Concepts of Biology

Chapter 2 CHEMISTRY OF LIFE
PowerPoint Image Slideshow

Concepts of Biology
Biology 20

openstax COLLEGE
Biological Order

Organism level
Zebra (Includes several organ systems)

Organ system level
Circulatory system

Organ level
Heart

Tissue level
Cardiac muscle tissue

Cellular level
Cardiac muscle cell

Organelle level
Cell nucleus

Molecular level
DNA

Atomic level
Oxygen atom

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All Matter Consists of Elements

- **Chemistry** is the study of matter
  - Matter is
    - Anything that has mass and occupies space
    - Composed of elements

- **Elements**
  - Cannot be broken down to a simpler form
  - Periodic table of elements: lists all known elements

- **Compound**
  - 2 or more elements
  - Fixed ratio
  - Water (H\(_2\)O), NaCl

\[
\text{Na}^+ + \text{Cl}^- = \text{NaCl}
\]

Compound formation
# Periodic Table

<table>
<thead>
<tr>
<th>Group number</th>
<th>Atomic number</th>
<th>Group number</th>
<th>Atomic number</th>
<th>Group number</th>
<th>Atomic number</th>
<th>Group number</th>
<th>Atomic number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>H</td>
<td>1.008</td>
<td>Li</td>
<td>6.941</td>
<td>Be</td>
<td>9.012</td>
<td>Mg</td>
<td>24.31</td>
</tr>
<tr>
<td>Na</td>
<td>22.99</td>
<td>K</td>
<td>39.10</td>
<td>Ca</td>
<td>40.08</td>
<td>Sc</td>
<td>44.96</td>
</tr>
<tr>
<td>Rb</td>
<td>85.47</td>
<td>Sr</td>
<td>87.62</td>
<td>Y</td>
<td>88.91</td>
<td>Zr</td>
<td>91.22</td>
</tr>
<tr>
<td>Cs</td>
<td>132.9</td>
<td>Ba</td>
<td>137.3</td>
<td>La</td>
<td>138.9</td>
<td>Hf</td>
<td>178.5</td>
</tr>
<tr>
<td>Fr</td>
<td>(223)</td>
<td>Ra</td>
<td>226</td>
<td>Ac</td>
<td>(227)</td>
<td>Rf</td>
<td>261</td>
</tr>
<tr>
<td>La</td>
<td>140.1</td>
<td>Ce</td>
<td>140.9</td>
<td>Nd</td>
<td>144.2</td>
<td>Sm</td>
<td>150.4</td>
</tr>
<tr>
<td>Eu</td>
<td>152.0</td>
<td>Gd</td>
<td>157.3</td>
<td>Tb</td>
<td>158.9</td>
<td>Dy</td>
<td>162.5</td>
</tr>
<tr>
<td>Tm</td>
<td>167.3</td>
<td>Yb</td>
<td>173.0</td>
<td>Lu</td>
<td>175.0</td>
<td>Th</td>
<td>232.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pb</td>
<td>207.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Bi</td>
<td>209.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Po</td>
<td>(209)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>At</td>
<td>(210)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rn</td>
<td>(221)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Nonmetals**

**Metals**

**Transition elements**

**Lanthanides**

**Actinides**

Figure 2.2
Elements in the body

Table 2.2  The most common and important elements in living organisms*

<table>
<thead>
<tr>
<th>Element</th>
<th>Atomic symbol</th>
<th>Atomic number</th>
<th>Atomic mass</th>
<th>% of Human weight</th>
<th>Functions in life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>O</td>
<td>8</td>
<td>16.0</td>
<td>65</td>
<td>Part of water and most organic molecules; also molecular oxygen</td>
</tr>
<tr>
<td>Carbon</td>
<td>C</td>
<td>6</td>
<td>12.0</td>
<td>18</td>
<td>The backbone of all organic molecules</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H</td>
<td>1</td>
<td>1.0</td>
<td>10</td>
<td>Part of all organic molecules and of water</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N</td>
<td>7</td>
<td>14.0</td>
<td>3</td>
<td>Component of proteins and nucleic acids</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ca</td>
<td>20</td>
<td>40.1</td>
<td>2</td>
<td>Constituent of bone; also essential for the action of nerves and muscles</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>P</td>
<td>15</td>
<td>31.0</td>
<td>1</td>
<td>Part of cell membranes and of energy storage molecules; also a constituent of bone</td>
</tr>
<tr>
<td>Potassium</td>
<td>K</td>
<td>19</td>
<td>39.1</td>
<td>0.3</td>
<td>Important in nerve action</td>
</tr>
<tr>
<td>Sulfur</td>
<td>S</td>
<td>16</td>
<td>32.1</td>
<td>0.2</td>
<td>Structural component of most proteins</td>
</tr>
<tr>
<td>Sodium</td>
<td>Na</td>
<td>11</td>
<td>23.0</td>
<td>0.1</td>
<td>The primary ion in body fluids; also important for nerve action</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Cl</td>
<td>17</td>
<td>35.5</td>
<td>0.1</td>
<td>Component of digestive acid; also a major ion in body fluids</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Mg</td>
<td>12</td>
<td>24.3</td>
<td>Trace</td>
<td>Important for the action of certain enzymes and for muscle contraction</td>
</tr>
<tr>
<td>Iron</td>
<td>Fe</td>
<td>26</td>
<td>55.8</td>
<td>Trace</td>
<td>A constituent of hemoglobin, the oxygen-carrying molecule</td>
</tr>
</tbody>
</table>

