Atoms

- **Matter** is made up of **atoms**
- Atoms join together to form chemicals with different characteristics
- Chemical characteristics determine physiology at the molecular and cellular levels
Atoms

- **Proton**
  - Positive charge, 1 mass unit

- **Neutron**
  - Neutral, 1 mass unit

- **Electron**
  - Negative charge, low mass
Atoms

- Atomic Structure
  - Atomic number
    - Number of protons
  - Mass number
    - Number of protons plus neutrons
Atoms

- Atomic Structure
  - Nucleus
    - Contains protons and neutrons
  - Electron cloud
    - Contains electrons
FIGURE 2–1 The Structure of Hydrogen Atoms.
# Atoms

<table>
<thead>
<tr>
<th>Element</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Oxygen, O</strong></td>
<td>A component of water and other compounds; gaseous form is essential for respiration</td>
</tr>
<tr>
<td><strong>Carbon, C</strong></td>
<td>Found in all organic molecules</td>
</tr>
<tr>
<td><strong>Hydrogen, H</strong></td>
<td>A component of water and most other compounds in the body</td>
</tr>
</tbody>
</table>
### TABLE 2–1  Principal Elements in the Human Body

<table>
<thead>
<tr>
<th>Element</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen, N (3.2)</td>
<td>Found in proteins, nucleic acids, and other organic compounds</td>
</tr>
<tr>
<td>Calcium, Ca (1.8)</td>
<td>Found in bones and teeth; important for membrane function, nerve impulses, muscle contraction, and blood clotting</td>
</tr>
<tr>
<td>Phosphorus, P (1.0)</td>
<td>Found in bones and teeth, nucleic acids, and high-energy compounds</td>
</tr>
<tr>
<td>Potassium, K (0.4)</td>
<td>Important for proper membrane function, nerve impulses, and muscle contraction</td>
</tr>
</tbody>
</table>
# Atoms

## TABLE 2-1 Principal Elements in the Human Body

<table>
<thead>
<tr>
<th>Element</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium, Na (0.2)</td>
<td>Important for blood volume, membrane function, nerve impulses, and muscle contraction</td>
</tr>
<tr>
<td>Chlorine, Cl (0.2)</td>
<td>Important for blood volume, membrane function, and water absorption</td>
</tr>
<tr>
<td>Magnesium, Mg (0.06)</td>
<td>A cofactor for many enzymes</td>
</tr>
<tr>
<td>Sulfur, S (0.04)</td>
<td>Found in many proteins</td>
</tr>
</tbody>
</table>
# Atoms

## TABLE 2–1 Principal Elements in the Human Body

<table>
<thead>
<tr>
<th>Element</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron, Fe (0.007)</td>
<td>Essential for oxygen transport and energy capture</td>
</tr>
<tr>
<td>Iodine, I (0.0002)</td>
<td>A component of thyroid hormones</td>
</tr>
<tr>
<td>Trace elements:</td>
<td>Some function as cofactors; the functions of many trace elements are poorly understood</td>
</tr>
<tr>
<td>silicon (Si), fluorine (F), copper (Cu), manganese (Mn), zinc (Zn), selenium (Se), cobalt (Co), molybdenum (Mo), cadmium (Cd), chromium (Cr), tin (Sn), aluminum (Al), boron (B), and vanadium (V)</td>
<td></td>
</tr>
</tbody>
</table>
Atoms

- **Elements and Isotopes**
  - **Elements** are determined by the atomic number of an atom
    - Remember atomic number = number of protons
    - Elements are the most basic chemicals
  - **Isotopes** are the specific version of an element based on its mass number
    - Remember that mass number = number of protons plus the number of neutrons
    - Only neutrons are different because the number of protons determines the element
Atoms

- Atomic Weights
  - Exact mass of all particles
    - Measured in Daltons
  - Average of the mass numbers of the isotopes
Atoms

- Electrons and Energy Levels
  - Electrons in the electron cloud determine the **reactivity** of an atom
  - The electron cloud contains **shells**, or energy levels that hold a maximum number of electrons
    - Lower shells fill first
    - Outermost shell is the **valence shell**, and it determines bonding
    - The number of electrons per shell corresponds to the number of atoms in that row of the **periodic table**
FIGURE 2–2 The Arrangement of Electrons into Energy Levels.

(a) Hydrogen (H)

(b) Helium (He)
FIGURE 2–2 The Arrangement of Electrons into Energy Levels.

