Think of what you need to survive, really just survive. Food? Water? Air? Facebook? Naturally, I'm going to concentrate on water here. Water is of major importance to all living things; in some organisms, up to 90% of their body weight comes from water. Up to 60% of the human adult body is water.

According to H.H. Mitchell, Journal of Biological Chemistry 158, the brain and heart are composed of 73% water, and the lungs are about 83% water. The skin contains 64% water, muscles and kidneys are 79%, and even the bones are watery: 31%.

Each day humans must consume a certain amount of water to survive. Of course, this varies according to age and gender, and also by where someone lives. Generally, an adult male needs about 3 liters per day while an adult female needs about 2.2 liters per day. Some of this water is gotten in food.

Water serves a number of essential functions to keep us all going:

- A vital nutrient to the life of every cell, acts first as a building material.
- It regulates our internal body temperature by sweating and respiration
- The carbohydrates and proteins that our bodies use as food are metabolized and transported by water in the bloodstream;
- It assists in flushing waste mainly through urination
- acts as a shock absorber for brain, spinal cord, and fetus
forms saliva
lubricates joints

According to Dr. Jeffrey Utz, Neuroscience, pediatrics, Allegheny University, different people have different percentages of their bodies made up of water. Babies have the most, being born at about 78%. By one year of age, that amount drops to about 65%. In adult men, about 60% of their bodies are water. However, fat tissue does not have as much water as lean tissue. In adult women, fat makes up more of the body than men, so they have about 55% of their bodies made of water. Thus:

- Babies and kids have more water (as a percentage) than adults.
- Women have less water than men (as a percentage).
- People with more fatty tissue have less water than people with less fatty tissue (as a percentage).

There just wouldn't be any you, me, or Fido the dog without the existence of an ample liquid water supply on Earth. The unique qualities and properties of water are what make it so important and basic to life. The cells in our bodies are full of water. The excellent ability of water to dissolve so many substances allows our cells to use valuable nutrients, minerals, and chemicals in biological processes.

Water's "stickiness" (from surface tension) plays a part in our body's ability to transport these materials all through ourselves. The carbohydrates and proteins that our bodies use as food are metabolized and transported by water in the bloodstream. No less important is the ability of water to transport waste material out of our bodies.

Water Properties
Facts and Figures About Water

Some of water's physical properties:

- Weight: 62.416 pounds/cubic foot at 32°F; 1,000 kilograms/cubic meter
- Weight: 61.998 pounds/cubic foot at 100°F; 993 kilograms/cubic meter
- Weight: 8.33 pounds/gallon; 1 kilogram/liter
- Density: 1 gram/cubic centimeter (cc) at 39.2°F, 0.95865 gram/cc at 212°F

Some water volume comparisons:

- 1 gallon = 4 quarts = 8 pints = 128 fluid ounces = 3.7854 liters
- 1 liter = 0.2642 gallons = 1.0568 quart
- 1 million gallons = 3.069 acre-feet = 133,685.64 cubic feet

Flow rates:

- 1 cubic foot/second (cfs) = 449 gallons/minute = 0.646 million gallons/day = 1.98 acre-feet/day
Water is unique in that it is the only natural substance that is found in all three physical states—liquid, solid, and gas—at the temperatures normally found on Earth.

Water freezes at 32° Fahrenheit (F) and boils at 212°F (at sea level, but 186.4° at 14,000 feet). Water is unusual in that the solid form, ice, is less dense than the liquid form, which is why ice floats.

Water is called the "universal solvent" because it dissolves more substances than any other liquid. This means that wherever water goes, either through the ground or through our bodies, it takes along valuable chemicals, minerals, and nutrients.

Pure water has a neutral pH of 7, which is neither acidic (<7) nor basic (>7).

The water molecule is highly cohesive—it is very sticky. Water is the most cohesive among the non-metallic liquids.

Pure water, which you won't ever find in the natural environment, does not conduct electricity. Water becomes a conductor once it starts dissolving substances around it.

Water has a high specific heat index—it absorbs a lot of heat before it begins to get hot. This is why water is valuable to industries and in your car's radiator as a coolant. The high specific heat index of water also helps regulate the rate at which air changes temperature, which is why the temperature change between seasons is gradual rather than sudden, especially near the oceans.

Water has a very high surface tension. In other words, water is sticky and elastic, and tends to clump together in drops rather than spread out in a thin film, like rubbing alcohol. Surface tension is responsible for capillary action, which allows water (and its dissolved substances) to move through the roots of plants and through the tiny blood vessels in our bodies.

The density of water means that sound moves through it long distances (ask a whale!). In sea water at 30°C, sound has a velocity of 1,545 meters per second (about 3,500 miles per hour).

Air pressure affects the boiling point of water, which is why it takes longer to boil and egg at Denver, Colorado than at the beach. The higher the altitude, the lower the air pressure, the lower the boiling point of water, and thus, the longer time to hard-boil an egg. At sea level water boils at 212°F (100°C), while at 5,000 feet, water boils at 202.9°F (94.9 °C).
Adhesion and Cohesion of Water

I used to wake up in a cold sweat in the middle of the night because I could not get the concepts of water adhesion and cohesion clear in my mind. If you have that problem, too, then do yourself a favor and read on to learn about these important properties of water.

**Cohesion**: Water is attracted to water

**Adhesion**: Water is attracted to other substances

Adhesion and cohesion are water properties that affect every water molecule on earth and also the interaction of water molecules with molecules of other substances. Essentially, cohesion and adhesion are the "stickiness" that water molecules have for each other and for other substances. You can see this in the picture to the right. The water drop is composed of water molecules that like to stick together, an example of the property of cohesion. The water drop is stuck to the end of the pine needles, which is an example of the property of adhesion. Notice I also threw in the all-important property of gravity, which is causing the water drops to roll along the pine needle, attempting to fall downwards. It is lucky for the drops that adhesion is holding them, at least for now, to the pine needle.

