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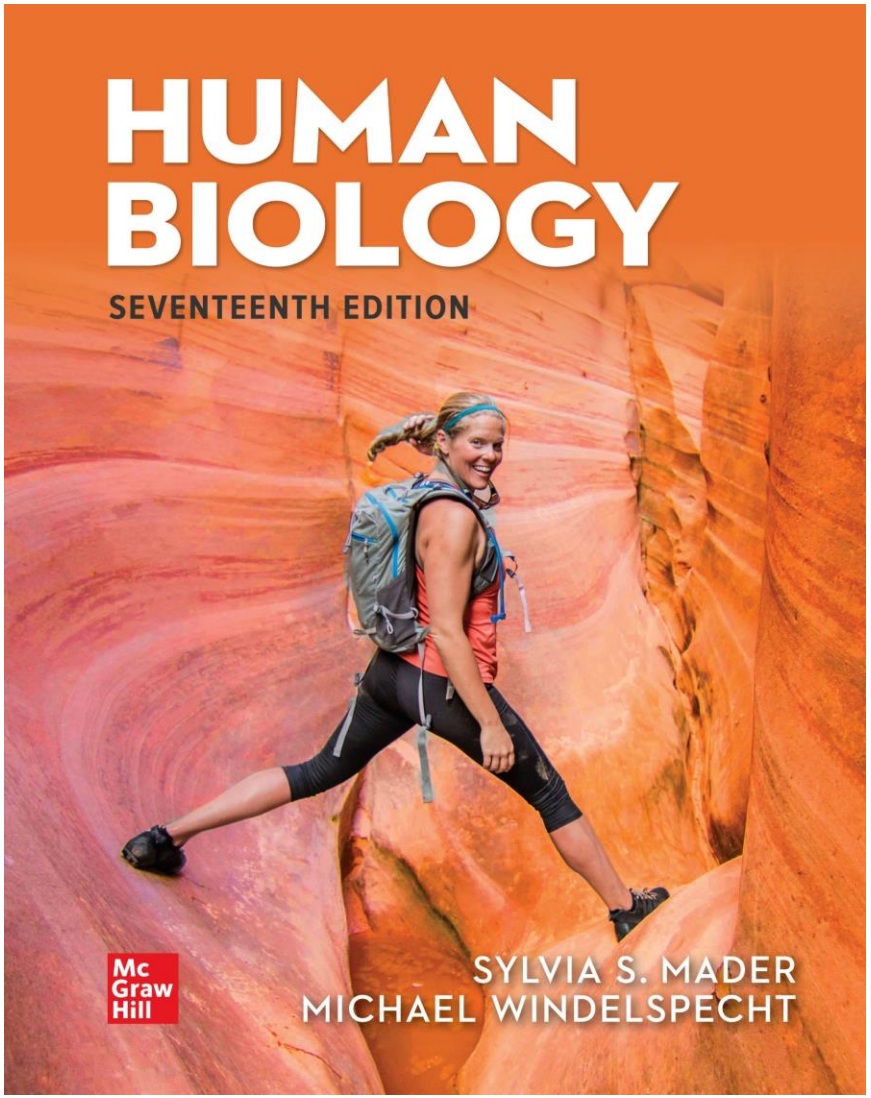

HUMAN BIOLOGY

Seventeenth Edition

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Michael Windelspecht

Chapter 2
Chemistry of Life

2.1 From Atoms to Molecules

Learning Outcomes:

- Distinguish between atoms and elements.
- Describe the structure of an atom.
- Define *isotope* and summarize its application in both medicine and biology.
- Distinguish between ionic and covalent bonds.

From Atoms to Molecules 1

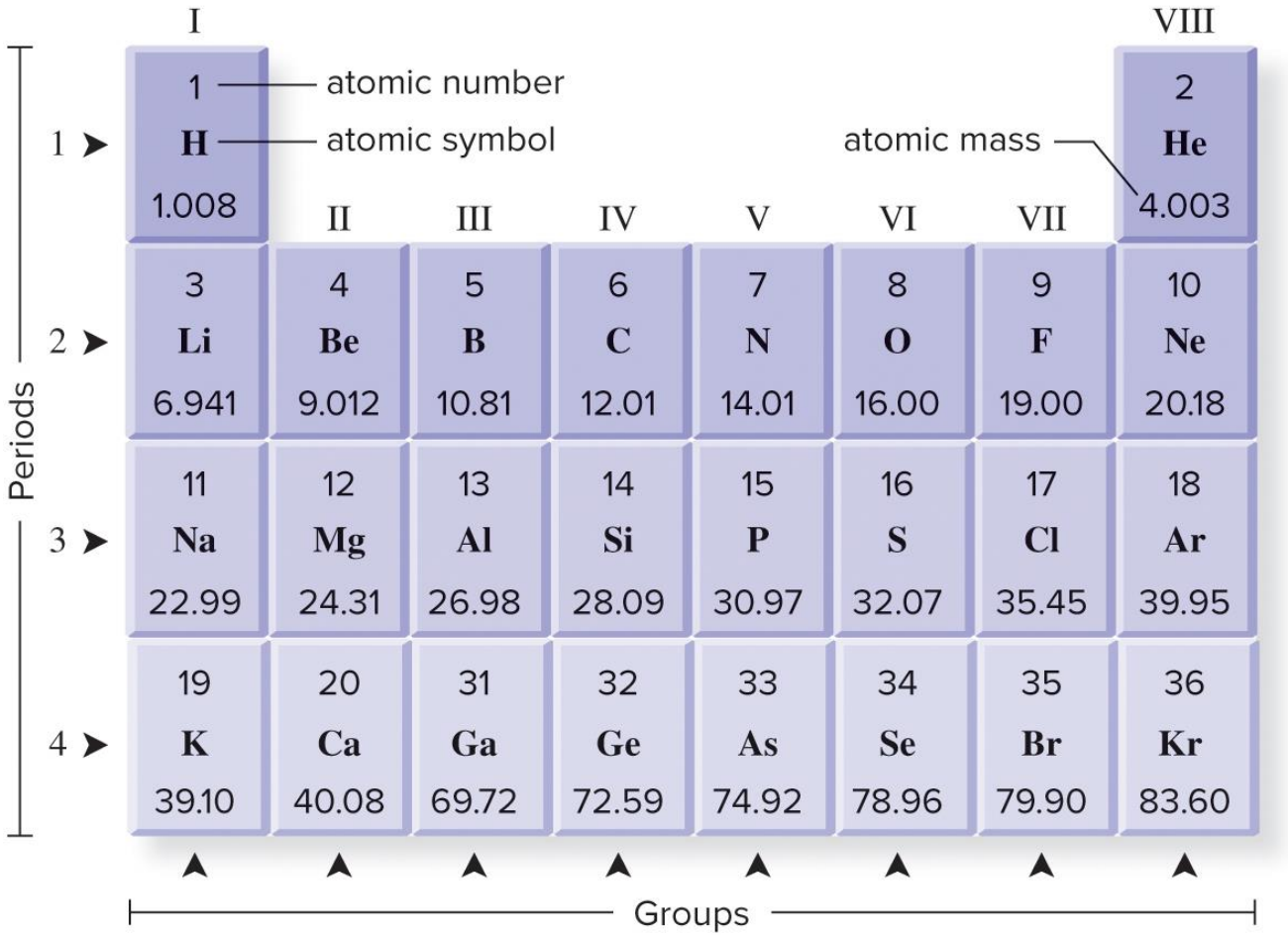
Matter—anything that has mass and takes up space.

