

Chapter 7

Fluids and Electrolyte Balance

7.1 Fluids

- Substances composed of freely moving molecules
- Have the ability to conform to the shape of the container that holds them
- There are different types of fluids in our bodies
 - $\frac{2}{3}$ of the body's fluid is **intracellular fluid**
 - The remaining $\frac{1}{3}$ is **extracellular fluid**

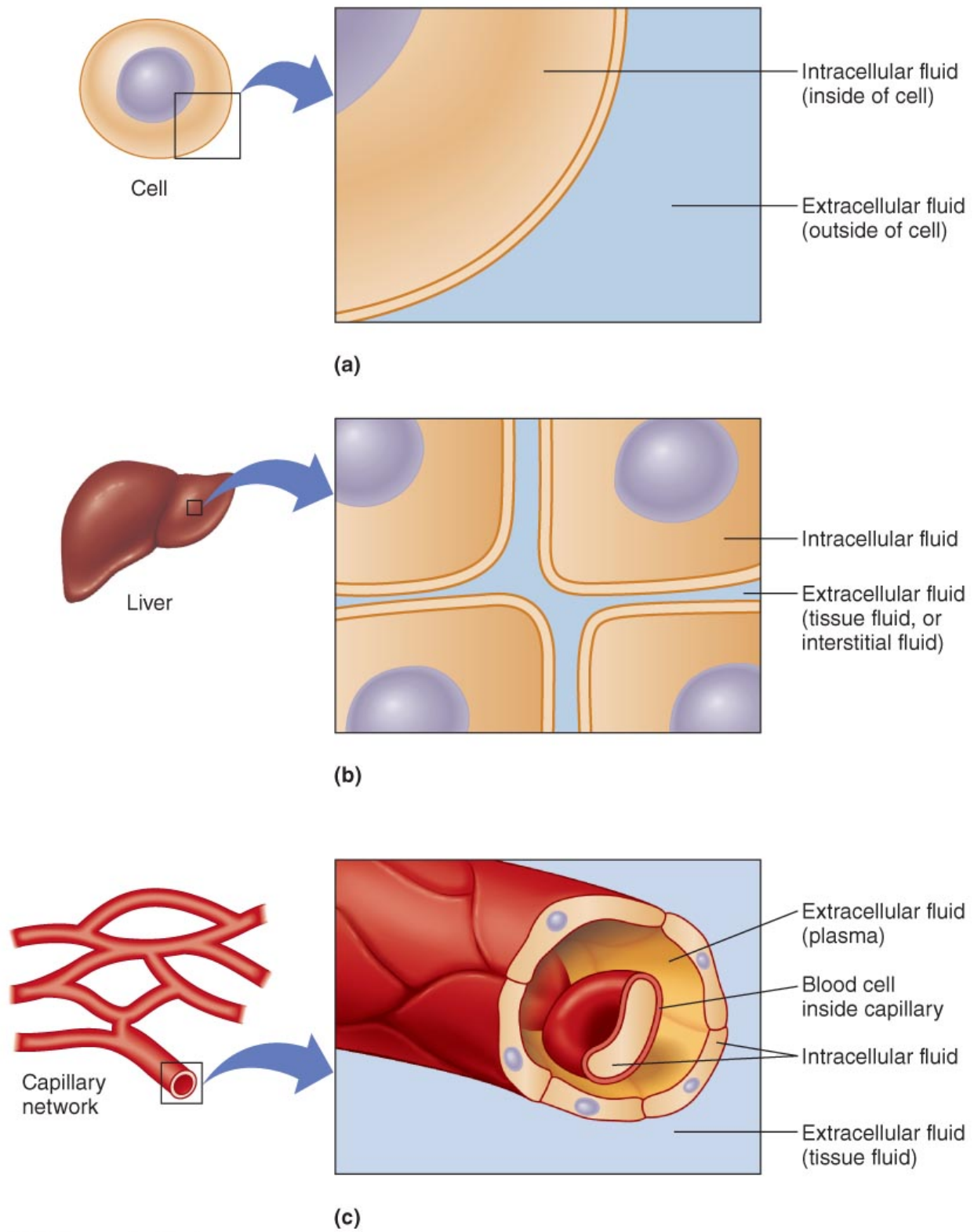


Figure 7.1: Components of Body Fluid

- Extracellular fluids include
 - **Tissue fluid** – found between the cells within tissues and organs of the body
 - **Plasma** – the fluid portion of blood that carries the blood cells
- The body fluid composition of tissue varies by
 - Tissue type** lean tissues have higher fluid content than fat tissues
 - Gender** males have more lean tissue and therefore more body fluid
 - Age** lean tissue is lost with age, and body fluid is lost with it

7.2 Electrolytes

- In intracellular fluid, K^+ and HPO_4^{2-} are the predominant electrolytes
- In extracellular fluid, Na^+ and Cl^- predominate
- There is a slight electrical charge difference on either side of the cell membrane

7.3 Functions of Fluids

- Fluids dissolve and transport substances
 - Water is an excellent **solvent** because it can dissolve many different substances
 - The dissolved materials, or **solutes**, include ions, carbohydrates, amino acids, vitamins, and minerals
- Fluids account for blood volume
 - **Blood volume** – the amount of fluid in the blood
 - Increased blood volume can cause blood pressure to rise (hypertension)
 - Decreased blood volume can cause low blood pressure
- Fluids help maintain body temperature
 - Because water has a high heat capacity, the temperature of our body fluids remain quite stable
 - Sweating releases heat as the evaporation of water from the skin cools the skin and blood