**Cohesion makes a water drop a drop**

It is easy to see that the drop seems to have a "skin" holding it into a sort of flattened sphere (although there is nothing flat about a water drop in outer space.). It turns out that this surface tension is the result of the tendency of water molecules to attract one another. The natural form of a water drop occurs in the "lowest energy state", the state where the atoms in the molecule are using the least amount of energy. For water, this state happens when a water molecule is surrounded on all sides by other water molecules, which creates a sphere or ball.
(perfectly round if it was in outer space). On Earth, the effect of gravity flattens this ideal sphere into the drop shape we see. Although you may have heard of a "skin" where water meets the air, this is not really an accurate description, as there is nothing other than water in the drop.

**Why is water sticky?**

Water is highly cohesive—it is the highest of the non-metallic liquids. Water is sticky and clumps together into drops because of its cohesive properties, but chemistry and electricity are involved at a more detailed level to make this possible. More precisely, the positive and negative charges of the hydrogen and oxygen atoms that make up water molecules makes them attracted to each other. If you’ve played with bar magnets you will know that the positive (+) side of one magnet will repel the other positive side, while a negative (-) side of one magnet will attract the positive side of the other magnet. Positive charges attract negative charges.

In a water molecule, the two hydrogen atoms align themselves along one side of the oxygen atom, with the result being that the oxygen side has a slight negative charge and the side with the hydrogen atoms has a slight positive charge. Thus when the positive side on one water molecule comes near the negative side of another water molecule, they attract each other and form a bond. This "bipolar" nature of water molecules gives water its cohesive nature, and thus, its stickiness and clumpability (maybe "dropability" is a better term?).

**Capillary action**

Even if you’ve never heard of capillary action, it is still important in your life. Capillary action is important for moving water (and all of the things that are dissolved in it) around. It is defined as the movement of water within the spaces of a porous material due to the forces of adhesion, cohesion, and surface tension.

Capillary action seen as water climbs to different levels in glass tubes of different diameters. Credit: Dr. Clay Robinson, PhD, West Texas A&M University.

Capillary action occurs because water is sticky, thanks to the forces of cohesion (water molecules like to stay close together) and adhesion (water molecules are attracted and stick to other substances). Adhesion of water to the walls of a vessel will cause an upward force on the liquid at the edges and result in a meniscus which turns upward. The surface tension acts to hold the surface intact. Capillary action occurs when the adhesion to the walls is stronger than the cohesive forces between the liquid molecules. The height to which capillary action will take water in a uniform circular tube (picture to left) is limited by surface tension and, of course, gravity.
Not only does water tend to stick together in a drop, it sticks to glass, cloth, organic tissues, soil, and, luckily, to the fibers in a paper towel. Dip a paper towel into a glass of water and the water will "climb" onto the paper towel. In fact, it will keep going up the towel until the pull of gravity is too much for it to overcome.

**Capillary action is all around us every day**

![Image](https://via.placeholder.com/150)

People use paper towels (and thus, capillary action) to wipe up liquid spills. Everyone, including Mona Lisa, benefits from capillary action.

When you spill your glass of BubblyBerryPowerGo (which is, of course, mostly water) on the kitchen table you rush to get a paper towel to wipe it up. First, you can thank surface tension, which keeps the liquid in a nice puddle on the table, instead of a thin film of sugary goo that spreads out onto the floor. When you put the paper towel onto your mess the liquid adheres itself to the paper fibers and the liquid moves to the spaces between and inside of the fibers. Obviously, Mona Lisa is a fan of capillary action.

- Plants and trees couldn't thrive without capillary action. Plants put down roots into the soil which are capable of carrying water from the soil up into the plant. Water, which contains dissolved nutrients, gets inside the roots and starts climbing up the plant tissue. As water molecule #1 starts climbing, it pulls along water molecule #2, which, of course, is dragging water molecule #3, and so on.

- Capillary action is also essential for the drainage of constantly produced tear fluid from the eye. Two tiny-diameter tubes, the lacrimal ducts, are present in the inner corner of the eyelid; these ducts secrete tears into the eye.

- Maybe you've used a fountain pen .... or maybe your parents or grandparents did. The ink moves from a reservoir in the body of the pen down to the tip and into the paper (which is composed of tiny paper fibers and air spaces between them), and not just turning into a blob. Of course gravity is responsible for the ink moving "downhill" to the pen tip, but capillary action is needed to keep the ink flowing onto the paper.

**The proof is in the pudding ... I mean, in the celery**

You can see capillary action in action (although slowly) by doing an experiment where you place the bottom of a celery stalk in a glass of water with food coloring and watch for the movement of
the color to the top leaves of the celery. You might want to use a piece of celery that has begun to whither, as it is in need of a quick drink. It can take a few days, but, as these pictures show, the colored water is "drawn" upward, against the pull of gravity. This effect happens because, in plants, water molecules move through narrow tubes that are called capillaries (or xylem).

A fresh-cut stalk of celery is placed into a glass of water that has been colored with food coloring.

You can see results in a day or two, but here are the results after a week.
Water Color

It may be true that a bit of color in water may not make it harmful to drink ... but it certainly makes it unappealing to drink. So, color in our water does matter when it comes to drinking it, as well as in water for other home uses, industrial uses, and in some aquatic environments.