- Exists in several forms: solid, gas, liquid, or plasma.

Elements—basic building blocks of matter; cannot be broken down by chemical means.

- Over 90% of the human body is made up of only four elements: carbon (C), nitrogen (N), oxygen (O), and hydrogen (H).

A Portion of the Periodic Table of Elements (Figure 2.1)



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Atoms

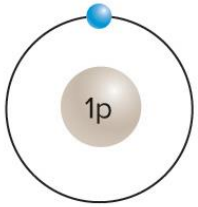
Atom—smallest unit of an element that retains its physical and chemical properties.

Atoms bond together to form **molecules.**

Parts of an atom (called subatomic particles):

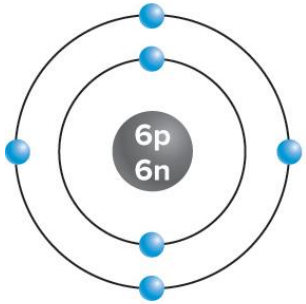
- **Neutrons**—neutral (uncharged).
- **Protons**—positively charged.
  - Neutrons and protons make up the nucleus.
- **Electrons**—negatively charged; orbit around the nucleus in **electron shells.**

The Atomic Structure of Select Elements (Figure 2.2)

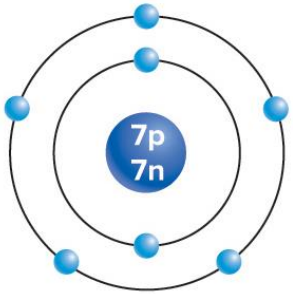


hydrogen
H

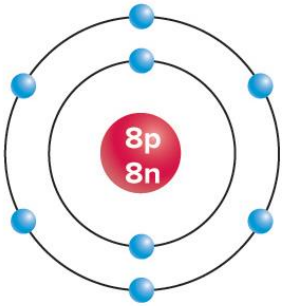
Subatomic Particles		
Particle	**Charge**	**Atomic Mass Unit (AMU)**
Proton	+1	1
Neutron	0	1
Electron	–1	0



carbon
C



nitrogen
N



oxygen
O

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The Periodic Table

Atomic number—the number of protons.

- Differs for every element.

Mass number—sum of the number of protons and neutrons.

- Protons and neutrons each have a mass equal to one atomic mass unit (AMU).
- Electrons have a negligible mass.

Atomic mass—the average AMU for all isotopes of that atom.

Isotopes

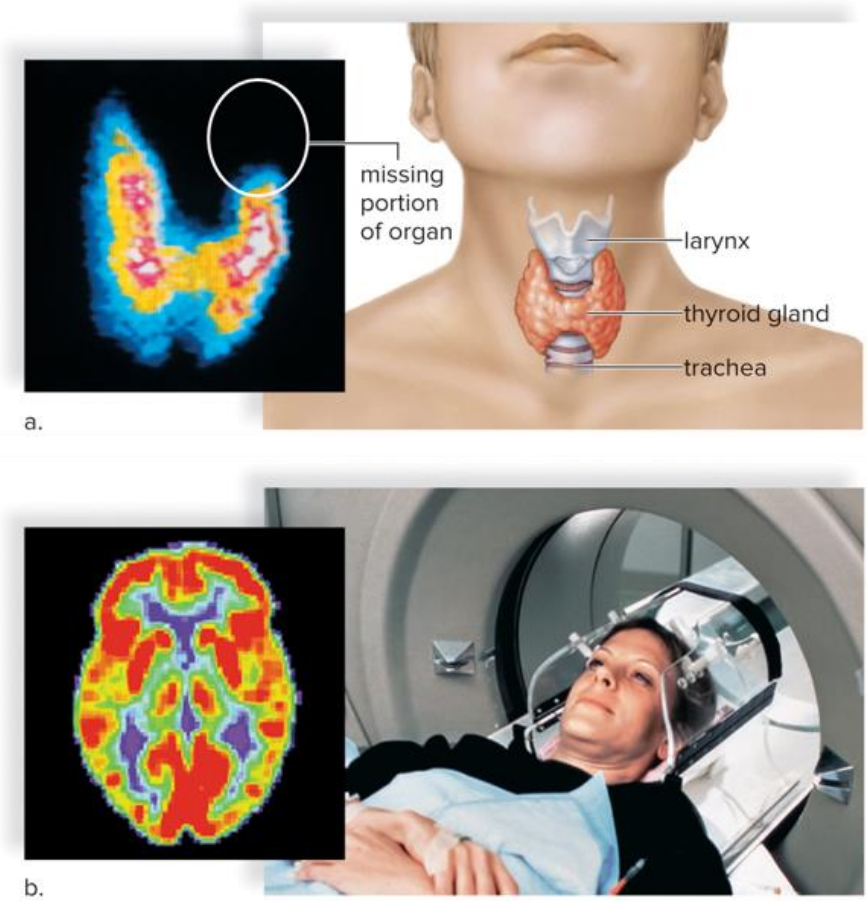
Isotopes—atoms of the same element (with the same atomic number) but a different number of neutrons.

