Nectar of Life

Module 2 • i2P • H2O Tour

"If there is magic on this planet, it is contained in water."
- Loran Eisely, The Immense Journey, 1957

A WALK ON THE LAKE

When Ray and Kevin cross Lake Baikal in March they will be treading on trillions of tiny water molecules bound together in a frozen state as ice; ice that is floating upon a body of liquid water that contains one fifth of the worlds surface liquid water stores. In other words under their feet will be the largest reservoir of liquid water in the world, a massive store of the simple molecule that is credited with being central to the creation of life on earth.

To be instrumental in the creation of life is pretty important stuff, particularly for a simple little molecule made of three atoms. Why among the countless number of molecules in the universe is water so essential to the creation and preservation of life? Perhaps the best way to try and answer this question is to first define the meaning of life. What is life, and where does it begin and end?; questions of a primordial nature, endlessly debated by scientific and religious circles and profoundly difficult to answer.

THE DEFINITION OF LIFE

According to molecular biologist Daniel E. Koshland Jr. life should be defined according to the following seven conditions (see: definition of life):

1. it can reproduce;
2. it has the ability to adapt;
3. it is organized into at least one specialized compartment called a cell;
4. it can take energy from the environment and change it from one form to another;
5. it will ultimately degrade into a state known as death;
6. it responds to the surrounding environment through sensory stimuli;
7. it is able to maintain numerous metabolic reactions simultaneously.

If we apply these criteria to Ray Zahab we can confirm that he does qualify as a life form. However, although Ray is a life form and is full of water (~ 68%), this does

Did You Know?

Part of the difficulty in defining life is the conundrum presented by viruses. Are viruses life or not? Some scientists define viruses as very complex organic molecules, while others suggest they are the simplest form of life.

not explain why water is essential to life.

To understand why water is essential to life it's useful to note that of the seven conditions of life listed above, three of them (points 3,4 and 7), are dependent upon water, specifically liquid water. Indeed scientists are agreed upon the fact that the form of water essential to life is liquid water. If water were not present in liquid form, only in gas (water vapor) and solid (ice) forms, life as we know it would not be possible.

Definition: Solvent

A solvent is a liquid or gas that dissolves a solid, liquid, or gaseous solute, resulting in a solution (see: solvent).

Very Special Liquid

Liquid water has very unusual properties that make it ideally suited to life as we know it. Dubbed the "Universal Solvent", it dissolves virtually every known substance to some degree, even gold. Although it is conceivable that a non-aqueous solvent, such as liquid ammonia, could serve as a somewhat-universal solvent, no substance is quite as unique as water in terms of range of temperatures in liquid form. Additionally, the so-called building blocks of life, nucleic acids and amino acids, are not soluble in liquids other than water. These "building blocks" or basic molecules of life that make up the substance of the cells from which all life is formed, must be dissolved in a solvent in order to interact and function. The only known solvent that can perform this function is water.

Did You Know ?

Gold in water.

According to calculations there is $0.0000004 worth of gold per metric ton of sea water. 1 million bathtubs of seawater would fetch but a meager pittance of 8 cents of gold (see: gold in water).

Water is Polar

One of the unique properties of water that allows for it to function as the "Universal Solvent" is its "polar" nature. The "polar" nature indicates that one end of the molecule has a negative partial charge and the other has a positive partial charge, essentially meaning that it has a negatively charged pole and a positively charged pole, and thus is "polar". Water is composed of three atoms; two hydrogen atoms and one oxygen atom (H2O). Atoms are composed of a nucleus of protons and neutrons surrounded by electrons. Electrons have a negative charge while protons have a positive charge (neutrons have no charge). The oxygen atom in H2O draws the two electrons from the two hydrogen atoms in a molecule of water closer to its end of the molecule, thus unbalancing the charge of the molecule. With the electrons (negative charge) pulled closer to the oxygen atom, the oxygen side of the H2O molecule develops a relative negative charge, while the hydrogen aspects of the molecule have a relative positive

Did You Know?

