LECTURE PRESENTATIONS
For CAMPBELL BIOLOGY, NINTH EDITION
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Chapter 3

Water and Life

Lectures by
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Overview: The Molecule That Supports All of Life

- Water is the **biological medium** on Earth
- All living organisms require water more than any other substance
- 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

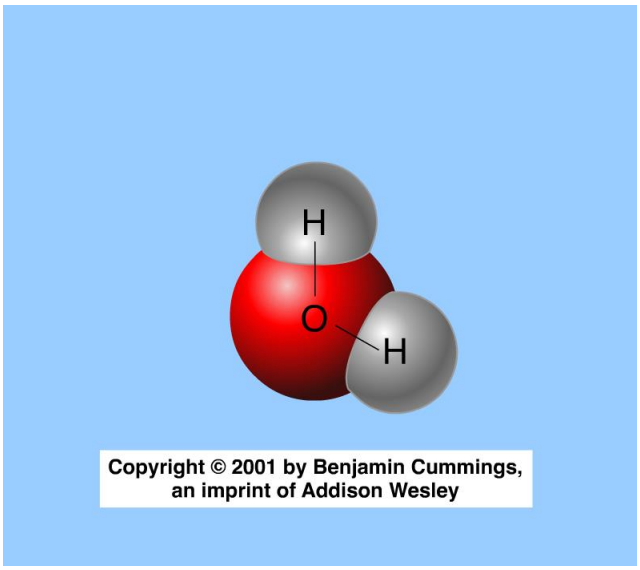
Fig. 3-1

Figure 3.1

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

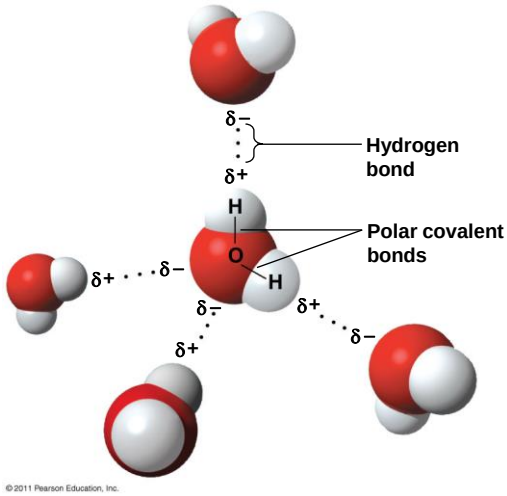
- The water molecule is a **polar molecule**: *The opposite ends have opposite charges*
- Polarity allows water molecules to form **hydrogen bonds** with each other

PLAY Animation: Water Structure



Animation: Water Structure
Right-click slide/select "Play"

Figure 3.2



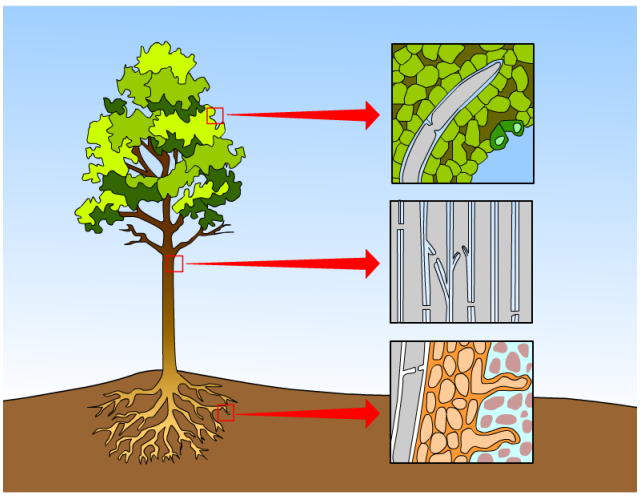
Concept 3.2: Four emergent properties of water contribute to Earth's fitness for life

- 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

PLAY Animation: Water Transport



Animation: Water Transport
Right-click slide/select "Play"

Water transport in plants.