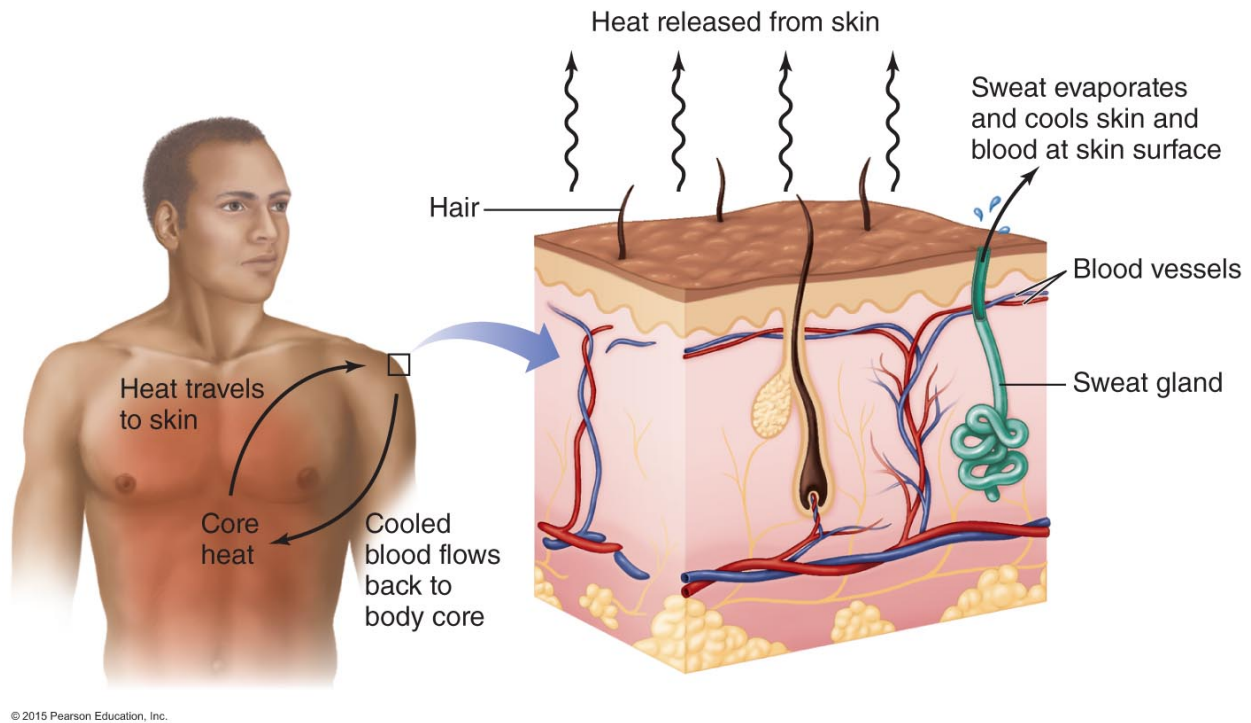


Figure 7.2: Fluids Help Maintain Body Temperature

- Fluids protect and lubricate our tissues
 - Cerebrospinal fluid protects the brain and spinal column
 - Amniotic fluid protects the fetus
 - Synovial fluid is a lubricant around joints
 - Digestive secretions allow for easy passage
 - Pleural fluid covering the lungs allows friction-free expansion and retraction

7.4 Functions of Electrolytes

- Electrolytes help regulate fluid balance
 - Water follows the movement of electrolytes, moving by osmosis to areas where the concentration of electrolytes is high
 - This allows for the controlled movement of fluids into and out of cells

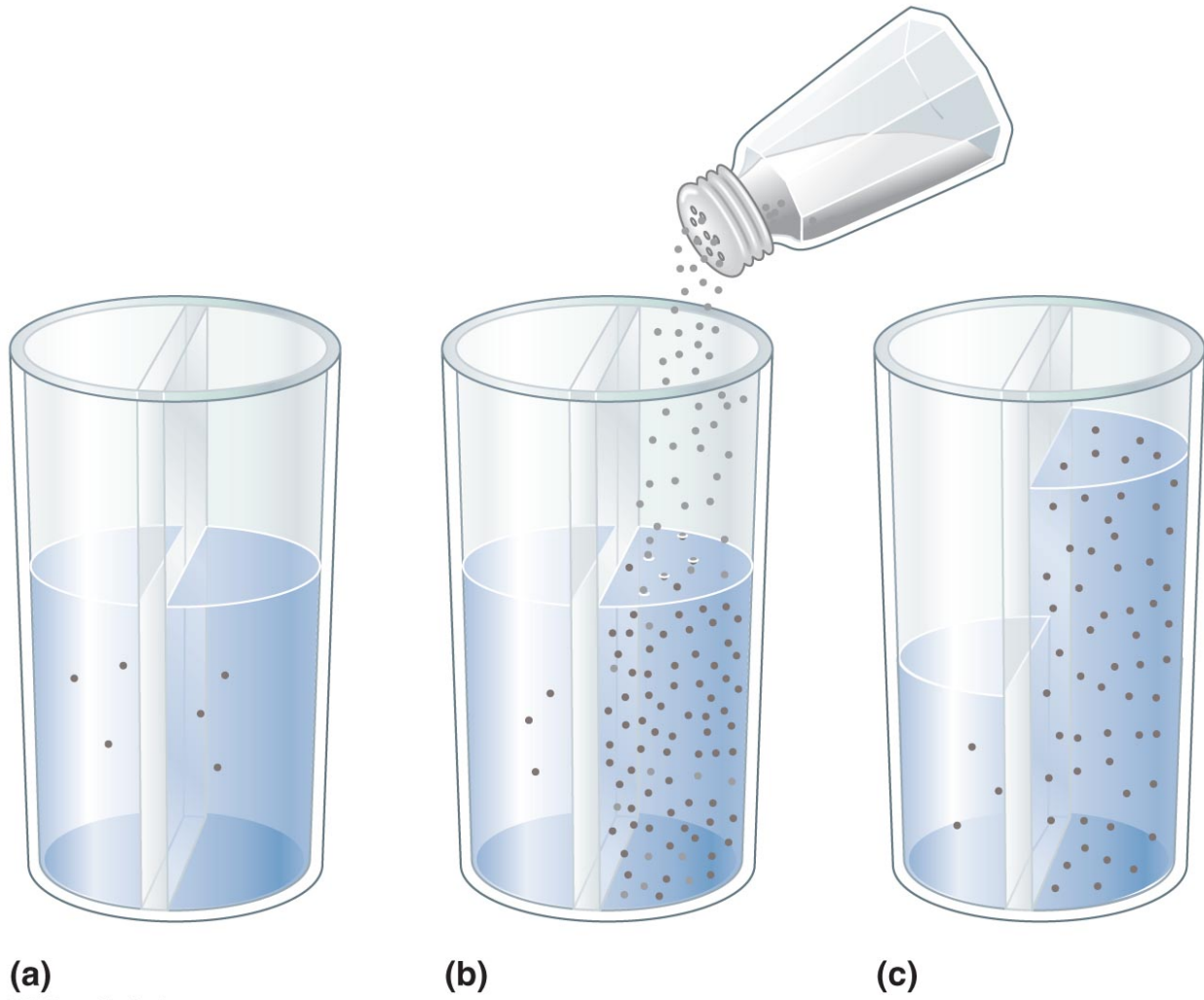


Figure 7.3: Osmosis



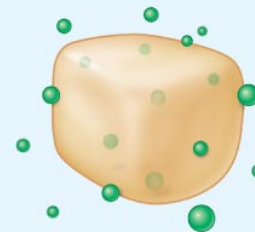
The health of our body's cells depends on maintaining the proper balance of fluids and electrolytes on both sides of the cell membrane, both at rest and during exercise. Let's examine how this balance can be altered under various conditions of exercise and fluid intake.

MODERATE EXERCISE

When you are appropriately hydrated, engaged in moderate exercise, and not too hot, the concentration of electrolytes is likely to be the same on both sides of cell membranes. You will be in fluid balance.



Concentration of electrolytes about equal inside and outside cell

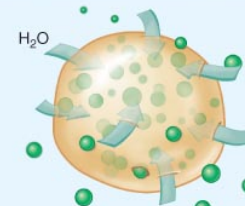


STRENUOUS EXERCISE WITH RAPID AND HIGH WATER INTAKE

If a person drinks a great deal of water quickly during intense, prolonged exercise, the extracellular fluid becomes diluted. This results in the concentration of electrolytes being greater inside the cells, which causes water to enter the cells, making them swell. Drinking moderate amounts of water or sports drinks more slowly will replace lost fluids and restore fluid balance.