(c) Lithium (Li)

(d) Neon (Ne)
Chemical Bonds

- Chemical bonds involve the sharing, gaining, and losing of electrons in the valence shell
  - Three majors types of chemical bonds
    - Ionic bonds:
      - attraction between cations (electron donor) and anions (electron acceptor)
    - Covalent bonds:
      - strong electron bonds involving shared electrons
    - Hydrogen bonds:
      - weak polar bonds based on partial electrical attractions
Chemical Bonds

- Chemical bonds form molecules and/or compounds
  - **Molecules**
    - Two or more atoms joined by strong bonds
  - **Compounds**
    - Two or more atoms of different elements joined by strong or weak bonds
- Compounds are all molecules, but not all molecules are compounds
  - $\text{H}_2 = \text{molecule only}$
  - $\text{H}_2\text{O} = \text{molecule and compound}$
Chemical Bonds

- Ionic Bonds
  - One atom— **the electron donor** —loses one or more electrons and becomes a cation, with a positive charge
  - Another atom— **the electron acceptor** —gains those same electrons and becomes an anion, with a negative charge
  - Attraction between the opposite charges then draws the two ions together
Chemical Bonds

FIGURE 2–3 The Formation of Ionic Bonds.

(a) Formation of an ionic bond
Chemical Bonds

Chloride ions (Cl⁻)  Sodium ions (Na⁺)

(b) Sodium chloride crystal

FIGURE 2–3 The Formation of Ionic Bonds.
Chemical Bonds

- **Covalent Bonds**
  - Involve the sharing of pairs of electrons between atoms
    - One electron is donated by each atom to make the pair of electrons
    - Sharing one pair of electrons is a **single covalent bond**
    - Sharing two pairs of electrons is a **double covalent bond**
    - Sharing three pairs of electrons is a **triple covalent bond**
## Chemical Bonds

### FIGURE 2–4 Covalent Bonds in Four Common Molecules.

<table>
<thead>
<tr>
<th>MOLECULE</th>
<th>ELECTRON-SHELL MODEL AND STRUCTURAL FORMULA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen ($\text{H}_2$)</td>
<td>$\text{H}–\text{H}$</td>
</tr>
<tr>
<td>Oxygen ($\text{O}_2$)</td>
<td>$\text{O}–\text{O}$</td>
</tr>
<tr>
<td>Carbon dioxide ($\text{CO}_2$)</td>
<td>$\text{O}–\text{C}–\text{O}$</td>
</tr>
<tr>
<td>Nitric oxide ($\text{NO}$)</td>
<td>$\text{N}–\text{O}$</td>
</tr>
</tbody>
</table>
Chemical Bonds

- **Covalent Bonds**
  - **Nonpolar covalent bonds**
    - Involve *equal* sharing of electrons because atoms involved in the bond have equal pull for the electrons
  - **Polar covalent bonds**
    - Involve the *unequal* sharing of electrons because one of the atoms involved in the bond has a disproportionately strong pull on the electrons
    - Form *polar molecules* — like water
Chemical Bonds

FIGURE 2–5 Polar Covalent Bonds and the Structure of Water.
Chemical Bonds

- **Hydrogen Bonds**
  - Bonds between adjacent molecules, not atoms
  - Involve slightly positive and slightly negative portions of polar molecules being attracted to one another
  - **Hydrogen bonds** between H$_2$O molecules cause **surface tension**
Chemical Bonds

FIGURE 2–6 Hydrogen Bonds between Water Molecules.
Chemical Bonds

- **States of Matter**
  - **Solid**
    - Constant volume and shape
  - **Liquid**
    - Constant volume but changes shape
  - **Gas**
    - Changes volume and shape
Chemical Bonds

- **Molecular Weights**
  - The molecular weight of a molecule is the sum of the atomic weights of its component atoms
    - $H = \text{approximately } 1$
    - $O = \text{approximately } 16$
    - $H_2 = \text{approximately } 2$
    - $H_2O = \text{approximately } 18$
Introduction to Chemical Reactions

- **Reactants**
  - Materials going into a reaction

- **Products**
  - Materials coming out of a reaction

- **Metabolism**
  - All of the reactions that are occurring at one time
Chemical Reactions

- Basic Energy Concepts
  - Energy
    - The power to do work
  - Work
    - A change in mass or distance
  - Kinetic energy
    - Energy of motion
  - Potential energy
    - Stored energy
  - Chemical energy
    - Potential energy stored in chemical bonds
Chemical Reactions

- **Decomposition reaction** (catabolism)
  - Breaks chemical bonds
  - \( AB \rightarrow A + B \)
  - Hydrolysis: \( ABCDE + H_2O \rightarrow ABC\text{—}H + HO\text{—}DE \)

