LECTURE PRESENTATIONS

For CAMPBELL BIOLOGY, NINTH EDITION

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Chapter 3

Water and Life

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Overview: The Molecule That Supports All of Life

- Water is the biological medium on Earth
- All living organisms require water

- Most cells are surrounded by water, and cells themselves are about 70–95% water

- The abundance of water is the main reason the Earth is habitable

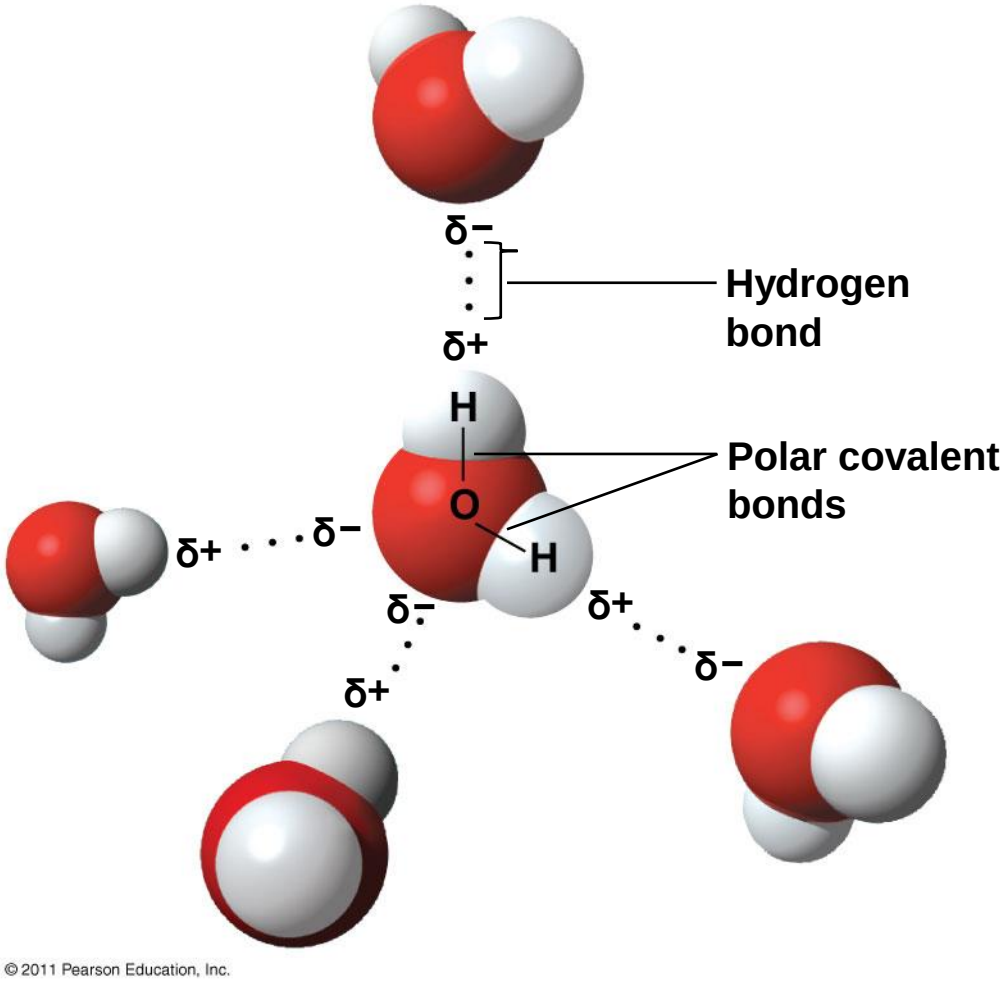
Fig. 3-1

Concept 3.1: The *polarity* of water molecules results in hydrogen bonding

- **The water molecule is a polar molecule: *The opposite ends have opposite charges***

