Water and the Fitness of the Environment

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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Overview: The Molecule That Supports All of Life

- **Topics Covered in this Module**
  - Properties of Water
  - How the Properties of Water Sustain Life
- **Major Objectives of this Module**
  - Describe the basic properties of water molecules.
  - Explain how the polarity of water molecules results in hydrogen bonding.
  - Summarize the unique properties of water that are important for sustaining life.

Overview: The Molecule That Supports All of Life

The required basic chemical concepts are summarized in **Chap. 2** and **5**

- WATER
  1. Physico-chemical properties of water
  2. Biochemical properties of water
- Macromolecules
  1. Protein
  2. Carbohydrates
  3. Lipid
  4. Nucleic acids

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

The blue planet: water

Structure of water molecule

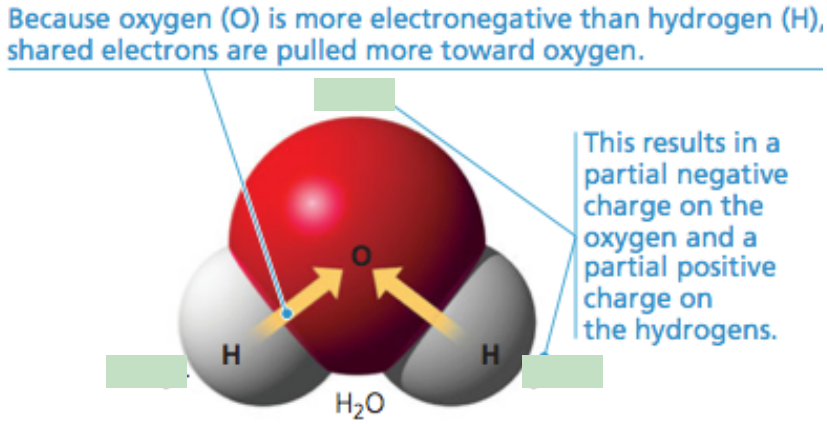


Fig. 3-2

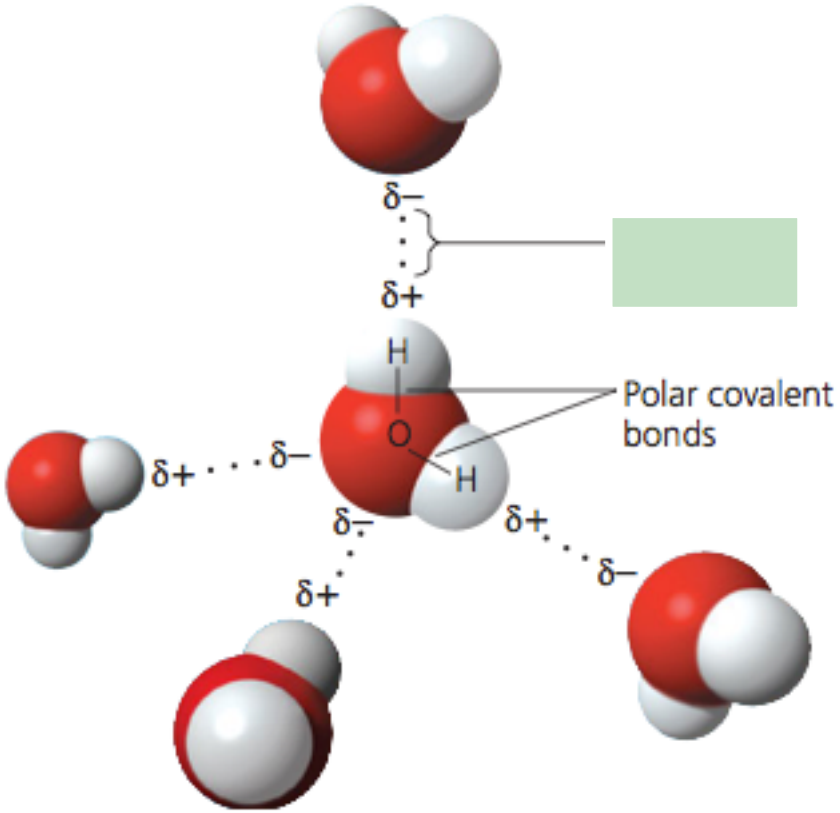


Fig. 3-2

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 - Adhesive behavior
  - Ability to moderate temperature
  - Expansion upon freezing
  - Versatility (not universal) as a solvent

