CAMPBELL
BIOLOGY TENTH EDITION

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3

Water and Life

Lecture Presentation by Nicole Tunbridge and Kathleen Fitzpatrick

The Molecule That Supports All of Life

- Water is the biological medium on Earth
- Water is the only common substance to exist in the natural environment in all three physical states of matter
- The structure of the water molecule allows it to interact with other molecules
- Water's unique emergent properties help make Earth suitable for life
- Most cells are surrounded by water, and cells themselves are about 70–95% water

Figure 3.1

Figure 3.1a

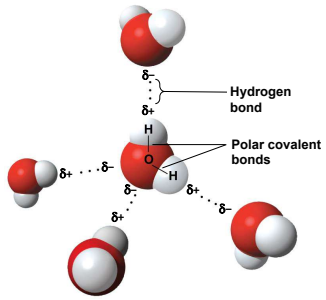
A young whooper swan paddles after its parent.

Fig. 3-1

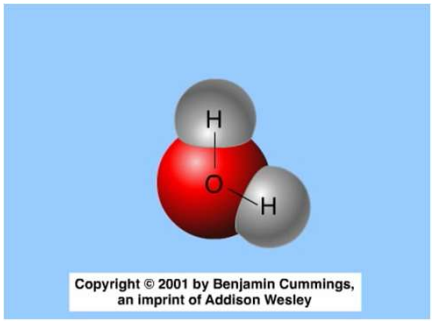
Concept 3.1: Polar covalent bonds in water molecules result in hydrogen bonding

- In the water molecule, the electrons of the **polar covalent bonds** spend more time near the oxygen than the hydrogen
- The water molecule is thus a **polar molecule**: the overall charge is unevenly distributed
- Polarity allows water molecules to form hydrogen bonds with each other

Figure 3.2



Animation: Water Structure



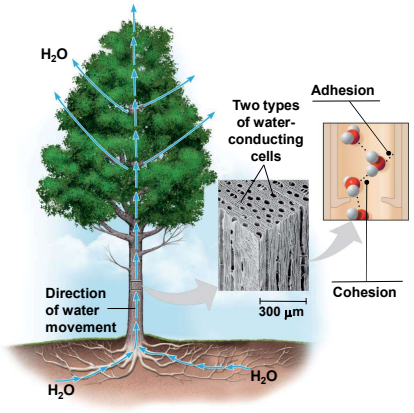
Concept 3.2: Four emergent properties of water contribute to Earth's suitability for life

- 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 of Water Molecules

- 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

Figure 3.3



BioFlix: Water Transport in Plants

Animation: Water Transport

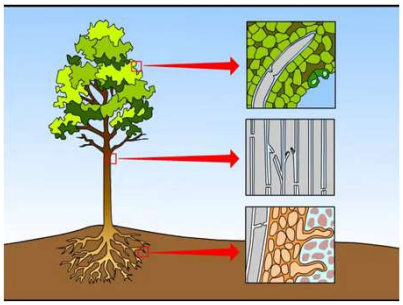
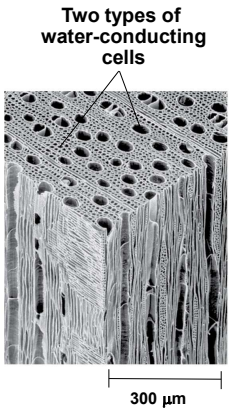


Figure 3.3a



- **Surface tension** is a measure of how hard it is to break the surface of a liquid
- Water has an unusually high surface tension due to hydrogen bonding between the molecules at the air-water interface and to the water below

Figure 3.4

Moderation of Temperature by Water

- 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

Temperature and Heat

- **Kinetic energy** is the energy of motion
- The kinetic energy associated with random motion of atoms or molecules is called **thermal energy**
- Temperature is a measure of **energy** that represents the average kinetic energy of the molecules in a body of matter
- Thermal energy in transfer from one body of matter to another is defined as **heat**

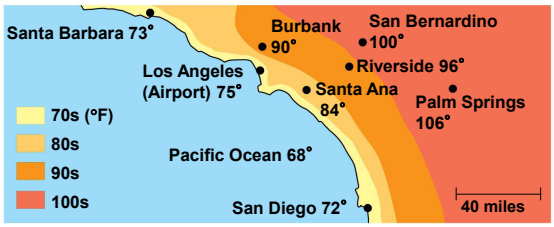
- A **calorie (cal)** is the amount of heat required to raise the temperature of 1 g of water by 1°C
- The "calories" on food packages are actually **kilocalories (kcal)**, where 1 kcal = 1,000 cal
- The **joule (J)** is another unit of energy where 1 J = 0.239 cal, or 1 cal = 4.184 J

