Water and the Major Minerals

Chapter 12
Water

- The body needs more water per day than any other nutrient
  - One can survive a deficiency of any other nutrient sometimes for months or years
  - One can only survive a few days without water
  - In less than a day, a lack of water alters the body’s chemistry and metabolism
Water

- Water makes up ≈60% of an adult’s body weight
- Water is found in
  - Blood vessels
  - Cells
  - Chemical structure of cells, tissues, organs
- Water participates in many chemical reactions
- Water constitutes 3/4 of lean tissue weight and less than 1/4 of the weight of fat
- The body adjusts water intake and output to balance
Water and the Body Fluids

- Carries nutrients and waste products throughout the body.
- Maintains structure of large molecules (proteins and glycogen).
- Participates in metabolic reactions.
- Solvent for minerals, vitamins, amino acids, glucose, and small molecules.
- Lubricates and cushions joints, protects spinal cord, surrounds amniotic sac, inside eyes.
- Aids in the regulation of body temperature.
- Maintains blood volume.
Water Balance and Recommended Intakes

- Cellular fluids
  - Intracellular fluid
  - Extracellular fluid
    - Interstitial fluid
    - Intravascular fluid
Water Intake

- Thirst and satiety influence intake
  - Thirst is a conscious desire to drink and is regulated by the mouth, hypothalamus, and nerves.
  - Thirst lags behind the body’s need

- Dehydration occurs with water deficiency
  - Symptoms include thirst, weakness, fatigue, dry mouth, decrease in urine, headache, loss of balance, exhaustion, collapse
  - At risk include the elderly, athletes, children playing outdoors, gardeners, etc.
# Signs of Dehydration

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

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.
Water Balance and Recommended Intakes

- Water intoxication
  - Excessive water contents in all body fluid compartments.
    - It is rare.
  - Related to excessive ingestion, kidney disorders
  - Symptoms include confusion, convulsions
Water Balance and Recommended Intake

- Sources
  - Water
  - Beverages
  - Foods
  - Condensation reactions
  - Oxidation of energy-yielding nutrients
### Percentage of Water in Selected Foods

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Foods</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>Water</td>
</tr>
<tr>
<td>90–99%</td>
<td>Fat-free milk, strawberries, watermelon, lettuce, cabbage, celery, spinach, broccoli</td>
</tr>
<tr>
<td>80–89%</td>
<td>Fruit juice, yogurt, apples, grapes, oranges, carrots</td>
</tr>
<tr>
<td>70–79%</td>
<td>Shrimp, bananas, corn, potatoes, avocados, cottage cheese, ricotta cheese</td>
</tr>
<tr>
<td>60–69%</td>
<td>Pasta, legumes, salmon, ice cream, chicken breast</td>
</tr>
<tr>
<td>50–59%</td>
<td>Ground beef, hot dogs, feta cheese</td>
</tr>
<tr>
<td>40–49%</td>
<td>Pizza</td>
</tr>
<tr>
<td>30–39%</td>
<td>Cheddar cheese, bagels, bread</td>
</tr>
<tr>
<td>20–29%</td>
<td>Pepperoni sausage, cake, biscuits</td>
</tr>
<tr>
<td>10–19%</td>
<td>Butter, margarine, raisins</td>
</tr>
<tr>
<td>1–9%</td>
<td>Crackers, cereals, pretzels, taco shells, peanut butter, nuts</td>
</tr>
<tr>
<td>0%</td>
<td>Oils, sugars</td>
</tr>
</tbody>
</table>
Water Balance and Recommended Intake

- Losses
  - Minimum excretion each day of 500 ml to carry away waste products as urine
  - Vapor from lungs
  - Sweat from skin
  - Loss in feces
- Above this excretion adjusts to intake-
  - if you drink more, you excrete more
**TABLE 12-3 Water Balance**

