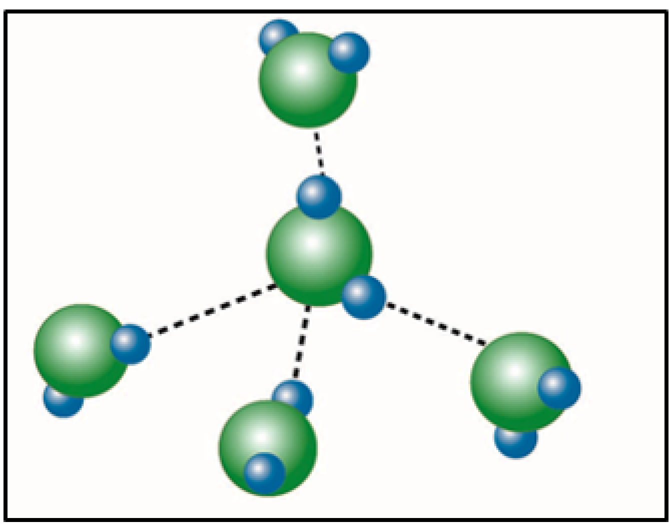
2.1.2

Chemical Characteristics of Water

Recall that the water molecule, H_2O, is held together by **polar covalent bonds**. Since the oxygen attracts the electrons in the covalent bonds more strongly than the hydrogen do, the oxygen end of the molecule has a slight negative charge while the hydrogen ends of the molecule have a slight positive charge. Also, recall that molecules composed of polar covalent bonds can participate in weak interactions with other polar molecules through hydrogen bonding. The figure below shows how water molecules form hydrogen bonds with each other. Each water molecule has the potential to form a maximum of four hydrogen bonds with other water molecules. Most of the characteristics of water that we will be talking about are the result of the polar nature of the water molecule and its ability to form hydrogen bonds with itself and other polar molecules. Remember that hydrogen bonds are very weak interactions and can be formed and broken relatively easily. However, as with all bonds, energy is required to break bonds, and energy is released when new bonds are formed. It is the number of these bonds that determine the physical state of the water. For example, in the solid state, each water molecule forms hydrogen bonds with four other molecules, resulting in the formation of a stable, crystal structure known as ice. In the liquid state, each water molecule forms fewer than four bonds (on average 3.4), which are continually rearranging. Water becomes steam when there is enough energy to break all of the hydrogen bonds between water molecules, and they can escape in the form of a gas.



***Hydrogen Bonds of Water Molecules**: Image created by BYU-I student Hannah Crowder Fall 2013*
The image above shows hydrogen bonds between water molecules in the solid state. In the liquid state, hydrogen bonds are constantly rearranging (breaking and reforming with other molecules) which allows more movement of the molecules. To our eyes and experience this liquid state can "flow".

Temperature Stabilization

The amount of energy in the form of heat that must be added to or taken from a substance in order to change its temperature is called the **heat capacity** of the substance. Water has a very high heat capacity. In fact, we define the calorie as based on the heat capacity of water. (One calorie is the amount of heat energy necessary to raise the temperature of 1 gram of water 1° Celsius. Note: when reporting the calorie content of food, calorie is written with a capital C. These "big" calories are actually kilocalories or 1000 calories.) Likewise, 1 calorie of energy must be taken away from water to lower the temperature of 1 gram of water by 1° Celsius. Compare this to the heat capacity of air, which is 0.24 calories per gram. This high heat capacity is due to the hydrogen bonds between the water molecules. Temperature is a measure of the total kinetic energy (motion) of a material. Before the water molecules can start moving faster, the hydrogen bonds between the molecules must be broken, which requires the input of energy. Therefore, much of the energy (heat) is used to break the bonds rather than increase the temperature (movement) of the water molecules. By the same token, when heat is removed and the water molecules begin to slow down, new hydrogen bonds form, releasing energy, which helps prevent a big drop in temperature.

Another property of water is its high **heat of vaporization**. This means that in order to convert water from a liquid to a gas, it requires the input of relatively large amounts of energy to increase the movement of the water molecules enough for them to break free from the water molecules around them. As these water molecules move faster and faster, they eventually will have enough energy to completely break away from the liquid and will be converted to a gas (water vapor). When the fastest moving molecules break free, their kinetic energy goes with them, removing heat. This is the basis for the cooling effect of the evaporation of sweat from human skin or off the tongue of a panting animal.

Adhesion, Cohesion and Lubrication

Water is able to stick to other polar substances. This property is referred to as **adhesion**. An excellent example of the importance of this property in the body involves the lungs. A thin layer of water between the outer surface of the lungs and the walls of the thoracic cavity "glues" the lungs to the walls and prevents them from collapsing. **Cohesion** is the sticking together of water molecules. This property prevents the blood from separating as it moves through the blood vessels. Finally, water can act as a lubricant and is found in areas of the body where structures are required to slide past each other. For example, synovial joints (knee, shoulder, ankle, etc.) have a thin layer of water (synovial fluid) between the opposing structures, allowing them to easily slide past one another as the joint moves.

Chemical Reactions

All of the thousands of chemical reactions taking place in our bodies require water. This is because in order to react, the chemicals must be in a watery solution. Water also participates directly in many of the important reactions taking place in the body.