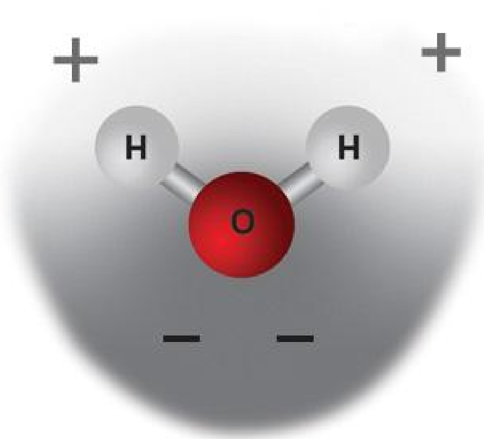
Life Depends on the Unique Properties of Water

Stop the process

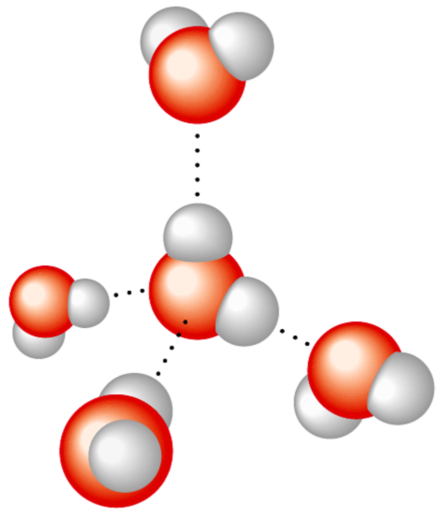
Learning Target
Explain the properties of water and its importance to life.

All living things are dependent on water. Inside your body, your cells are surrounded by a fluid that is mostly water, and your cells themselves are 70-95 percent water. The abundance of water is a major reason Earth can support life. Water is so common that it is easy to overlook its extraordinary properties, which are linked to the structure and interactions of its molecules.



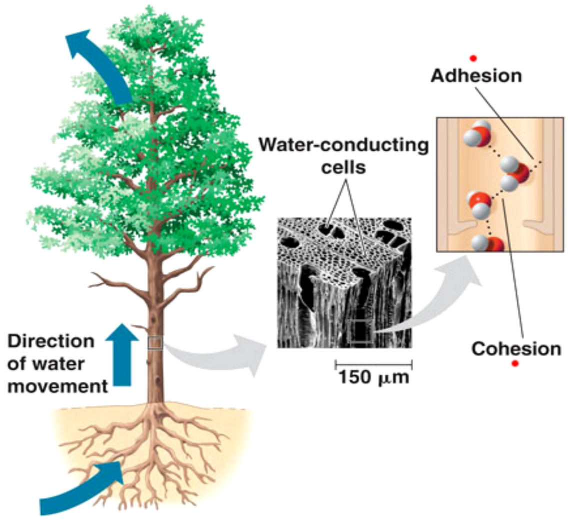
The Structure of Water
A water molecule at first may seem pretty simple. Its two hydrogen atoms are each joined to an oxygen atom by a single covalent bond. However, the key to water's unusual properties is that the electrons of each covalent bond are not shared equally between oxygen and hydrogen atoms. Oxygen pulls electrons much more strongly than does hydrogen. Part of the reason is that the oxygen nucleus has eight protons, and therefore has a stronger positive charge than the hydrogen nucleus, which has one proton. This unequal pull results in the shared electrons spending more of their time in the "neighborhood" of the oxygen atom. Note the "V" shape of the water molecule, with the oxygen atom at the base of the "V" opposite the two hydrogen atoms. The unequal sharing of electrons causes the oxygen end of the molecule to have a sight negative charge, while the end which the two hydrogen atoms is slightly positive. A molecule in which opposite ends have opposite electric charges is called a **polar molecule**. Water is a compound consisting of polar molecules.

Water molecules are attracted to one another in a specific way. The slightly negative oxygen end of one molecule attracts the slightly positive hydrogen ends of adjacent water molecules, causing the molecules to become arranged as you see in the picture below. This type of weak attraction between the hydrogen atom of one molecule and a slightly negative atom within another molecule is a type of chemical bond called a **hydrogen bond**. Because the atoms within the water molecules have not transferred an electron (and thus a full unit of charge) to another atom, the attraction in a hydrogen bond is not as strong as that in an ionic bond.



Cohesion & Adhesion
Each hydrogen bond between molecules of liquid water lasts for only a few trillionths of a second. Yet, at any instant most of the molecules are involved in hydrogen bonding with other molecules because new hydrogen bonds form as fast as old ones break. This tendency of molecules of the same kind to stick to one another is called **cohesion.** Cohesion is much stronger for water than for most other liquids. Water molecules are also attracted to certain other molecules. This type of attraction that occurs between unlike molecules is called **adhesion**. Both cohesion and adhesion are important in the living world. One of the most important effects of these forces is keeping large molecules organized and arranged in a way that enables them to function properly in cells.

As another example, trees depend on cohesion and adhesion to help transport water from their roots to their leaves. The evaporation of water from leaves pulls water upward from the roots through narrow tubes in the trunk of the tree. Adhesion between water molecules and the walls of the tubes helps resist the downward pull of gravity on the water. And because of cohesion between water molecules, the pulled force caused by evaporation from the leaves is relayed through the tubes all the way down to the roots. As a result, water moves against the force of gravity even to the top of a very tall tree. You've witnessed another example of cohesion if you've ever seen an insect "skating" across the surface of a pond. Cohesion pulls the molecules at the surface tightly together, forming a film-like boundary that can support the insect. This effect is known as **surface tension**.