Lower concentration of electrolytes outside



Higher concentration of electrolytes inside

STRENUOUS EXERCISE WITH INADEQUATE FLUID INTAKE

If a person does not consume adequate amounts of fluid during strenuous exercise of long duration, the concentration of electrolytes becomes greater outside the cells, drawing water away from the inside of the cells and making them shrink. Consuming sports drinks will replace lost fluids and electrolytes.



Higher concentration of electrolytes outside



Lower concentration of electrolytes inside

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Figure 7.4: Fluid and Electrolyte Balance

- Electrolytes enable our nerves to respond to stimuli
 - Movement of sodium (Na^+) and potassium (K^+) across the membranes of nerve cells changes the electrical charge across the membrane
 - This change in electrical charge carries the nerve impulse along the nerve cell

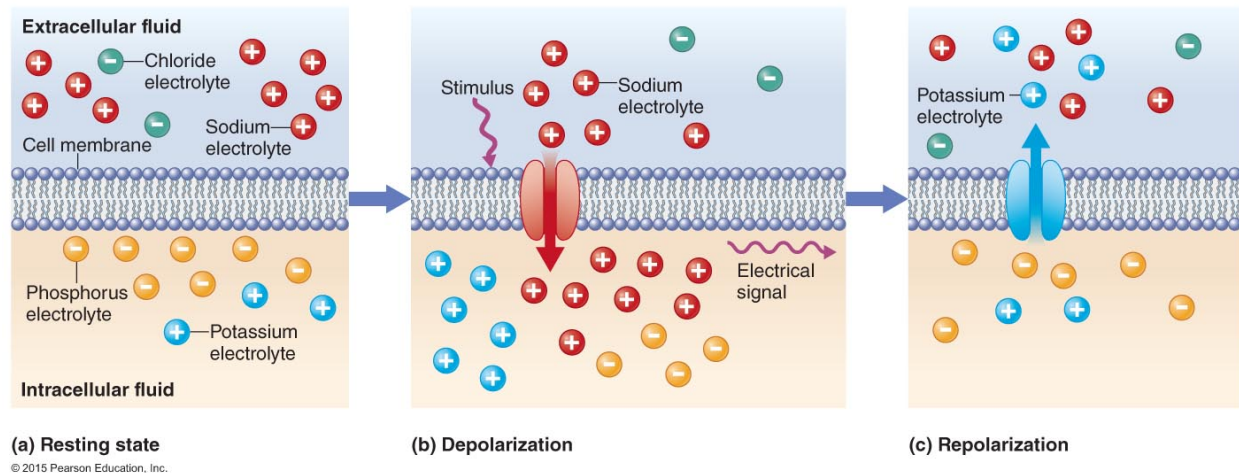


Figure 7.5: Role of Electrolytes in Nerve Function

- Electrolytes signal our muscles to contract
 - The movement of calcium (Ca^{2+}) into a muscle cell stimulates the muscle to contract
 - The (Ca^{2+}) is pumped back out of the cell after the muscle contraction

7.5 Maintaining Fluid Balance

- Fluid balance is maintained by different mechanisms prompting us to drink and retain fluid
- The **thirst mechanism** occurs from a cluster of nerve cells (in the hypothalamus) that stimulate our desire to drink
- However, the thirst mechanism is not always sufficient; the amount of fluids people drink may not be enough to achieve fluid balance
- Water lost from the body must be replaced
- Water is lost through urine, sweat, evaporation, exhalation, and feces
- Water is gained through beverages, food, and metabolic reactions
 - **Metabolic water** contributes about 10–14% of the water the body needs

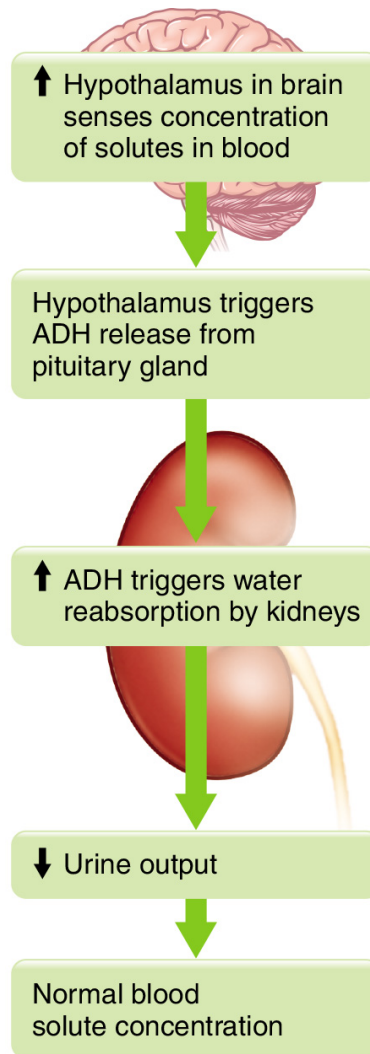


Figure 7.6: Fluid Balance

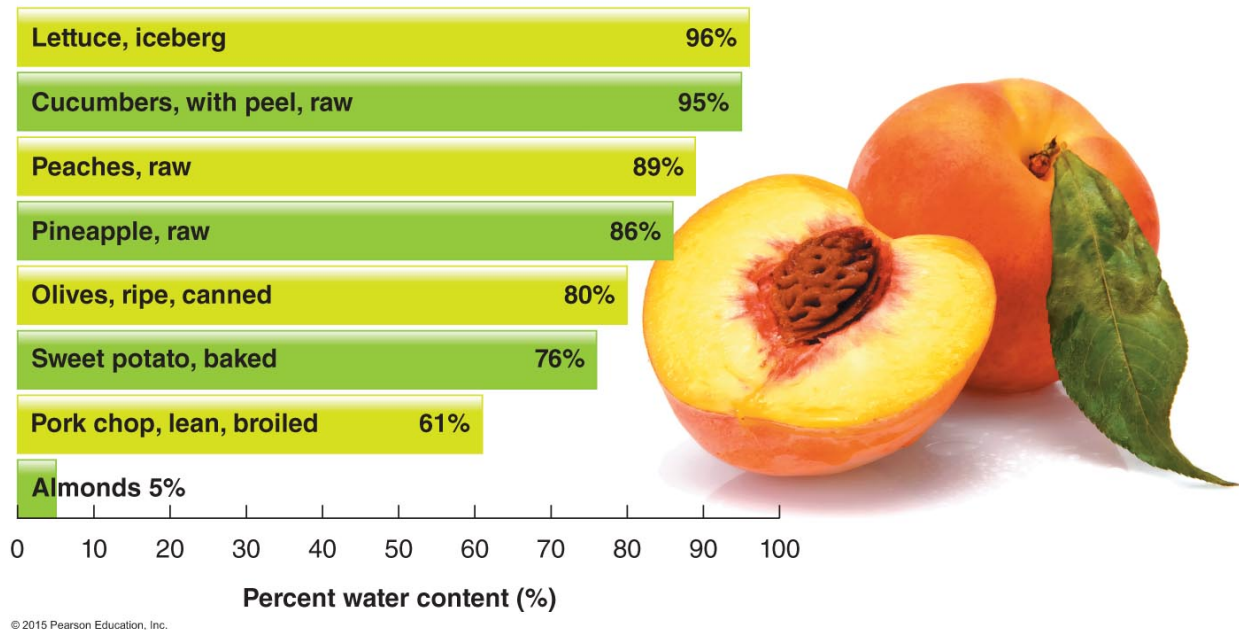


Figure 7.7: Water Content of Various Foods

- Loss of water

Sensible water loss occurs through urine and sweat

- Most water is lost through urine
- The kidneys control how much water is reabsorbed; excess water is processed by the kidneys and excreted as urine