Cohesion – Adhesion

- 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

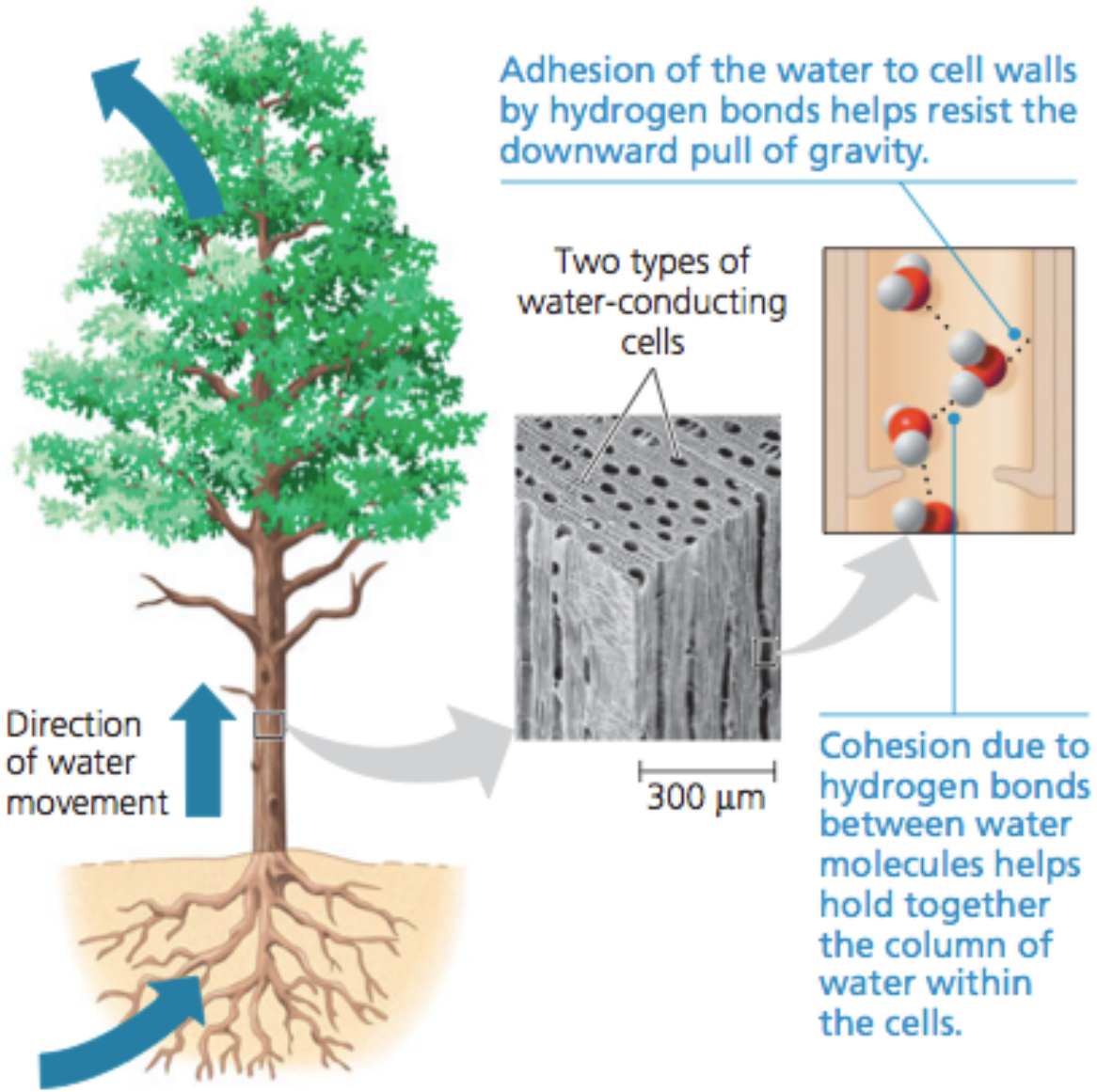

Adhesion of the water to cell walls by hydrogen bonds helps resist the downward pull of gravity.
Two types of water-conducting cells
Direction of water movement
300 µm
Cohesion due to hydrogen bonds between water molecules helps hold together the column of water within the cells.