- **Polarity allows water molecules to form *hydrogen bonds* with each other**

Figure 3.2



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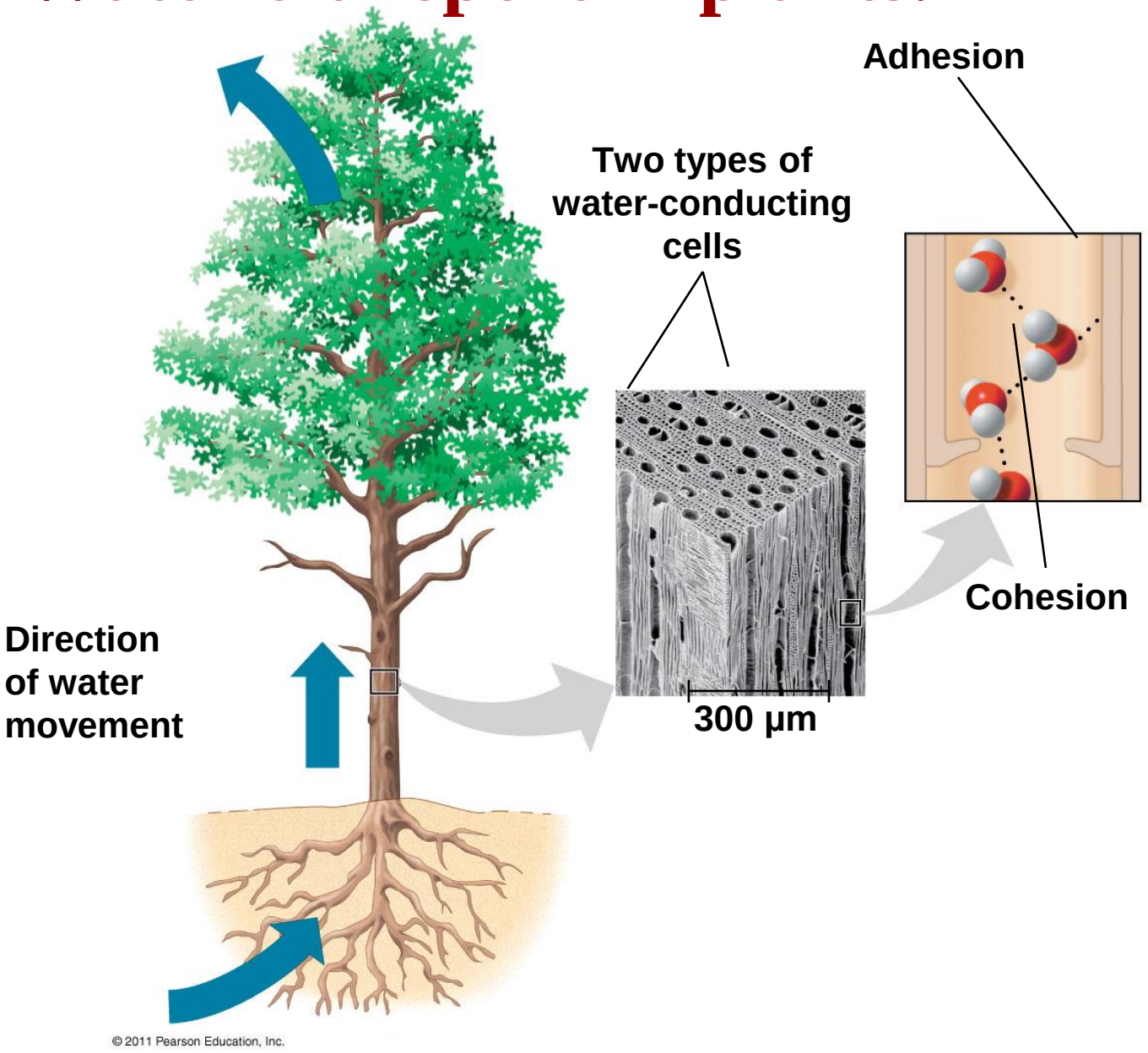
Concept 3.2: Four emergent properties of water contribute to Earth's fitness for life

- Four of water's properties that facilitate an environment for life are:
  - Cohesive behavior
  - Ability to moderate temperature
  - Expansion upon freezing
  - Versatility as a solvent

Cohesion

- Collectively, hydrogen bonds **hold water molecules together**, a phenomenon called **cohesion**
- Cohesion helps the transport of water against gravity in plants
- **Adhesion** is an attraction between different substances, for example, between water and plant cell walls

Water transport in plants.



