drugs or supplements can cause nausea, vomiting, low blood pressure, and other cardiovascular changes
Magnesium sources

- Sunflower seeds (1/4 c)
- Almonds (1/4 c)
- Garbanzo beans (1 c)
- Tofu (1/2 c)
- Beef (3 oz)
- Sardines, canned (3 oz)
- Chicken (3 oz)
- 1% Milk (1 c)
- Cheese, cheddar (1.5 oz)
- Yogurt (1 c)
- Orange (1 med)
- Kiwi (2 med)
- Apple (1 med)
- Carrots (1 c)
- Broccoli (1 c)
- Spinach, cooked (1 c)
- Potato (1 med)
- Oatmeal (1 c)
- Spaghetti (1 c)
- White bread (2 sl)
- Whole-wheat bread (2 sl)

RDA:
- women >30
- men >30

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Sulfur

- Part of:
  - amino acids and proteins
  - glutathione – needed for detoxification
  - B vitamins thiamin and biotin

- Regulates acidity

- **RDA:** none

- **Sources:** part of dietary proteins and sulfur-containing vitamins, found in some food preservatives

- **Deficiency:** none known
# Calcium, Phosphorous, Magnesium & Sulfur

## A summary of calcium, phosphorus, magnesium, and sulfur

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Sources</th>
<th>Recommended intake for adults</th>
<th>Major functions</th>
<th>Deficiency diseases and symptoms</th>
<th>Groups at risk of deficiency</th>
<th>Toxicity</th>
<th>UL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>Dairy products, fish consumed with bones, leafy green vegetables, fortified foods</td>
<td>1000–1200 mg/day</td>
<td>Bone and tooth structure, nerve transmission, muscle contraction, blood clotting, blood pressure regulation, hormone secretion</td>
<td>Increased risk of osteoporosis</td>
<td>Postmenopausal women; elderly people; those who consume a vegan diet, are lactose intolerant, or have kidney disease</td>
<td>Elevated blood calcium, kidney stones, and other problems in susceptible individuals</td>
<td>2000-2500 mg/day from food and supplements</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Meat, dairy, cereals, baked goods</td>
<td>700 mg/day</td>
<td>Structure of bones and teeth, membranes, ATP, and DNA; acid-base balance</td>
<td>Bone loss, weakness, lack of appetite</td>
<td>Premature infants, alcoholics, elderly people</td>
<td>None likely</td>
<td>4000 mg/day</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Greens, whole grains, legumes, nuts, seeds</td>
<td>310–420 mg/day</td>
<td>Bone structure, ATP stabilization, enzyme activity, nerve and muscle function</td>
<td>Nausea, vomiting, weakness, muscle pain, heart changes</td>
<td>Alcoholics, individuals with kidney and gastrointestinal disease</td>
<td>Nausea, vomiting, low blood pressure</td>
<td>350 mg/day from nonfood sources</td>
</tr>
<tr>
<td>Sulfur</td>
<td>Protein foods, preservatives</td>
<td>None specified</td>
<td>Part of some amino acids and vitamins, acid-base balance</td>
<td>None when protein needs are met</td>
<td>None</td>
<td>None likely</td>
<td>ND</td>
</tr>
</tbody>
</table>

**Note:** UL. Tolerable Upper Intake Level; ND. not determined.
Concept check

- Why are women at greater risk for osteoporosis than are men?

- What happens when blood calcium levels decrease?

- How can vegans meet their calcium needs?

- What is the relationship between magnesium and ATP?
Iron

- Part of hemoglobin which transports oxygen to body cells and carries carbon dioxide away from them for elimination by the lungs

- Needed for other iron-containing proteins such as myoglobin, a muscle protein which increases oxygen available for contraction

- Essential for ATP production

- Heme iron in proteins is absorbed more than twice as efficiently as the nonheme iron in plant sources
Iron availability

Iron in food:
The amount of iron absorbed into the mucosal cells depends on whether it is heme or non-heme iron and on the presence of other dietary factors that may enhance or inhibit absorption.

Body cells: Iron used to make myoglobin and other iron-containing proteins needed for energy metabolism.

Bone marrow: Iron used to make hemoglobin for RBC synthesis.

Iron from old RBCs is reused.

Iron loss through blood loss.

Iron storage in the liver and spleen.

More iron is lost when body stores are high than when stores are low or the need for iron increases.

More iron is transported when body stores are low or needs increase than when stores are high.

Blood — Iron transport in the blood.

Iron lost in shed mucosal cells.