Fig. 3-3

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

Fig. 3-5

- High temperature retention
  - Stabilize ocean temperatures
  - Stabilize organismal temperatures

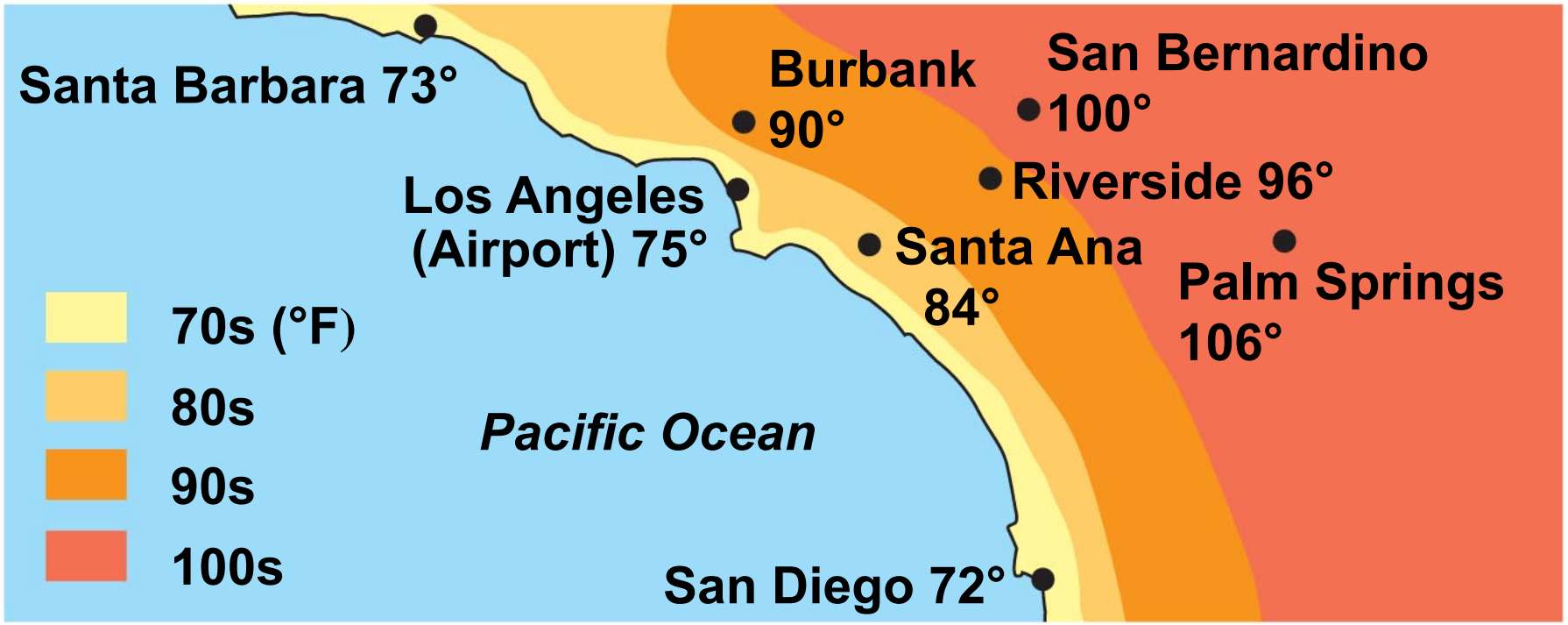
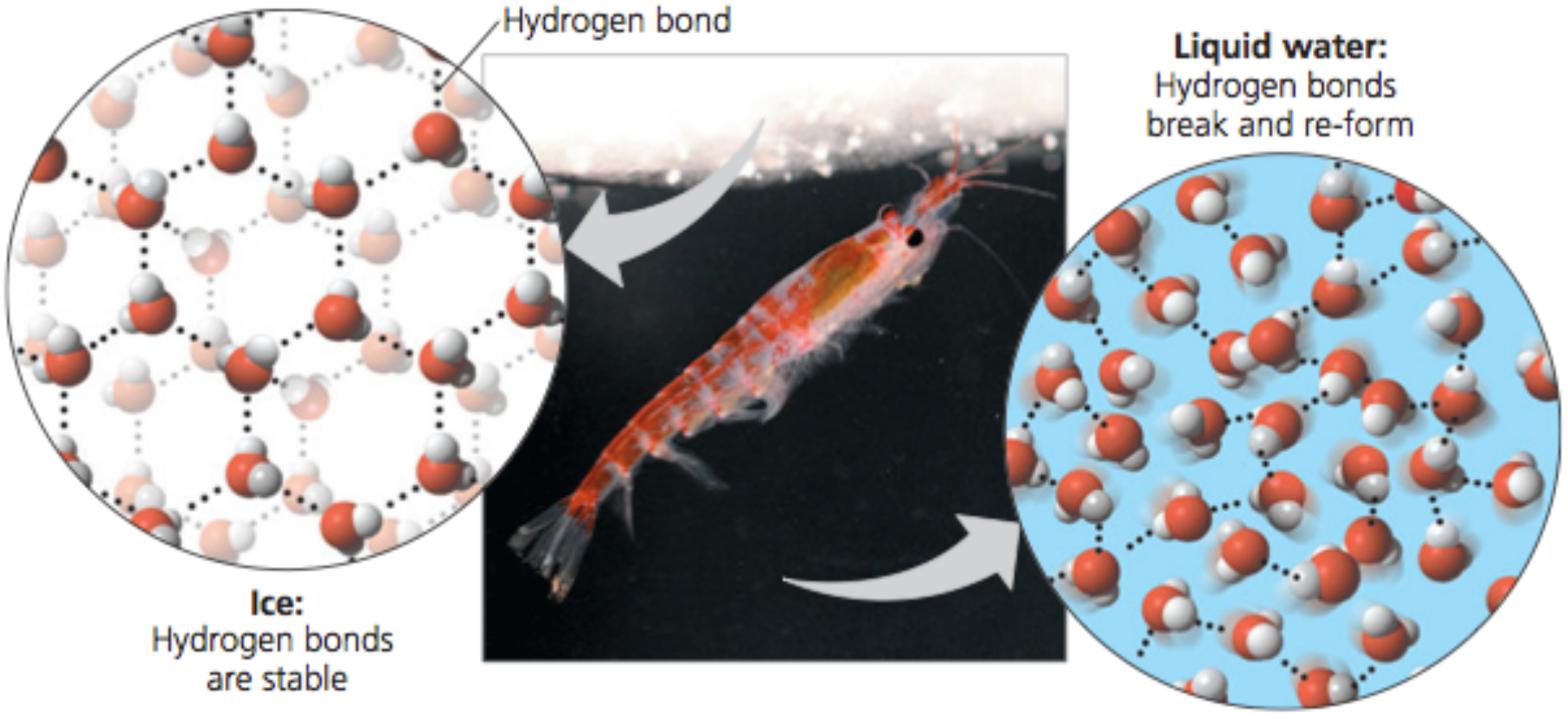