- They differ in their atomic mass.

Radioisotopes—unstable isotopes; they emit energy called **radiation**.

- Radiation can damage cells and cause cancer.
- Useful for imaging the body, killing bacteria in food, sterilizing equipment, and killing cancer cells.

Medical Uses for Low-Level Radiation (Figure 2.3)



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(photos) (a): Southern Illinois University/Science Source; (b, PET scan): Photo Researchers/Science History Images/Alamy Stock Photo; (b, patient): Courtesy of National Institutes of Health

Molecules and Compounds

Molecules—atoms bonded together.

- Can be made of the same atom or different atoms.
- That is, O_2, H_2O.

Compounds—molecules made of different atoms.

- That is, H_2O (not O_2).

Two types of bonds join atoms: **ionic bonds** and **covalent bonds**.

Ionic Bonding

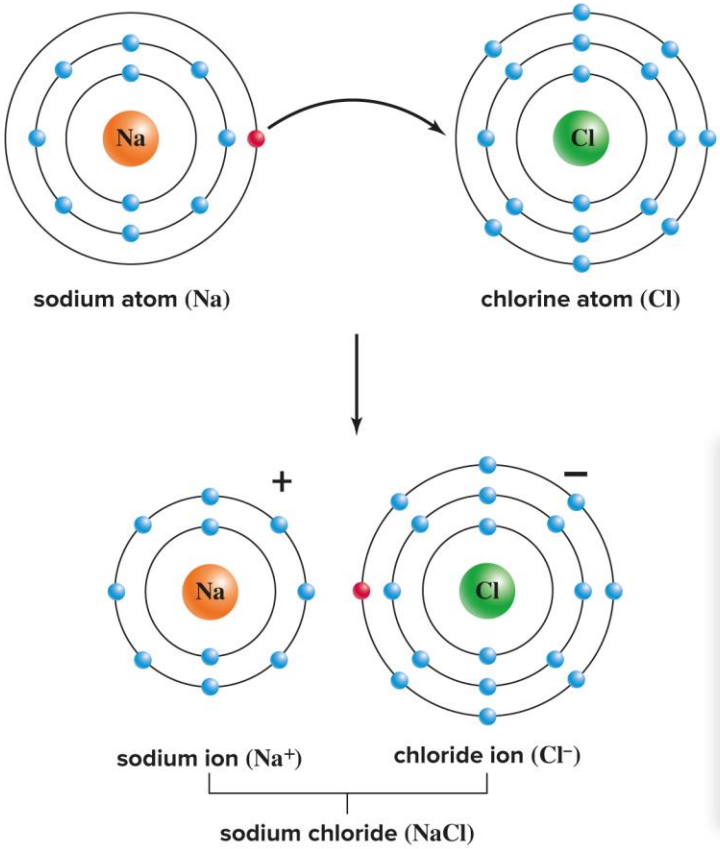
Atoms are most stable when their outer electron shell, the **valence shell**, is full.

During an ionic reaction, atoms donate or take on electrons to fill their valence shell.

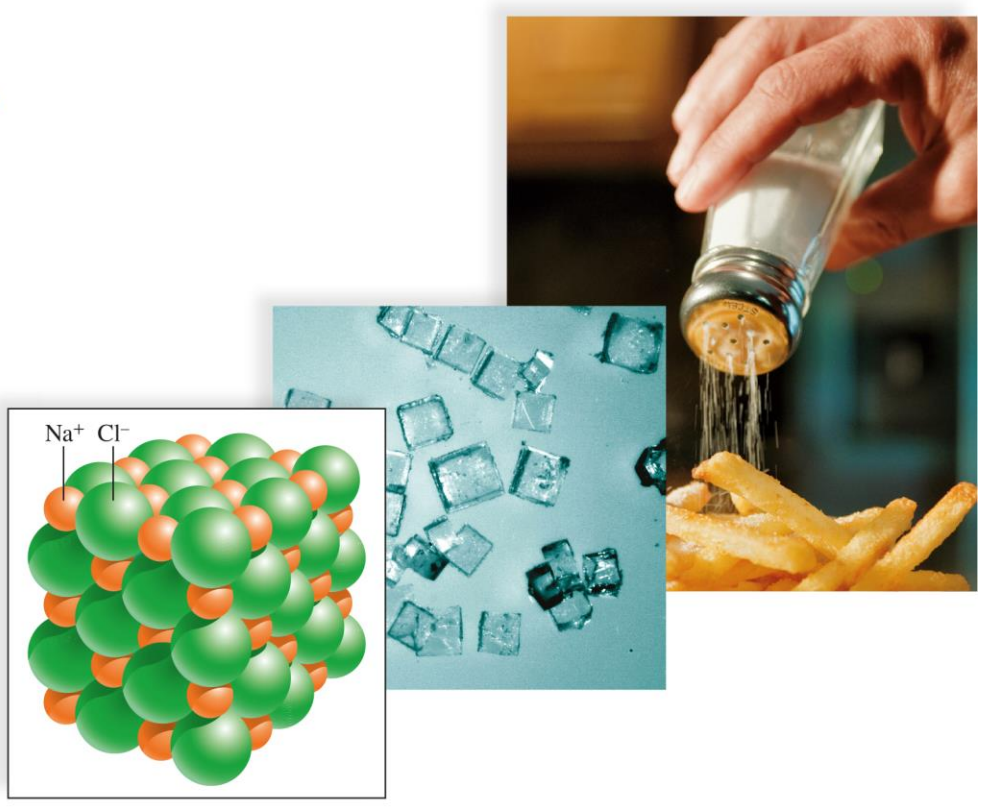
- This results in the formation of positive or negative **ions** (charged particles).

