The polarity of water molecules results from hydrogen bonding

- In a water molecule two hydrogen atoms form single polar covalent bonds with an oxygen atom.
  - Oxygen is more electronegative (6 valence electrons) - region around oxygen has partial *negative* charge.
  - Hydrogen is less electronegative (1 valence electron) -region near the two hydrogen atoms has a partial *positive* charge.
- A water molecule is a ***polar molecule*** with opposite ends of the molecule with opposite charges.
  - Slightly negative regions of one molecule are attracted to slightly positive regions of nearby molecules, forming a hydrogen bond.
  - Each water molecule can form hydrogen bonds with up to four neighbors.

Water has many important properties that make it so vital to life

- The hydrogen bonds joining water molecules are weak, about $1/20^{th}$ as strong as covalent bonds.
- They form, break, and reform with great frequency.
- At any instant, a large percentage of all water molecules are bonded to their neighbors – this creates a high level of structure.
- Hydrogen bonds hold water together, a phenomenon called ***cohesion***.
  - Cohesion is the "stickiness" of water (due to the H bonds)
  - Cohesion plays a key role in the transport of water against gravity in plants (allows it to move upward in xylem).
- Water molecules stick to other polar compounds too (like the walls of the xylem)
- This phenomenon is called ***adhesion***
- **Surface tension,** a measure of the force necessary to stretch or break the surface of a liquid, is related to cohesion.
  - Water has a greater surface tension than most other liquids because hydrogen bonds among surface water molecules resist stretching or breaking the surface.
  - Water behaves as if covered by an invisible film.
  - Some animals can stand, walk, or run on water without breaking the surface.

Water moderates temperatures on Earth

- Water stabilizes air temperatures:
  - Absorbs heat from warmer air ➔ releases heat to cooler air.
  - Can absorb/release relatively large amounts of heat with only a slight change in its own temperature.
- Water stabilizes temperature because it has a ***high specific heat.***
- **Specific heat** of a substance:

  - Amount of heat that must be absorbed or lost for **1g** of that substance to change its temperature by **1°C**.
- Water has a high specific heat compared to other substances.
- Water's high specific heat is due to *hydrogen bonding*.
  - Heat must be absorbed to break hydrogen bonds and is released when hydrogen bonds form.
  - Use of 1 calorie of heat causes relatively little change to the temperature of water
  - Much of the energy is used to *disrupt* hydrogen bonds, **NOT** move molecules faster (small increase in kinetic energy).
- Water resists changes in temperature because it takes a lot of energy to speed up its molecules.
- The impact of water's high specific heat ranges from the level of the whole environment of Earth to that of individual organisms.
  - Ocean temperatures to body temperatures are more constant
- The transformation of a molecule from a liquid to a gas is called vaporization or evaporation.
- **Heat of vaporization** is the quantity of heat that a liquid must absorb for 1 g of it to be converted from the liquid to the gaseous state.
  - Water has a relatively high heat of vaporization (double the heat required to vaporize same quantity of alcohol or ammonia)
  - This is because hydrogen bonds must be broken before a water molecule can evaporate from the liquid.
- Water's high heat of vaporization moderates climate by absorbing heat in the tropics via evaporation and releasing it at higher latitudes as rain.
- As a liquid evaporates, the surface of the liquid that remains behind cools - **evaporative cooling**.
- Evaporative cooling moderates temperature in lakes and ponds and prevents terrestrial organisms from overheating.
  - Evaporation of water from the leaves of plants or the skin of humans removes excess heat.

Oceans and lakes don't freeze solid
because ice floats! ☺

- Water is unusual because it is ***less dense*** as a *solid* than as a *liquid*.
  - Most materials contract as they solidify, ***but water expands***.
  - At temperatures above 4°C, water behaves like other liquids; expands when warm, contracts when cool
  - Water begins to freeze when its molecules are no longer moving vigorously enough to break their hydrogen bonds.
  - When water reaches 0°C it becomes locked into a crystalline lattice-each molecule bonded to the maximum of four partners.
  - Molecules are farther apart

  - Ice is about 10% less dense than water at $4^{o}C$.
- Therefore, ice floats on the cool water below, acting as an insulator.
- ***<u>This oddity has important consequences for life.</u>***
  - If ice sank, eventually all ponds, lakes, and even the ocean would freeze solid.
  - During the summer, only the upper few inches of the ocean would thaw.
  - Instead, the surface layer of ice insulates liquid water below, preventing it from freezing and allowing life to exist under the frozen surface.

Water is the solvent of life

- Water is an effective solvent because it readily forms hydrogen bonds with ionic and polar molecules.
- Even large molecules, like proteins, can dissolve in water if they have ionic and polar regions.
- Any substance that has an affinity for water is **hydrophilic**.
  - These substances are dominated by ionic or polar bonds.
- Substances that have no affinity for water are **hydrophobic**.
  - These substances are dominated by non-ionic and non polar covalent bonds.
  - Because there are no consistent regions with partial or full charges, water molecules cannot form hydrogen bonds with these molecules.
  - Oils, such as vegetable oil, are hydrophobic because the dominant bonds, carbon-carbon and carbon-hydrogen, exhibit equal or near equal sharing of electrons.
- Hydrophobic molecules are major ingredients of cell membranes.