Temperature Moderation
If you have ever burned your finger on a metal pot while waiting for the water in it to boil, you know that water heats up much more slowly than metal. In fact, because of hydrogen bonding, water has a better ability to resist temperature change than most other substances. To understand why, it is first helpful to know a little about energy and temperature. **Thermal energy** is the total amount of energy associated with the random movement of atoms and molecules in a sample of matter. **Temperature** is a measure of the average energy of random motion of the particles in a substance. When two substances differ in temperature, thermal energy in the form of heat is transferred from the warmer substance to the cooler one.

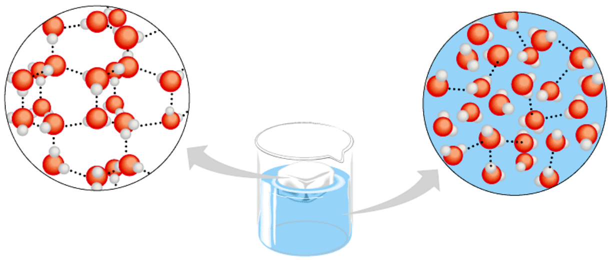
When you heat a substance–such as a metal pan or water–its temperature rises because its molecules move faster. But in water, some of the thermal energy that is absorbed goes to break hydrogen bonds. As a result, the water absorbs the same amount of thermal energy but undergoes less temperature change than the metal. Conversely, when you cool a substance, the molecules slow and the temperature drops. But as water cools, it forms hydrogen bonds. This releases thermal energy in the form of heat, so there is less of a drop in temperature than in metal.

One result of this property is that it causes oceans and large lakes to moderate the temperatures of nearby land areas. In other words, coastal areas generally have less extreme temperatures than inland areas. For example, a large lake can store a huge amount of thermal energy from the sun during the day. Then at night, heat given off by the gradually cooling water moderates the otherwise more rapid cooling of the air and land.

Water also moderates temperature through evaporation, such as when you sweat. Evaporation occurs when molecules at the surface of a liquid escape to the air. As water molecules evaporate, the remaining liquid becomes cooler. The process of evaporation requires thermal energy to break hydrogen bonds and release water molecules into the air. In sweating, this energy is absorbed from the skin, cooling the body.

Low Density of Ice
Density is the amount of matter in a given volume. A high-density substance is more tightly "packed" than a low-density substance. In most substance, the solid state is more dense than the liquid state. Water is just the opposite–its solid form (ice) is less dense than the cool liquid form. Once again, hydrogen bonds are the reason. Every water molecules in ice forms four long-lasting hydrogen bonds with neighboring water molecules, which keep the molecules spaced in a regular pattern. Because the

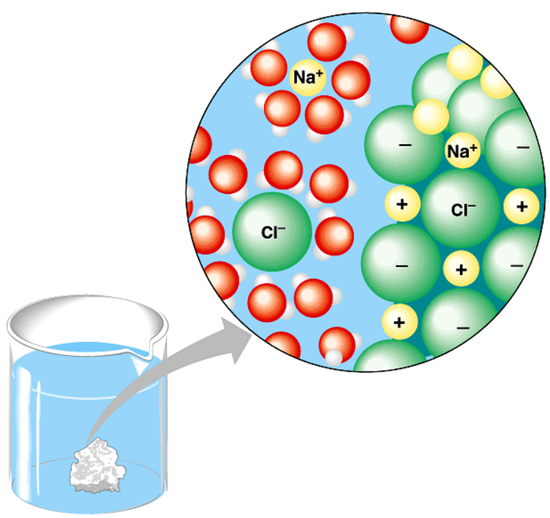
molecules in liquid water are moving faster than those in ice, there are fewer and more short-lived hydrogen bonds between molecules. The liquid water molecules can fit more closely together than the molecules in ice. Since substances of lesser density float in substances of greater density, ice floats in liquid water.



Universal Solvent

When you stir table salt into a glass of water, you are forming a **solution**, a uniform mixture of two or more substances. The substance that dissolves the other substance and is present in the greater amount is the **solvent** (in this case, water). The substance that is dissolved and is present in a lesser amount is the **solute** (in this case, salt). When water is the solvent, the result is called an **aqueous solution** (from the Latin word *aqua* meaning water).

Water is the main solvent inside all cells, in blood, and in plant sap. Water dissolves an enormous variety of solutes necessary for life. Water is very good at dissolving ionic compounds such as table salt (sodium chloride). The positive sodium ions at the surface of a sodium chloride crystal attract the oxygen ends of the water molecules. The negative chloride ions attract the hydrogen ends of the water molecules. As a result, water molecules surround each ion, breaking the salt crystal apart in the process.



Water can also dissolve many nonionic compounds, such as sugars. The structure of sugar molecules include polar areas where electrons are shared unevenly between atoms. These areas of slight electric charge attract the polar ends of water molecules. Water molecules cling to these charged regions and separate the sugar molecules from one enough.

Because water is so good at dissolving so many different substances, it is often referred to as the universal solvent!