Pure water and color

Is pure water really clear? First, you will rarely see pure water as it is not found in a natural setting. The everyday water you see contains dissolved minerals and often suspended materials. But, for practical purposes, if you fill a glass from your faucet the water will look colorless to you. The water is in fact not colorless; even pure water is not colorless, but has a slight blue tint to it, best seen when looking through a long column of water. The blueness in water is not caused by the scattering of light, which is responsible for the sky being blue. Rather, water blueness comes from the water molecules absorbing the red end of the spectrum of visible light. To be even more detailed, the absorption of light in water is due to the way the atoms vibrate and absorb different wavelengths of light. The details are beyond the scope of this Website, but Webexhibits explains this in much more detail.

Color and drinking water

If you have ever drunk water containing a bit of iron in it, you would know from the metallic taste left in your mouth that dissolved chemicals in drinking water can be less than desirable. Color in drinking water can be caused by dissolved and suspended materials, and a brown shade in water often comes from rust in the water pipes. Although water can contain contaminants, which are usually removed by water-supply systems, the plus side is that the water you drink likely contains a number of dissolved minerals that are beneficial for human health. And, if you have ever drunk "pure" water, such as distilled or deionized water, you would have noticed that it tasted "flat". Most people prefer water with dissolved minerals, although they still want it to be clear.

Have you ever gotten a glass of water from your faucet and the water is milky white water or hazy? This is almost always caused by air in the water. To see if the white color in the water is due to air, fill a clear glass with water and set it on the counter. Observe the glass of water for 2 or 3 minutes. If the white color is due to air, the water will begin to clear at the bottom of the glass first and then gradually will clear all the way to the top. This is a natural phenomenon and is caused by dissolved air in the water that is released when the faucet is opened. When you relieve the pressure by opening the faucet and filling your glass with water, the air is now free to escape from the water, giving it a milky appearance for a few minutes.
Color and water in the environment

Color in water you see around you can be imparted in two ways: dissolved and suspended components. An example of dissolved substances is tannin, which is caused by organic matter coming from leaves, roots, and plant remains (left-side picture). Another example would be the cup of hot tea your grandmother has in the afternoon. In the picture below the color is probably attributable to naturally dissolved organic acids formed when plant material is slowly broken down by into tiny particles that are essentially dissolved in the water. If you filtered that tannin-water in the picture the color would probably remain.

Most of the color in water you see around you comes from suspended material, as you can see in the right-side picture of a tributary contributing highly-turbid water containing suspended sediment (fine particles of clay, since this picture is in Georgia) to clearer, but still colored, water in the main stem of the river. Algae and suspended sediment particles are very common particulate matter that cause natural waters to become colored. Even though the muddy water below would not be appealing to swim in, in a way that water has less color than the water containing dissolved tannins. That is because suspended matter can be filtered out of even very dirty-looking water. If the water is put into a glass and left to settle for a number of days, most of the material will settle to the bottom (this method is used in sewage-treatment facilities) and the water will become clearer and have less color. So, if an industry wanted needed some color-free water for an industrial process, they would probably rather start with the sediment-laden water, rather than the tannin colored water.

Suspended material in water bodies may be a result of natural causes and/or human activity. Transparent water with a low accumulation of dissolved materials appears blue. Dissolved organic matter, such as humus, peat or decaying plant matter, can produce a yellow or brown color. Some algae or dinoflagellates produce reddish or deep yellow waters. Water rich in phytoplankton and other algae usually appears green. Soil runoff produces a variety of yellow, red, brown and gray colors.

Effects of color on ecosystems

Highly colored water has significant effects on aquatic plants and algal growth. Light is very critical for the growth of aquatic plants and colored water can limit the penetration of light. Thus a highly colored body of water could not sustain aquatic life which could lead to the long term impairment of the ecosystem. Very high algal growth that stays suspended in a water body can almost totally block light penetration as well as use up the dissolved oxygen in the water body,
causing a eutrophic condition that can drastically reduce all life in the water body. At home, colored water may stain textile and fixtures and can cause permanent damage, as the picture of the sink above shows.

**Water Compressibility**

A high-pressure water fountain like this one is a good example of water’s lack of compressibility. Water is essentially incompressible, especially under normal conditions. If you fill a sandwich bag with water and put a straw into it, when you squeeze the baggie the water won’t compress, but rather will shoot out the straw. If the water compressed, it wouldn’t "push back" out of the straw. Incompressibility is a common property of liquids, but water is especially incompressible. Water’s lack of compressibility helps to push water out of water hoses (handy for putting out fires), water pistols (handy for bothering Dad), and in artistic water fountains (handy for relaxing). In these instances, some pressure is applied to a container full of water and rather than compress, it comes shooting out of an opening, such as the end of the hose or the end of a small pipe, as in this fountain. If water was highly compressible, it would be harder to create enough pressure for water to shoot out of the nearest opening.

Kids make good use of water’s uncompessibility when they play a game of water-balloon tossing. When you squeeze the balloon too much, the balloon’s skin will fail before the water inside compresses—it will burst in your face way before the water will compress even an infinitesimal amount.

**Water compressibility experiment**

When I was 7 years old, water’s incompressibility got me in big trouble. I was analyzing the compressibility of water by soaking a sponge with water, smushing it up, and watching how much water came back out. To test if water compressed, I added some red food color to the water, soaked it up, and sat on my parent’s new white carpeting to prove my theorem. I thought that since water was trapped in the sponge, I could squeeze the sponge and the water would compress. My theorem was (painfully) disproved, as the water squirted out rather than compress. Well, I was a kid, how was I to know that the compressibility of water at room temperature is only about 0.000053 for an increase of about 14.7 pounds per square inch in pressure?
Pressure and temperature can affect compressibility

An abrasive water-jet cutter cuts through metal to create tools, Elmendorf Air Force Base, Alaska. Credit: U.S. Air Force photo, Staff Sgt. Alan Port

But, squeeze hard enough and water will compress—shrink in size and become more dense ... but not by very much. Envision the water a mile deep in the ocean. At that depth, the weight of the water above, pushing downwards, is about 150 times normal atmospheric pressure (Ask the Van). Even with this much pressure, water only compresses less than one percent.