- **Surface tension is a measure of how hard it is to break the surface of a liquid**

- **Surface tension is related to cohesion**

Moderation of Temperature

- **Water absorbs heat from warmer air and releases stored heat to cooler air**
- **Water can absorb or release a large amount of heat with only a slight change in its own temperature**

Heat and Temperature (study alone)

- **Kinetic energy** is the energy of motion
- **Heat** is a measure of the ***total amount*** of kinetic energy due to molecular motion
- **Temperature** measures ***the intensity*** of heat due to the ***average*** kinetic energy of molecules

Heat and Temperature (study alone)

- **The Celsius scale is a measure of temperature using Celsius degrees (°C)**
- **A calorie (cal) is the amount of heat required to raise the temperature of 1 g of water by 1°C**
- **The "calories" on food packages are actually kilocalories (kcal), where 1 kcal = 1,000 cal**
- **The joule (J) is another unit of energy where 1 J = 0.239 cal, or 1 cal = 4.184 J**

Water's High Specific Heat

- **The specific heat of a substance is the amount of heat that must be absorbed or lost for 1 g of that substance to change its temperature by 1ºC**
- **The specific heat of water is 1 cal/g/ºC**
- **Water resists changing its temperature because of its high specific heat**

- **Water's high specific heat can be traced to hydrogen bonding**
  - **Heat is absorbed when hydrogen bonds break**
  - **Heat is released when hydrogen bonds form**

- **The high specific heat of water minimizes temperature fluctuations to within limits that permit life**

Evaporative Cooling

- ***Evaporation*** **is transformation of a substance from liquid to gas**

- **Heat of vaporization is the heat a liquid must absorb for 1 g to be converted to gas**

- **As a liquid evaporates, its remaining surface cools, a process called**

evaporative cooling

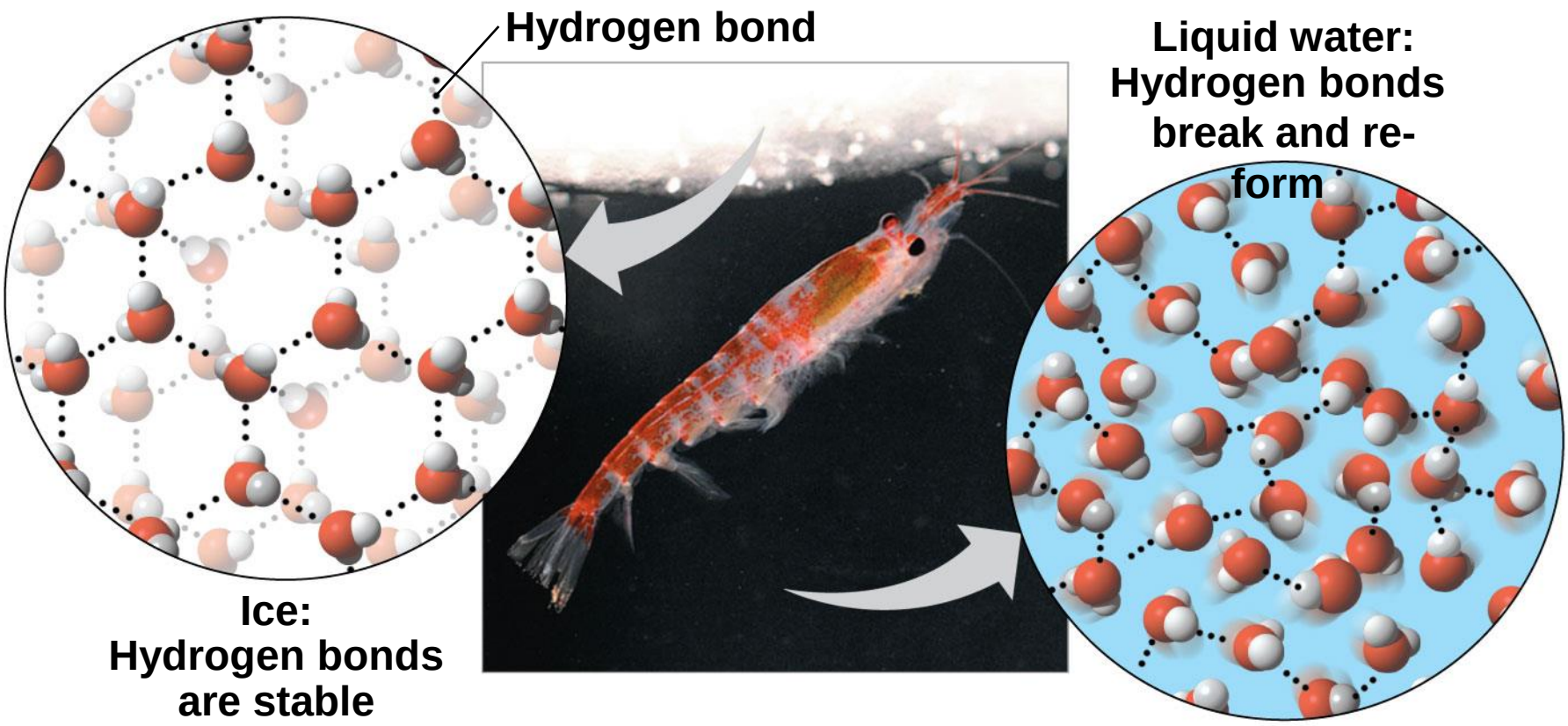
Insulation of Bodies of Water by Floating Ice

