



# Chapter 3: Water and Life

AP Biology

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## Water Molecule

- Molecule that supports all life
- Biological medium on Earth
- All living organisms require water more than any other substance
- The only common substance that exists in its natural environment in all three physical states of matter

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## Polarity

- Oxygen is more electronegative than hydrogen
- Bonds are polar covalent
- Oxygen region is a partial negative charge ( $\delta^-$ ) and the hydrogens have partial positive charge ( $\delta^+$ )
- This allows it to form hydrogen bonds with adjacent water molecules

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# Four Important Properties

- Cohesion
- Moderation of temperature
- Expansion upon freezing
- Solvent of life

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# Cohesion

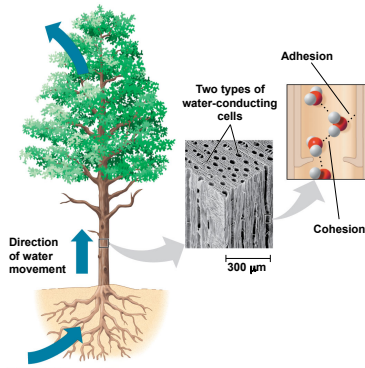
- Cohesion - attraction of like molecules
- Water molecules stay close together because of hydrogen bonding
- Hydrogen bonds form, break, and reform within trillionths of a second

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# Cohesion in Plants

Fig. 3.3

- Allows for transport of water and dissolved nutrients against gravity in plants
- Water evaporates from a leaf and hydrogen bonds tug the molecules farther down
- Adhesion - attraction of unlike molecules (helps counter the downward pull of gravity)



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## Cohesion: Surface Tension

- Measure of how difficult it is to stretch or break the surface of the liquid
- Water molecules organized themselves because of hydrogen bonding
- Makes water behave as if it were coated by an invisible film



Fig. 3.4

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## Moderation of Temperature

- Water moderates air temperature by absorbing heat from air that is warmer releasing the stored heat to air that is cooler
- Water can absorb or release a large amount of heat with only a slight change in its own temperature

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## Heat and Temperature

- Kinetic Energy - energy of motion
- Heat - total amount of kinetic energy due to molecular motion
- Temperature - measures the intensity of heat due to average kinetic energy
- Heat is related to the movement of molecules
- calorie - amount of heat it takes to raise the temperature of 1g of water by 1°C
- kilocalorie - 1000 cal

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# Water's Specific Heat

- Specific heat - amount of heat that must be absorbed or lost for 1g of the substance to change its temperature 1°C
- Water has a high specific heat (1 cal/g/°C)
- High specific heat because of hydrogen bonding
- Keeps temperature fluctuations within limits that can support life

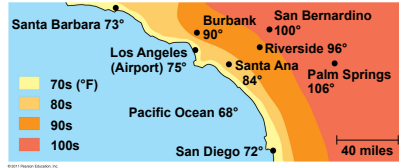


Fig. 3.5

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# Evaporative Cooling

- Evaporation - transformation from a liquid to a gas
- Heat of Vaporization - quantity of heat that must be absorbed for 1g to be converted from liquid to gas
- Water has a high heat of vaporization
- Evaporative Cooling - “hottest” molecules (those with greatest kinetic energy) leave as a gas
  - Those left behind are on average cooler

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# Insulation by Floating Ice

- Water is less dense as a solid than a liquid
  - Water expands as a solid (most substances contract)
- This is also caused by hydrogen bonding
- Water is at its most dense at 4°C

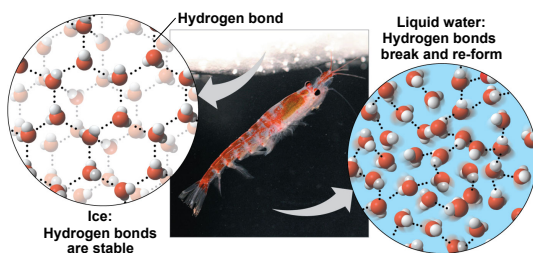


Fig. 3.6

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# Solvent of Life

- Solution - homogenous mixture of two or more substances
  - Solvent - dissolving agent
  - Solute - substances dissolved
- Aqueous solution - water acts as solvent
- Successful solvent because of polarity
- When ionic compounds are dissolved in water, they are surrounded by a hydration shell

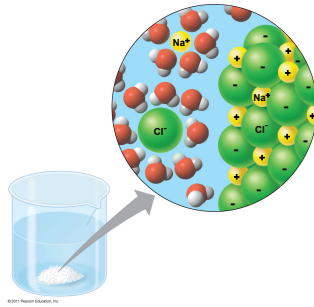


Fig. 3.7

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# Hydrophobic vs. Hydrophilic