- **Synthesis reaction** (anabolism)
  - Forms chemical bonds
  - \( A + B \rightarrow AB \)
  - Dehydration synthesis (condensation)
    \[ ABC\text{—}H + HO\text{—}DE \rightarrow ABCDE + H_2O \]
Chemical Reactions

- Exchange reaction
  - Involves decomposition first, then synthesis
  - $\text{AB} + \text{CD} \rightarrow \text{AD} + \text{CB}$
Chemical Reactions

- **Reversible reaction**
  - A reaction that occurs simultaneously in both directions
  - $AB \leftrightarrow A + B$
  - At equilibrium the amounts of chemicals do not change even though the reactions are still occurring:
    - reversible reactions seek equilibrium, balancing opposing reaction rates
    - add or remove reactants:
      - reaction rates adjust to reach a new equilibrium
# Chemical Reactions

## TABLE 2-2 Rules of Chemical Notation

1. The symbol of an element indicates one atom of that element:
   - \( H \) = one atom of hydrogen
   - \( O \) = one atom of oxygen

2. A number preceding the symbol of an element indicates more than one atom of that element:
   - \( 2H \) = two atoms of hydrogen
   - \( 2O \) = two atoms of oxygen

3. A subscript following the symbol of an element indicates a molecule with that number of atoms of that element:
   - \( H_2 \) = hydrogen molecule, composed of two hydrogen atoms
   - \( O_2 \) = oxygen molecule, composed of two oxygen atoms
   - \( H_2O \) = water molecule, composed of two hydrogen atoms and one oxygen atom

4. In a description of a chemical reaction, the participants at the start of the reaction are called reactants, and the reaction generates one or more products. An arrow indicates the direction of the reaction, from reactants (usually on the left) to products (usually on the right). In the following reaction, two atoms of hydrogen combine with one atom of oxygen to produce a single molecule of water:
   - \( 2H + O \rightarrow H_2O \)

5. A superscript plus or minus sign following the symbol of an element indicates an ion. A single plus sign indicates a cation with a charge of +1. (The original atom has lost one electron.) A single minus sign indicates an anion with a charge of −1. (The original atom has gained one electron.) If more than one electron has been lost or gained, the charge on the ion is indicated by a number preceding the plus or minus sign:
   - \( Na^+ \) = sodium ion [the sodium atom has lost one electron]
   - \( Cl^- \) = chloride ion [the chlorine atom has gained one electron]
   - \( Ca^{2+} \) = calcium ion [the calcium atom has lost two electrons]

6. Chemical reactions neither create nor destroy atoms; they merely rearrange atoms into new combinations. Therefore, the numbers of atoms of each element must always be the same on both sides of the equation for a chemical reaction. When this is the case, the equation is balanced:
   - Unbalanced : \( H_2 + O_2 \rightarrow H_2O \)
   - Balanced : \( 2H_2 + O_2 \rightarrow 2H_2O \)
Enzymes

- Chemical reactions in cells cannot start without help
  - Activation energy is the amount of energy needed to get a reaction started
  - Enzymes are protein catalysts that lower the activation energy of reactions
Enzymes

FIGURE 2–7 The Effect of Enzymes on Activation Energy.
Enzymes

- **Exergonic** (exothermic) reactions
  - Produce more energy than they use

- **Endergonic** (endothermic) reactions
  - Use more energy than they produce
Inorganic Versus Organic Compounds

- **Nutrients**
  - Essential molecules obtained from food

- **Metabolites**
  - Molecules made or broken down in the body

- **Inorganic**
  - Molecules not based on carbon and hydrogen
  - Carbon dioxide, oxygen, water, and inorganic acids, bases, and salts

- **Organic**
  - Molecules based on carbon and hydrogen
  - Carbohydrates, proteins, lipids, nucleic acids
Importance of Water

- Water accounts for up to two-thirds of your total body weight.
- A solution is a uniform mixture of two or more substances.
  - It consists of a solvent, or medium, in which atoms, ions, or molecules of another substance, called a solute, are individually dispersed.
Importance of Water

- **Solubility**
  - Water’s ability to dissolve a **solute** in a **solvent** to make a **solution**

- **Reactivity**
  - Most body chemistry occurs in water

- **High heat capacity**
  - Water’s ability to absorb and retain heat

- **Lubrication**
  - To moisten and reduce friction
The Properties of Aqueous Solutions

- Ions and polar compounds undergo *ionization*, or *dissociation* in water
- Polar water molecules form *hydration spheres* around ions and small polar molecules to keep them in solution
FIGURE 2–8 The Activities of Water Molecules in Aqueous Solutions.
# Importance of Water