*The elements are listed in descending order of their contribution to total body weight. Atomic number represents the number of protons in the nucleus. Atomic mass is roughly equivalent to the total number of protons and neutrons because electrons have very little mass. Note that 99% of your body weight is accounted for by just six elements.
Trace Elements: required in small amounts

Trace minerals and functions

<table>
<thead>
<tr>
<th>Body System</th>
<th>Trace minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immune Systems</td>
<td>Cu, Zn, Fe, Se</td>
</tr>
<tr>
<td>Energy Production</td>
<td>Mn</td>
</tr>
<tr>
<td>Hormone System</td>
<td>Fe, Mn, Zn, Cu</td>
</tr>
<tr>
<td>Vitamin Production</td>
<td>Co</td>
</tr>
<tr>
<td>Blood Production</td>
<td>Cu, Fe</td>
</tr>
<tr>
<td>Enzyme Systems</td>
<td>Zn, Cu, Fe, Mo</td>
</tr>
<tr>
<td>Skeletal Systems</td>
<td>Zn, Mn</td>
</tr>
<tr>
<td>Reproduction</td>
<td>Cu, Mn, Zn</td>
</tr>
</tbody>
</table>
Deficiencies
## Fortified Foods

### Nutrition Facts

**Serving Size**: ⅓ cup (30g)

<table>
<thead>
<tr>
<th>Serving Per Container about 17</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Amount Per Serving</th>
<th>Whole Grain Total</th>
<th>with % Daily Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories</td>
<td>100 g</td>
<td>140</td>
</tr>
<tr>
<td>Calories from Fat</td>
<td>5 g</td>
<td>10</td>
</tr>
<tr>
<td>Total Fat</td>
<td>0.5 g</td>
<td>1%</td>
</tr>
<tr>
<td>Saturated Fat</td>
<td>0 g</td>
<td>0%</td>
</tr>
<tr>
<td>Trans Fat</td>
<td>0 g</td>
<td>0%</td>
</tr>
<tr>
<td>Polyunsaturated Fat</td>
<td>0 g</td>
<td>0%</td>
</tr>
<tr>
<td>Monounsaturated Fat</td>
<td>0 g</td>
<td>0%</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>0 mg</td>
<td>0%</td>
</tr>
<tr>
<td>Sodium</td>
<td>190 mg</td>
<td>8%</td>
</tr>
<tr>
<td>Potassium</td>
<td>90 mg</td>
<td>3%</td>
</tr>
<tr>
<td>Total Carbohydrate</td>
<td>23 g</td>
<td>8%</td>
</tr>
<tr>
<td>Dietary Fiber</td>
<td>3 g</td>
<td>10%</td>
</tr>
<tr>
<td>Sugars</td>
<td>8 g</td>
<td>10%</td>
</tr>
<tr>
<td>Other Carbohydrate</td>
<td>15 g</td>
<td>5%</td>
</tr>
</tbody>
</table>

**Protein**: 3 g

- Vitamin A: 10% (15%)
- Vitamin C: 100% (100%)
- Calcium: 100% (100%)
- Iron: 100% (100%)
- Vitamin D: 10% (25%)
- Vitamin E: 100% (100%)
- Thiamin: 100% (100%)
- Riboflavin: 100% (110%)
- Niacin: 100% (100%)
- Vitamin B6: 100% (100%)
- Folic Acid: 100% (100%)
- Vitamin B12: 100% (110%)
- Pantothenic Acid: 100% (100%)
- Phosphorus: 8% (10%)
- Magnesium: 6% (10%)
- Zinc: 100% (100%)
- Copper: 4% (4%)

* Amount in cereal, A serving of cereal plus skim milk provides 1g total fat, less than 0mg cholesterol, 190mg sodium, 90mg potassium, 25g total carbohydrate (11g sugars) and 3g protein.

**Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.**

<table>
<thead>
<tr>
<th></th>
<th>Calories</th>
<th>Total Fat</th>
<th>Saturated Fat</th>
<th>Trans Fat</th>
<th>Polyunsaturated Fat</th>
<th>Monounsaturated Fat</th>
<th>Cholesterol</th>
<th>Sodium</th>
<th>Potassium</th>
<th>Total Carbohydrate</th>
<th>Dietary Fiber</th>
<th>Sugars</th>
<th>Other Carbohydrate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2,000</td>
<td>0.5 mg</td>
<td>0 mg</td>
<td>0 mg</td>
<td>0 mg</td>
<td>0 mg</td>
<td>0 mg</td>
<td>190 mg</td>
<td>90 mg</td>
<td>23 g</td>
<td>3 g</td>
<td>8 g</td>
<td>15 g</td>
</tr>
</tbody>
</table>

**NET WT**: 1 LB 2 OZ (18 oz) [151 g]

---

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Which of the following elements do you need in small quantities to help bind oxygen?