Yet, in industrial applications water can be tremendously compressed and used to do things like cut through metal (especially if an abrasive material is added to the water and the water is hot). Water being pushed out at tremendous speed through a tiny hole is used in industry to cut through everything from metal to ceramics to plastics and even foods. It is the preferred method when the materials being cut are sensitive to the high temperatures generated by other methods. It has found applications in a diverse number of industries from mining to aerospace where it is used for operations such as cutting, shaping, carving, and reaming. Of course, to cut through stone a stream of water must be moving very fast and producing a tremendous amount of pressure. A pump is used to pressurize water in a container at pressure values up to 90,000 pounds/square inch (psi) and then shoot it out of the nozzle at speeds up to 600 mph. (Source: NASA).

Water Density

If you are still in school, you've probably heard the statement in the box to the right a number of times:

**Density**

*Density is the mass per unit volume of a substance. On Earth, you can assume mass is the same as weight, if that makes it easier.*

If you're not still in school, then you probably forgot you ever even heard it. The definition of density, also known as "specific gravity", makes a lot more sense with a little bit of explanation. As long as an object is made up of molecules, and thus has size, it has a density. Density is just the weight for a chosen amount (volume) of the material.
Growing up with an older brother was difficult, especially when he had his friends over, for their favorite activity was thinking of ways to antagonize me. I was able to use water density once to at least play a trick on them, though. One hot summer day they climbed the huge hill next to our house to dig a hole to hide their bottle-cap collection. They got thirsty and made me go back home and bring them a gallon of water. That gallon of tap water at 70°F weighed 8.329 pounds, which was a lot for a scrawny 70-pound kid to haul up a huge hill.

So, when they demanded another gallon of water, I consulted the "Internet" of that day—an encyclopaedia—and found out that a gallon of water at the boiling point only weighed 7.996 pounds! I ran up the hill carrying my gallon of water that weighed 0.333 pounds less; and ran back down even faster, their angry voices fading behind me.

<table>
<thead>
<tr>
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<th>Density</th>
<th>Weight</th>
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<tbody>
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<td>pounds/ft³</td>
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<td>50°/10°</td>
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</tr>
<tr>
<td>212°/100°</td>
<td>0.95865</td>
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</tbody>
</table>
Ice is less dense than water

If you look at this picture you can see that some of the iceberg is below the water level. This is not a surprise, but actually almost all of the volume of an iceberg is below the water line, not above it. This is due to ice's density being less than liquid water's density. Upon freezing, the density of ice decreases by about 9 percent.

The best way to visualize how water can have different densities is to look at the frozen form of water. Ice actually has a very different structure than liquid water, in that the molecules align themselves in a regular lattice rather than more randomly as in the liquid form. It happens that the lattice arrangement allows water molecules to be more spread out than in a liquid, and, thus, ice is less dense than water. Again, lucky for us, as we would not hear that delightful tingle of ice cubes against the side of a glass if the ice in our ice tea sank to the bottom. The density of ice is about 90 percent that of water, but that can vary because ice can contain air, too. That means that about 10 percent of an ice cube (or iceberg) will be above the water line.

This property of water is critical for all life on earth. Since water at about 39°F (4°C) is more dense than water at 32°F (0°C), in lakes and other water bodies the denser water sinks below less-dense water. If water was most dense at the freezing point, then in winter the very cold water at the surface of lakes would sink, the lake could freeze from the bottom up, and all life in them would be killed. And, with water being such a good insulator (due to its heat capacity), some frozen lakes might not totally thaw in summer.

The real-world explanation of water density is actually more complicated, as the density of water also varies with the amount of material that is dissolved in it. Water in nature contains minerals, gasses, salts, and even pesticides and bacteria, some of which are dissolved. As more material is dissolved in a gallon of water then that gallon will weigh more and be more dense—ocean water is denser than pure water.

We said ice floats on water, but what about "heavy ice"?

We already said ice floats on water because it is less dense, but ice of a special kind can be denser than normal water. "Heavy ice" is denser than normal water because the ice is made from "heavy water". Heavy water, D₂O instead of H₂O, is water in which both hydrogen atoms have been replaced with deuterium, the isotope of hydrogen containing one proton and one neutron.
Heavy water is indeed heavier than normal water (which contains a tiny amount of heavy water molecules naturally), and heavy-water ice will sink in normal water.

**Measuring Density**

The instrument to measure the density of a liquid is called a hydrometer. It is one of the simplest of scientific-measuring devices, and you can even make your own out of a plastic straws (see links below). More often, though, it is made of glass and look a lot like a thermometer. It consists of a cylindrical stem and a weighted bulb at the bottom to make it float upright. The hydrometer is gently lowered into the liquid to be measured until the hydrometer floats freely. There are etched or marked lines on the device so the user can see how high or low the hydrometer is floating. In less dense liquids the hydrometer will float lower, while in more dense liquids it will float higher. Since water is the "standard" by which other liquids are measured, the mark for water is probably labeled as "1.000"; hence, the specific gravity of water at about 4°C is 1.000.

Hydrometers have many uses, not the least being to measure the salinity of water, or even urine, for science classes in schools. They are also used in the dairy industry to get estimates of the fat content of milk, as milk with higher fat content will be less dense than lower-fat milk. Hydrometers are often used by people who make beer and wine at home, as it offers an indication of how much sugar is in the liquid, and lets the brewer know how far along the fermentation process has gone.

**Specific Heat Capacity of Water**

**Specific Heat Capacity**

Water has a high specific heat index—it absorbs a lot of heat before it begins to get hot. This is why water is valuable to industries and in your car's radiator as a coolant. The high specific heat index of water also helps regulate the rate at which air changes temperature, which is why the temperature change between seasons is gradual rather than sudden, especially near the oceans.