## TABLE 2–3 Important Electrolytes That Dissociate in Body Fluids

<table>
<thead>
<tr>
<th>Electrolyte</th>
<th>Ions Released</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaCl (sodium chloride)</td>
<td>Na&lt;sup&gt;+&lt;/sup&gt; + Cl&lt;sup&gt;-&lt;/sup&gt;</td>
</tr>
<tr>
<td>KCl (potassium chloride)</td>
<td>K&lt;sup&gt;+&lt;/sup&gt; + Cl&lt;sup&gt;-&lt;/sup&gt;</td>
</tr>
<tr>
<td>CaPO&lt;sub&gt;4&lt;/sub&gt; (calcium phosphate)</td>
<td>Ca&lt;sup&gt;2+&lt;/sup&gt; + PO&lt;sub&gt;4&lt;/sub&gt;&lt;sup&gt;2-&lt;/sup&gt;</td>
</tr>
<tr>
<td>NaHCO&lt;sub&gt;3&lt;/sub&gt; (sodium bicarbonate)</td>
<td>Na&lt;sup&gt;+&lt;/sup&gt; + HCO&lt;sub&gt;3&lt;/sub&gt;−</td>
</tr>
<tr>
<td>MgCl&lt;sub&gt;2&lt;/sub&gt; (magnesium chloride)</td>
<td>Mg&lt;sup&gt;2+&lt;/sup&gt; + 2Cl&lt;sup&gt;-&lt;/sup&gt;</td>
</tr>
<tr>
<td>Na&lt;sub&gt;2&lt;/sub&gt;HPO&lt;sub&gt;4&lt;/sub&gt; (sodium hydrogen phosphate)</td>
<td>2Na&lt;sup&gt;+&lt;/sup&gt; + HPO&lt;sub&gt;4&lt;/sub&gt;&lt;sup&gt;2-&lt;/sup&gt;</td>
</tr>
<tr>
<td>Na&lt;sub&gt;2&lt;/sub&gt;SO&lt;sub&gt;4&lt;/sub&gt; (sodium sulfate)</td>
<td>2Na&lt;sup&gt;+&lt;/sup&gt; + SO&lt;sub&gt;4&lt;/sub&gt;&lt;sup&gt;2-&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
Importance of Water

The Properties of Aqueous Solutions

Electrolytes and body fluids

- Electrolytes are inorganic ions that conduct electricity in solution
- **Electrolyte imbalance** seriously disturbs vital body functions
Importance of Water

The Properties of Aqueous Solutions

Hydrophilic and hydrophobic compounds

Hydrophilic
- hydro- = water, philos = loving
- interacts with water
- includes ions and polar molecules

Hydrophobic
- phobos = fear
- does NOT interact with water
- includes nonpolar molecules, fats, and oils
Importance of Water

- Colloids and Suspensions
  - Colloid
    - A solution of very large organic molecules
    - For example, blood plasma
  - Suspension
    - A solution in which particles settle (sediment)
    - For example, whole blood
  - Concentration
    - The amount of solute in a solvent (mol/L, mg/mL)
pH and Homeostasis

- **pH**
  - The concentration of hydrogen ions (H\(^+\)) in a solution

- **Neutral pH**
  - A balance of H\(^+\) and OH\(^-\)
  - Pure water = 7.0

- **pH of human blood**
  - Ranges from 7.35 to 7.45
pH and Homeostasis

- **Acidic**: pH lower than 7.0
  - High H\(^+\) concentration
  - Low OH\(^-\) concentration

- **Basic (or alkaline)**: pH higher than 7.0
  - Low H\(^+\) concentration
  - High OH\(^-\) concentration
pH and Homeostasis

- **pH Scale**
  - Has an *inverse* relationship with $H^+$ concentration
    - More $H^+$ ions mean *lower* pH, less $H^+$ ions mean *higher* pH
pH and Homeostasis

FIGURE 2–9 pH and Hydrogen Ion Concentration.
Acids, Bases, and Salts

- **Acid**
  - A solute that adds hydrogen ions to a solution
  - Proton donor
  - Strong acids dissociate completely in solution

- **Base**
  - A solute that removes hydrogen ions from a solution
  - Proton acceptor
  - Strong bases dissociate completely in solution

- **Weak acids and weak bases**
  - Fail to dissociate completely
  - Help to balance the pH
Acids, Bases, and Salts

- **Salts**
  - Solutes that dissociate into cations and anions other than hydrogen ions and hydroxide ions
Buffers and pH Control

Buffers

- Weak acid/salt compounds
- Neutralizes either strong acid or strong base
- Sodium bicarbonate is very important in humans