Insensible water loss occurs through evaporation from the skin or exhalation from the lungs, as well as through feces

Diuretics increase fluid loss via the urine

7.6 Water

- Functions of water

- Essential for life
- Required for fluid and electrolyte balance and many metabolic reactions

- Recommended intake

- Varies with environment and activity level

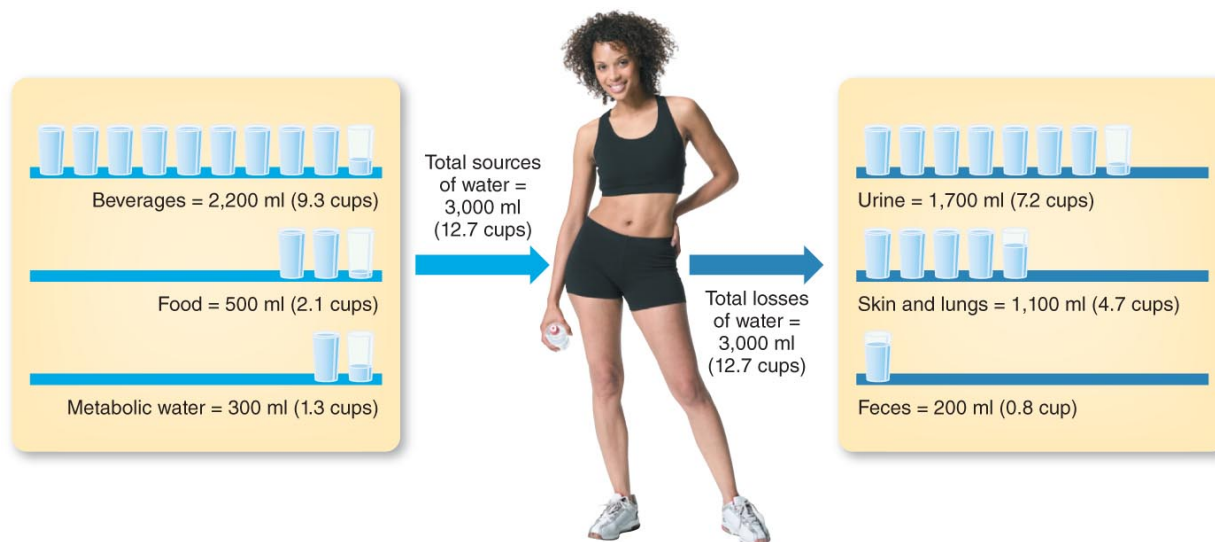


Figure 7.8: For a Woman Expending 2,500 kcal/day

- Surface water comes from lakes, rivers, and reservoirs
- Groundwater comes from underground rock formations called aquifers
- “Hard water” is relatively high in calcium
- The U.S. Environmental Protection Agency (EPA) sets and monitors standards for public water systems and is responsible for regulation of bottled water
- What is you drink too much water?
 - Becoming overhydrated is rare
 - Can resulted in a dilution of sodium (hyponatremia)
- What is you don't drink enough water?
 - Dehydration
 - Infants and the elderly are especially vulnerable

7.7 Commercial Beverages

- Low-fat and skim milk provide protein, calcium, phosphorus, vitamin D, and, usually, vitamin A
- Moderate consumption of beverages with caffeine is safe and potentially healthful
- Most soft drinks, juice drinks, flavored waters, and bottled tea and coffee drinks are loaded with added sugars

- “Designer waters” with added nutrients and/or herbs can add more than 300 Calories to the day’s intake and rarely contribute to better health
- Many energy drinks, typically consumed quickly, contain a high amount of caffeine, which can cause a dramatic rise in blood pressure and heart rate
 - The can also contain a significant amount of added sugar

Table 7.1: Overview of Minerals Involved in Hydration and Neuromuscular Function

Nutrient	Recommended Intake
Sodium	AI for 19 to 50 years of age: 1.5 g/day
Potassium	AI for 19 years of age and older: 4.7 g/day
Chloride	AI for 19 to 50 years of age: 2.3/day
Phosphorus	RDA for 19 years of age and older: 700 mg/day

To see the full profile of all micronutrients, turn to the **In Depth** essay following Chapter 6, Vitamins and Minerals: Micronutrients with Macro Powers (pages 211–221).

7.8 Sodium

- Functions of sodium
 - Fluid and electrolyte balance
 - Associated with blood pressure and pH balance in the body
 - Required for nerve impulse transmission
 - Assists in the transport of certain nutrients (e.g., glucose) into body cells
- Recommended intake
 - 1.5 g/day is required
 - No more than 2.3 g/day is recommended
- Sources of sodium
 - Processed foods and restaurant foods are generally high in sodium

Table 7.2: High-Sodium Foods and Lower-Sodium Alternatives

High-Sodium Food	Sodium (mg)	Lower-Sodium Food	Sodium (mg)
Dill pickle (1 large, 4 in.)	1,731	Low-sodium dill pickle (1 large, 4 in)	23
Ham, cured, roasted (3 oz)	1,023	Pork, loin roast (3 oz)	54
Turkey pastrami (3 oz)	915	Roasted turkey, cooked (3 oz)	54
Tomato juice, regular (1 cup)	877	Tomato juice, lower sodium (1 cup)	24
Macaroni and cheese (1 cup)	800	Spanish rice (1 cup)	5
Ramen noodle soup (chicken flavor) (1 pack-age [85 g])	1,960	Ramen noodle soup made with sodium-free chicken bouillon (1 cup)	0
Teriyaki chicken (1 cup)	3,210	Stir-fried pork/rice/vegetables (1 cup)	575
Tomato sauce, canned ($\frac{1}{2}$ cup)	741	Fresh tomato (1 medium)	11
Creamed corn, canned (1 cup)	730	Cooked corn, fresh (1 cup)	28
Tomato soup, canned (1 cup)	695	Lower-sodium tomato soup, canned (1 cup)	480
Potato chips, salted (1 oz)	168	Baked potato, unsalted (1 medium)	14
Saltine crackers (4 crackers)	156	Saltine crackers, unsalted (4 crackers)	100

Data from: U.S. Department of Agriculture. 2011. USDA Nutrient Database for Standard Reference, Release 24.