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Iron

- **RDA:** adults = 8 mg/day; UL = 45 mg/day

- **Sources:** red and organ meats, legumes, leafy greens, whole and enriched grains

- **Deficiency:** iron-deficiency anemia causing fatigue, weakness, headache, decreased work capacity, body temperature problems, behavior changes, increased infection, impaired development, lead poisoning

- **Excess:** intestinal lining damage, abnormal body acidity, shock, liver failure; iron overload from inherited hemochromatosis
Iron sources

- Sunflower seeds (1/4 c)
- Walnuts (1/4 c)
- Lentils (1 c)
- Beef (3 oz)
- Salmon (3 oz)
- Chicken (3 oz)
- 1% Milk (1 c)
- Cheddar cheese (1.5 oz)
- Yogurt (1 c)
- Orange (1 med)
- Kiwi (2 med)
- Apple (1 med)
- Raisins (1/2 c)
- Tomato (1 med)
- Broccoli, cooked (1/2 c)
- Spinach, cooked (1 c)
- Potato, baked (1 med)
- Oatmeal (1 c)
- Spaghetti (1 c)
- White bread (2 sl)
- Whole-wheat bread (2 sl)

Iron (mg)
Iron deficiency

Normal red blood cells

Iron deficiency anemia

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Iron stores
Iron in plasma
Iron in RBCs

Adequate iron status
Low iron stores
Depleted iron stores
Low levels of circulating iron
Iron deficiency anemia

Normal Depletion Deficiency
Iron Status

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Iron deficiency

Demographic

Women of childbearing age, pregnant women, infants, children, and teens have increased iron needs due to growth and development.

Dietary

Diets that are low in meat, which contains the most readily absorbed form of iron (heme iron), and high in phytates and fiber, which reduce iron absorption, increase the risk of deficiency. Low-calorie diets can also reduce iron intake.

Social/medical

Poverty, intestinal parasites

Individuals living in poverty are less likely than others to consume adequate iron. Intestinal parasites cause blood loss, which increases iron losses.
Iron excess

**WARNING:** CLOSE TIGHTLY AND KEEP OUT OF REACH OF CHILDREN. CONTAINS IRON, WHICH CAN BE HARMFUL OR FATAL TO CHILDREN IN LARGE DOSES. IN CASE OF ACCIDENTAL OVERDOSE, SEEK PROFESSIONAL ASSISTANCE OR CONTACT A POISON CONTROL CENTER IMMEDIATELY.
Copper

- A copper-containing protein is needed for iron transport from intestinal cells

- Component of proteins and enzymes involved in:
  - Connective tissue synthesis
  - Lipid metabolism
  - Heart muscle maintenance
  - Immune and central nervous system functions
Copper

- **RDA**: adults = 900 micrograms/day; **UL** = 10 mg/day

- **Sources**: organ meats, seafood, nuts, seeds, whole-grain breads and cereals, chocolate

- **Deficiency**: iron-deficiency anemia, decreased collagen, high blood cholesterol, impaired growth, heart and nervous system degeneration, hair color and structure changes, increased infections, decreased antioxidants

- **Excess**: from supplements, copper containers, contaminated water, causing abdominal pain, vomiting, diarrhea
Zinc

- Involved in the functioning enzymes involved in:
  - Scavenging free radicals
  - DNA and RNA synthesis
  - Carbohydrate metabolism
  - Acid–base balance
  - Absorption of folate from food
  - Storage and release of insulin
  - Mobilization of vitamin A from liver
  - Stabilization of cell membranes
  - Influences hormonal regulation of cell division
Zinc & gene expression

Vitamin A, vitamin D, or hormones

DNA-binding protein

Zn

Zinc “fingers”

DNA

Regulatory region
Zinc

- **RDA**: men = 11 mg/day; women = 8 mg/day

- **Sources**: meat, liver, eggs, dairy products, vegetables, legumes, seeds

- **Deficiency**: decreased growth, development and immunity; skin rashes; diarrhea

- **Excess**: from supplements causing gastrointestinal irritation; vomiting; appetite loss; diarrhea, abdominal cramps; headaches; decreased immunity, HDL, copper and iron absorption
Zinc sources

- Sunflower seeds (1/4 c)
- Walnuts (1/4 c)
- Lentils (1 c)
- Eggs (1)
- Beef (3 oz)
- Crab (3 oz)
- Salmon (3 oz)
- Chicken (3 oz)
- 1% Milk (1 c)
- Cheese cheddar (1.5 oz)
- Yogurt (1 c)
- Orange (1 med)
- Kiwi (2 med)
- Apple (1 med)
- Broccoli (1 c)
- Spinach, cooked (1 c)
- Potato, baked (1 med)
- Oatmeal (1 c)
- Spaghetti (1 c)
- White bread (2 sl)
- Whole-wheat bread (2 sl)

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Selenium

- Incorporated into the structure of certain proteins:
  - Glutathione peroxidase which decreases oxidative damage
  - A protein needed to make thyroid hormones
- **RDA**: adults = 55 mg/day; **UL** = 400 mg/day
- **Sources**: seafood, kidney, liver, eggs, grains, nuts, seeds
- **Deficiency**: Keshan disease = heart disease in China /// increased risk of cancer
Selenium

Glutathione peroxidase (selenium) neutralizes peroxides, preventing the formation of free radicals. Vitamin E neutralizes free radicals, preventing cellular damage. Without selenium and vitamin E, peroxides can cause cellular damage.
Selenium deficiency

Hair and nail brittleness and loss occur in people living in regions of China with high levels of selenium in the soil. Other toxicity symptoms include nausea, diarrhea, abdominal pain, nervous system abnormalities, fatigue, and irritability.