- **Ice floats in liquid water because hydrogen bonds in ice are more "ordered," making ice less dense**

- **Water reaches its greatest density at 4°C**

- **If ice sank, all bodies of water would eventually freeze solid, making life impossible on Earth**

Figure 3.6



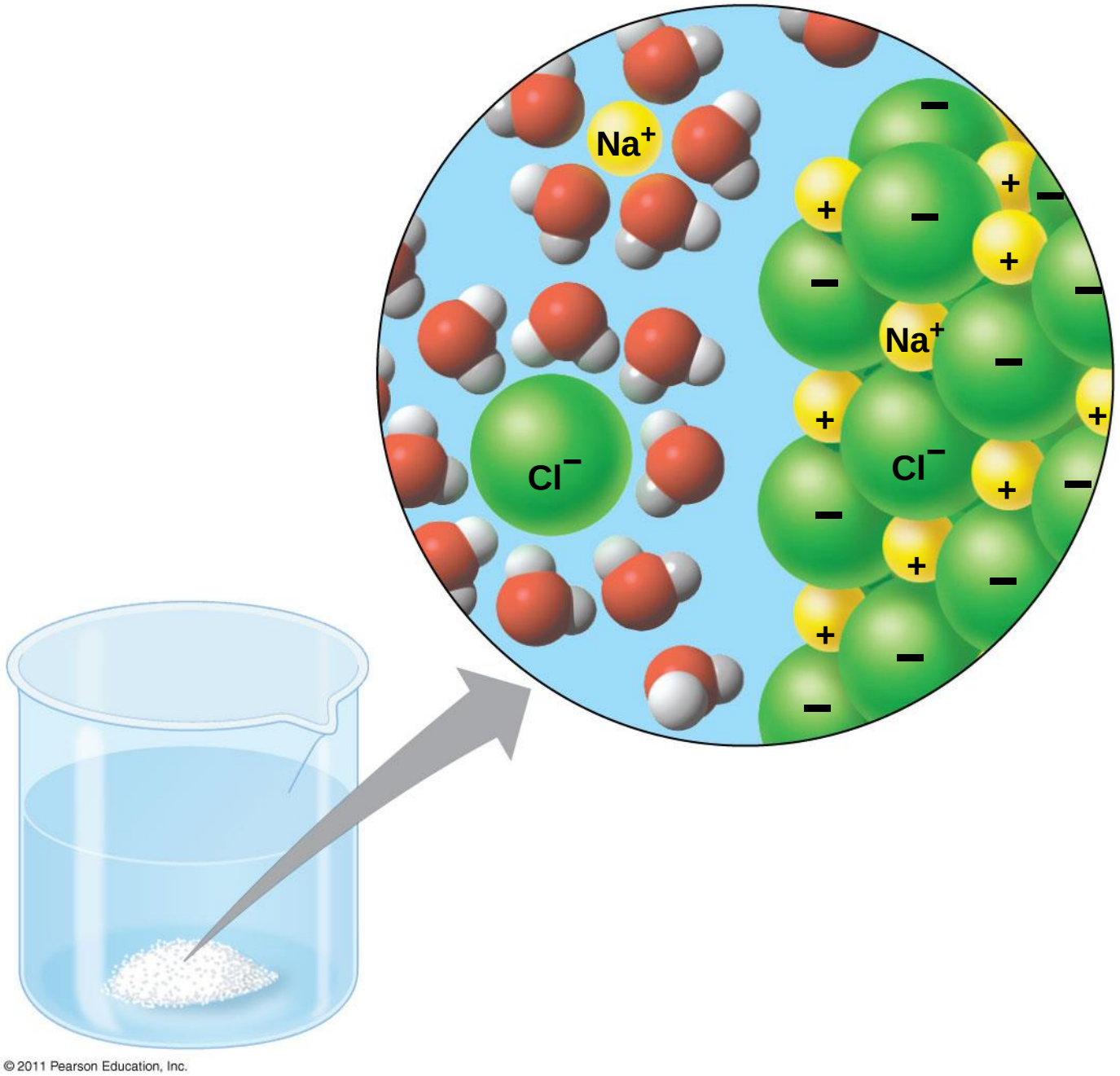
Water: The Solvent of Life

- A **solution** is a liquid that is a homogeneous mixture of substances
- A **solvent** is the dissolving agent of a solution
- The **solute** is the substance that is dissolved
- An **aqueous solution** is one in which water is the solvent

- **Water is a versatile solvent due to its polarity, which allows it to form hydrogen bonds easily**

- **When an ionic compound is dissolved in water, each ion is surrounded by a sphere of water molecules called a hydration shell**