Ionic bond—the attraction between a positive and negative ion.

Formation of an Ionic Bond (Figure 2.5)



a.



b.

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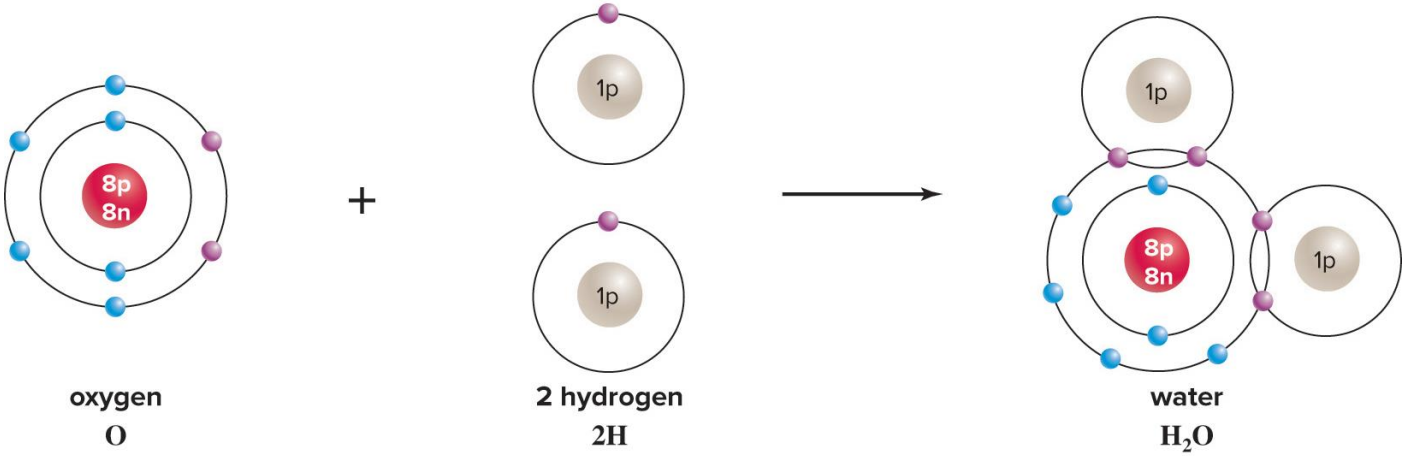
(photos) (b, salt crystals): Evelyn Jo Johnson/McGraw Hill; (b, salt shaker): PM Images/Photodisc/Getty Images

Covalent Bonding

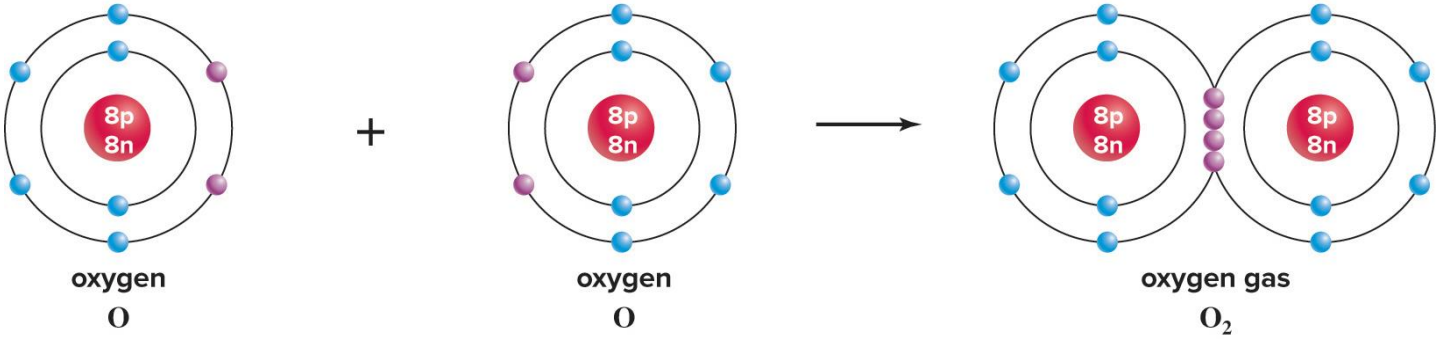
Covalent bonds—atoms share electrons to fill their valence shells.