A. Carbon
B. Oxygen
C. Sodium
D. Iron
E. Lead
Atoms → smallest functional unit of elements

- Charges: (+) proton
  (-) electron
  (0) neutron

- Mass in Daltons:
  protons → 1
  neutrons → 1
  electrons → 1/1000

A. Helium atom
B. Carbon atom
Structure of Atoms

a) Hydrogen
   1 proton

b) Oxygen
   8 protons
   8 neutrons
   8 electrons
   in 2 shells

c) Sodium
   11 protons
   11 neutrons
   11 electrons
   in 3 shells

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ATOMS → Atomic & Mass Number

- Atomic number
  - # protons
- Atomic mass or mass number
  - # of protons + # neutrons
- Neutral atom
  - # protons = # electrons

6 C

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Electron Orbital

• Arranged in shells
• Chemical property → outmost shell
• Full electron shell → 8
  – Exception: 1st shell → 2

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<table>
<thead>
<tr>
<th>Element</th>
<th>Atomic number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen (H)</td>
<td>1</td>
</tr>
<tr>
<td>Carbon (C)</td>
<td>6</td>
</tr>
<tr>
<td>Nitrogen (N)</td>
<td>7</td>
</tr>
<tr>
<td>Oxygen (O)</td>
<td>8</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>15</td>
</tr>
</tbody>
</table>
Unfilled Electron Orbital

- Gain, lose or share electrons
- How many electrons do each of the following need to have a full orbital?

Hydrogen (H)  
Atomic number = 1

Carbon (C)  
Atomic number = 6

Nitrogen (N)  
Atomic number = 7

Oxygen (O)  
Atomic number = 8

Phosphorus (P)  
Atomic number = 15
Electron Configurations

<table>
<thead>
<tr>
<th>First shell</th>
<th>Hydrogen $^1\text{H}$</th>
<th>Helium $^2\text{He}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second shell</td>
<td>Lithium $^3\text{Li}$</td>
<td>Beryllium $^4\text{Be}$</td>
</tr>
<tr>
<td>Third shell</td>
<td>Sodium $^{11}\text{Na}$</td>
<td>Magnesium $^{12}\text{Mg}$</td>
</tr>
</tbody>
</table>
Isotopes

- Different # of neutrons
- Same # of protons & electron
Radioactive Isotopes

- Dangerous $\rightarrow$ unstable
  - Emits energy $\rightarrow$ radiation

- Usefulness:
  - Imaging (PET scan)
  - Metabolic tracers
  - Dating fossils
  - Power supply $\rightarrow$ pacemakers
Isotopes

Figure 2.3 Medical uses for low-level radiation.

a. Irradiated (left) and nonirradiated (right) fruit

b. Radiation therapy
What is the atomic mass of helium?

A. 1
B. 2
C. 3
D. 4
E. none
How many electrons does He (Helium) have?

A. 1  B. 2  C. 3  D. 4  E. none
Chemical Bonds

- Between elements
  - Covalent bonds
  - Ionic bonds

- Between molecules
  - Hydrogen bonds
Covalent Bond Types

- Sharing of electrons
  - Equal sharing
- Non-polar covalent
  - Unequal sharing
- Polar covalent
  - Unequal sharing

**Animation** – covalent bond

**Figure 2.5**

<table>
<thead>
<tr>
<th>Written formula</th>
<th>Structural representation</th>
<th>Structural formula with covalent bond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen (H₂)</td>
<td><img src="image" alt="Single covalent bond" /></td>
<td>H—H</td>
</tr>
<tr>
<td>Oxygen (O₂)</td>
<td><img src="image" alt="Double covalent bond" /></td>
<td>O=O</td>
</tr>
<tr>
<td>Water (H₂O)</td>
<td><img src="image" alt="Two single covalent bonds" /></td>
<td>O—H</td>
</tr>
</tbody>
</table>
 Ionic Bond

- Electron transfer
- Ion: atom with a charge (+ or -)

**sodium Ion (Na\(^+\))** | **Chloride Ion (Cl\(^-\))**
---|---
11 protons (+) | 17 protons (+)
10 electrons (-) | 18 electrons (-)
One (+) charge | One (-) charge
Electrolytes

- Free ions in solution
- Physiologically important ones:
- Examples: \( \text{Na}^+, \text{K}^+, \text{Ca}^{2+}, \text{Mg}^{2+}, \text{Cl}^-, \text{HPO}_4^{2-}, \text{HCO}_3^- \)

Hydration room
LA Times article – Paula Newby Frazer
Hydrogen Bond

- Occurs BETWEEN molecules
- Opposite charges
- Importance:
  - Water & its unique properties
  - DNA structure
  - Temporary communication
- Animation – water structure
Hydrogen Bond $\rightarrow$ between H$_2$O

**Figure 2.7**

- **Molecule**
- **Oxygen (O)**
- **Hydrogen (H)**

Water

Ice
Water

- 75% of Earth’s surface
- 70-95% of living organisms
- Polar molecule – why?
- 3 forms (solid/liquid/gas)
- 5 unique properties
Properties of Water

1) Cohesiveness
   - Cohesion: sticks to H₂O
   - Adhesion: ability to cling
   - Surface Tension: ability to stretch or break liquid’s surface

   • Importance:
     – Water transport from roots to leaves
Properties of Water

1) Cohesiveness

- Drawback:
  - Premature babies → Neonatal respiratory distress syndrome
Properties of Water

2) High Specific Heat
   - How much heat must be absorbed or lost to raise 1 g of water 1°C?
   - Heat?
   - Temperature?