<table>
<thead>
<tr>
<th>Water Sources</th>
<th>Amount (mL)</th>
<th>Water Losses</th>
<th>Amount (mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beverages</td>
<td>550 to 1500</td>
<td>Kidneys (urine)</td>
<td>500 to 1400</td>
</tr>
<tr>
<td>Foods</td>
<td>700 to 1000</td>
<td>Skin (sweat)</td>
<td>450 to 900</td>
</tr>
<tr>
<td>Metabolism</td>
<td>200 to 300</td>
<td>Lungs (breath)</td>
<td>350</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GI tract (feces)</td>
<td>150</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1450 to 2800</strong></td>
<td><strong>Total</strong></td>
<td><strong>1450 to 2800</strong></td>
</tr>
</tbody>
</table>

NOTE: For perspective, 100 milliliters is a little less than ½ cup and 1000 milliliters is a little more than 1 quart (1 mL = 0.03 oz).
Recommendations

1. Recommendations
   - 1.0 - 1.5 ml per kcal expended
   - 2000 kcal = 2-3 liters (8-12 cups)
     - Adequate Intake for males is 3.7 L/day.
     - Adequate Intake for females is 2.7 L/day.
     - Alcohol can have a diuretic effect
Water Balance and Recommended Intake

- Health Effects of Water
  - Meeting bodily fluid needs
  - Protects against kidney stones and constipation
  - Concentrations, alertness and short term memory
Water Balance and Recommended Intake

- **Kinds of water**
  - **Hard Water**
    - Water with high calcium and magnesium content
    - Leaves residues
    - May benefit hypertension and heart disease
  - **Soft water**
    - Water with high sodium and potassium content
    - May aggravate hypertension and heart disease
    - Dissolves contaminate minerals in pipes
    - Practical advantages-makes more bubbles with less soap
Water is the body’s cleansing agent

- Nitrogen wastes, produced during metabolism, must be removed before they build up to toxic levels
- Kidneys filter these wastes from the blood and, mixed with water, excrete them as urine
  - Diseased kidneys cannot perform this function thus necessitating dialysis
- Body must excrete about 500 ml of water as urine to carry away waste products
A nephron (a working unit of the kidney). Each kidney contains over one million nephrons.

1. Blood flows into the glomerulus, and some of its fluid, with dissolved substances, is absorbed into the tubule.

2. Then the fluid and substances needed by the body are returned to the blood in vessels alongside the tubule.

3. The tubule passes waste materials on to the bladder.

The cleaning of blood in the nephron is roughly analogous to the way you might clean your car. First 1. you remove all your possessions and trash so that the car can be vacuumed. Then 2. you put back in the car what you want to keep and 3. throw away the trash.
Blood Volume and Blood Pressure

- Fluid maintains the blood volume
  - which in turn influences blood pressure
- Kidneys reabsorb needed water and substances
  - and excrete unneeded water and waste in the urine
- The kidneys adjust the volume and substances in the urine to accommodate the needs of the body
How the Body Regulates Blood Volume & Blood Pressure

Low blood volume
Low blood pressure

Angiotensinogen

Renin

Angiotensin I

Angiotensin II

Constricts blood vessels

ADH

Aldosterone

Retains water
(and thereby retains sodium and excretes potassium)

Retains sodium
Excretes potassium
(and thereby retains water)

Increases blood volume
Increases blood pressure

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Fluid and Electrolyte Balance

- The body maintains about 2/3 of the body fluids inside the cell and about 1/3 outside the cell.
- To control the movement of water, the cells control the movement of the major minerals.
  - Sodium, Potassium, Chloride, Magnesium, Calcium, Phosphate, Sulfate.
Fluid and Electrolyte Balance

- Electrolytes attract water
  - Water molecules have net charge of zero
- Water follows electrolytes
  - Electrolytes predominantly outside of cell
    - Sodium and chloride
  - Electrolytes predominantly inside of cell
    - Potassium, magnesium, phosphate, sulfate
- Selectively permeable membranes
A Cell and Its Electrolytes

Chemical symbols:
- K = potassium
- P = phosphorus
- Mg = magnesium
- S = sulfate
- Na = sodium
- Cl = chloride