- All relates to water's polarity
- Hydrophilic - affinity for water
- Colloid - stable suspension of particles in liquid
- Hydrophobic - non-ionic and non-polar molecules that repel water

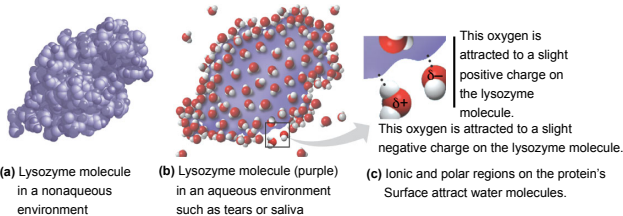


Fig. 3.8

Figure 3.7

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# Solute Concentration

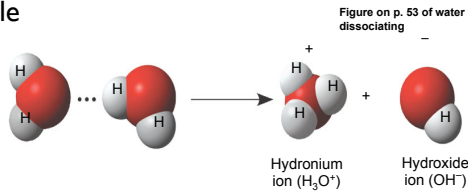
- Most biochemical reactions occur in aqueous solution that rely on collisions of molecules and concentrations of solutes
- Molecular mass - sum of all masses of the atoms in a molecule
- Mole -  $6.02 \times 10^{23}$
- Molarity - number of moles of a solute per liter of solution

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# Acids and Bases

- Hydrogen bonding can cause one hydrogen to shift to another water molecule

- Hydrogen ion
- Hydroxide ion
- Hydronium ion



- Hydrogen and hydroxide ions are very reactive
  - They can drastically impact proteins and other molecules

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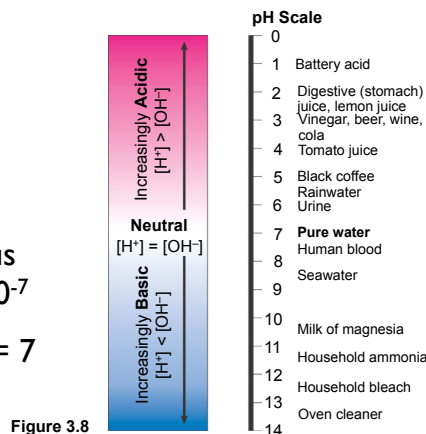
# Acids and Bases

- Acid - substance that increases the hydrogen ion concentration in a solution
  - Hydrochloric acid added to water
    - $\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^-$
- Base - substance that reduces hydrogen ion concentration
  - Ammonia added to water
    - $\text{NH}_3 + \text{H}^+ \rightleftharpoons \text{NH}_4^+$

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# pH Scale

- $\text{pH} = -\log[\text{H}^+]$
- For neutral aqueous solutions,  $[\text{H}^+]$  is  $10^{-7}$ 
  - $-\log 10^{-7} = -(-7) = 7$



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# Buffers

- Internal cell pH should be near 7
- Slight changes could damage components
- Buffers - substances that minimize changes in concentrations of  $H^+$  and  $OH^-$
- Buffer works by accepting excess hydrogen ions

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# Ocean Acidification

- Caused by burning of fossil fuels ( $CO_2$  is the main product of fossil fuel combustion)
- 25% of human-generate  $CO_2$  is absorbed by the oceans
- $CO_2$  dissolved in sea water forms carbonic acid
- $H^+$  ions combine with carbonate ions to produced bicarbonate
- Carbonate is required for calcification by reef building corals

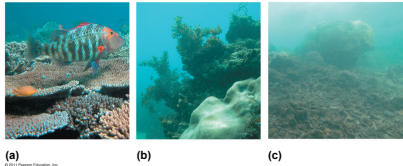


Fig. 3.12

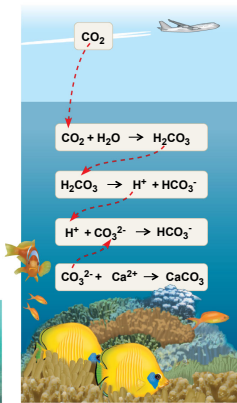


Fig. 3.11

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# Acid Precipitation

- Acid precipitation - refers to rain, snow, or fog with a pH lower than 5.6
- Caused by sulfur oxides and nitrogen oxides

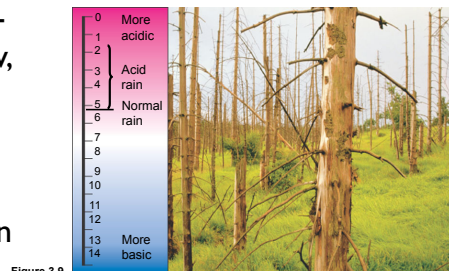


Figure 3.9

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