It is always said that a person should be thankful for all the little things in life. But what about the really big things that have a dramatic effect of our lives. When was the last time you sat down and thought about what your life would be like if water did not have such a high specific heat capacity?

Lucky for me, you, and our fish in the pond, water does indeed have a very high specific heat capacity. The specific heat of water is the amount of heat needed to raise its temperature a certain amount. One of water's most significant properties is that it takes a lot of heat to it to make
it get hot. Precisely, water has to absorb 4.184 Joules of heat for the temperature of one gram of water to increase 1 degree celsius (°C). For comparison sake, it only takes 0.385 Joules of heat to raise 1 gram of copper 1°C.

If you leave a bucket of water outside in the sun in summer it will certainly get hot, but not hot enough to boil an egg. But, if you walk barefoot on the black asphalt of a street here in Atlanta, Georgia in August, you’ll burn your feet. Dropping an egg on the metal of my car hood on an August day will produce a fried egg. Metals have a much lower specific heat capacity than water. If you’ve ever held onto a needle and put the other end in a flame you know how fast the needle gets hot, and how fast the heat is moved through the length of the needle. Not so with water.

**Why specific heat capacity is important**

The high specific heat capacity of water has a great deal to do with regulating extremes in the environment. For instance, our fish in the pond is indeed happy because the heat capacity of the water in his pond above means the temperature of the water will stay relatively the same from day to night. He doesn’t have to worry about either turning on his air conditioner or putting on his woolen flipper gloves.

This same concept can be expanded to a world-wide scale. The oceans and lakes help regulate the temperature ranges that billions of people experience in their towns and cities. Water surrounding or near cities take longer to heat up and longer to cool down than do land masses, so cities near the oceans will tend to have less change and less extreme temperatures than inland cities. This property of water is one reason why states on the coast and in the center of the United States can differ so much in temperature patterns. A Midwest state, such as Nebraska, will have colder winters and hotter summers than Oregon, which has a higher latitude but has the Pacific Ocean nearby.

**Water Meniscus**

**What is a meniscus?**

A meniscus is a curve in the surface of a molecular substance (water, of course) when it touches another material. With water, you can think of it as when water sticks to the inside of a glass.

**Why a meniscus occurs**

Adhesion is responsible for a meniscus and this has to do in part with water's fairly high surface tension. Water molecules are attracted to the molecules in the wall of the glass beaker. And since water molecules like to stick together, when the molecules touching the glass cling to it, other water molecules cling to the molecules touching the glass, forming the meniscus. They'll travel up the glass as far as water's cohesive forces will allow them, until gravity prevents them from going further. Cohesion is an intermolecular attraction between like molecules (other water molecules in this case).
Sad tale of a meniscus misread

Few people take the time to consider the importance of a water meniscus in their lives. But, imagine this chilling scenario:

In your high-school chemistry final exam you mistakenly read a meniscus as 72 milliliters (ml) instead of the correct 66 ml (in this picture), and thus you get an 89 on the test instead of a 90. Your GPA falls from 4.00 to 3.99 and you don't get into that Engineering college program you wanted. Consequently, you don't get that prestigious engineering job, where, 20 years later, you would have invented a new water-based chemical to allow rubber to grip better. Sadly, 10 years later, a mother and her adorable 4-year old daughter are leaving the ice cream store and the little girl, whose shoes don't have your un-invented coating, slips on a napkin and drops her ice cream cone. She cries at her loss ... because you misread the meniscus in the 12th grade.

The moral of this silly tale is that it is important to read the measurement correctly, and yes, in this picture the true volume in the graduated cylinder is at the bottom of the water level—66 milliliters.

How to read a meniscus

As this diagram shows, a meniscus can go up or down. It all depends on if the molecules of the liquid are more attracted to the outside material or to themselves. A concave meniscus, which is what you normally will see, occurs when the molecules of the liquid are attracted to those of the container. This occurs with water and a glass tube. A convex meniscus occurs when the molecules have a stronger attraction to each other than to the container, as with mercury and glass. A flat meniscus occurs when water in some types of plastic tubes; tubes made out of material that water does not stick to. In any case, you get the true volume of the liquid by reading the center of the liquid in the tube, as shown by the middle of the dashed line in the diagram.
Rainbows (Water and Light)

Yes, this rainbow can honestly tell this leprechaun that his gold is safely stored at the end of the rainbow. After all, have you ever known anyone who has ever even gotten to the end of rainbow, even with a pot of gold tempting them? Even if a rainbow is right in front of you, it always still seems to stay out of reach. And, the concept of gold being at the rainbow is actually a historical rearrangement of the original concept that your chance of finding the end of a rainbow was about the same as your finding a pot of gold.

Maybe it is best not to try to analyze one of nature's magical wonders as a rainbow too much (care to vote for your favorite water body?), as even the concept of the rainbow being a bow (arc) is not entirely true. Did you know that if the horizon wasn't in the way, a rainbow would take the shape of a circle (as seen from an airplane)?

Sun Dogs

Does this picture look familiar? It shows a parhelion, more commonly known as a "sun dog". Oddly, I have seen these but never knew the official name until researching this article. In fact, sun dogs are a lot more common than rainbows. They are formed by light refracting through the ice crystals of cirriform clouds.

The most common parhelia are seen about 22° on either side of the sun; they are created by falling ice crystals in the Earth's atmosphere. As water freezes in the atmosphere, small, flat, six-sided, ice crystals might be formed. As these crystals flutter to the ground, much time is spent with their faces flat, parallel to the ground.

Why all the color?