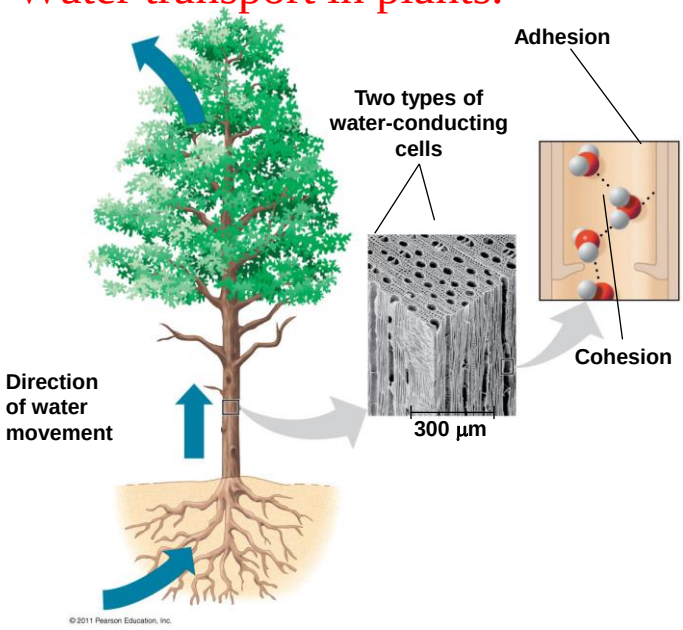


Figure 3.3a

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

Walking on water

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

- **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

- 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**
- Evaporative cooling of water helps stabilize temperatures in organisms and bodies of water