Fig. 3-6

Expansion upon freezing (highest density at 4°C)



Ice floats

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

- When an [redacted] or [redacted] is dissolved in water, each ion is surrounded by a sphere of water molecules called a **hydration shell**

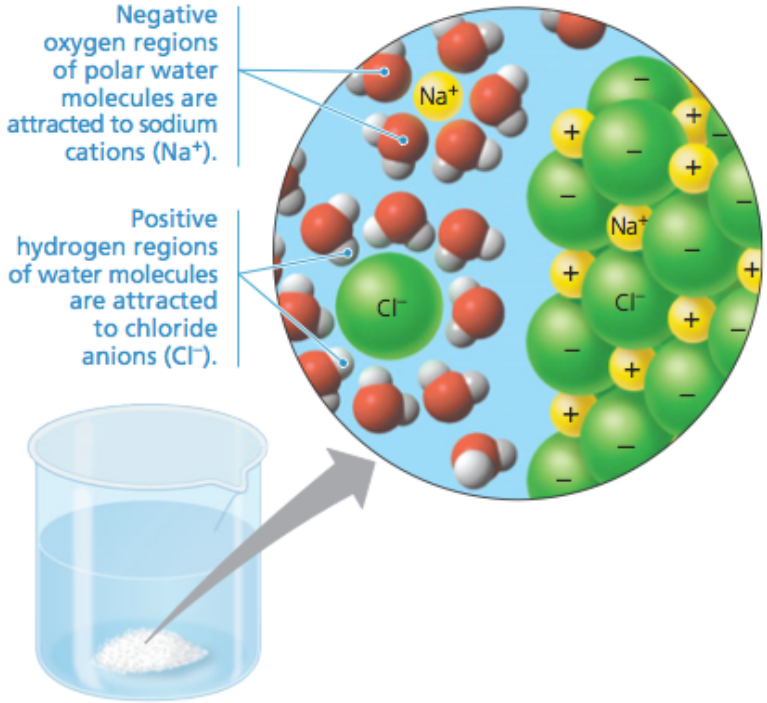


Fig. 3-7

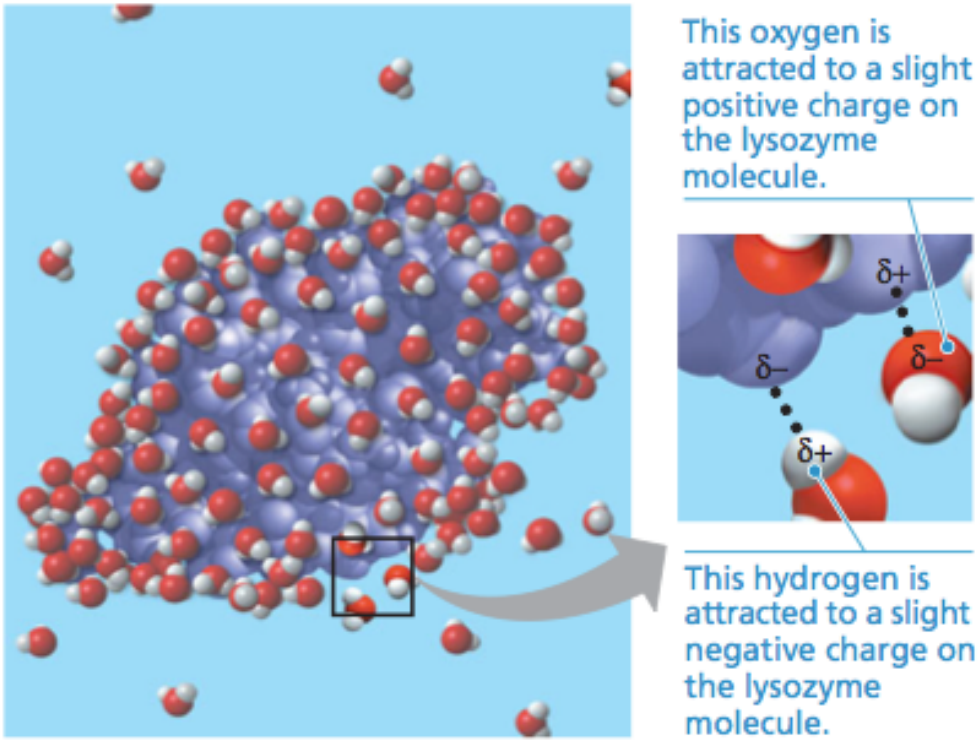
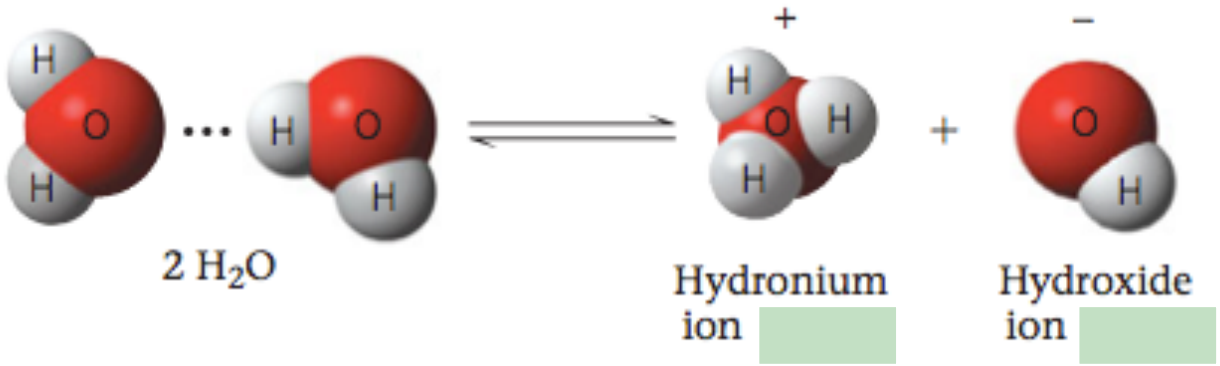


Fig. 3-8

- Water is a versatile (not universal) solvent due to its polarity, which allows it to form hydrogen bonds easily

Fig. 3-UN2

- Dissociation of protons
  - Highly reactive species (H^+, OH^-)
  - Importance of buffers



- 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 $[H^+]$ is 10^{-7} M = –(–7) = 7 = 1 H^+ per 554 million H_2O

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

- Reactant/product of macromolecule formation

  Condensation