Key:
- Cations
- Anions
# Table 12-4: Important Body Electrolytes

<table>
<thead>
<tr>
<th>Electrolytes</th>
<th>Intracellular (inside cells)</th>
<th>Extracellular (outside cells)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Concentration (mEq/L)</td>
<td>Concentration (mEq/L)</td>
</tr>
<tr>
<td><strong>Cations (positively charged ions)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium (Na⁺)</td>
<td>10</td>
<td>142</td>
</tr>
<tr>
<td>Potassium (K⁺)</td>
<td>150</td>
<td>5</td>
</tr>
<tr>
<td>Calcium (Ca²⁺)</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Magnesium (Mg²⁺)</td>
<td>40</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>202</td>
<td>155</td>
</tr>
<tr>
<td><strong>Anions (negatively charged ions)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloride (Cl⁻)</td>
<td>2</td>
<td>103</td>
</tr>
<tr>
<td>Bicarbonate (HCO₃⁻)</td>
<td>10</td>
<td>27</td>
</tr>
<tr>
<td>Phosphate (H₂PO₄⁻)</td>
<td>103</td>
<td>2</td>
</tr>
<tr>
<td>Sulfate (SO₄²⁻)</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>Organic acids (lactate, pyruvate)</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>Proteins</td>
<td>57</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>202</td>
<td>155</td>
</tr>
</tbody>
</table>

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.
Water Dissolves Salts and Follows Electrolytes

The negatively charged electrons that bond the hydrogens to the oxygen spend most of their time near the oxygen atom. As a result, the oxygen is slightly negative, and the hydrogens are slightly positive (see Appendix B).

In an electrolyte solution, water molecules are attracted to both anions and cations. Notice that the negative oxygen atoms of the water molecules are drawn to the sodium cation ($\text{Na}^+$), whereas the positive hydrogen atoms of the water molecules are drawn to the chloride ions ($\text{Cl}^-$).
Osmosis

Water flows in the direction of the more highly concentrated solution

1. With equal numbers of solute particles on both sides, the concentrations are equal, and the tendency of water to move in either direction is about the same.

2. Now additional solute is added to side B. Solute cannot flow across the divider (in the case of a cell, its membrane).

3. Water can flow both ways across the divider, but has a greater tendency to move from side A to side B, where there is a greater concentration of solute. The volume of water becomes greater on side B, and the concentrations on side A and B become equal.
• Vegetables “sweat” when sprinkled with salt

• Raisins plump up when immersed in water
Regulation of Fluid and Electrolyte Balance

- The amounts of the minerals must remain nearly constant.
- The kidneys and gastrointestinal tract are continuously regulating the minerals.
- The large intestine reabsorbs minerals and fluids as needed (up to 8 liters of fluid a day!)
- The kidneys regulate fluid and electrolytes via aldosterone and ADH.
Fluid and Electrolyte Imbalance

- Fluid loss: diarrhea, vomiting, heavy sweating, burns
- Sodium and chloride lost first in sweating, bleeding, excretion
- Generally you can replace with cool water and eating regular foods
- Simple formulas may also be used (pedialyte)
Minerals

- Inorganic elements
- Retain their structure
- Cannot be destroyed by heat, air or acid
- Bioavailability is variable; some readily bind with phytates and oxalates
- Some minerals may interact with each other
  - The presence or absence of one may affect the absorption, metabolism or excretion
Minerals in a 60-kilogram (132 pound) Human Body

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Amount (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>1150</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>600</td>
</tr>
<tr>
<td>Potassium</td>
<td>210</td>
</tr>
<tr>
<td>Sulfur</td>
<td>150</td>
</tr>
<tr>
<td>Sodium</td>
<td>90</td>
</tr>
<tr>
<td>Chloride</td>
<td>90</td>
</tr>
<tr>
<td>Magnesium</td>
<td>30</td>
</tr>
<tr>
<td>Iron</td>
<td>2.4</td>
</tr>
<tr>
<td>Zinc</td>
<td>2.0</td>
</tr>
<tr>
<td>Copper</td>
<td>0.09</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.02</td>
</tr>
<tr>
<td>Iodine</td>
<td>0.02</td>
</tr>
<tr>
<td>Selenium</td>
<td>0.02</td>
</tr>
</tbody>
</table>

**MAJOR MINERALS**
The major minerals are those present in amounts larger than 5 g (a teaspoon). A pound is about 454 g; thus only calcium and phosphorus appear in amounts larger than a pound.