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

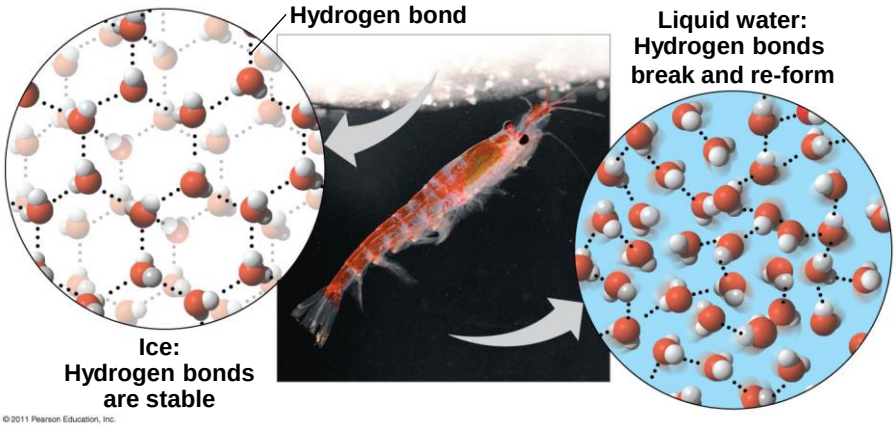


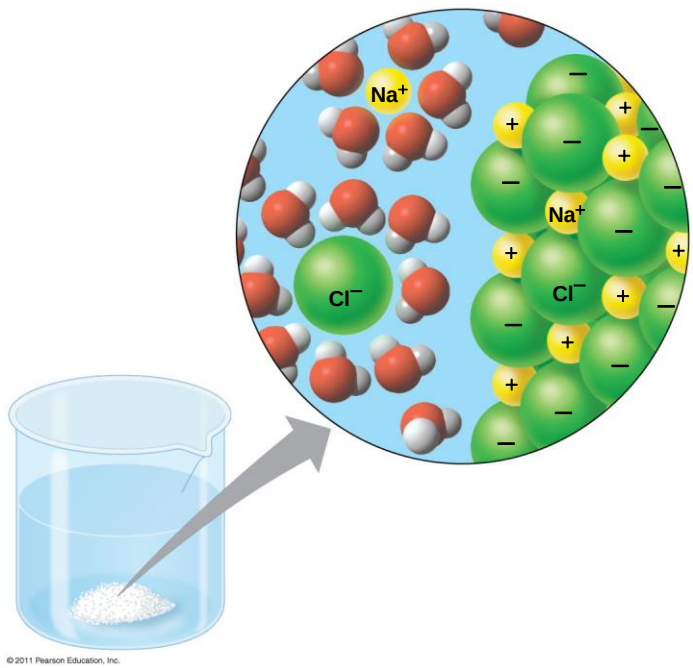
Figure 3.6a

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

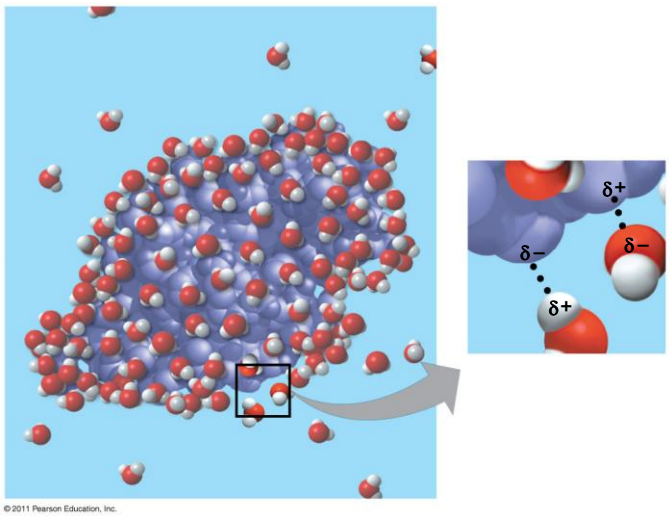
- Water is a versatile solvent due to its polarity, which allows it to form hydrogen bonds easily
- When an ionic compound is dissolved in water, each ion is surrounded by a sphere of water molecules called a **hydration shell**

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

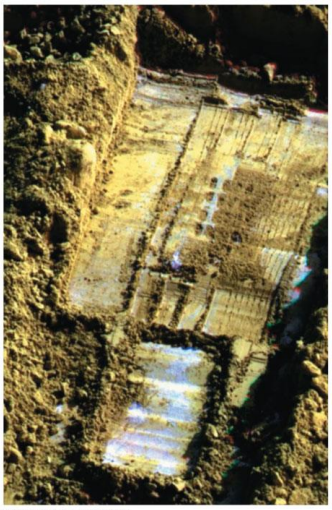
- Most biochemical reactions occur in water
- Chemical reactions **depend on collisions** of molecules and therefore on **the concentration of solutes in an aqueous solution**

- **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*

Possible Evolution of Life on Other Planets with Water

- The **remarkable properties of water** support life on Earth in many ways
- Astrobiologists seeking life on other planets are concentrating their search on planets with water
- To date, more than **200 planets** have been found outside our solar system; **one or two of them contain water**
- In our solar system, **Mars** has been found to have water

Subsurface ice and morning frost on Mars.

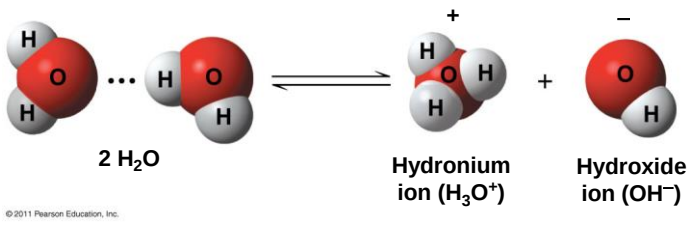


Concept 3.3: Acidic and basic conditions affect living organisms

- A hydrogen atom in a hydrogen bond between two water molecules can shift from one to the other:
  - The hydrogen atom leaves its electron behind and is transferred as a proton, or **hydrogen ion** (H^+)
  - The molecule with the extra proton is now a **hydronium ion (H_3O^+)**, though it is often represented as **H^+**
  - The molecule that lost the proton is now a **hydroxide ion (OH^-)**