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 1°C
- The specific heat of water is 1 cal/g/°C
- 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

Figure 3.5



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 (No change in temperature)
- 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

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Floating of Ice on Liquid Water

- Ice floats in liquid water because hydrogen bonds in ice are more "ordered," making ice less dense than water
- Water reaches its greatest density at 4°C
- If ice sank, all bodies of water would eventually freeze solid, making life impossible on Earth

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Figure 3.6

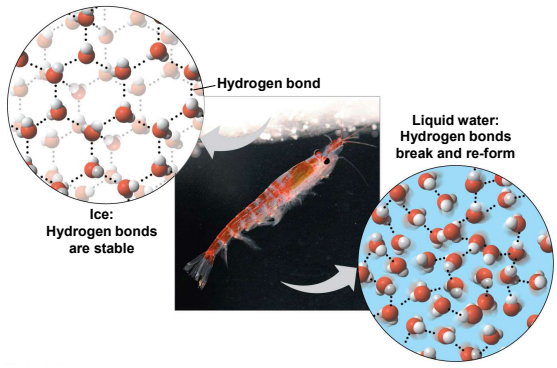


Figure 3.6a

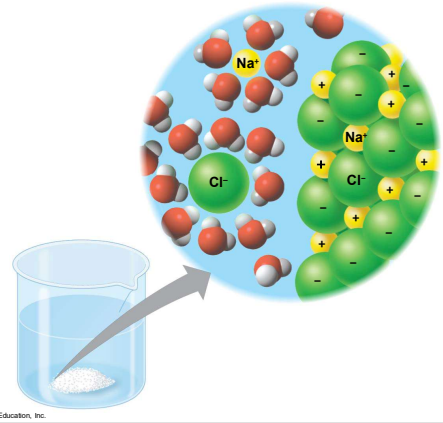
- Many scientists are worried that global warming, caused by carbon dioxide and other greenhouse gases, is having a profound effect on icy environments around the globe
- The rate at which glaciers and Arctic sea ice are disappearing is posing an extreme challenge to animals that depend on ice for their survival

Water: The Solvent of Life

- A **solution** is a liquid that is a completely 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

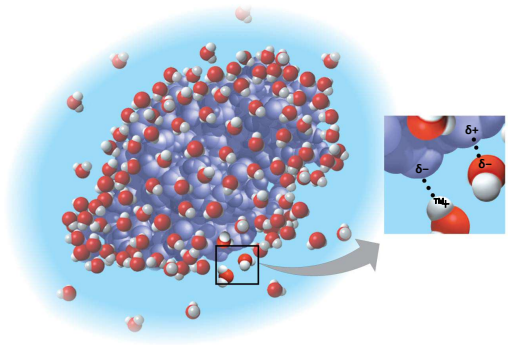
- Water is a versatile solvent due to its polarity
- When an ionic compound is dissolved in water, each ion is surrounded by a sphere of water molecules called a **hydration shell**

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
- Hydrophobic molecules related to oils are the major ingredients of cell membranes

Solute Concentration in Aqueous Solutions

- Most chemical reactions in organisms involve solutes dissolved in water
- When carrying out experiments, we use mass to calculate the number of solute molecules 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)** = 6.02×10^{23} molecules
- Avogadro's number and the unit *dalton* were defined such that 6.02×10^{23} daltons = 1 g
- **Molarity (*M*)** is the number of moles of solute per liter of solution

Possible Evolution of Life on Other Planets

- Biologists seeking life on other planets have concentrated their search on planets with water
- To date, more than 200 planets have been found outside our solar system; there is evidence that a few of them have water vapor
- In our solar system, Mars has been found to have water

Figure 3.9

Figure 3.10

Assignment

Acidification: A Threat to Water Quality

Acidification: A Threat to Water Quality

- Human activities such as burning fossil fuels threaten water quality
- CO_2 is the main product of fossil fuel combustion
- About 25% of human-generated CO_2 is absorbed by the oceans
- CO_2 dissolved in sea water forms carbonic acid; this process is called **ocean acidification**