**TRACE MINERALS**
There are more than a dozen trace minerals, although only six are shown here.
Sodium

Roles:

- Principal cation of extracellular fluid
  - Primary regulator of fluid volume
- Assists in nerve transmission
- Muscle contraction
- Helps maintain acid-base balance
- Kidney filters sodium out of the blood and then returns what is needed back to the blood
- Normally the amount excreted is equal to the amount ingested
Sodium Recommendations

Recommendations:
- Adequate Intake is 1500 mg for (19-50 yr)
- Adequate Intake is 1300 mg for (51-70 yr)
- Adequate Intake is 1500 mg for (>70 yr)
- UL is 2300 mg
- Average sodium intake in U.S. adults is 3400 mg
Sodium

Sodium and Hypertension:

- Salt (sodium chloride, not sodium, which affects hypertension
- Blood pressure increases in response to excess salt
- Restriction helpful in “Salt Sensitive” individuals
  - Those with high blood pressure, kidney disease, diabetes, African Americans, people over age 40, overweight individuals
- Low salt intake decreases risk
Sodium

- **Sodium in Foods**
  - Large amounts in processed foods (approximately 75% of sodium in the diet)
  - Table salt (approximately 15% from added sodium in the diet)
  - Sodium may be present in surprisingly high amounts if chloride is removed.
  - Moderate amounts in meats, milks, breads and vegetables (approximately 10% of sodium in the diet)
Sodium
Sodium

- **Sodium Deficiency**
  - Vomiting, diarrhea or heavy sweating.
  - Symptoms are muscle cramps, mental apathy, and loss of appetite.
  - Salt tablets without water induce dehydration.

- **Sodium Toxicity and Excessive Intakes**
  - Edema and acute hypertension
  - Prolonged high intake may contribute to hypertension.
Chloride

Functions:
- Major anion in extracellular fluid.
- Maintains fluid and electrolyte balance.
- Part of hydrochloric acid in stomach

Recommendations:
- Adequate Intake: 1500 mg/day 19-50 year olds

Deficiency:
- May occur with sweating, diarrhea, vomiting

Toxicity:
- May occur with dehydration
Potassium

Function:

- Major intracellular cation
- Maintains fluid and electrolyte balance
- Cell integrity
- Nerve transmission and muscle contraction
- Helps maintain normal heart beat
Potassium

Recommendation:
- Minimum 2300 mg/day-19-50 year olds

Potassium and Hypertension
- Low potassium diets seem to raise blood pressure
- High potassium diets appear to prevent/correct high blood pressure

Sources
- Fresh foods are the richest sources
Potassium

- Deficiency
  - Increase in blood pressure
  - Salt sensitivity
  - Kidney stones
  - Bone turnover
  - Irregular heartbeats
  - Muscle weakness
  - Glucose intolerance

- Toxicity
  - No UL
  - Overconsumption of potassium salts or supplements
  - Certain diseases or treatments
  - Kidneys accelerate excretion
Potassium in Selected Foods

Adequate Intake for adults: 4700 mg/day

- Broccoli: 526 mg per 1 spear cooked
- Spinach: 312 mg per 1 cup raw
- Eggplant: 199 mg per 1/2 cup cooked
- Cantaloupe: 825 mg per 1/2 cantaloupe
- Legumes: >300 mg per 1/2 cup cooked
- Butternut squash: 348 mg per 1/2 cup mashed
- Artichoke: 435 mg per artichoke
- Acorn squash: 332 mg per 1.2 cup mashed
- Carrots: 232 mg per carrot
# Potassium in Selected Foods