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

Figure 3.UN02



- Though statistically rare, the dissociation of water molecules has a great effect on organisms
- Changes in concentrations of H^+ and OH^- can drastically affect the chemistry of a cell

Effects of Changes in pH

- Concentrations of H^+ and OH^- are equal in pure water
- 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

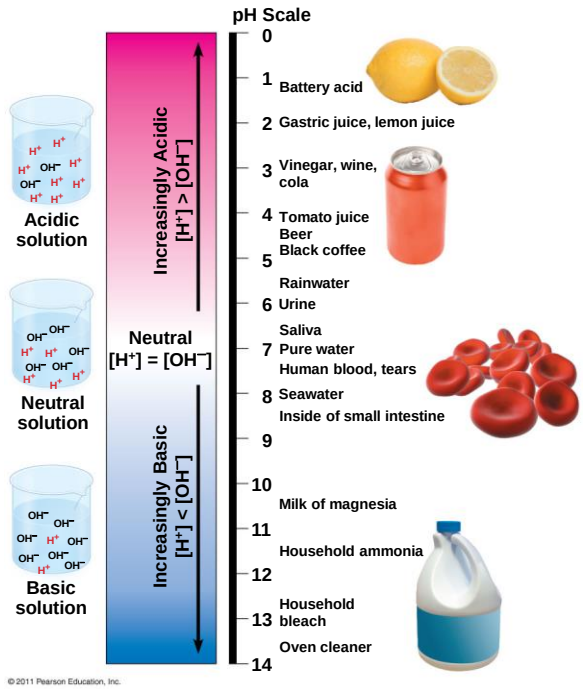


Figure 3.10a

Figure 3.10b

Figure 3.10c

Figure 3.10d

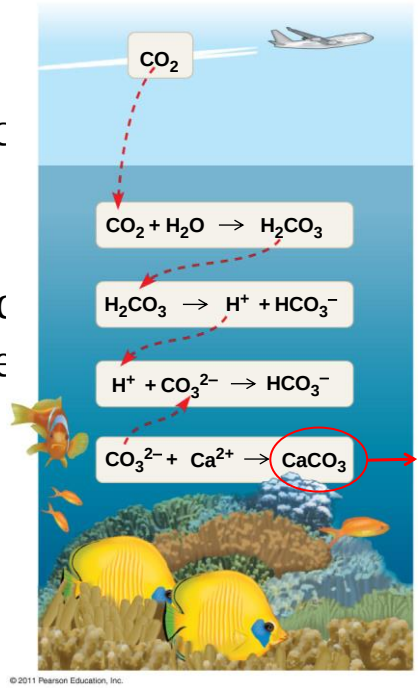
Buffers

- 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
- Most buffers consist of an acid-base pair that reversibly combines with H^+
- Buffers are made either of weak acid + its conjugate base or weak base + its conjugate acid

Acidification: A Threat to Water Quality

- **Acid precipitation** refers to rain, snow, or fog with a pH lower than 5.6
- Acid precipitation is caused mainly by the mixing of different pollutants (Sulfur oxides and nitric oxides) with water in the air and can fall at some distance from the source of pollutants
- Acid precipitation **can damage life in lakes and streams**
- Effects of acid precipitation on **soil chemistry** are contributing to the decline of some forests

Atmospheric CO_2 from human activities and its fate in the oceans.



Less carbonate ions are available for calcification by marine organisms like corals!!

- As seawater acidifies, **H^+ ions combine with carbonate ions to produce bicarbonate**
- Carbonate is required for **calcification** (production of calcium carbonate) by many **marine organism**, including **reef-building corals**

- The **burning of fossil fuels** is also a major source of sulfur oxides and nitrogen oxides
- These compounds react with water in the air to form strong acids that fall in rain or snow
- Acid precipitation is rain, fog, or snow with a ph **lower than 5.2**
- Acid precipitation damages life in lakes and streams and changes soil chemistry on land