Antacids

- A basic compound that neutralizes acid and forms a salt
- Tums, Rolaids, etc
Organic Molecules

- Contain H, C, and usually O
- Covalently bonded
- Contain functional groups that determine chemistry
  - Carbohydrates
  - Lipids
  - Proteins (or amino acids)
  - Nucleic acids
# Organic Molecules

## TABLE 2-4 Important Functional Groups of Organic Compounds

<table>
<thead>
<tr>
<th>Functional Group</th>
<th>Structural Formula*</th>
<th>Importance</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carboxylic acid, — COOH</td>
<td><img src="image" alt="Structural Formula" /></td>
<td>Acts as an acid, releasing H⁺ to become R—COO⁻</td>
<td>Fatty acids, amino acids</td>
</tr>
<tr>
<td>Amino group, — NH₂</td>
<td><img src="image" alt="Structural Formula" /></td>
<td>Can accept or release H⁺, depending on pH; can form bonds with other molecules</td>
<td>Amino acids</td>
</tr>
<tr>
<td>Hydroxyl group, — OH</td>
<td><img src="image" alt="Structural Formula" /></td>
<td>Strong bases dissociate to release hydroxide ions [OH⁻]; may link molecules through dehydration synthesis (condensation)</td>
<td>Carbohydrates, fatty acids, amino acids</td>
</tr>
<tr>
<td>Phosphate group, — PO₄</td>
<td><img src="image" alt="Structural Formula" /></td>
<td>May link other molecules to form larger structures; may store energy in high-energy bonds</td>
<td>Phospholipids, nucleic acids, high-energy compounds</td>
</tr>
</tbody>
</table>

*The term R group is used to denote the rest of the molecule, whatever that might be. The R group is also known as a side chain.*
Carbohydrates

- Carbohydrates contain carbon, hydrogen, and oxygen in a 1:2:1 ratio
  - Monosaccharide — simple sugar
  - Disaccharide — two sugars
  - Polysaccharide — many sugars
Carbohydrates

- **Monosaccharides**
  - Simple sugars with 3 to 7 carbon atoms
  - Glucose, fructose, galactose

- **Disaccharides**
  - Two simple sugars condensed by dehydration synthesis
  - Sucrose, maltose

- **Polysaccharides**
  - Many monosaccharides condensed by dehydration synthesis
  - Glycogen, starch, cellulose
FIGURE 2–10 The Structure of Glucose.
FIGURE 2–11 The Formation and Breakdown of Complex Sugars.
FIGURE 2–11 The Formation and Breakdown of Complex Sugars.

Sucrose
FIGURE 2–11 The Formation and Breakdown of Complex Sugars.
FIGURE 2–11 The Formation and Breakdown of Complex Sugars.
Carbohydrates

FIGURE 2–12 The Structure of the Polysaccharide Glycogen.
# Carbohydrates

## TABLE 2–5 Carbohydrates in the Body

<table>
<thead>
<tr>
<th>Structural Class</th>
<th>Examples</th>
<th>Primary Function</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Monosaccharides</strong></td>
<td>Glucose, fructose</td>
<td>Energy source</td>
<td>Manufactured in the body and obtained from food; distributed in body fluids</td>
</tr>
<tr>
<td><strong>(simple sugars)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Disaccharides</strong></td>
<td>Sucrose, lactose, maltose</td>
<td>Energy source</td>
<td>Sucrose is table sugar, lactose is in milk, and maltose is malt sugar; all must be broken down to monosaccharides before absorption</td>
</tr>
<tr>
<td><strong>Polysaccharides</strong></td>
<td>Glycogen</td>
<td>Storage of glucose</td>
<td>Glycogen is in animal cells; other starches and cellulose are within or surround plant cells</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Lipids

- Mainly hydrophobic molecules such as fats, oils, and waxes
- Made mostly of carbon and hydrogen atoms
- Include
  - Fatty acids
  - Eicosanoids
  - Glycerides
  - Steroids
  - Phospholipids and glycolipids
Lipids

- **Fatty Acids**
  - Long chains of carbon and hydrogen with a *carboxylic acid group* (COOH) at one end
  - Are relatively nonpolar, *except* the carboxylic group
  - Fatty acids may be
    - **Saturated** with hydrogen (no covalent bonds)
    - **Unsaturated** (one or more double bonds):
      - monounsaturated = one double bond
      - polyunsaturated = two or more double bonds
Lauric acid (C\textsubscript{12}H\textsubscript{24}O\textsubscript{2})

(a)