• Significance:
  - Stabilizes environment
  - Prevents drastic changes in temperature
Moderates/stabilizes environment

- Santa Barbara: 73°
- Burbank: 90°
- San Bernardino: 100°
- Riverside: 96°
- Palm Springs: 106°
- Los Angeles (Airport): 75°
- Santa Ana: 84°
- San Diego: 72°

Legend:
- 70s (°F)
- 80s
- 90s
- 100s

Pacific Ocean

Scale: 40 miles
Properties of Water

3) Heat of Vaporization
   – Amt of heat absorbed to go from liquid to a gas

   • Significance
     – Evaporative Cooling
     • High humidity & hot days
Properties of Water

4) Density of Water
   - Solid water (ice)
     - Crystal structure is spacious
     - Fewer molecules/equal vol.
     - Less dense $\rightarrow$ floats
   - Significance
     - Insulation for aquatic organisms

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Properties of Water

Figure 2.13

H₂O molecule

Ice

Liquid water
Properties of Water

5) Versatile Solvent

- Ionic or polar

- Significance
  - Chemical reactions
  - Digestion

Figure 2.8
The salt NaCl dissolves in water.
Versatile solvent uses

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Water as a Solvent

- **Solvent**: Substance that does the dissolving
- **Solute**: Substance being dissolved
- **Solution**: A mixture of 2 or more substances
- **Aqueous solution**: Water is the solvent

**Solute + Solvent = Solution**

<table>
<thead>
<tr>
<th>Solute</th>
<th>Solvent</th>
<th>Concentration = Solute/Solvent</th>
</tr>
</thead>
<tbody>
<tr>
<td>sucrose (table sugar)</td>
<td>water</td>
<td></td>
</tr>
</tbody>
</table>

**Concentration** = Solute/Solvent
Which of the following is the solute?

A. [Image of Osmo Nutrition Active Hydration]

B. [Image of Cyclist]

C. [Image of Glass of Water]
Which of the following is the **solution**?

A. 

B. 

C.
Dissociation of Water

\[ \text{H}_2\text{O} \rightarrow \text{H}^+ + \text{OH}^- \]

Hydronium ion (\(\text{H}_3\text{O}^+\))    Hydroxide ion (\(\text{OH}^-\))

H\(\text{O}\)H \(\rightleftharpoons\) H\(^+\) + OH\(^-\)

water    hydrogen    hydroxide
ion      ion
pH scale

- pH = - \log [H^+] 
- pH = 7 \rightarrow \text{neutral}
- pH > 7 \rightarrow \text{basic/alkaline}
- pH < 7 \rightarrow \text{acidic}
- Inverse relationship
  - Increase [H^+] \rightarrow \text{decrease pH}
  - Decrease [H^+] \rightarrow \text{increase pH}
- pH: 6 – 8/9

<table>
<thead>
<tr>
<th>[H^+] (moles per liter)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0000001 = 1 \times 10^{-6}</td>
<td>6</td>
</tr>
<tr>
<td>0.00000001 = 1 \times 10^{-7}</td>
<td>7</td>
</tr>
<tr>
<td>0.000000001 = 1 \times 10^{-8}</td>
<td>8</td>
</tr>
</tbody>
</table>
pH Scale

1. pH values of acidic solutions
2. pH values of basic (alkaline) solutions
3. point at which H+ equal OH-
4. progressing from a weak to strong acid
5. progressing from a weak to a strong base
6. results of adding more hydrogen to a solution
Acids & Bases

- **Acids**
  - Donate $H^+$
  - Lowers pH

- **Bases**
  - Accepts $H^+$
  - Raises pH

Common Household Acids & Bases

Acids and Bases
Buffers

- Minimizes changes in pH
- Accept $H^+$ when in excess
- Donate $H^+$, when depleted

Carbonic Acid/ Bicarbonate

- $H_2CO_3 \rightarrow$ carbonic acid
- $HCO_3^- \rightarrow$ bicarbonate

Blood pH = 7.4 ± 0.05

- If pH falls below 7.35
- If pH rises above 7.45

$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+$

carbonic acid

bicarbonate
\[ \text{H}_2\text{CO}_3 \quad \text{dissociates} \quad \text{re-forms} \quad \text{H}^+ \quad + \quad \text{HCO}_3^- \]

**Antacids**

Medication enters stomach

Acid stomach contents

Neutralised stomach contents
Figure 42.32a

Body tissue

CO₂ produced

Interstitial fluid

Plasma within capillary

CO₂ transport from tissues

Capillary wall

H₂CO₃ → H⁺ + HCO₃⁻

Red blood cell

Carbonic acid

H₂CO₃

H⁺

HCO₃⁻

Bicarbonate

Hb

H₂CO₃ picks up CO₂ and H⁺.

H⁺ + HCO₃⁻ → CO₂

H₂O

To lungs

HCO₃⁻
Hemoglobin releases CO₂ and H⁺.

CO₂ transport to lungs

Figure 42.32b
Because of a sudden hormonal imbalance, a patient’s blood pH was tested and was 7.5. What does this pH value mean?

A. This is more acidic than normal blood
B. Is a little more basic (alkaline) than normal
C. This is caused by a release of large amounts of H\(^+\) into the system
D. H\(_2\)CO\(_3\) → HCO\(_3^-\) + H\(^+\) is pushed to the left
E. This is probably caused by excess CO\(_2\) in the blood
The Organic Molecules of Living Organisms

• Carbon, the building block of living things
  • Comprises 18% of the body by weight
  • Forms four covalent bonds
  • Can form single or double bonds
  • Can build micro- or macromolecules
The Organic Molecules of Living Organisms

Organic chemistry $\rightarrow$ carbon

• Atomic # $\rightarrow$ 6
• 4 valance electrons
• Bonds with: C, H, O, N
# Carbon Skeletons

<table>
<thead>
<tr>
<th>Structural formula</th>
<th>Ball-and-stick model</th>
<th>Space-filling model</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td><img src="image1" alt="Ball-and-stick model" /></td>
<td><img src="image2" alt="Space-filling model" /></td>
</tr>
<tr>
<td>H-C-H</td>
<td>[Image of Ball-and-stick model]</td>
<td>[Image of Space-filling model]</td>
</tr>
<tr>
<td>Methane</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The four single bonds of carbon point to the corners of a tetrahedron.