- What is you consume too much sodium?
 - **Hypernatremia** – abnormally high blood sodium concentration
 - Can occur in patients with congestive heart failure or kidney disease
 - Results in high blood volume, edema, and high blood pressure
- What is you don't consume enough sodium?
 - **Hyponatremia** – an abnormally low blood sodium level
 - Can result from prolonged vomiting, diarrhea, or sweating
 - Has been seen in marathon athletes who consume too much water and fail to replace sodium

7.9 Potassium

- Functions of potassium
 - Fluid and electrolyte balance
 - Very important in muscle contractions and transmission of nerve impulses
 - High potassium intake helps to maintain a lower blood pressure
- Recommended intake
 - 4.7 g/day
- Sources of potassium

- Processed foods are usually low in potassium
- Fresh fruit and vegetables and whole grains are good sources of potassium

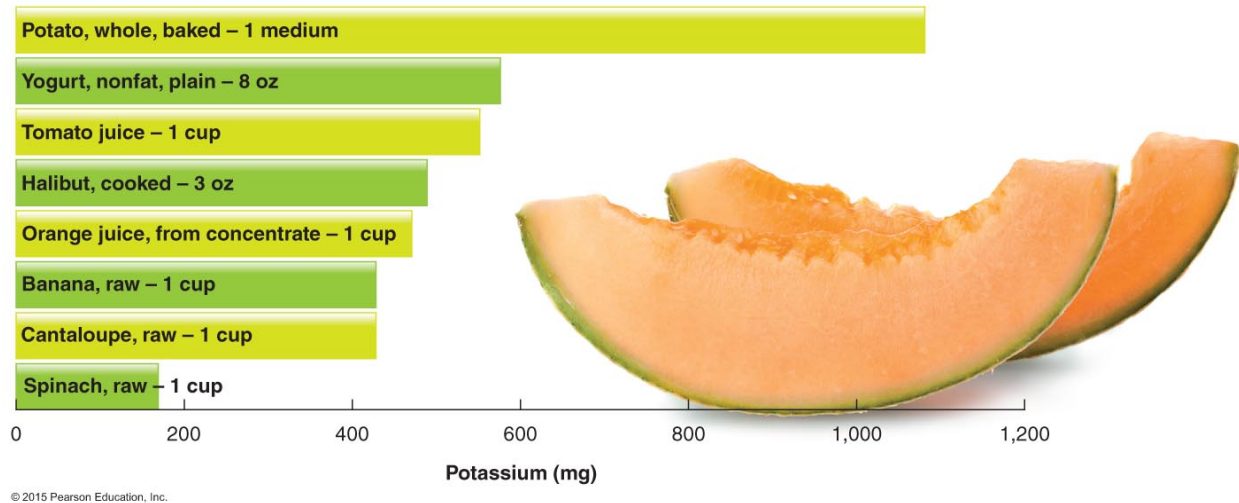


Figure 7.9: Common Food Sources of Potassium

- What if you consume too much potassium?
 - **Hyperkalemia** – a high blood potassium level
 - Can occur in patients with kidney disease
 - Can alter normal heart rhythm, resulting in a heart attack
- What if you don't consume enough potassium?
 - **Hypokalemia** – a low blood potassium level
 - Can be seen in patients with kidney disease or diabetic acidosis
 - Can occur when taking certain diuretic medications

7.10 Chloride

- Functions of chloride
 - Assists with maintaining fluid balance
 - Assists the immune system
 - Component of HCl in the stomach
- Recommended intake
 - Minimum recommendation is 2.3 g/day

- What if you consume too much chloride?
 - May lead to hypertension in salt-sensitive patients
- What if you don't consume enough chloride?
 - This is rare but can occur in people with eating disorders

7.11 Phosphorus

- Functions of phosphorus
 - The major intracellular negatively charged electrolyte
 - Required for fluid balance
 - Critical role in bone formation (85% of body's phosphorus is found in bone)
 - Regulated biochemical pathways by activating or deactivating enzymes
 - Found in ATP, DNA, RNA
- Recommended intake
 - Recommended Dietary Allowance (RDA) for phosphorus is 700 mg/day
- Sources of phosphorus
 - Widespread in many foods
 - Found in high amounts in foods that contain protein (e.g., meat, milk, eggs)

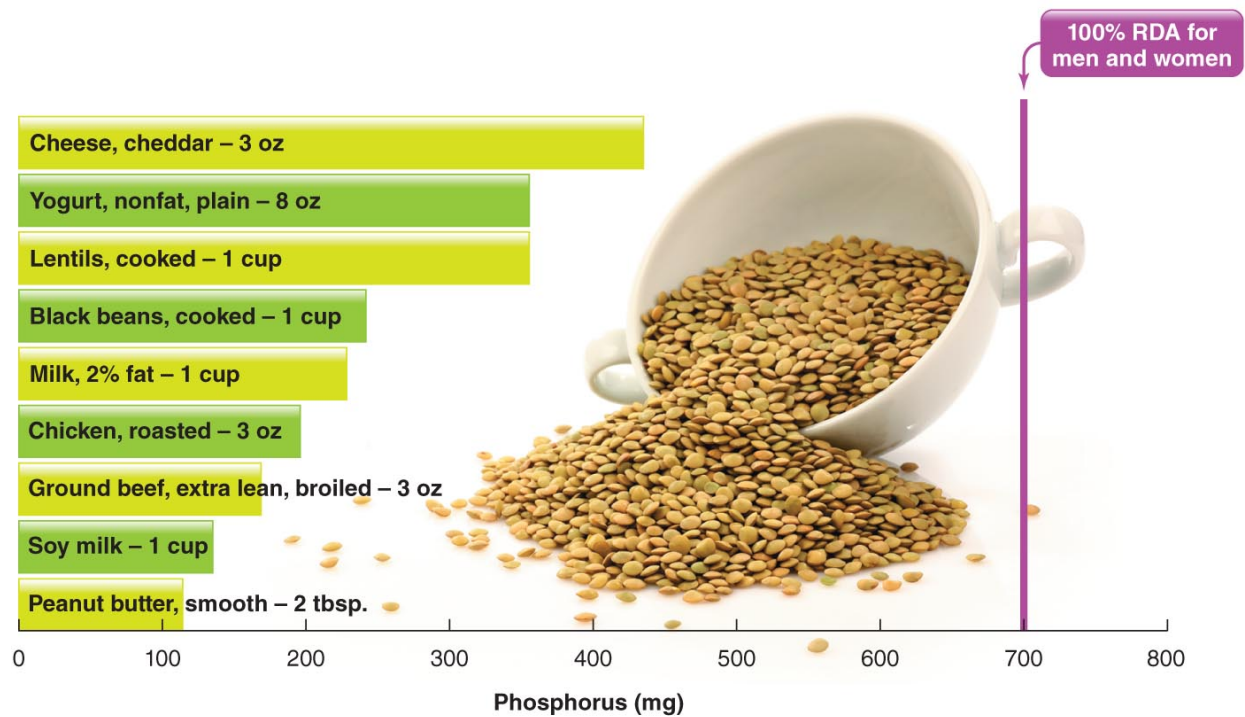


Figure 7.10: Common Food Sources of Phosphorus

- What if you consume too much phosphorus?
 - High blood levels of phosphorus can occur with kidney disease or when taking too much vitamin D supplements
 - Causes muscles spasms, and convulsions
- What if you don't consume enough phosphorus?
 - Deficiencies of phosphorus are rare