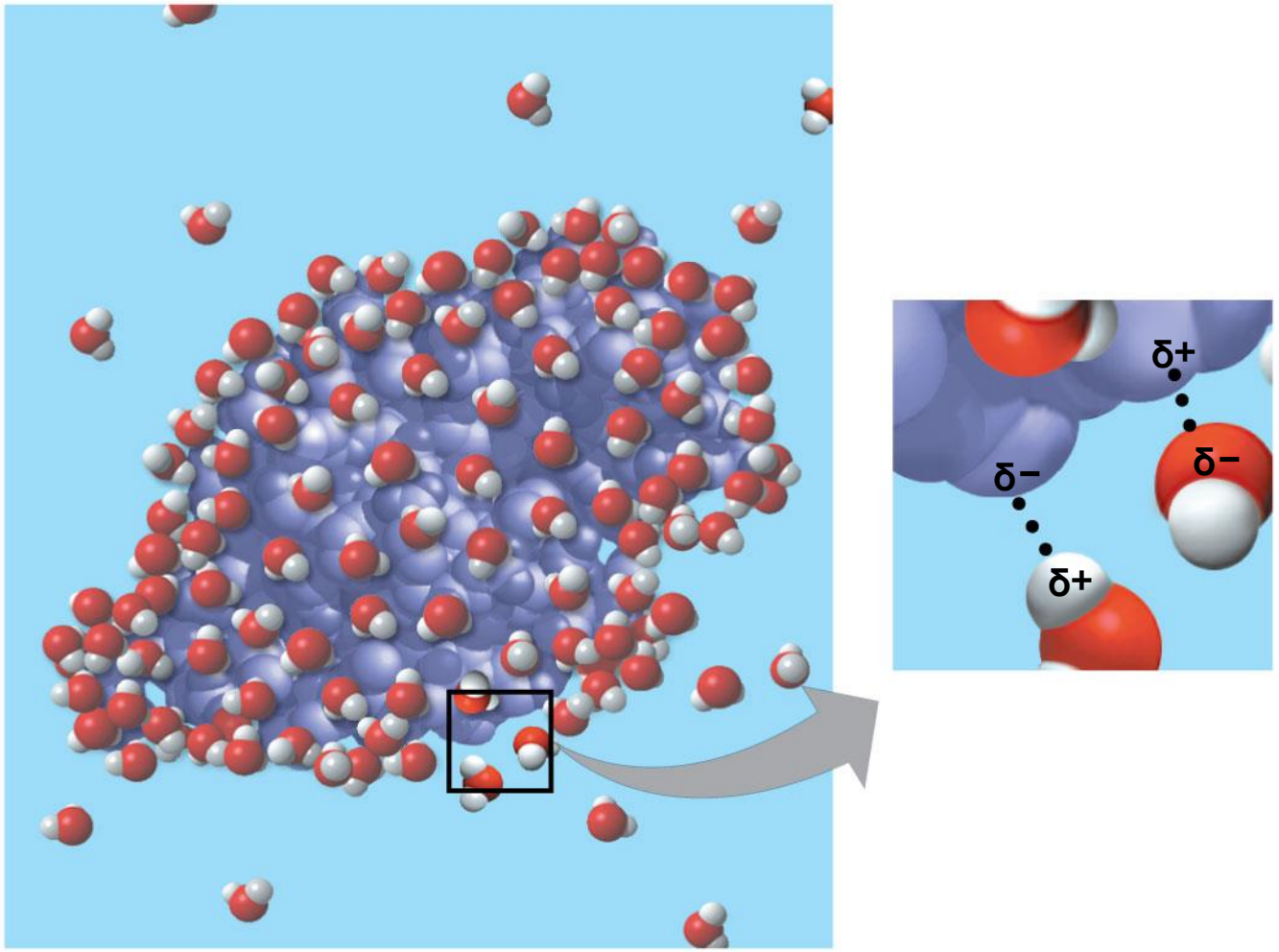
Figure 3.7



- **Water can also dissolve compounds made of nonionic polar molecules**

- **Even large polar molecules such as proteins can dissolve in water if they have ionic and polar regions**

Figure 3.8



Hydrophilic and Hydrophobic Substances

- A **hydrophilic** substance is one that has an affinity for water
- A **hydrophobic** substance is one that does not have an affinity for water
- **Oil molecules** are **hydrophobic** because they have relatively nonpolar bonds
- A **colloid** is a stable suspension of fine particles in a liquid

Solute Concentration in Aqueous Solutions

- **Most biochemical reactions occur in water**

- **Chemical reactions depend on collisions of molecules and therefore on the concentration of solutes in an aqueous solution**

- **Molecular mass** ***is the sum of all masses of all atoms in a molecule***
- **Numbers of molecules are usually measured in moles, where 1 mole (mol) = 6.02 x 10^{23} molecules**
- **Avogadro's number and the unit *dalton* were defined such that 6.02 x 10^{23} daltons = 1 g**

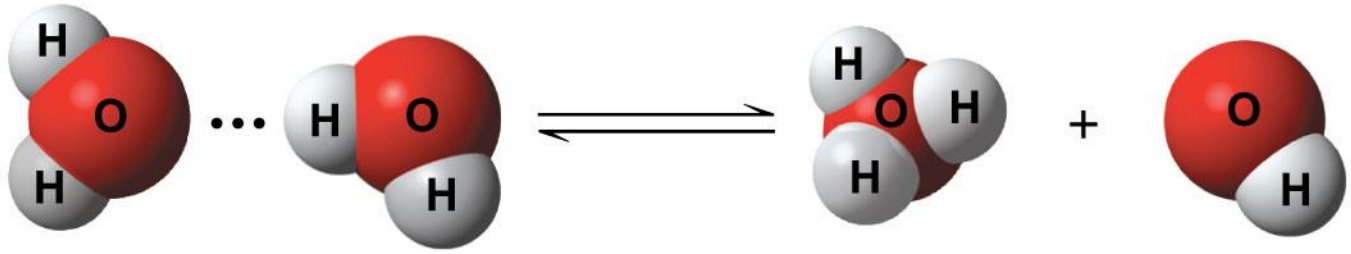
- **Molarity (*M*)** ***is the number of moles of solute per liter of solution***

Concept 3.3: Acidic and basic conditions affect living organisms

- The hydrogen atom in water molecules may leave its electron behind and transferred as a proton, or hydrogen ion (H^+)

- Water molecules may lose the proton = hydroxide ion (OH^-) is formed

- **Water is in a state of dynamic equilibrium in which water molecules dissociate at the same rate at which they are being reformed**



Effects of Changes in pH

- **Adding certain solutes, called acids and bases, modifies the concentrations of H^+ and OH^-**

- **Biologists use something called the pH scale to describe whether a solution is acidic or basic (the opposite of acidic)**

Acids and Bases

- **An acid is any substance that increases the H^+ concentration of a solution**

- **A base is any substance that reduces the H^+ concentration of a solution**

The pH Scale

- **In any aqueous solution at 25°C the product of H^+ and OH^- is constant and can be written as**

$$[H^+][OH^-] = 10^{-14}$$

- **The pH of a solution is defined by the negative logarithm of H^+ concentration, written as**

$$pH = -\log [H^+]$$

- **For a neutral aqueous solution**

$$[H^+] \text{ is } 10^{-7} = -(-7) = 7$$

- **Acidic solutions have pH values less than 7**
- **Basic solutions have pH values greater than 7**
- **Most biological fluids have pH values in the range of 6 to 8**