## Isomers

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Structural Formula</th>
<th>Ball-and-stick Model</th>
<th>Space-filling Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethane</td>
<td>H₂C₂H₂</td>
<td><img src="image3" alt="Ethane Ball-and-stick Model" /></td>
<td><img src="image4" alt="Ethane Space-filling Model" /></td>
</tr>
<tr>
<td>Propane</td>
<td>H₂C₃H₈</td>
<td><img src="image5" alt="Propane Ball-and-stick Model" /></td>
<td><img src="image6" alt="Propane Space-filling Model" /></td>
</tr>
<tr>
<td>Butane</td>
<td>H₂C₄H₁₀</td>
<td><img src="image7" alt="Butane Ball-and-stick Model" /></td>
<td><img src="image8" alt="Butane Space-filling Model" /></td>
</tr>
<tr>
<td>Isobutane</td>
<td>H₂C₅H₁₂</td>
<td><img src="image9" alt="Isobutane Ball-and-stick Model" /></td>
<td><img src="image10" alt="Isobutane Space-filling Model" /></td>
</tr>
<tr>
<td>1-Butene</td>
<td>H₂C₅H₈</td>
<td><img src="image11" alt="1-Butene Ball-and-stick Model" /></td>
<td><img src="image12" alt="1-Butene Space-filling Model" /></td>
</tr>
<tr>
<td>2-Butene</td>
<td>H₂C₅H₈</td>
<td><img src="image13" alt="2-Butene Ball-and-stick Model" /></td>
<td><img src="image14" alt="2-Butene Space-filling Model" /></td>
</tr>
<tr>
<td>Cyclohexane</td>
<td>H₆C₆H₁₂</td>
<td><img src="image15" alt="Cyclohexane Ball-and-stick Model" /></td>
<td><img src="image16" alt="Cyclohexane Space-filling Model" /></td>
</tr>
<tr>
<td>Benzene</td>
<td>H₆C₆H₁₂</td>
<td><img src="image17" alt="Benzene Ball-and-stick Model" /></td>
<td><img src="image18" alt="Benzene Space-filling Model" /></td>
</tr>
</tbody>
</table>

Length. Carbon skeletons vary in length.

Branching. Skeletons may be unbranched or branched.

Double bonds. Skeletons may have double bonds, which can vary in location.

Rings. Skeletons may be arranged in rings.
Hydrocarbons

- Consists of C & H only
- Energy stores
- Found:
  - Petroleum
  - Fatty acids
### Functional Groups of Organic Compounds

<table>
<thead>
<tr>
<th>Functional Group</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydroxyl group</td>
<td>—OH</td>
</tr>
<tr>
<td>Alcohol</td>
<td></td>
</tr>
<tr>
<td>Carbonyl group</td>
<td>—C=O</td>
</tr>
<tr>
<td>Aldehyde</td>
<td></td>
</tr>
<tr>
<td>Ketone</td>
<td></td>
</tr>
<tr>
<td>Carboxyl group</td>
<td>—COOH</td>
</tr>
<tr>
<td>Carboxylic acid</td>
<td>—COOH</td>
</tr>
<tr>
<td>Ionized</td>
<td></td>
</tr>
<tr>
<td>Amino group</td>
<td>—NH₂</td>
</tr>
<tr>
<td>Amine</td>
<td>—NH₂</td>
</tr>
<tr>
<td>Ionized</td>
<td></td>
</tr>
<tr>
<td>Phosphate group</td>
<td>—OPO₃⁻</td>
</tr>
<tr>
<td>Adenosine</td>
<td>—OPO₃⁻</td>
</tr>
<tr>
<td>Organic phosphate (ATP)</td>
<td></td>
</tr>
<tr>
<td>Methyl group</td>
<td>—CH₃</td>
</tr>
<tr>
<td>Methylated compound</td>
<td>—CH₃</td>
</tr>
</tbody>
</table>

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**Functional groups song**

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Large Biological Molecule Terms

• 4 classes of bio. molecules
  – Carbohydrates (sugars)
  – Proteins
  – Nucleic acids
  – Lipids

• Monomers (subunits): single-part
  – Building blocks for macromolecules

• Polymers: many-parts
  – Composed of many monomers
  – Covalently bonded
How do we build and break down organic molecules?

2.3 Molecules of Life

Hydrolysis
- Add $\text{H}_2\text{O}$
- Break bonds
- Catabolic
- “Digestion”

Dehydration reaction
- Remove $\text{H}_2\text{O}$
- Form bonds
- Polymer formation
- Anabolic

Figure 2.11 The breakdown and synthesis of macromolecules.

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Dehydration reactions (synthesis) are used in forming which of the following compounds?

A. Fats
B. Proteins
C. Polysaccharides
D. Nucleic acids such as DNA
E. All of these
Carbohydrates: Used for Energy and Structural Support

- General formula: $C_n(H_2O)_n$
- Monosaccharides: “simple” sugars
  - Glucose
  - Fructose
  - Galactose
  - Ribose
  - Deoxyribose
Carbohydrates

- **Disaccharides**
  - Dehydration synthesis
  - Examples:
    - Maltose
    - Lactose
    - Sucrose
b) Two 6-carbon monosaccharides (glucose and fructose) are joined together by dehydration synthesis, forming sucrose.
What are complex carbohydrates?