<table>
<thead>
<tr>
<th>Food</th>
<th>Serving size (kcalories)</th>
<th>Milligrams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bread, whole wheat</td>
<td>1 oz slice (70 kcal)</td>
<td></td>
</tr>
<tr>
<td>Cornflakes, fortified</td>
<td>1 oz (110 kcal)</td>
<td></td>
</tr>
<tr>
<td>Spaghetti pasta</td>
<td>¾ c cooked (99 kcal)</td>
<td></td>
</tr>
<tr>
<td>Tortilla, flour</td>
<td>1 10^-round (234 kcal)</td>
<td></td>
</tr>
<tr>
<td>Broccoli</td>
<td>½ c cooked (22 kcal)</td>
<td></td>
</tr>
<tr>
<td>Carrots</td>
<td>¾ c shredded raw (24 kcal)</td>
<td></td>
</tr>
<tr>
<td>Potato</td>
<td>1 medium baked w/skin (133 kcal)</td>
<td></td>
</tr>
<tr>
<td>Tomato juice</td>
<td>¾ c (31 kcal)</td>
<td></td>
</tr>
<tr>
<td>Banana</td>
<td>1 medium raw (109 kcal)</td>
<td></td>
</tr>
<tr>
<td>Orange</td>
<td>1 medium raw (62 kcal)</td>
<td></td>
</tr>
<tr>
<td>Strawberries</td>
<td>½ c fresh (22 kcal)</td>
<td></td>
</tr>
<tr>
<td>Watermelon</td>
<td>1 slice (92 kcal)</td>
<td></td>
</tr>
<tr>
<td>Milk</td>
<td>1 c reduced-fat 2% (121 kcal)</td>
<td></td>
</tr>
<tr>
<td>Yogurt, plain</td>
<td>1 c low-fat (155 kcal)</td>
<td></td>
</tr>
<tr>
<td>Cheddar cheese</td>
<td>1½ oz (171 kcal)</td>
<td></td>
</tr>
<tr>
<td>Cottage cheese</td>
<td>½ c low-fat 2% (101 kcal)</td>
<td></td>
</tr>
<tr>
<td>Pinto beans</td>
<td>¼ c cooked (117 kcal)</td>
<td></td>
</tr>
<tr>
<td>Peanut butter</td>
<td>2 lbs (188 kcal)</td>
<td></td>
</tr>
<tr>
<td>Sunflower seeds</td>
<td>1 oz dry (165 kcal)</td>
<td></td>
</tr>
<tr>
<td>Tofu (soybean curd)</td>
<td>½ c (76 kcal)</td>
<td></td>
</tr>
<tr>
<td>Ground beef, lean</td>
<td>3 oz broiled (244 kcal)</td>
<td></td>
</tr>
<tr>
<td>Chicken breast</td>
<td>3 oz roasted (140 kcal)</td>
<td></td>
</tr>
<tr>
<td>Tuna, canned in water</td>
<td>3 oz (99 kcal)</td>
<td></td>
</tr>
<tr>
<td>Egg</td>
<td>1 hard cooked (78 kcal)</td>
<td></td>
</tr>
<tr>
<td><strong>Excellent, and sometimes unusual, sources:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Squash, acorn</td>
<td>½ c baked (69 kcal)</td>
<td></td>
</tr>
<tr>
<td>Soybeans</td>
<td>½ c cooked (149 kcal)</td>
<td></td>
</tr>
<tr>
<td>Artichoke</td>
<td>1 (60 kcal)</td>
<td></td>
</tr>
</tbody>
</table>

The AI for potassium is 4700 mg per day.

**POTASSIUM**
Fresh fruits (purple), vegetables (green), legumes, nuts, and seeds (brown), and meats, poultry, and seafood (red) contribute potassium to the diet.

**Key:**
- Grains
- Vegetables
- Fruits
- Milk and milk products
- Legumes, nuts, seeds
- Meats, poultry, seafood
- Best sources per kcalorie
Calcium

Most abundant mineral in the body

**Roles:**
- Mineralization of bones and teeth - 99%
- Muscle contraction and relaxation
- Nerve transmission
- Blood clotting - 1%
- Blood pressure
- Immune defense
Calcium

- In Bones
  - Provides rigid structure to hold body upright
  - Serves as a bone bank
  - Calcium salts form crystals
    - Hydroxyapatite
  - Strength and rigidity to maturing bones
  - Bone remodeling

- In teeth
  - Fluoride stabilizes calcium crystals in teeth
Calcium Balance

Rising blood calcium signals the thyroid gland to secrete calcitonin.*

1. Calcitonin inhibits the activation of vitamin D.
2. Calcitonin prevents calcium reabsorption in the kidneys.
3. Calcitonin limits calcium absorption in the intestines.
4. Calcitonin inhibits osteoclast cells from breaking down bone, preventing the release of calcium.

All these actions lower blood calcium levels, which inhibits calcitonin secretion.