The hydrogen bonding between individual water molecules shows a unique phenomenon on the surface of a body of water called “surface tension”. Because the water molecules on the surface have fewer neighbors surrounding them, this leads to a stronger attraction to those few adjacent molecules below, leading to a surface that is slightly more resistant to penetration. The Basilisk lizard takes advantage of this phenomenon, propelling itself by “running” on the slightly resistant surface.

see video: Jesus Lizard

Figure 1(at right): The surface tension of water carries the weight of a paper clip (source: Wikimedia Commons)

charge (see: properties of water). This is what causes the molecule to be “polar” - to have a partial negative and positive charge on opposite sides of the molecule. This gives water electrical properties.

Electrical Attraction

Because of their polarity, or relative electrical charge, H2O molecules are attracted to each other. The molecules group together with the negative pole (the oxygen atom) lining up with the positive pole (the hydrogen atom) in a union called a hydrogen bond (see: properties of water). Hydrogen bonding gives water its ability to dissolve other substances The negatively charged oxygens of H_2O molecules clump around and cling to positive ions and the positive end of the hydrogens clump around and cling to their respective negatively charged ions, suspending them in solution (the bonds between the water molecules and the ions are stronger than the ionic bonds within the dissolving molecule – the bonds that hold the ions together in solid form). Unfortunately, this ready ability to dissolve also means toxic and environmentally harmful substances are held in solution in the majority

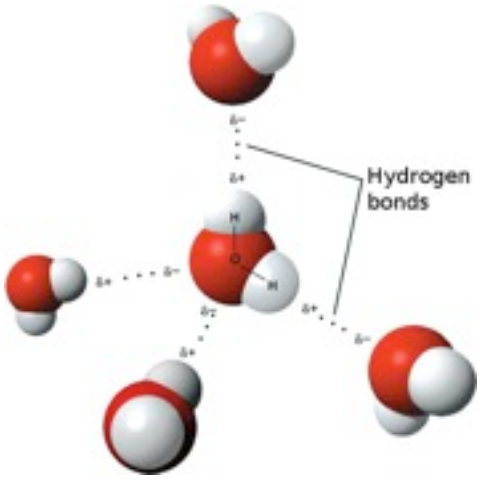

Figure 2: Hydrogen bonding. The positive charge of the hydrogen atoms align with the negative charge of the oxygen atoms (source: Wikimedia Commons)

of Earth's water supply, a topic to be covered in a later module called Dirty Water (Module 13).

Thermal Conduction

One of the byproducts of hydrogen bonding is that it makes water a great sink for heat, allowing it to absorb and hold large volumes of heat (or cold). This property contributes

Figure 3: Ice on Lake Baikal (source: Wikimedia Commons)

to the fact that large bodies of water such as the ocean and large lakes moderate the temperature of seaboard cities. Lake Baikal, as the largest volume of fresh water in the world, is a case in point. Although Lake Baikal will be covered in ice when Ray and Kevin cross in March, there will still be heat remaining in the liquid water beneath the ice that will moderate the temperature of the surrounding areas. In the summertime it will have a

Water and the Origins of Life

Although water is not directly (nor definitively) linked with the creation of the first organic compounds on Earth, one fascinating experiment was undertaken by Stanley Miller (of the famous Miller-Urey experiment that demonstrated electrical events in Earth's early atmosphere potentially linking atoms into the first organic monomers) in which a container of ammonia and cyanide dissolved in water was placed in a -108F freezer for 25 years, from 1972-1997. Upon removing the blocks of ice from the deep freeze, it was observed, and might I add amazingly, that complex polymers in the form of nucleobases and amino acids had formed. When the solvent initially froze, the ammonia and cyanide fell out of solution as the ice crystals of pure water began to form. The ammonia and cyanide became concentrated in small pockets of liquid within the ice block amongst the crystals, greatly increasing collisions between molecules leading to chemical reactions resulting in the production of the aforementioned building blocks of life. This case of "eutectic freezing" could be an indicator of how early life formed on Earth, especially during a time of cooling (Earth's average surface temperature at -40F) following a period of asteroid bombardment 4 billion years ago (see: origin of life).