- Polysaccharides are made of many carbon rings.
- Energy storage
- Structural support

Figure 2.13  Starch is a plant complex carbohydrate.
Storage Polysaccharide

- **Starch**
  - Plant storage form
  - Roots & tubers
Storage Polysaccharides

Glycogen

❖ More branched
❖ Animal storage form
❖ Liver & skeletal muscles

Figure 2.15

a) Glycogen is formed by dehydration synthesis from glucose subunits.

b) A representation of the highly branched nature of glycogen.

c) A portion of an animal cell showing granules of stored glycogen (blue). The large pink structures are mitochondria.
Structural Polysaccharides

- **Cellulose**
  - Most abundant polysacc.
  - Plant structural support
  - Different bond arrangement

- **Chitin**
  - Exoskeleton of arthropods
  - Cell wall of fungi
Lactose, found in milk, is formed by joining glucose and galactose. How would you classify this lactose molecule?

A. A monosaccharide
B. A polysaccharide
C. A disaccharide
D. A pentose sugar
E. Tasty?
Lactose, found in milk, is formed by joining glucose and galactose. How would you classify this lactose molecule?

A. A monosaccharide
B. A polysaccharide
C. A disaccharide
D. A pentose sugar
E. Tasty?
Proteins

- Monomers: amino acids
- 20 different amino acids
  - Amine & carboxyl groups
- Peptide bond
Dehydration synthesis for polymer formation

Amino acids

Isoleucine (Ile)

Alanine (Ala)

Valine (Val)

Polypeptide

Ile  Ala  Val

Figure 2.20
20 Amino Acids

Figure 2.19

Amino acids with nonpolar R groups
- Alanine (Ala)
- Isoleucine (Ile)
- Leucine (Leu)
- Methionine (Met)
- Phenylalanine (Phe)
- Proline (Pro)
- Tryptophan (Trp)
- Valine (Val)

Amino acids with negatively charged R groups
- Aspartic acid (Asp)
- Glutamic acid (Glu)

Amino acids with uncharged polar R groups
- Asparagine (Asn)
- Cysteine (Cys)
- Glutamine (Gln)
- Glycine (Gly)
- Serine (Ser)
- Threonine (Thr)
- Tyrosine (Tyr)

Amino acids with positively charged R groups
- Arginine (Arg)
- Histidine (His)
- Lysine (Lys)
4 Levels of Protein Structure

**Primary structure** (sequence of amino acids)

**Secondary structure** (orientation in space of chains of amino acids)
- Alpha helix
- Beta sheet
- Random coil

**Tertiary structure** (three-dimensional shape)
- Alpha helix
- Beta sheet
- Random coil

**Quaternary structure** (number of polypeptide chains and their association)

Figure 2.21
Figure 2.19

Primary structure:
Amino acid sequence of polypeptide

Secondary structure:
Localized areas of coils, sheets, and loops within a polypeptide

Tertiary structure:
Overall shape of one polypeptide

Quaternary structure:
Overall protein shape, arising from interaction between the multiple polypeptides that make up the functional protein
4 Levels of Protein Structure

- **Primary level**
  - Amino acids linked w/ peptide bonds (polypeptide)
  - Linear sequence
  - Errors in DNA sequence
4 Levels of Protein Structure

- **Secondary level**
  - Results from H-bonds
  - Alpha helix
  - Beta-pleated sheets

[Diagram showing secondary structure, alpha helix, beta sheet, and random coil]
4 Levels of Protein Structure

- **Tertiary level**
  - 3-dimensional shape
  - Globular or fibrous shape
4 Levels of Protein Structure

- **Quaternary level**
  - 2 or more polypeptide chains aggregated together
Denaturation

- Bond disruption
  - Inactive protein
- Causes:
  - Excessive heat
  - Wrong pH
  - Wrong ionic concentrations
  - Organic solvents
Figure 2.21

Normal

Denatured

Heat

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8 Protein Functions

1. Structural protein
2. Storage protein

cotyledon

albumin
8 Protein Functions

3. Transport protein
8 Protein Functions

4. Hormonal protein

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Structure</th>
<th>Gland</th>
<th>Primary Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antidiuretic hormone</td>
<td>8 amino acids</td>
<td>Posterior pituitary</td>
<td>Water retention and vasoconstriction</td>
</tr>
<tr>
<td>Oxytocin</td>
<td>8 amino acids</td>
<td>Posterior pituitary</td>
<td>Uterine and mammary contraction</td>
</tr>
<tr>
<td>Insulin</td>
<td>21 and 30 amino acids (double chain)</td>
<td>Beta cells in islets of Langerhans</td>
<td>Cellular glucose uptake, lipogenesis, and glycogenesis</td>
</tr>
<tr>
<td>Glucagon</td>
<td>29 amino acids</td>
<td>Alpha cells in islets of Langerhans</td>
<td>Hydrolysis of stored glycogen and fat</td>
</tr>
<tr>
<td>ACTH</td>
<td>39 amino acids</td>
<td>Anterior pituitary</td>
<td>Stimulation of adrenal cortex</td>
</tr>
<tr>
<td>Parathyroid hormone</td>
<td>84 amino acids</td>
<td>Parathyroid</td>
<td>Increase in blood $\text{Ca}^{2+}$ concentration</td>
</tr>
<tr>
<td>FSH, LH, TSH</td>
<td>Glycoproteins</td>
<td>Anterior pituitary</td>
<td>Stimulation of growth, development, and secretory activity of target glands</td>
</tr>
</tbody>
</table>
5. Receptor protein
8 Protein Functions

6. Contractile protein
8 Protein Functions

7. Defense proteins (antibodies)

1. The B cell finds an antigen which matches its receptors.
2. It waits until it is activated by a helper T cell.
3. Then the B cell divides to produce plasma and memory cells.