7.12 Fluid and Electrolyte Balance Disorders

- Serious health problems that can occur when fluid excretion exceeds fluid intake include
 - Dehydration
 - * Occurs when fluid excretion exceeds fluid intake
 - Heat illnesses
 - * Heat cramps
 - * Heat exhaustion
 - * Heat stroke

7.13 Dehydration

- Occurs when water loss exceeds water intake
 - Commonly due to heavy exercise or high environmental temperatures
 - Infants and the elderly are more at risk
- Other common causes of dehydration include
 - Diarrhea
 - Vomiting
 - Fever
 - Burns, including sunburn
 - Poorly controlled diabetes
 - Abuse of diuretics or laxatives
- Dehydration is classified in terms of percentage of weight loss that is exclusively due to the loss of fluids

Table 7.3: Percentages of Body Fluid Loss Correlated with Weight Loss and Symptoms

Body Water Loss (%)	Weight Lost If You Weight 160 lb	Weight Lost If You Weight 130 lb	Symptoms
1–2	1.6–3.2 lb	1.3–2.6 lb	Strong thirst, loss of appetite, feeling uncomfortable
3–5	4.8–8.0 lb	3.9–6.5 lb	Dry mouth, reduced urine output, greater difficulty working and concentrating, flushed skin, tingling extremities, impatience, sleepiness, nausea, emotional instability
6–8	9.6–12.8 lb	7.8–10.4 lb	Increased body temperature that doesn't decrease, increased heart rate and breathing rate, dizziness, difficulty breathing, slurred speech, mental confusion, muscle weakness, blue lips
9–11	14.4–17.6 lb	11.7–14.3 lb	Muscle spasms, delirium, swollen tongue, poor balance, and circulation, kidney failure, decreased blood volume and blood pressure

Data from: *Nutrition and Aerobic Exercise*, edited by D. K. Layman. ©1986 American Chemical Society.

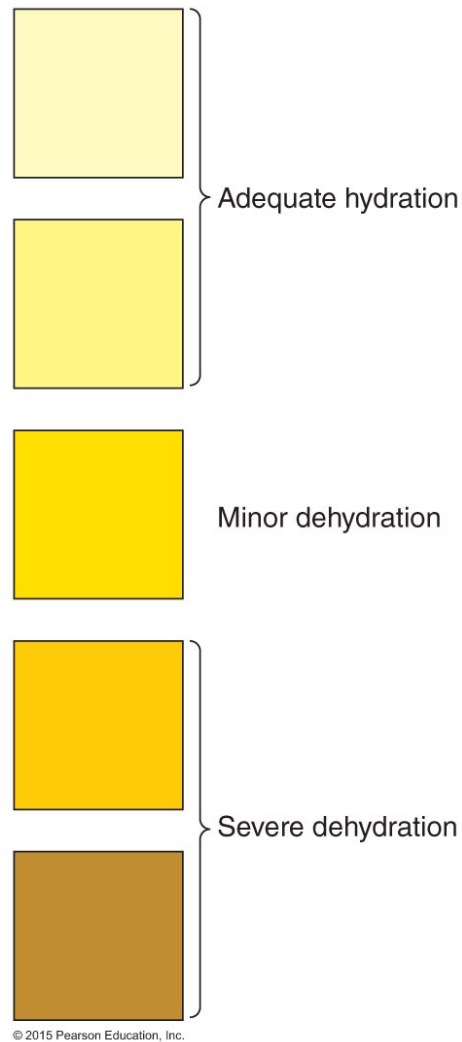


Figure 7.11: Using Urine Color to Gauge Hydration

7.14 Heat Illnesses

- Three common types of heat illnesses closely linked to dehydration are
 - Heat cramps
 - Heat exhaustion
 - Heatstroke

7.14.1 Heat Cramps

- Painful muscle cramps, usually in the abdomen, arms, or legs
- Develop during vigorous activity sessions in the heat

- Spasms can last seconds or minutes
- Important to stop activity immediately, cool down, and rest; cramps may signal a more serious problem

7.14.2 Heat Exhaustion

- Typically occurs from vigorous activity in heat
- May develop after several days in high heat when fluids are inadequate
- Symptoms include cramps, weakness, vomiting, dizziness, and elevated blood pressure and pulse
- Must be treated promptly and aggressively to prevent heatstroke from developing

7.14.3 Heatstroke

- Occurs if the body's temperature regulation mechanisms fail
- Occurs in hot, humid environments
- Symptoms include rapid pulse, hot and dry skin, high body temperature, and weakness
- Has been fatal for athletes during exercise in extreme heat
- If it occurs, provide immediate cooling and rest, and contact emergency medical help quickly

7.15 In Depth: Alcohol

- Alcohols are chemical compounds characterized by a hydroxyl group
- In common usage, beverages containing ethanol made from fermented fruits, vegetables, or grains



Figure 7.12: What Does One Drink Look Like?

- What is moderate alcohol intake?
 - A **drink** is defined as the amount of a beverage that provides $\frac{1}{2}$ fluid ounce of pure alcohol
 - **Proof** – a measurement of alcohol content
 - Moderate alcohol intake is defined as the consumption of up to one drink per day for women, and up to two drinks per day for men
- Benefits of moderate consumption include
 - Stress and anxiety reduction
 - Appetite improvement
 - Lower rates of heart disease
 - Possible lower risks for diseases such as diabetes, heart disease, and liver disease
- Concerns about moderate alcohol intake include
 - Women appear to be at higher risk of breast cancer
 - Increased risk of hypertension
 - Higher rates of bleeding in the brain

- Relatively high Calorie content
- Potential risk of adverse drug interactions

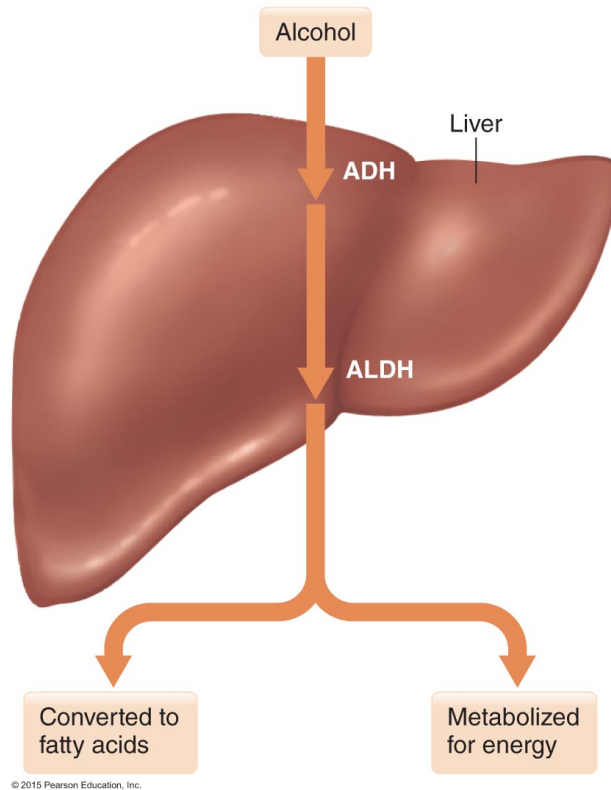


Figure 7.13: Metabolism of Alcohol

Table 7.4: Myths About Alcohol Metabolism

The Claim	The Reality
Physical activity, such as walking around, will speed up the breakdown of alcohol.	Muscles don't metabolize alcohol; the liver does.
Drinking a lot of coffee will keep you from getting drunk.	Coffee intake simply leaves you both wired and drunk.
Using a sauna or steam room will force the alcohol out of your body.	Very little alcohol is lost in sweat; the alcohol will remain in your bloodstream.
Herbal and nutritional products are available that speed up the breakdown of alcohol.	No commercial supplement is effective in increasing the rate of alcohol metabolism.