Figure 3.10

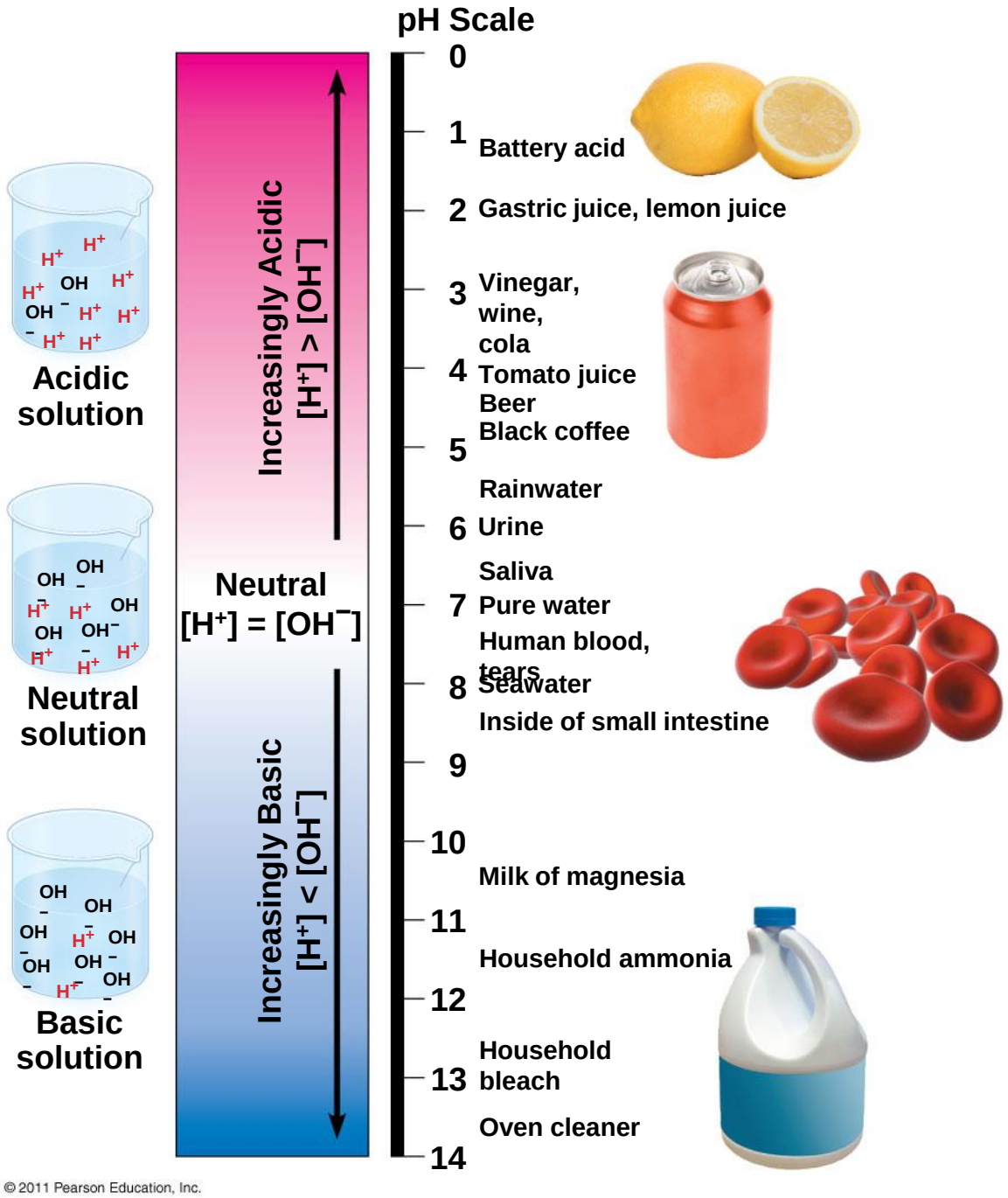


Figure 3.10a

Buffers

- **The internal pH of most living cells must remain close to pH 7**
- **Buffers are substances that *minimize* changes in concentrations of H^+ and OH^- in a solution**
- **Buffers are made either of weak acid + its conjugate base or weak base + its conjugate acid**