- Each atom contributes one electron to the shared pair.
- The electrons spend time in the valence shells of both atoms.
- **Double covalent bonds** share two pairs of electrons; **triple covalent bonds** share three pairs.
- Depicted by one, two, or three straight lines.

Covalent Bonds (Figure 2.6)



a. When an oxygen and two hydrogen atoms covalently bond, water results.



b. When two oxygen atoms covalently bond, oxygen gas results.

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Check Your Progress 2.1

List the number of electrons, neutrons, and protons in an atom of magnesium (Mg; see Fig. 2.1).

Determine the number of neutrons found in the isotopes of oxygen ^{16}O and ^{18}O (see Fig. 2.1).

Explain the beneficial uses of radioisotopes.

Summarize the differences between ionic and covalent bonds, and give an example of each.

2.2 Water and Life 1

Learning Outcomes:

- Describe the properties of water.
- Explain the role of hydrogen bonds in the properties of water.
- Summarize the structure of the pH scale and the importance of buffers to biological systems.

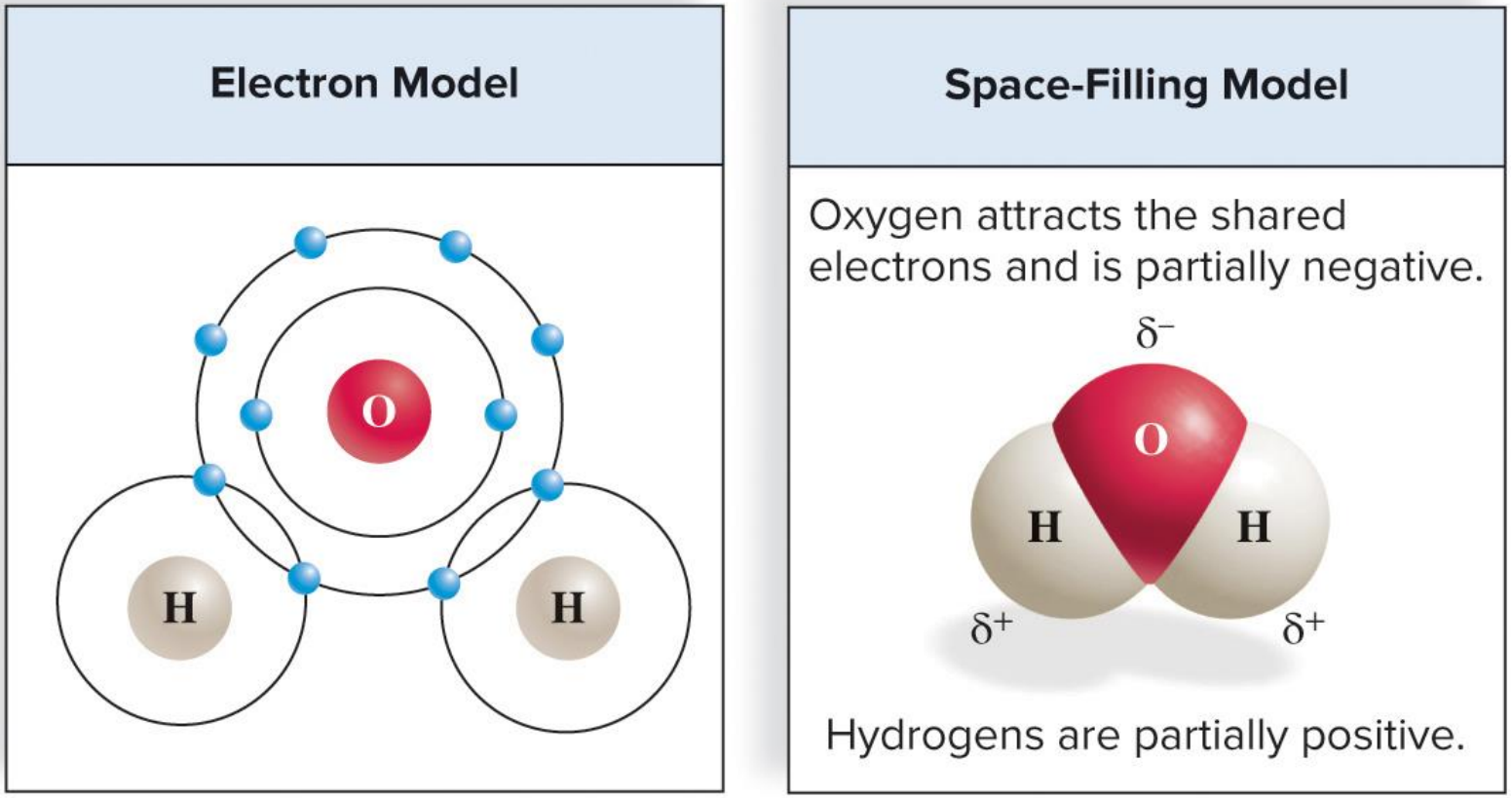
2.2 Water and Life 2

Water is the most abundant molecule in organisms, making up about 60–70% of the total body weight.

Water is a **polar** molecule.

- Electrons spend more time around the oxygen than the hydrogens, creating a partial negative charge.