Falling blood calcium signals the parathyroid glands to secrete parathyroid hormone.

1. Parathyroid hormone stimulates the activation of vitamin D.
2. Vitamin D and parathyroid hormone stimulate calcium reabsorption in the kidneys.
3. Vitamin D enhances calcium absorption in the intestines.
4. Vitamin D and parathyroid hormone stimulate osteoclast cells to break down bone, releasing calcium into the blood.

All these actions raise blood calcium levels, which inhibits parathyroid hormone secretion.

*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.
# Blood Calcium Balance

<table>
<thead>
<tr>
<th>IF BLOOD CALCIUM IS TOO LOW</th>
<th>IF BLOOD CALCIUM IS TOO HIGH</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thyroid</strong>&lt;br&gt;Parathyroid (imbedded in the thyroid)</td>
<td><strong>Thyroid</strong>&lt;br&gt;Parathyroid (imbedded in the thyroid)</td>
</tr>
<tr>
<td>Falling blood calcium signals the parathyroid glands to secrete parathormone.</td>
<td>Rising blood calcium signals the thyroid gland to secrete calcitonin.</td>
</tr>
<tr>
<td>Vitamin D enhances calcium absorption in the intestines.</td>
<td>Calcitonin limits calcium absorption in the intestines.</td>
</tr>
<tr>
<td>Parathormone stimulates the activation of vitamin D.</td>
<td>Calcitonin inhibits the activation of vitamin D.</td>
</tr>
<tr>
<td>Vitamin D and parathormone stimulate calcium reabsorption in the kidneys.</td>
<td>Calcitonin stimulates calcium excretion in the kidneys.</td>
</tr>
<tr>
<td>Vitamin D and parathormone stimulate osteoclast cells to break down bone, releasing calcium into the blood.</td>
<td>Calcitonin inhibits osteoclast cells from breaking down bone, preventing a rise in blood calcium.</td>
</tr>
<tr>
<td>All these actions raise blood calcium, which inhibits parathormone secretion.</td>
<td>All these actions lower blood calcium, which inhibits calcitonin secretion.</td>
</tr>
</tbody>
</table>
Calcium Absorption

- Calcium binding protein is needed for absorption
- When calcium is needed, the body increases its production of the calcium binding protein
- Adults absorb approximately 30% of what they ingest
- Pregnant women absorb approximately 50%
- Growing children absorb approximately 50-60%
Calcium Absorption

- Factors that enhance absorption:
  - Stomach acid
  - Vitamin D
  - Lactose (in infants) growth hormone

- Factors that decrease absorption:
  - Lack of stomach acid
  - Vitamin D deficiency
  - High phosphorus intake
  - Phytates (nuts, seeds, grains)
  - Oxalates (greens, spinach, sweet potatoes)
Calcium

With an adequate intake of calcium-rich food, blood calcium remains normal . . .

With a dietary deficiency, blood calcium still remains normal . . .

. . . and bones deposit calcium. The result is strong, dense bones.

. . . because bones give up calcium to the blood. The result is weak, osteoporotic bones.
Cauliflower, watercress, brussels sprouts, rutabaga, kale, mustard greens, bok choy, broccoli, turnip greens

Milk, calcium-fortified soy milk, calcium-set tofu, cheese, yogurt, calcium-fortified foods and beverages

Almonds, sesame seeds, pinto beans, sweet potatoes

Spinach, rhubarb, Swiss chard
Calcium

**Recommendations:**
- 19-50- 1000 mg
- > 51- 1200 mg

**Sources:**
- Milk and milk products
- Non-milk sources: some tofu, some nuts, seeds, oysters, sardines, some greens
Calcium in Selected Foods

RDA for adults (19-50 yr): 1000 mg/day
RDA for adults (51 and older): 1200 mg/day

Milk: 300 mg (30% DV) per cup
Pork and beans: 80 mg (8% DV) per 1/2 cup
Cheddar cheese: 306 mg (31% DV) per 1 1/2 oz
Almonds: 100 mg (10% DV) per 2 tbs

Broccoli: 94 mg (9% DV) per 1/2 cup cooked
Sardines: 324 mg (32% DV) per 3 oz
### Calcium in Selected Foods