Probably in school you did an experiment where the teacher shines a white light through a glass triangle—a prism, as in the left-side picture. The white light emerges from the prism split up into individual beams of different colors. The colors coming out of the prism, and in the rainbow, too, thus come from light, sunlight in the rainbow's case. Sunlight is white light, but white light actually contains all of the colors of the rainbow all ready for you to see, but blended together. Light has wavelengths (don't ask me what this means!) and each color of light has a different wavelength. When the light enters the glass, which is denser than air, it slows down and is bent, with the different wavelengths that make up white light bending at different angles (red on one side to violet on the other).

A similar situation happens in a raindrop, as the right side picture shows. The water drop is acting
like a prism, except the light is being refracted at three different points (some of the light bounces off the back of the raindrop and back out to you as you watch). Each time the light beam bounces, it gets wider, and the rainbow you see is a combination of millions of these light beams coming back to you.

♫ Somewhere over the raincircle ♫...
just doesn't sound right

The brightest rainbows appear when the water drops in the sky are large, so if a big rainstorm is moving off in front of you, the rainbows will be more spectacular. The lower the sun is to the horizon the more arc you will see. And, if you could float upwards, the higher you got the more circular the rainbow would become, especially if the sun is directly behind you. Circular rainbows are seen all the time—not by floating people but by passengers flying in airplanes.

Multiple rainbows—a rarity

Six rainbows, in the sky and as reflections on a lake, in Norway.
Have you ever seen six rainbows at once? They are not only rare to see -- they are a puzzle to understand. The common rainbow is caused by sunlight internally reflected by the backs of falling raindrops, while also being refracted at the air/water boundary. The sunlight in this picture is coming from behind the observer, and the rainbows are in the rainstorm. The brightest rainbow is the primary rainbow. Above and to the left of the main rainbow is a secondary rainbow, caused by multiple internal reflections inside water droplets, with colors reversed. Harder to explain is the intermediate rainbow, between the two. This rainbow is likely caused by sunlight that has first reflected off the lake before striking the distant raindrops that is reflecting sunlight back toward the observer. That accounts for the three rainbows in the sky, and the other three are reflections of the rainbows in the sky on the lake's surface. Kind of cheating to say there are six rainbows, but why argue with such a spectacular show? (NASA).

You're probably wondering the same thing that I'm wondering—why are the colors of the secondary rainbow reversed? And why is there a secondary rainbow at all? After researching this I still can't understand it, so here is an explanation from the National Center for Atmospheric Research and the UCAR Office of Programs:

"Sometimes we see two rainbows at once, what causes this? We have followed the path of a ray of sunlight as it enters and is reflected inside the raindrop. But not all of the energy of the ray escapes the raindrop after it is reflected once. A part of the ray is reflected again and travels along inside the drop to emerge from the drop. The rainbow we normally see is called the primary rainbow and is produced by one internal reflection; the secondary rainbow arises from two internal reflections and the rays exit the drop at an angle of 50 degrees° rather than the 42°degrees for the red primary bow. Blue light emerges at an even
larger angle of 53 degrees°, this effect produces a secondary rainbow that has its colors reversed compared to the primary.

Rainbows are rare—so make your own

Homemade rainbow by using a yard sprinkler. When my daughter was 10 years old she made us get a dog by saying "Every child should have a dog". Maybe so; but it is definitely sure that every child should see a rainbow. Children growing up in Iquique, Chile, where it may not rain for years at a time, can still experience rainbows because anyone can make their own. All you have to do is use a garden hose or yard sprinkler. Just set up the yard sprinkler, and stand between it and the sun. The rainbow appearing before you is just as real and natural as the one you see from a rainstorm ... and, a lot closer.

Surface Tension and Water

Surface tension

The property of the surface of a liquid that allows it to resist an external force, due to the cohesive nature of its molecules.

The cohesive forces between liquid molecules are responsible for the phenomenon known as surface tension. The molecules at the surface of a glass of water do not have other water molecules on all sides of them and consequently they cohere more strongly to those directly associated with them (in this case, next to and below them, but not above). It is not really true that a "skin" forms on the water surface; the stronger cohesion between the water molecules as opposed to the attraction of the water molecules to the air makes it more difficult to move an object through the surface than to move it when it is completely submersed.

Cohesion and Surface Tension

The cohesive forces between molecules in a liquid are shared with all neighboring molecules. Those on the surface have no neighboring molecules above and, thus, exhibit stronger attractive forces upon their nearest neighbors on and below the surface. Surface tension could be defined as the property of the surface of a liquid that allows it to resist an external force, due to the cohesive nature of the water molecules.
Surface tension at a molecular level

Water molecules want to cling to each other. At the surface, however, there are fewer water molecules to cling to since there is air above (thus, no water molecules). This results in a stronger bond between those molecules that actually do come in contact with one another, and a layer of strongly bonded water (see diagram). This surface layer (held together by surface tension) creates a considerable barrier between the atmosphere and the water. In fact, other than mercury, water has the greatest surface tension of any liquid. (Source: Lakes of Missouri)

Within a body of a liquid, a molecule will not experience a net force because the forces by the neighboring molecules all cancel out (diagram). However for a molecule on the surface of the liquid, there will be a net inward force since there will be no attractive force acting from above. This inward net force causes the molecules on the surface to contract and to resist being stretched or broken. Thus the surface is under tension, which is probably where the name "surface tension" came from. (Source: Woodrow Wilson Foundation).

Due to the surface tension, small objects will "float" on the surface of a fluid, as long as the object cannot break through and separate the top layer of water molecules. When an object is on the surface of the fluid, the surface under tension will behave like an elastic membrane.

Examples of surface tension

Walking on water: Small insects such as the water strider can walk on water because their weight is not enough to penetrate the surface.