FIGURE 2–13 Fatty Acids.
FIGURE 2–13 Fatty Acids.
Lipids

- **Eicosanoids**
  - Derived from the fatty acid called *arachidonic acid*
- **Leukotrienes**
  - Active in immune system
- **Prostaglandins**
  - Local hormones, short-chain fatty acids
FIGURE 2–14 Prostaglandins.
Lipids

- **Glycerides**
  - Fatty acids attached to a glycerol molecule
  - **Triglycerides** are the three fatty-acid tails
    - Also called triacylglycerols or neutral fats
    - Have three important functions:
      - energy source
      - insulation
      - protection
FIGURE 2–15 Triglyceride Formation.
Lipids

- Steroids
  - Four rings of carbon and hydrogen with an assortment of functional groups
- Types of steroids
  - Cholesterol:
    - component of plasma (cell) membranes
  - Estrogens and testosterone:
    - sex hormones
  - Corticosteroids and calcitriol:
    - metabolic regulation
  - Bile salts:
    - derived from steroids
FIGURE 2–16 Steroids.
Lipids

- **Phospholipids and Glycolipids**
  - **Diglycerides** attached to either a phosphate group (phospholipid) or a sugar (glycolipid)
  - Generally, both have hydrophilic heads and hydrophobic tails and are structural lipids, components of plasma (cell) membranes
(a) Phospholipid

FIGURE 2–17 Phospholipids and Glycolipids.
FIGURE 2–17 Phospholipids and Glycolipids.
FIGURE 2–17 Phospholipids and Glycolipids.
<table>
<thead>
<tr>
<th>Lipid Type</th>
<th>Example(s)</th>
<th>Primary Function(s)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fatty acids</strong></td>
<td>Lauric acid</td>
<td>Energy source</td>
<td>Absorbed from food or synthesized in cells; transported in the blood</td>
</tr>
<tr>
<td><strong>Eicosanoids</strong></td>
<td>Prostaglandins, leukotrienes</td>
<td>Chemical messengers coordinating local cellular activities</td>
<td>Prostaglandins are produced in most body tissues</td>
</tr>
<tr>
<td><strong>Glycerides</strong></td>
<td>Monoglycerides, diglycerides, triglycerides</td>
<td>Energy source, energy storage, insulation, and physical protection</td>
<td>Stored in fat deposits; must be broken down to fatty acids and glycerol before they can be used as an energy source</td>
</tr>
<tr>
<td><strong>Steroids</strong></td>
<td>Cholesterol, estrogen, testosterone</td>
<td>Structural component of plasma membranes, hormones, digestive secretions in bile</td>
<td>All have the same carbon ring framework</td>
</tr>
<tr>
<td><strong>Phospholipids, glycolipids</strong></td>
<td>Lecithin (a phospholipid)</td>
<td>Structural components of plasma membranes</td>
<td>Derived from fatty acids and nonlipid components</td>
</tr>
</tbody>
</table>
Proteins

- **Proteins** are the most abundant and important organic molecules
- Contain basic elements
  - Carbon (C), hydrogen (H), oxygen (O), and nitrogen (N)
- Basic building blocks
  - 20 amino acids
Proteins

Seven major protein functions

- **Support**
  - Structural proteins
- **Movement**
  - Contractile proteins
- **Transport**
  - Transport (carrier) proteins
- **Buffering**
  - Regulation of pH
- **Metabolic regulation**
  - Enzymes
- **Coordination and control**
  - Hormones
- **Defense**
  - Antibodies
Proteins

- **Protein Structure**
  - Long chains of amino acids
  - **Amino acid structure**
    - Central carbon atom
    - Hydrogen atom
    - Amino group (—NH₂)
    - Carboxylic acid group (—COOH)
    - Variable side chain or **R group**
Proteins

Structure of an amino acid

FIGURE 2–18 Amino Acids.
Proteins

- Hooking amino acids together requires
  - A dehydration synthesis between
    - The amino group of one amino acid
    - And the carboxylic acid group of another amino acid
  - Producing a peptide
FIGURE 2–19 The Formation of Peptide Bonds.
Proteins

- **Protein Shape**
  - **Primary structure**
    - The sequence of amino acids along a polypeptide
  - **Secondary structure**
    - Hydrogen bonds form spirals or pleats
  - **Tertiary structure**
    - Secondary structure folds into a unique shape
  - **Quaternary structure**
    - Final protein shape:
      - several tertiary structures together
FIGURE 2-20 Protein Structure.
Proteins

(c) Tertiary structure

Heme units

Hemoglobin (globular protein)

(d) Quaternary structure

FIGURE 2–20 Protein Structure.
Proteins

- **Fibrous proteins**
  - Structural sheets or strands

- **Globular proteins**
  - Soluble spheres with active functions
  - Protein function is based on shape

- Shape is based on sequence of amino acids
FIGURE 2–20 Protein Structure.
Proteins

- Enzyme Function
  - Enzymes are catalysts
    - Proteins that lower the activation energy of a chemical reaction
    - Are not changed or used up in the reaction
  - Enzymes are also
    - specific — will only work on limited types of substrates
    - limited — by their saturation
    - regulated — by other cellular chemicals
Proteins

FIGURE 2–21 A Simplified View of Enzyme Structure and Function.