<table>
<thead>
<tr>
<th>Food</th>
<th>Serving size (kcalories)</th>
<th>Milligrams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bread, whole wheat</td>
<td>1 oz slice (70 kcal)</td>
<td></td>
</tr>
<tr>
<td>Cornflakes, fortified</td>
<td>1 oz (110 kcal)</td>
<td></td>
</tr>
<tr>
<td>Spaghetti pasta</td>
<td>⅛ c cooked (99 kcal)</td>
<td></td>
</tr>
<tr>
<td>Tortilla, flour</td>
<td>1 10”-round (234 kcal)</td>
<td></td>
</tr>
<tr>
<td>Broccoli</td>
<td>¼ c cooked (22 kcal)</td>
<td></td>
</tr>
<tr>
<td>Carrots</td>
<td>⅛ c shredded raw (24 kcal)</td>
<td></td>
</tr>
<tr>
<td>Potato</td>
<td>1 medium baked w/skin (133 kcal)</td>
<td></td>
</tr>
<tr>
<td>Tomato juice</td>
<td>¼ c (31 kcal)</td>
<td></td>
</tr>
<tr>
<td>Banana</td>
<td>1 medium raw (109 kcal)</td>
<td></td>
</tr>
<tr>
<td>Orange</td>
<td>1 medium raw (62 kcal)</td>
<td></td>
</tr>
<tr>
<td>Strawberries</td>
<td>¼ c fresh (22 kcal)</td>
<td></td>
</tr>
<tr>
<td>Watermelon</td>
<td>1 slice (92 kcal)</td>
<td></td>
</tr>
<tr>
<td>Milk</td>
<td>1 c reduced-fat 2% (121 kcal)</td>
<td></td>
</tr>
<tr>
<td>Yogurt, plain</td>
<td>1 c low-fat (155 kcal)</td>
<td></td>
</tr>
<tr>
<td>Cheddar cheese</td>
<td>1½ oz (171 kcal)</td>
<td></td>
</tr>
<tr>
<td>Cottage cheese</td>
<td>¼ c low-fat 2% (101 kcal)</td>
<td></td>
</tr>
<tr>
<td>Pinto beans</td>
<td>⅛ c cooked (117 kcal)</td>
<td></td>
</tr>
<tr>
<td>Peanut butter</td>
<td>2 tbs (188 kcal)</td>
<td></td>
</tr>
<tr>
<td>Sunflower seeds</td>
<td>1 oz dry (165 kcal)</td>
<td></td>
</tr>
<tr>
<td>Tofu (soybean curd)</td>
<td>⅛ c (76 kcal)</td>
<td></td>
</tr>
<tr>
<td>Ground beef, lean</td>
<td>3 oz broiled (244 kcal)</td>
<td></td>
</tr>
<tr>
<td>Chicken breast</td>
<td>3 oz roasted (140 kcal)</td>
<td></td>
</tr>
<tr>
<td>Tuna, canned in water</td>
<td>3 oz (99 kcal)</td>
<td></td>
</tr>
<tr>
<td>Egg</td>
<td>1 hard cooked (78 kcal)</td>
<td></td>
</tr>
</tbody>
</table>

**Excellent, and sometimes unusual, sources:**

- Sardines, with bones
  - 3 oz canned (176 kcal)
- Bok choy (Chinese cabbage)
  - ¼ c cooked (10 kcal)
- Almonds
  - 1 oz (167 kcal)

---

**Key:**

- Grains
- Vegetables
- Fruits
- Milk and milk products
- Legumes, nuts, seeds
- Meats, poultry, seafood

**CALCIUM**

As in the riboflavin figure, milk and milk products (white) dominate the calcium figure. Most people need at least three selections from the milk group to meet recommendations.

\[ \text{Values based on products containing added calcium salts; the calcium in } \frac{1}{4} \text{c soybeans is about two-thirds as much as in } \frac{1}{4} \text{c tofu.} \]

\[ \text{If bones are discarded, calcium declines dramatically.} \]
Calcium

Deficiency:
- Peak bone mass by late 20s
- All adults lose bone with age beginning between 30-40
- Limited bone mass and density
- Osteoporosis
Calcium

- Deficiency symptoms
  - Stunted growth in children
  - Bone loss (osteoporosis) in adults

![Bone density chart showing peak bone mass, active growth, and bone loss over time.](Image)
Bone development and Disintegration

- **Cortical bone**
  - Hard outer shell
  - Gives up calcium to blood
    - Slow and steady rate

- **Trabecular bone**
  - Lacy matrix
  - Give up calcium when diet runs short
    - Impacted by day-to-day intake and need for calcium
Healthy and Osteoporotic Trabecular Bone

Trabecular bone is the lacy network of calcium-containing crystals that fills the interior. Cortical bone is the dense, ivorylike bone that forms the exterior shell.