- Alcohol use disorder (AUD)
 - Medical diagnosis for problem drinking that has become severe and is characterized by either abuse or dependence

7.15.1 Types Alcohol Abuse

Alcohol abuse

excessive intake of alcohol

Binge drinking

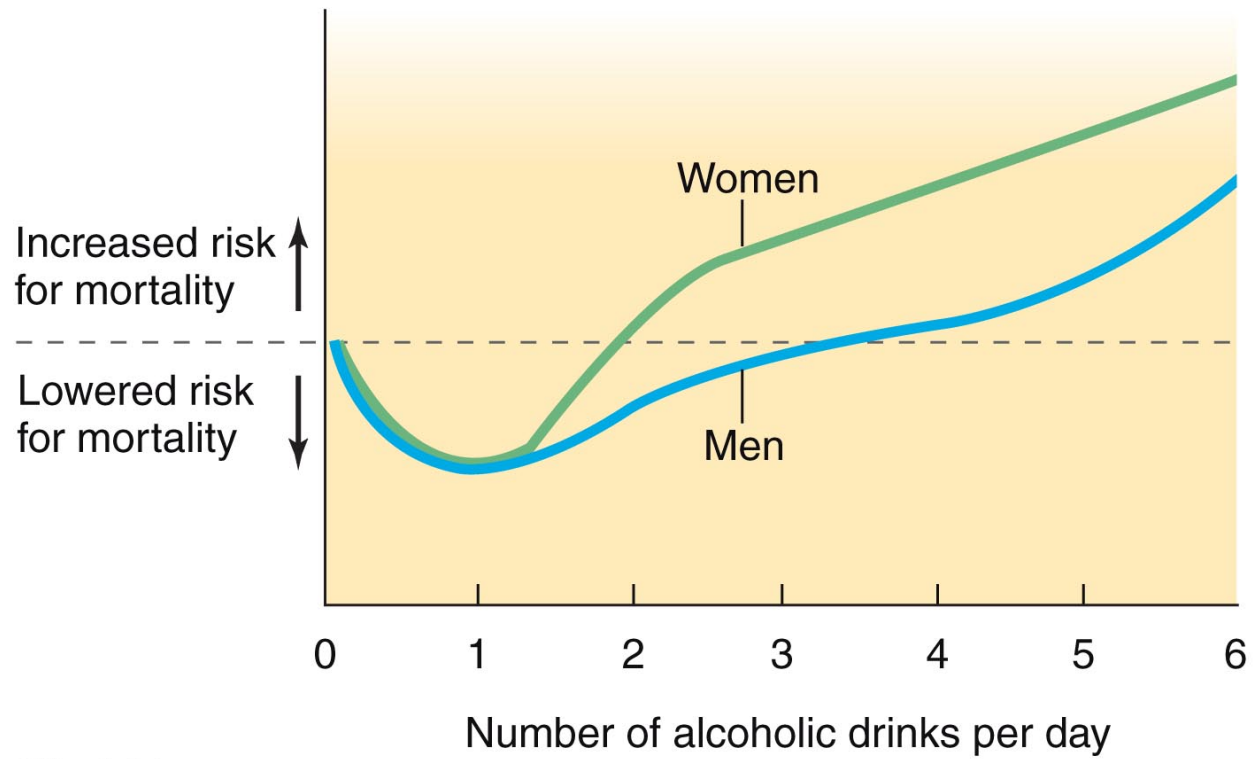
consumption of five or more drinks per occasion

Alcoholism

a disease characterized by chronic dependence on alcohol

7.15.2 Effects of alcohol abuse

- A **hangover** is a consequence of drinking too much alcohol; symptoms include headache, fatigue, dizziness, muscle aches and nausea
- Even at low intakes, alcohol impairs reasoning and judgement
- **Alcohol poisoning** – a potentially fatal metabolic state involving cardiac or respiratory failure
- Alcohol abuse can lead to traumatic injury from falls, drownings, assaults, and traffic accidents



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Figure 7.14: Effects of Alcohol on Mortality Risk

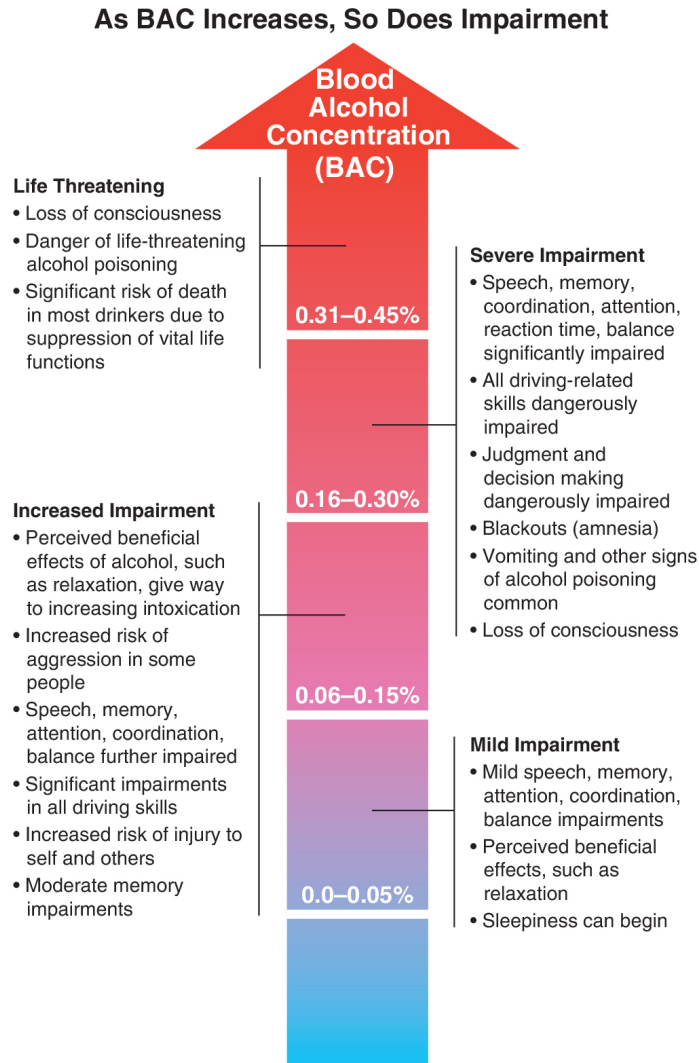
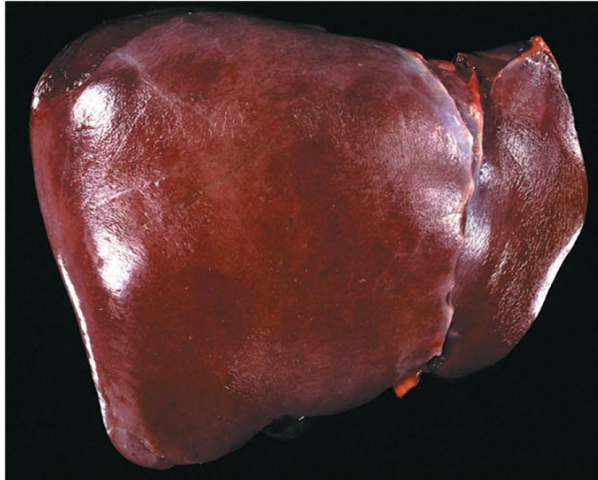
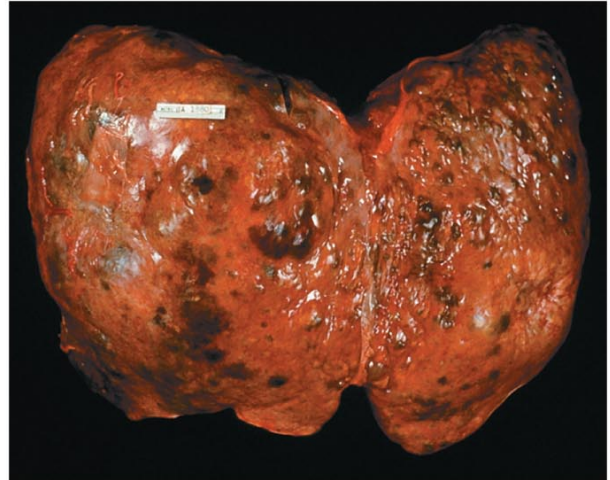