Floating a needle: A carefully placed small needle can be made to float on the surface of water even though it is several times as dense as water. If the surface is agitated to break up the surface tension, then needle will quickly sink.

Don't touch the tent!: Common tent materials are somewhat rainproof in that the surface tension of water will bridge the pores in the finely woven material. But if you touch the tent material with your finger, you break the surface tension and the rain will drip through.

Clinical test for jaundice: Normal urine has a surface tension of about 66 dynes/centimeter but if bile is present (a test for jaundice), it drops to about 55. In the Hay test, powdered sulfur is sprinkled on the urine surface. It will float on normal urine, but will sink if the surface tension is lowered by the bile.

Surface tension disinfectants: Disinfectants are usually solutions of low surface tension. This allow them to spread out on the cell walls of bacteria and disrupt them.
Soaps and detergents: These help the cleaning of clothes by lowering the surface tension of the water so that it more readily soaks into pores and soiled areas.

Washing with cold water: The major reason for using hot water for washing is that its surface tension is lower and it is a better wetting agent. But if the detergent lowers the surface tension, the heating may be unnecessary.

Why bubbles are round: The surface tension of water provides the necessary wall tension for the formation of bubbles with water. The tendency to minimize that wall tension pulls the bubbles into spherical shapes.

Surface Tension and Droplets: Surface tension is responsible for the shape of liquid droplets. Although easily deformed, droplets of water tend to be pulled into a spherical shape by the cohesive forces of the surface layer.

Water properties: Temperature

The U.S. Geological Survey (USGS) has been measuring how much water is flowing in rivers, determining the water levels of groundwater, and collecting water samples to describe what the quality of those waters are for over a century. Millions of measurements and analyses have been made. Water temperature is taken almost every time water is sampled and investigated, no matter where water is being studied.

Significance of water temperature

Temperature exerts a major influence on biological activity and growth. Temperature governs the kinds of organisms that can live in rivers and lakes. Fish, insects, zooplankton, phytoplankton, and other aquatic species all have a preferred temperature range. As temperatures get too far above or below this preferred range, the number of individuals of the species decreases until finally there are none.

Temperature is also important because of its influence on water chemistry. The rate of chemical reactions generally increases at higher temperature. Water, particularly groundwater, with higher temperatures can dissolve more minerals from the rocks it is in and will therefore have a higher electrical conductivity. It is the opposite when considering a gas, such as oxygen, dissolved in the water. Think about how much bubblier a cold soda is compared to a warm one. The cold soda can keep more of the carbon dioxide bubbles dissolved in the liquid than the warm one can, which makes it seem fizzier when you drink it. How warm stream water is can affect the aquatic life in the stream. Warm water holds less dissolved oxygen than cool water, and may not contain enough dissolved oxygen for the survival of different species of aquatic life. Some compounds are also more toxic to aquatic life at higher temperatures.
Impervious surfaces contribute hot water to streams

You might not think that water temperature is considered an important water-quality measurement. After all, temperature is not a chemical and it doesn't have physical properties. But, if you ask a fish if the temperature of the water it is living in is important, it would yell yes! (if it could talk). In natural environments, temperature is not too much of a concern for aquatic life, since the animals and plants in the water have evolved to best survive in that environment. It is when the temperature of a water body changes, either by a natural event or by a human-induced event, that the fish start to worry.

The picture to the left shows a typical parking lot after a strong summer rainstorm. Parking lots and roads, which are examples of impervious surfaces, where water runs off into local streams instead of soaking into the ground, as in natural environments, act as “fast lanes” for rainfall to make its way into streams. Rain that falls on a parking lot that has been baking in the sun all day during summer gets super heated and then runs off into streams. This heated water can be a shock to the aquatic life in the stream and can, thus, harm the water quality of the stream.

Along with the heat, runoff from parking lots can contain pollutants, such as leaking motor oil, hydrocarbons from exhaust, leftover fertilizer, and normal trash. Some communities are experimenting with using permeable pavement in the parking lot and water gardens and absorbent plants alongside the lot to see if this cuts down on harmful runoff from the lots into streams. In the right side picture the parking surfaces are tilted so that they drain into a natural area that allows runoff to soak into the ground. Water-loving plants are also being grown in the area. A significant amount of the runoff should be captured by these areas, and by the time a portion of the runoff reaches a stream, the water temperatures should be closer to normal stream temperatures.
**Seasonal changes in lakes and reservoirs**

Temperature is also important in lakes and reservoirs. It is related to the dissolved-oxygen concentration in water, which is very important to all aquatic life. Many lakes experience a "turning" of its water layers when the seasons change. In summer, the top of the lake becomes warmer than the lower layers. You've probably noticed this when swimming in a lake in summer - your shoulders feel like they're in a warm bath while your feet are chilled. Since warm water is less dense that colder water, it stays on top of the lake surface. But, in winter some lake surfaces can get very cold. When this happens, the surface water becomes more dense than the deeper water with a more constant year-round temperature (which is now warmer than the surface), and the lake "turns", when the colder surface water sinks to the lake bottom.

The way that temperatures vary in lakes over seasons depends on where they are located. In warm climates the surface may never get so cold as to cause the lake "to turn." But, in climates that have a cold winter, temperature stratifications and turning do occur. This chart is an illustration of temperatures profiles for a lake in Minnesota, USA (where it gets really cold during winter). You can see that in May the surface starts to warm (green color), but the warming only goes down to about 5 meters in depth. Even though the surface continues to warm all summer, the less dense water still stays on top of the lake. Even in summer the bottom half of the lake still stays almost as cold as it was in winter. During summer, the less dense warmer water stays on top of the colder water; no mixing of water occurs. Notice in October, as the temperature starts to consistently get down near freezing at night, the surface water cools, becomes a little colder in temperature and a little more dense than the water in the bottom of the lake, and, thus, sinks, causing mixing. The lake " has turned." After October, the temperature throughout the vertical column of water is about the same, cold temperature, until the ice is melted and the sun can warm the top of the lake again.
Temperature Effects of Dam Operations

Aerial view of Cougar Dam and Reservoir, Oregon, looking south.