4. Plasma cells produce antibodies that attach to the current type of invader.
5. “Eater cells,” prefer intruders marked with antibodies, and “eat” loads of them.
6. If the same intruder invades again, memory cells help the immune system to activate much faster.
8. Enzymatic proteins
8 Protein Functions

1. Structural
2. Storage
3. Transport
4. Hormonal
5. Receptor
6. Contractile
7. Defense
8. Enzymatic

1. Connective tissue (tendons, ligaments)
2. Albumin, casein
3. Hemoglobin, ion channels, etc
4. Insulin
5. Detects other signals (stimuli)
6. Movement
7. Immune system (antibodies)
8. Increase chemical reactions (Digestion, cellular respiration)
Which of the following is NOT a protein?

A. Hemoglobin
B. Cholesterol
C. An antibody
D. An enzyme
E. insulin
Nucleic Acids Store Genetic Information

- **Nucleotides**: building blocks of nucleic acids
- Each nucleotide contains
  - 5 carbon sugar
    - DNA nucleotides: deoxyribose
    - RNA nucleotides: ribose
  - Nitrogenous base
  - Phosphate group
Figure 2.22

a. Nucleotides and nitrogenous bases

<table>
<thead>
<tr>
<th>Phosphate group</th>
<th>Sugar (Deoxyribose)</th>
<th>Nitrogenous base</th>
</tr>
</thead>
<tbody>
<tr>
<td>OH</td>
<td>H</td>
<td>N</td>
</tr>
<tr>
<td>O=P-O</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>O</td>
<td>H</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>CH2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Adenine (A)  Cytosine (C)  Guanine (G)  Thymine (T)  Uracil (U)

DNA and RNA  DNA only  RNA only

b. Nucleic acid formation and breakdown

Dehydration synthesis:  \( \text{H}_2\text{O} \)

Hydrolysis:  \( \text{H}_2\text{O} \)
5 Nitrogenous Bases

Adenine (A)
Phosphate
Deoxyribose

Thymine (T)

Cytosine (C)

Guanine (G)
Nucleic Acids Store Genetic Information

• Two main types:
  • DNA: deoxyribonucleic acid
  • RNA: ribonucleic acid

• Functions
  • Store genetic information
  • Provide information used in making proteins
Nucleic Acids Store Genetic Information

- Structure of DNA (deoxyribonucleic acid)
  - Double–stranded (dbl helix)
  - Nucleotides contain
    - Deoxyribose (sugar)
    - Nitrogenous bases
      - Adenine
      - Guanine
      - Cytosine
      - Thymine
  - Pairing
    - Adenine - Thymine
    - Guanine - Cytosine
Nucleic Acids Store Genetic Information

• Structure of RNA (ribonucleic acid)
  • Single–stranded
  • Nucleotides contain
    – Ribose
    – Nitrogenous bases
      » Adenine
      » Guanine
      » Cytosine
      » Uracil
DNA → RNA → Protein

1. Synthesis of mRNA in the nucleus
2. Movement of mRNA into cytoplasm via nuclear pore
3. Synthesis of protein
ATP Carries Energy

- Structure and function of adenosine triphosphate (ATP)
  - Nucleotide – adenosine triphosphate
  - Universal energy source
  - Break the bonds releases energy

- High energy bond
- ATP → ADP + P + energy

a) The structure of ATP.
ATP Cycle

- Where does the energy Come from for ATP?

b) The breakdown and synthesis of ATP. The breakdown (hydrolysis) of ATP yields energy for the cell. The reaction is reversible, meaning that ATP may be resynthesized using energy from other sources. Figure 2.26b
Nucleic Acid Function

• DNA: instructions for making proteins via RNA
  • Information storage
  • Information transfer

• RNA: instructions for making proteins
  • Protein synthesis → DNA → RNA → Proteins

• Proteins: direct most of life’s processes

• Transfer of chemical energy
RNA differs from DNA because:

A. RNA contains Uracil and DNA does not
B. RNA is more stable and broken down by enzymes less easily than DNA
C. RNA has the 6 carbon sugar
D. RNA is double stranded
E. RNA is a much larger molecule than DNA
Lipids: Insoluble in Water

• Three important classes of lipids
  – **Triglycerides**: energy storage molecules
  – **Phospholipids**: cell membrane structure
  – **Steroids**: hormones, communication
  – **Waxes**: waterproofing, decrease water loss
Triglycerides

- Includes fats and oils
- Composed of glycerol and three fatty acids
  - Fatty acids
    - Saturated (in fats)
    - Unsaturated (in oils)
- Stored in adipose tissue
- Energy storage molecules
Copyright © McGraw-Hill Education. All rights reserved. No reproduction or distribution without the prior written consent of McGraw-Hill Education.
Triglycerides a) Triglycerides (neutral fats) are synthesized from glycerol and three fatty acids by dehydration synthesis.
Triglycerides