Selenium deficiency causes muscular discomfort, weakness, and in some cases Keshan disease. However, Keshan disease is not caused entirely by selenium deficiency. It is believed to be due to a combination of selenium deficiency and a viral infection.48

Soil selenium

- Deficient
- Low
- Normal
- High
- Very high
- Not investigated
Iodine

- ¾ of mineral found in the thyroid gland
- Component of thyroid hormones which regulate metabolic rate, growth, and development and promote protein synthesis
Iodine


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Iodine

- **RDA**: adults = 150 mg/day; **UL** = 1100 mg/day

- **Sources**: seafood, iodinized salt, food contaminants and additives

- **Deficiency**: decreased thyroid hormones causing decreased metabolic rate, fatigue, weight gain; *goiter* (enlarged thyroid); during pregnancy causes spontaneous abortions, stillbirths, *cretinism* (brain damage)

- **Excess**: *goiter*
Iodinized salt
Chromium

- Component of “glucose tolerance factor,” a small peptide required to maintain normal blood glucose levels

- **RDA**: ages 19–50: men = 35 micrograms/day; women = 25 micrograms/day

- **Sources**: liver, brewer’s yeast, nuts, whole grains

- **Deficiency**: rare in US

- **Excess**: little evidence
Fluoride

- Incorporated into crystals in tooth enamel which protects against cavity-causing acids produced by bacteria

- In saliva, decreases bacterial acid production, inhibits dissolution of tooth enamel by acid, and increase enamel re-mineralization after acid exposure

- Incorporated into crystals in bone
Fluoride

- RDA: 0.05 mg/kg/day; UL = 0.1 mg/kg/day for infants and children less than 9 years old and 10 mg/day between 9 and 70 years

- Sources: in small amounts in almost all soil, water, plants, and animals; toothpaste; tea; marine fish with bones; **fluoridated water**

- **Deficiency**: tooth decay

- **Excess**: fluorosis causing black and brown stains and cracking and pitting of the teeth
Fluoride

The optimal amount of fluoride makes teeth resistant to decay and does not cause fluorosis.

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Hypertension & diet

Based on this graph what concentration of water fluoride will protect against dental caries but not cause fluorosis?

a) 2.5 mg/liter
b) 2 mg/liter
c) 1 mg/liter
d) 0.5 mg/liter

The optimal amount of fluoride makes teeth resistant to decay and does not cause fluorosis.
Manganese

- Constituent of some enzymes and activator of others involved in:
  - Carbohydrate and cholesterol metabolism
  - Bone formation
  - Urea synthesis
  - Oxidative damage prevention

- **RDA**: men = 2.3 mg/day; women = 1.8 mg/day

- **Sources**: whole grains, nuts, legumes, leafy green vegetables
Molybdenum

- Needed to activate enzymes functioning in:
  - Metabolism of sulfur-containing amino acids and nitrogen-containing compounds in DNA and RNA
  - Production of uric acid (waste product)
  - Oxidation and detoxification of other compounds

- Readily absorbed from foods

- Regulated by excretion in the urine and bile

- **RDA**: adults = 45 mg/day

- **Sources**: milk and milk products, organ meats, breads, cereals, legumes
## Trace minerals