Hydrogen Bonds and Water Molecules (Figure 2.7a)



a. Water (H_2O)

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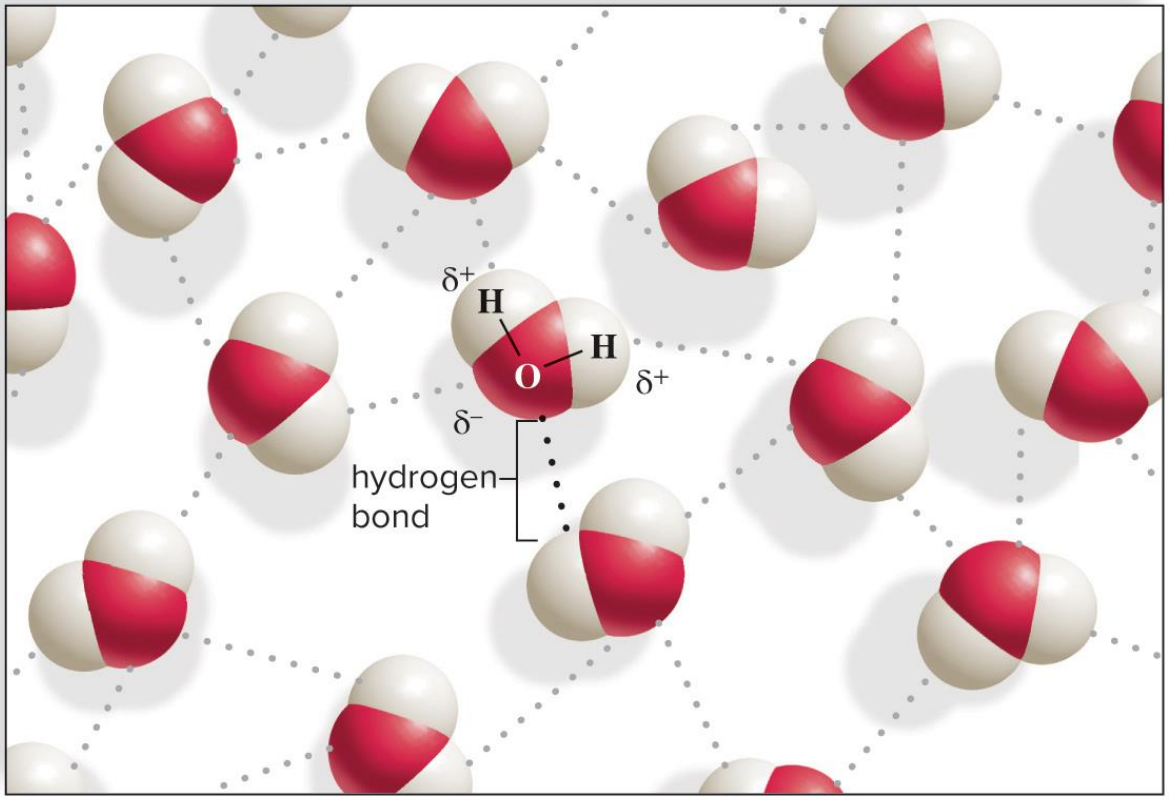
Hydrogen Bonds

Hydrogen bond—attraction between a slightly positive hydrogen to a slightly negative oxygen or nitrogen.

- Depicted by dotted lines.
- Relatively weak bonds.

Hydrogen Bonds and Water Molecules (Figure 2.7b)



b. Hydrogen bonding between water molecules

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Properties of Water

Hydrogen bonds between water molecules impart special properties:

Water is liquid at room temperature.

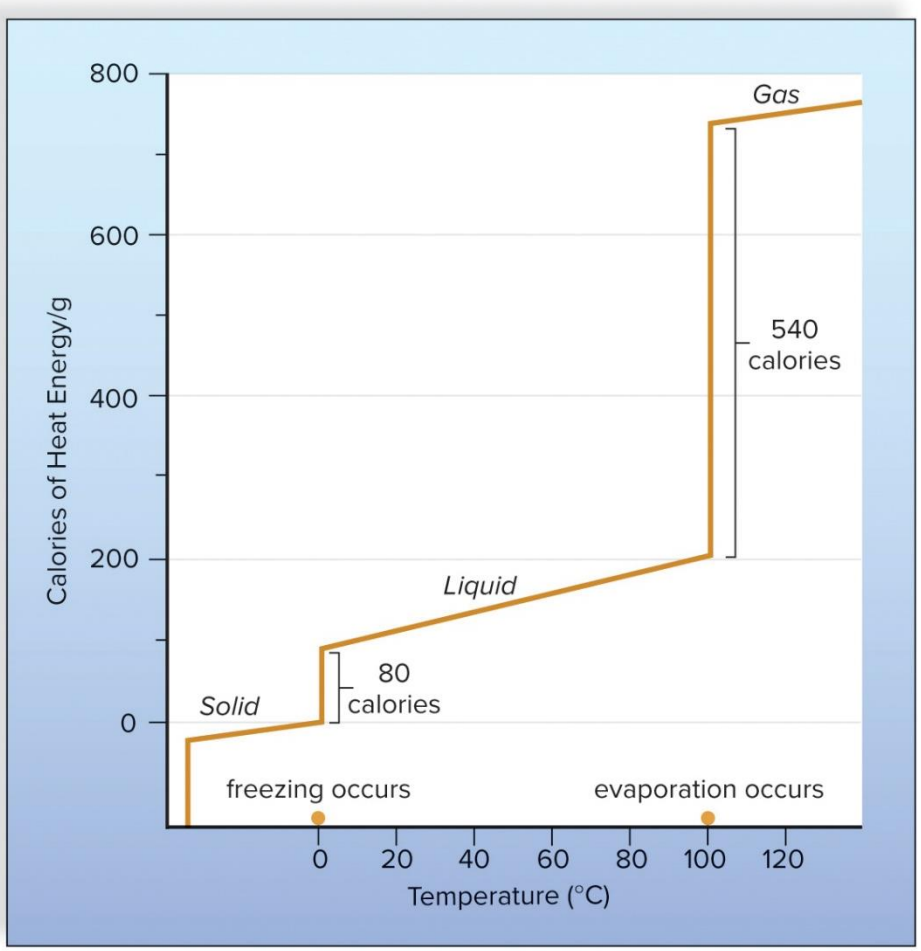
High heat capacity.