Figure 7.15: Effects of Alcohol on Brain Activity

- Effects of alcohol abuse:
 - When the rate of alcohol intake exceeds the ability of the liver to break alcohol down, liver cells are damaged or destroyed
 - Fatty liver** is an early but reversible sign of liver damage
 - Alcohol hepatitis** results in loss of appetite, nausea and vomiting, abdominal pain, and jaundice
 - Cirrhosis of the liver** involves permanent scarring after years of alcohol abuse



(a)



(b)

Figure 7.16: Cirrhosis of the liver

- Chronically high intake increases risk of
 - Impaired bone health
 - Pancreatic injury and diabetes
 - Cancer
 - Abdominal obesity
 - Malnutrition

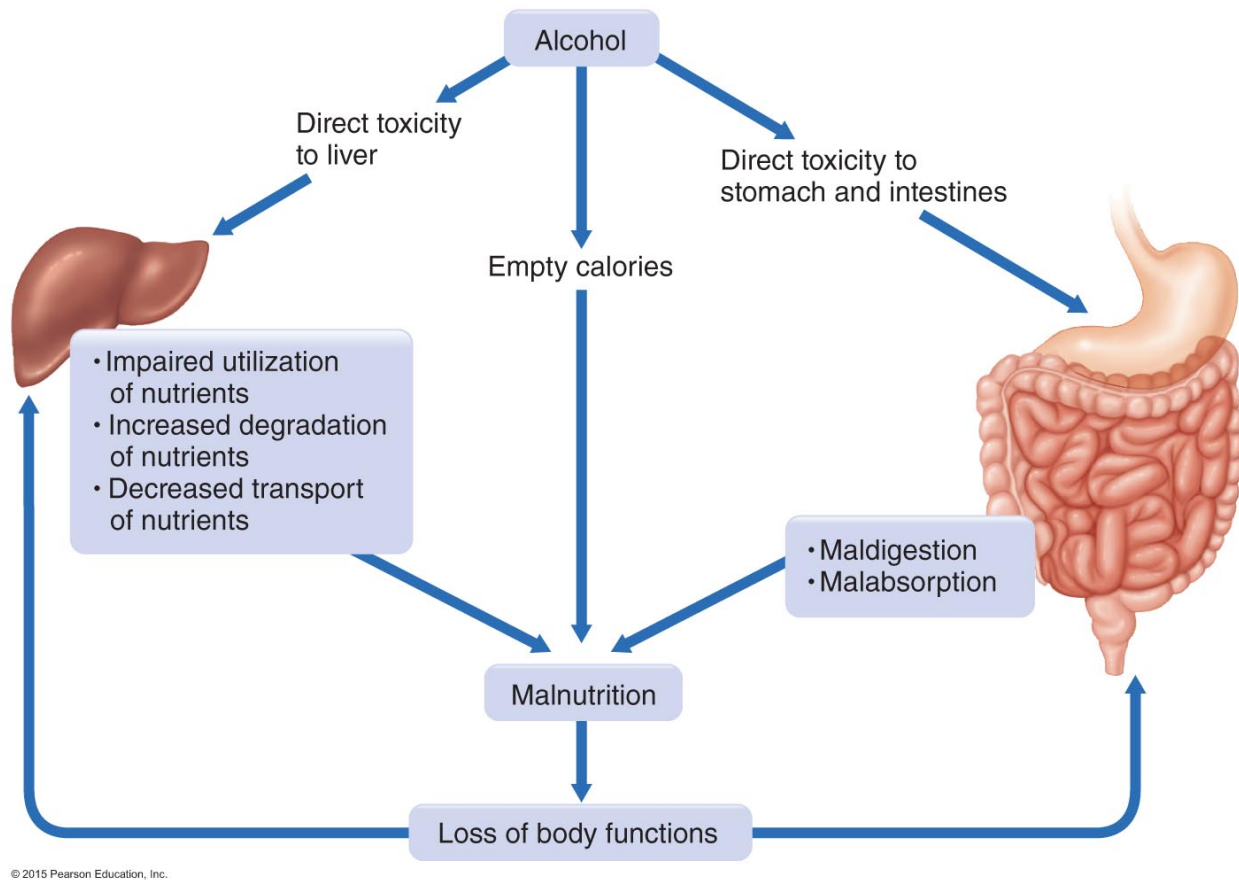


Figure 7.17: Alcohol-Related Malnutrition

- Fetal and infant health problems include
 - **Fetal alcohol syndrome (FAS)** – a set of serious, irreversible birth defects, including physical, emotional, behavioral, and developmental problems
 - **Fetal alcohol effects (FAE)** – subtler consequences that may be exhibited later, including hyperactivity, attention deficit disorder (ADD), and impaired learning abilities



Figure 7.18: Fetal Alcohol Syndrome (FAS)

- You should be concerned about your alcohol intake if you engage in binge drinking or drink at inappropriate times

- Speak with a trusted friend, coach, teacher, counselor, or healthcare provider