Water & the Birth of the Planet

In the early stages of the tumultuous formation and development of Earth, water was largely present in vapor form, spewing from the omnipresent volcanic eruptions in a gaseous brew along with carbon dioxide, carbon monoxide, methane, ammonia and hydrogen sulfide. Liquid water existed at this time, but was found in temperatures exceeding 100 degrees Celsius on the seething hot surface of Earth. This may seem counterintuitive, as it is common knowledge that water boils and becomes vapor at 100 degrees Celsius, under current day conditions at sea level, anyways. Back then, the composition of the atmosphere was much different than today and atmospheric pressure was much higher, leading to a greater boiling point temperature for water and thus allowing it to exist in liquid form to temperatures in excess of 100 degrees Celsius. It is the same reason that causes water to boil at 69° C (156.2° F) at the top of Mt. Everest where the atmospheric pressure is only 26.39 kPa. Today's Celsius temperature scale describes water as becoming a solid at 0° C and boiling and becoming vapor at 100° C at sea level.

cooling effect, as the lake will be cold relative to the surrounding heat of a Siberian summer (see: Lake Baikal weather).

Life in Water

Understanding the fundamental properties of water that allow it to house and enable the building blocks of life - liquid phase, solubility, polarity, thermal capacitance - allows us to turn our attention to how water is used by life forms.

Life requires a source of energy to survive and propagate. Virtually all energy used by life forms on Earth comes from the sun. Some forms of life, principally plants, obtain their energy directly from the sun. Animals in turn consume plants or other life forms to obtain their energy. Photosynthesis is the process by which plants capture the suns energy. Photosynthesis requires three ingredients; carbon dioxide, water and sunlight which are converted into oxygen and the simple sugar glucose. Not only is water an essential ingredient of photosynthesis, but the photosynthetic chemical reaction must take place in the physical matrix of water.

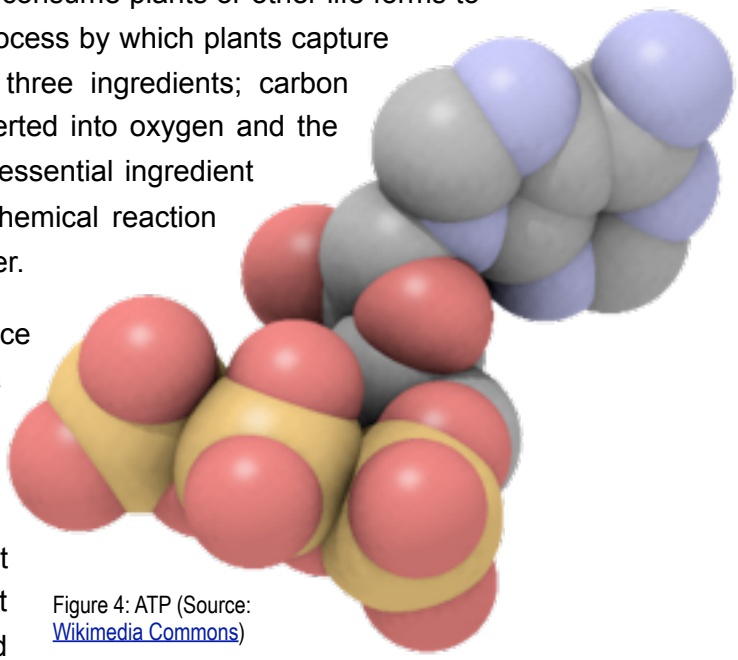

Figure 4: ATP (Source: Wikimedia Commons)

Did You Know?

Water is the most abundant molecule on the surface of the Earth, accounting for 70% of the planet's surface area.

When you eat a piece of corn or a carrot for lunch you are capturing the sun's energy that the corn or carrot plant captured

through photosynthesis. The energy released from the carrot or corn is converted into a molecule called ATP (Adenosine Triphosphate). ATP is what fuels practically all metabolic processes in life forms, processes such as running to class when you're late, or the normal function of your brain when you sit in class, learning. The use of ATP - the universal molecule of energy - requires none other than water to be 'burned' to release energy. So, once more, water is required not only for the chemical capture of energy by the sun, but for the burning of energy by all life forms.

Nectar of Life

The coupling of two very common elements in our universe, hydrogen and oxygen into one simple yet extraordinary molecule has dramatically shaped our planet and the life that inhabits it. Water drives the erosive forces that shape the world's geology, provides a vast aquatic environment that supports much of life on earth and generates weather patterns driven by its unique thermodynamic properties. It provides the life force to grow all plants and animals, and enables you, whose body is more than half composed of water, to read this module, to sit and think, learn and move and feel, all powered by your body's water-dependent energy metabolism.