STEP 1
Substrates bind to active site of enzyme

STEP 2
Aided by enzyme, substrates interact to form product

STEP 3
Product detaches from enzyme; entire process can now be repeated
Cofactors and Enzyme Function

- **Cofactor**
  - An ion or molecule that binds to an enzyme before substrates can bind

- **Coenzyme**
  - Nonprotein organic cofactors (vitamins)

- **Isozymes**
  - Two enzymes that can catalyze the same reaction
Proteins

- Effects of Temperature and pH on Enzyme Function
  - Denaturation
    - Loss of shape and function due to heat or pH
Proteins

- Glycoproteins and Proteoglycans
  - Glycoproteins
    - Large protein + small carbohydrate
      - includes enzymes, antibodies, hormones, and mucus production
  - Proteoglycans
    - Large polysaccharides + polypeptides
      - promote viscosity
Nucleic Acids

- Nucleic acids are large organic molecules, found in the nucleus, which *store and process information* at the molecular level
  - Deoxyribonucleic Acid (DNA)
    - Determines inherited characteristics
    - Directs protein synthesis
    - Controls enzyme production
    - Controls metabolism
  - Ribonucleic Acid (RNA)
    - Controls intermediate steps in protein synthesis
Nucleic Acids

Structure of Nucleic Acids

- DNA and RNA are strings of nucleotides

Nucleotides

- Are the building blocks of DNA and RNA
- Have three molecular parts:
  - A sugar (deoxyribose or ribose)
  - phosphate group
  - nitrogenous base (A, G, T, C, or U)
FIGURE 2–22 Nucleotides and Nitrogenous Bases.
FIGURE 2–22 Nucleotides and Nitrogenous Bases.
FIGURE 2–22 Nucleotides and Nitrogenous Bases.
Nucleic Acids

- DNA is double stranded, and the bases form hydrogen bonds to hold the DNA together
- Sometimes RNA can bind to itself but is usually a single strand
- DNA forms a twisting double helix
- Complementary base pairs
  - Purines pair with pyrimidines
    - DNA:
      - adenine (A) and thymine (T)
      - cytosine (C) and guanine (G)
    - RNA:
      - uracil (U) replaces thymine (T)
FIGURE 2–23 The Structure of Nucleic Acids.
Nucleic Acids

- Types of RNA
  - Messenger RNA (mRNA)
  - Transfer RNA (tRNA)
  - Ribosomal RNA (rRNA)
# Nucleic Acids

## TABLE 2–7 Comparison of RNA with DNA

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>RNA</th>
<th>DNA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sugar</strong></td>
<td>Ribose</td>
<td>Deoxyribose</td>
</tr>
<tr>
<td><strong>Nitrogenous bases</strong></td>
<td>Adenine (A)</td>
<td>Adenine</td>
</tr>
<tr>
<td></td>
<td>Guanine (G)</td>
<td>Guanine</td>
</tr>
<tr>
<td></td>
<td>Cytosine (C)</td>
<td>Cytosine</td>
</tr>
<tr>
<td></td>
<td>Uracil (U)</td>
<td>Thymine (T)</td>
</tr>
<tr>
<td><strong>Number of nucleotides in</strong></td>
<td>Varies from fewer than 100</td>
<td>Always more</td>
</tr>
<tr>
<td><strong>typical molecule</strong></td>
<td>nucleotides to about 50,000</td>
<td>than 45 million</td>
</tr>
<tr>
<td><strong>Shape of molecule</strong></td>
<td>Varies with hydrogen bonding</td>
<td>Paired strands</td>
</tr>
<tr>
<td></td>
<td>along the length of the</td>
<td>coiled in a</td>
</tr>
<tr>
<td></td>
<td>strand; three main types (mRNA, rRNA, tRNA)</td>
<td>double helix</td>
</tr>
<tr>
<td><strong>Function</strong></td>
<td>Performs protein synthesis</td>
<td>Stores genetic</td>
</tr>
<tr>
<td></td>
<td>as directed by DNA</td>
<td>information</td>
</tr>
<tr>
<td></td>
<td></td>
<td>that controls</td>
</tr>
<tr>
<td></td>
<td></td>
<td>protein</td>
</tr>
<tr>
<td></td>
<td></td>
<td>synthesis</td>
</tr>
</tbody>
</table>
ATP