Saturated Fats

- Max. # of H to C ratio
- No DBL bonds btn C’s
- Solid @ room temp
- Most animal fats
- Lard, butter, grease

b) Triglycerides with saturated fatty acids have straight tails, allowing them to pack closely together.
**Triglycerides**

- **Unsaturated Fats**
  - 1 or more DBL bonds btn C’s
  - Tails kinked (C=C)
  - Liquid @ room temp
  - Most plant fats
  - Corn, olive, peanut oils

- c) Triglycerides with unsaturated fatty acids have kinked tails, preventing them from packing closely together.
Fats

• Saturated
  – Max. # of H to C ratio
  – No DBL bonds btn C’s
  – Solid @ room temp
  – Most animal fats
    Lard, butter, grease

• Unsaturated
  – 1 or more DBL bonds btn C’s
  – Tails kinked (C=C)
  – Liquid @ room temp
  – Most plant fats
    Corn, olive, peanut oils
Which is has more saturated fats?
What are Trans fats?

**SATURATED**
Stearic acid (found in butter)

**UNSATURATED**
Linoleic acid (found in vegetable oil)

**TRANS**
trans-Linoleic acid (found in some margarine)

Trans fats (also known as partially hydrogenated oils) are created by adding hydrogen to liquid vegetable oil. This process makes the fat more solid, lengthens its shelf life and makes it more suitable for frying and other uses. However, trans fats are also more unhealthy than regular, unsaturated fats. Here’s why:

**Bad cholesterol**
Low-density lipoproteins (LDL) transport cholesterol throughout the body. As cholesterol builds up in the walls of the body’s arteries, the arteries become narrow and hardened, reducing blood flow and leading to an increased chance of heart attack and stroke.

**Good cholesterol**
High-density lipoproteins (HDL) pick up excess cholesterol and transport it back to the body’s liver for processing. Consuming trans fats lowers the body’s HDL levels:

Sources: The Mayo Clinic; American Heart Association
Brian Moore / The Register
Omega-3 and Omega-6 fatty acids

**FIG. 1 OMEGA-3 AND OMEGA-6 FATTY ACIDS**

- **Alpha-linolenic acid (ALA, C18:3, omega-3)**
- **Eicosapentaenoic acid (EPA, C20:5, omega-3)**
- **Docosahexaenoic acid (DHA, C22:6, omega-3)**
- **Linoleic acid (LA, C18:2, omega-6)**
- **Arachidonic acid (AA, C20:4, omega-6)**

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Phospholipids

Hydrophilic head

Hydrophobic tails

(a) Micelle

(b) Phospholipid bilayer

Phosphate

Polar head

Glycerol

Fatty acid

Nonpolar tail

Figure 2.17
Steroids

- Structure
  - Composed of four carbon rings

- Examples:
  - Cholesterol
  - Estrogen
  - Progesterone
  - Testosterone

a) Cholesterol:
   A normal component of the cell membrane.

b) Estrogen (estradiol):
   Female sex hormone synthesized from cholesterol.

c) Testosterone:
   Male sex hormone synthesized from cholesterol.
Sex hormones

Female lion

Male lion

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Steroids $\rightarrow$ sex hormones (communication)

a. Cholesterol

b. Testosterone

c. Estrogen

(photos b, c): © Purestock/Superstock RF

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Lipid Functions

- Energy storage
- Insulation
- Cushioning organs
- Prevents water loss
- Chemical messengers
- Membranes
Lipids that are liquid at room temperature:

A. Are fats
B. Contain more hydrogen atoms than lipids that are solid at room temperature
C. Are polyunsaturated and contain several double bonds in their fatty acid chains
D. Lack glycerol
E. Are not stored in cells as triglycerides
### Table 2.4 The Macromolecules of Life: A Summary

<table>
<thead>
<tr>
<th>Type of Molecule</th>
<th>Chemical Structure</th>
<th>Function(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carbohydrates</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple sugars</td>
<td>Monosaccharides and disaccharides</td>
<td>Provide quick energy</td>
</tr>
<tr>
<td>Complex carbohydrates</td>
<td>Polymers of monosaccharides</td>
<td>Support cells and organisms (cellulose, chitin); store energy (starch, glycogen)</td>
</tr>
<tr>
<td>(cellulose, chitin, starch, glycogen)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Proteins</strong></td>
<td>Polymers of amino acids</td>
<td>Carry out nearly all the work of the cell</td>
</tr>
<tr>
<td><strong>Nucleic acids (DNA, RNA)</strong></td>
<td>Polymers of nucleotides</td>
<td>Store and use genetic information and transmit it to the next generation</td>
</tr>
<tr>
<td><strong>Lipids</strong></td>
<td>Diverse; hydrophobic</td>
<td></td>
</tr>
<tr>
<td>Triglycerides (fats, oils)</td>
<td>Glycerol + 3 fatty acids</td>
<td>Store energy</td>
</tr>
<tr>
<td>Phospholipids</td>
<td>Glycerol + 2 fatty acids + phosphate group (see chapter 3)</td>
<td>Form major part of biological membranes</td>
</tr>
<tr>
<td>Sterols</td>
<td>Four fused rings, mostly of C and H</td>
<td>Stabilize animal membranes; sex hormones</td>
</tr>
<tr>
<td>Waxes</td>
<td>Fatty acids + other hydrocarbons or alcohols</td>
<td>Provide waterproofing</td>
</tr>
</tbody>
</table>

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