- **Calorie**—amount of heat required to raise one gram of water one degree Celsius.
- Prevents large temperature changes in the body.

High heat of vaporization.

- Hydrogen bonds must break for water to boil.
- Why sweating cools us off.

Temperature and Water (Figure 2.8a)



a. Calories lost when 1 g of liquid water freezes and calories required when 1 g of liquid water evaporates.

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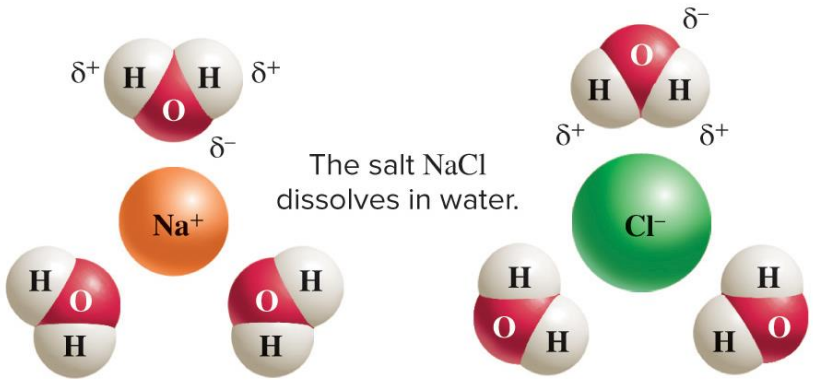
Water Is a Solvent 1

Properties of water, continued:

Water is a **solvent** (dissolves many substances).

- **Solution**—water with dissolved **solutes.**
- Salts dissociate, or separate, when dissolved in water, facilitating chemical reactions.



Water Is a Solvent 2

Properties of water, continued:

Water is a solvent, continued:

- Polar molecules attract water, so are **hydrophilic.**
- **Hydrophobic** molecules do not attract water; are **nonpolar**.
  - In nonpolar covalent bonds, the electrons are shared equally (no partial charges).
  - That is, vegetable oil is nonpolar, so won't dissolve in water.

Water Molecules Are Cohesive and Adhesive

Cohesion—water molecules cling to each other through hydrogen bonds.

- Water flows freely without separating.

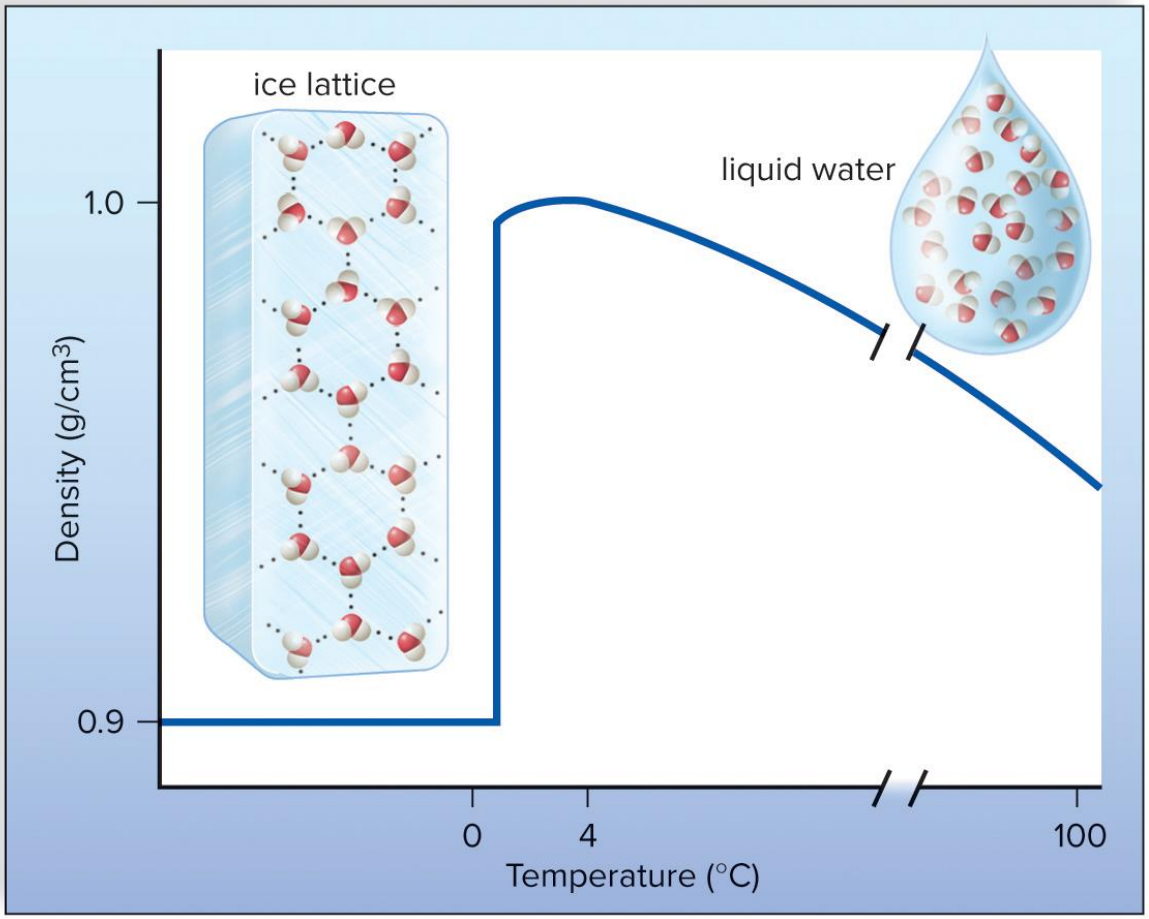
Adhesion—water molecules cling to surfaces, like blood vessels.