- Nucleotides can be used to store energy
  - Adenosine diphosphate (ADP)
    - Two phosphate groups; di- = 2
  - Adenosine triphosphate (ATP)
    - Three phosphate groups; tri- = 3
- Adding a phosphate group to ADP with a high-energy bond to form the high-energy compound ATP
- ATPase
  
  The enzyme that catalyzes phosphorylation (the addition of a high-energy phosphate group to a molecule)
FIGURE 2–24 The Structure of ATP.
Chemicals Form Cells

- Biochemical building blocks form functional units called cells
- **Metabolic turnover** lets your body grow, change, and adapt to new conditions and activities
- Your body recycles and renews all of its chemical components at intervals ranging from minutes to years
# Chemicals Form Cells

## SUMMARY TABLE 2-8  Classes of Inorganic and Organic Compounds

<table>
<thead>
<tr>
<th>Class</th>
<th>Building Blocks</th>
<th>Sources</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INORGANIC</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>Hydrogen and oxygen atoms</td>
<td>Absorbed from the diet or generated by metabolism</td>
<td>Solvent; transport medium for dissolved materials and heat; cooling through evaporation; medium for chemical reactions; reactant in hydrolysis</td>
</tr>
<tr>
<td>Acids, bases, salts</td>
<td>H(^+), OH(^-), various anions and cations</td>
<td>Obtained from the diet or generated by metabolism</td>
<td>Structural components; buffers; sources of ions</td>
</tr>
<tr>
<td>Dissolved gases</td>
<td>O, C, N, and other atoms</td>
<td>Atmosphere, metabolism</td>
<td>O(_2): required for cellular metabolism</td>
</tr>
<tr>
<td><strong>ORGANIC</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>C, H, O, in some cases N; CHO in a 1:2:1 ratio</td>
<td>Obtained from the diet or manufactured in the body</td>
<td>Energy source; some structural role when attached to lipids or proteins; energy storage</td>
</tr>
<tr>
<td>Lipids</td>
<td>C, H, O, in some cases N or P; CHO not in 1:2:1 ratio</td>
<td>Obtained from the diet or manufactured in the body</td>
<td>Energy source; energy storage; insulation; structural components; chemical messengers; protection</td>
</tr>
<tr>
<td>Proteins</td>
<td>C, H, O, N, commonly S</td>
<td>20 common amino acids; roughly half can be manufactured in the body, others must be obtained from the diet</td>
<td>Catalysts for metabolic reactions; structural components; movement; transport; buffers; defense; control and coordination of activities</td>
</tr>
<tr>
<td>Nucleic acids</td>
<td>C, H, O, N, and P; nucleotides composed of phosphates, sugars, and nitrogenous bases</td>
<td>Obtained from the diet or manufactured in the body</td>
<td>Storage and processing of genetic information</td>
</tr>
<tr>
<td>High-energy compounds</td>
<td>Nucleotides joined to phosphates by high-energy bonds</td>
<td>Synthesized by all cells</td>
<td>Storage or transfer of energy</td>
</tr>
</tbody>
</table>
## Chemicals Form Cells

### TABLE 2–9  Turnover Times

<table>
<thead>
<tr>
<th>Cell Type</th>
<th>Component</th>
<th>Average Recycling Time*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liver</td>
<td>Total protein</td>
<td>5–6 days</td>
</tr>
<tr>
<td></td>
<td>Enzymes</td>
<td>1 hour to several days, depending on the enzyme</td>
</tr>
<tr>
<td></td>
<td>Glycogen</td>
<td>1–2 days</td>
</tr>
<tr>
<td></td>
<td>Cholesterol</td>
<td>5–7 days</td>
</tr>
<tr>
<td>Muscle cell</td>
<td>Total protein</td>
<td>30 days</td>
</tr>
<tr>
<td></td>
<td>Glycogen</td>
<td>12–24 hours</td>
</tr>
<tr>
<td>Neuron</td>
<td>Phospholipids</td>
<td>200 days</td>
</tr>
<tr>
<td></td>
<td>Cholesterol</td>
<td>100+ days</td>
</tr>
<tr>
<td>Fat cell</td>
<td>Triglycerides</td>
<td>15–20 days</td>
</tr>
</tbody>
</table>

*Most values were obtained from studies on mammals other than humans.