### Table 8.4

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Sources</th>
<th>Recommended intake for adults</th>
<th>Major functions</th>
<th>Deficiency diseases and symptoms</th>
<th>Groups at risk of deficiency</th>
<th>Toxicity</th>
<th>UL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>Red meats, leafy greens, dried fruit, legumes, whole and enriched grains</td>
<td>8–18 mg/day</td>
<td>Part of hemoglobin (which delivers oxygen to cells), myoglobin (which holds oxygen in muscle), and proteins needed for ATP production; needed for immune function</td>
<td>Iron deficiency anemia: fatigue; weakness; small, pale red blood cells; low hemoglobin levels; inability to maintain normal body temperature</td>
<td>Infants and preschool children, adolescents, women of childbearing age, pregnant women, athletes, vegetarians</td>
<td>Acute: Gastro-intestinal upset, liver damage Chronic: fatigue, heart and liver damage, increased risk of diabetes and cancer</td>
<td>45 mg/day</td>
</tr>
<tr>
<td>Copper</td>
<td>Organ meats, nuts, seeds, whole grains, seafood, cocoa</td>
<td>900 μg/day</td>
<td>A component of proteins needed for iron transport, lipid metabolism, collagen synthesis, nerve and immune function, protection against oxidative damage</td>
<td>Anemia, poor growth, skeletal abnormalities</td>
<td>People who consume excessive amounts of zinc in supplements</td>
<td>Vomiting, abdominal pain, diarrhea, liver damage</td>
<td>10 mg/day</td>
</tr>
<tr>
<td>Zinc</td>
<td>Meat, seafood, whole grains, dairy products, legumes, nuts</td>
<td>8–11 mg/day</td>
<td>Regulates protein synthesis; functions in growth, development, wound healing, immunity, and antioxidant enzymes</td>
<td>Poor growth and development, skin rashes, decreased immune function</td>
<td>Vegetarians, low-income children, elderly people</td>
<td>Decreased copper absorption, depressed immune function</td>
<td>40 mg/day</td>
</tr>
<tr>
<td>Selenium</td>
<td>Meats, seafood, eggs, whole grains, nuts, seeds</td>
<td>55 μg/day</td>
<td>Antioxidant as part of glutathione peroxidase, synthesis of thyroid hormones, spares vitamin E</td>
<td>Muscle pain, weakness, Keshan disease</td>
<td>Populations in areas where the soil is low in selenium</td>
<td>Nausea, diarrhea, vomiting, fatigue, changes in hair and nails</td>
<td>400 μg/day</td>
</tr>
</tbody>
</table>
## Trace minerals

<table>
<thead>
<tr>
<th>Mineral</th>
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<th>Toxicity</th>
<th>UL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iodine</td>
<td>Iodized salt, seafood, seaweed, dairy products</td>
<td>150 µg/day</td>
<td>Needed for synthesis of thyroid hormones</td>
<td>Goiter, cretinism, impaired brain function, growth and developmental abnormalities</td>
<td>Populations in areas where the soil is low in iodine and iodized salt is not used</td>
<td>Enlarged thyroid</td>
<td>1110 µg/day</td>
</tr>
<tr>
<td>Chromium</td>
<td>Brewer’s yeast, nuts, whole grains, meat, mushrooms</td>
<td>25–35 µg/day</td>
<td>Enhances insulin action</td>
<td>High blood glucose</td>
<td>Malnourished children</td>
<td>None reported</td>
<td>ND</td>
</tr>
<tr>
<td>Fluoride</td>
<td>Fluoridated water, tea, fish, toothpaste</td>
<td>3–4 mg/day</td>
<td>Strengthens tooth enamel, enhances re-mineralization of tooth enamel, reduces acid production by bacteria in the mouth</td>
<td>Increased risk of dental caries</td>
<td>Populations in areas with unfluoridated water, those who drink mostly bottled water</td>
<td>Fluorosis: mottled teeth, kidney damage, bone abnormalities</td>
<td>10 mg/day</td>
</tr>
<tr>
<td>Manganese</td>
<td>Nuts, legumes, whole grains, tea, leafy vegetables</td>
<td>1.8–2.3 mg/day</td>
<td>Functions in carbohydrate and cholesterol metabolism and antioxidant enzymes</td>
<td>Growth retardation</td>
<td>None</td>
<td>Nerve damage</td>
<td>11 mg/day</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>Milk, organ meats, grains, legumes</td>
<td>45 µg/day</td>
<td>Cofactor for a number of enzymes</td>
<td>Unknown in humans</td>
<td>None</td>
<td>Arthritis, joint inflammation</td>
<td>2 mg/day</td>
</tr>
</tbody>
</table>

**Note:** UL, Tolerable Upper Intake Level; ND, not determined.
What should I eat?

- Stay hydrated
- Increase potassium intake
- Decrease sodium intake
- Get calcium into your body and your bones
- Don’t fret about phosphorus
- Maximize your magnesium
- Add more iron and increase iron absorption
- Think zinc
- Trace down your minerals
Minerals

Major

Electrolytes
- Sodium
- Potassium
- Chloride

Bone Health
- Calcium
- Phosphorus
- Magnesium
- Sulfur

Trace

Iron
- Copper
- Zinc
- Selenium
- Chromium
- Fluoride
- Manganese
- Molybdenum
What are similarities and differences between:

- Minerals and vitamins?
- Major and trace minerals?
- Sodium, potassium, and chloride?
- Calcium, phosphorus, magnesium, and sulfur?
Nutrition in the news

- Bottled vs. tap water
- Privatization of water
- Water shortages
- Soda decreasing bone density
- Fluoride in water
Checking student learning outcomes

- What advice would you give to a loved one about water and mineral consumption?