Frozen Water Is Less Dense than Liquid Water

As liquid water cools, it becomes less dense.

- It expands as it freezes.
- Ice floats on liquid water; this acts as an insulator.

Frozen Water Is Less Dense than Liquid Water (Figure 2.9)



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Acids and Bases 1

Acids are substances that dissociate in water, releasing hydrogen ions (H^+).

- That is, hydrochloric acid (HCl) is produced by the stomach and aids in digestion.

$$HCl \rightarrow H^+ + Cl^-$$

Acids and Bases 2

Bases are substances that take up hydrogen ions (H^+) or release hydroxide ions (OH^-).

- That is, sodium hydroxide (NaOH) is a strong base.

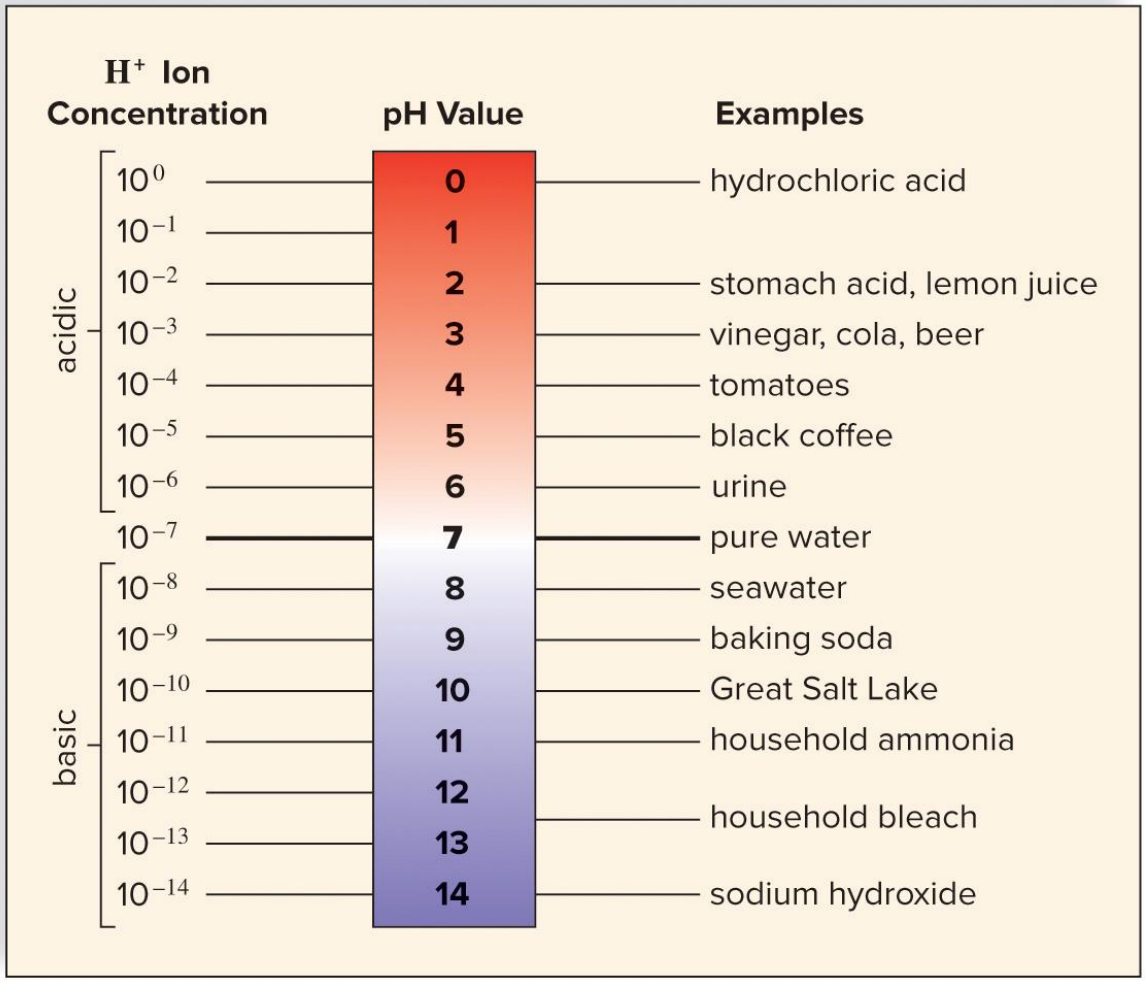
$$NaOH \rightarrow Na^+ + OH^-$$

pH Scale

The **pH scale** is a measure of acidity or basicity (alkalinity) of a solution.

- Ranges from 0 to 14.
- 7 is neutral; hydrogen ion (H^+) concentration is equal to hydroxide (OH^-) concentration.
- A pH below 7 is acidic (H^+ is greater than OH^-) and above 7 is basic (OH^- is greater than H^+).
- The concentration of hydrogen ions between each pH number changes by a factor of 10.

The pH Scale (Figure 2.10)



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Buffers

Buffer—a solution that resists changes in pH when acids or bases are added to it.

Important within the body or in the ecosystem as a whole; pH values need to stay within a narrow range.

That is, carbonic acid and bicarbonate ions act as buffers in the blood; they absorb H^+ and OH^- produced by metabolism.

- This prevents changes in pH.

Check Your Progress 2.2

List the characteristics of water and explain how hydrogen bonds contribute to these properties.

Explain the difference between a solution with a pH of 5 and a solution with a pH of 3.

Contrast the hydrogen ion concentrations of acids and bases.