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**Woman A** entered adulthood with enough calcium in her bones to last a lifetime.

**Woman B** had less bone mass starting out and so suffered ill effects from bone loss later on.
Loss of Height in a Woman Caused by Osteoporosis
## Risk Factors for Osteoporosis

### TABLE H12-1  Risk Factors for Osteoporosis

<table>
<thead>
<tr>
<th>Nonmodifiable</th>
<th>Modifiable</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Female gender</td>
<td>• Sedentary lifestyle</td>
</tr>
<tr>
<td>• Older age</td>
<td>• Diet inadequate in calcium and vitamin D</td>
</tr>
<tr>
<td>• Small frame</td>
<td>• Diet excessive in protein, sodium, caffeine</td>
</tr>
<tr>
<td>• Caucasian, Asian, or Hispanic/Latino</td>
<td>• Cigarette smoking</td>
</tr>
<tr>
<td>• Family history of osteoporosis or fractures</td>
<td>• Alcohol abuse</td>
</tr>
<tr>
<td>• Personal history of fractures</td>
<td>• Low body weight</td>
</tr>
<tr>
<td>• Estrogen deficiency in women (amenorrhea or menopause, especially early or surgically induced); testosterone deficiency in men</td>
<td>• Certain medications, such as glucocorticoids and anticonvulsants</td>
</tr>
</tbody>
</table>
Nutrients

- Dietary Calcium – the key to prevention
- Other Nutrients
  - Adequate protein
  - Adequate vitamin D
  - Vitamin K protects against hip fractures.
  - Magnesium and potassium help to maintain bone mineral density.
  - Vitamin A
  - Omega-3 fatty acids
  - Fruits and vegetables
  - Reduce salt
A Perspective on Supplements

- Calcium-rich foods are best.
- Supplements may be needed with inadequate dietary calcium.
- Small doses are better absorbed (500 mg or less).
  - Different absorption rates from different types of calcium supplements.
    - Calcium citrate, carbonate or phosphate are usually well absorbed.
- Do not take with iron rich meal.
  - Calcium decreases iron absorption.
Phosphorus

Functions:
- Mineralization of bones & teeth
- Part DNA, RNA
- Phospholipid
- Involved in energy metabolism
- Part of ATP
- Maintains acid/base balance (buffer system)
Phosphorus

**Recommendation:**
- 700 mg/day

**Deficiency:**
Unlikely; commonly found in most foods
Weakness, bone pain

**Source:**
- Animal products
- Meat and dairy
Magnesium

Magnesium Roles in the Body

- Bone mineralization
- Building of protein
- Enzyme action
- Normal muscle contraction
- Nerve impulse transmission
- Maintenance of teeth by preventing dental caries
- Functioning of the immune system
- Blood clotting
Magnesium

- **Magnesium Deficiency**
  - Deficiencies are rare.
  - **Symptoms**
    - Weakness and confusion
    - Convulsions in extreme deficiency
    - Bizarre muscle movements of the eye and face
    - Hallucinations
    - Difficulties in swallowing
    - Growth failure in children
  - Develops from alcohol abuse, protein malnutrition, kidney disorders and prolonged vomiting and diarrhea
Magnesium

- **Magnesium Intakes**
  - RDA Adult Men: 400 mg/day for 19-30 years of age
  - RDA Adult Women: 310 mg/day for 19-30 years of age
  - Upper level for adults: 350 mg nonfood magnesium/day

- **Sources**
  - Nuts and legumes, whole grains, dark green vegetables, seafood, chocolate and cocoa
  - Hard water and some mineral waters
End of Chapter 12

Water and Minerals