I'm sure fish have been living in the McKenzie River in Oregon for many thousands of years—way before many people lived there and definitely before the Cougar Dam was built. For eons fish were adapted to live and reproduce in a river having certain environmental characteristics that would not change quickly. But, after the construction of Cougar Dam, one thing that did change for the fish was the water-temperature patterns below the dam at certain times of year. The McKenzie River supports the largest remaining wild population of Chinook salmon in the upper Willamette River basin, and the South Fork McKenzie River provides good spawning habitat. It was found that the altered temperature pattern downstream of Cougar Dam created problems with regard to the timing of migration, spawning, and egg hatching for the fish (Cassie, 2006).

This detrimental environmental consequence was realized in the mid 2000s and to restore the suitability of this reach for salmon spawning, the U.S. Army Corps of Engineers (USACE) added a sliding gate assembly to the intake structure at Cougar Dam. Water temperature patterns below the dam have become more like natural patterns recently, with the result being a lot of smiling salmon. The chart below shows the differences in temperature patterns for sites above and below the dam before any adjustments were made to fix the situation.


**Impoundements can alter natural temperature patterns of a river**

This chart compares a year's temperature pattern for monitoring sites on the South Fork McKenzie River upstream and downstream of Cougar Dam. The intent is to show how, due to certain construction aspects of the dam, that seasonal temperature patterns below the data were severely altered after the dam became operational. The altered temperature patterns had adverse effects on fish populations below the dam.

The light grey line shows, for the upstream site, a pattern as you might expect—temperatures heating up in late spring and rising during the summer with the fall bringing lower temperatures. It shows a normal bell-curve type of pattern that closely follows seasonal air temperature patterns. Fish living in this reach of the river would be adapted for these normal temperature patterns.
Cougar Dam controls the flow and greatly influences the temperature in the South Fork McKenzie River downstream of the dam. Cougar Reservoir becomes thermally stratified in summer, with warmer, less-dense water near the surface and colder, denser water at the bottom. Western Oregon’s warm and sunny summer weather adds additional heat to the reservoir’s surface, stabilizing its stratification throughout the summer. Because the dam was built with its major release point at a relatively low elevation, the dam historically released relatively cold water from near the bottom of the reservoir in mid-summer. As the reservoir was drawn down in autumn to make room for flood-control storage, the heat that was captured in the reservoir’s upper layer during the summer was released downstream. As a result, the seasonal temperature pattern (darker line on chart) downstream of Cougar Dam through 2001 was quite different from the pattern upstream of Cougar Reservoir.

**Power plants must cool their used water**

Aerial photo of Beaver Valley Power Station in Pennsylvania, showing evaporation from the large cooling towers.

Certain industries have to be very concerned with water temperature. The best example of this is the thermoelectric-power industry that produces most of the electricity that the Nation uses. One of the main uses of water in the power industry is to cool the power-producing equipment. Water used for this purpose does cool the equipment, but at the same time, the hot equipment heats up the cooling water. Overly hot water cannot be released back
into the environment—fish downstream from a power plant releasing the hot water would protest. So, the used water must first be cooled. One way to do this is to build very large cooling towers and to spray the water inside the towers. Evaporation occurs and water is cooled. That is why large power-production facilities are often located near rivers.

Turbidity

Sediment-data collection in the Little Colorado River a kilometer upstream from the Colorado River, Grand Canyon, Arizona

Turbidity is the measure of relative clarity of a liquid. It is an optical characteristic of water and is an expression of the amount of light that is scattered by material in the water when a light is shined through the water sample. The higher the intensity of scattered light, the higher the turbidity. Material that causes water to be turbid include clay, silt, finely divided inorganic and organic matter, algae, soluble colored organic compounds, and plankton and other microscopic organisms.

Turbidity makes water cloudy or opaque. The picture to the left shows a USGS hydrologist sampling highly turbid water in the Colorado River in Arizona. The water collected in the bottle will be used to find out the turbidity, which is measured by shining a light through the water and is reported in nephelometric turbidity units (NTU). During periods of low flow (base flow), many rivers are a clear green color, and turbidities are low, usually less than 10 NTU. During a rainstorm, particles from the surrounding land are washed into the river making the water a muddy brown color, indicating water that has higher turbidity values. Also, during high flows, water velocities are faster and water volumes are higher, which can more easily stir up and suspend material from the stream bed, causing higher turbidities.
Turbidity and water quality

Sediment-laden water from a inflow stream entering a much clearer Lake Tuscaloosa, Alabama, USA (Credit: City of Tuscaloosa, Alabama)

High concentrations of particulate matter affect light penetration and productivity, recreational values, and habitat quality, and cause lakes to fill in faster. In streams, increased sedimentation and siltation can occur, which can result in harm to habitat areas for fish and other aquatic life. Particles also provide attachment places for other pollutants, notably metals and bacteria. For this reason, turbidity readings can be used as an indicator of potential pollution in a water body.

Turbidity and human health

Excessive turbidity, or cloudiness, in drinking water is aesthetically unappealing, and may also represent a health concern. Turbidity can provide food and shelter for pathogens. If not removed, turbidity can promote regrowth of pathogens in the distribution system, leading to waterborne disease outbreaks, which have caused significant cases of gastroenteritis throughout the United States and the world. Although turbidity is not a direct indicator of health risk, numerous studies show a strong relationship between removal of turbidity and removal of protozoa. The particles of turbidity provide "shelter" for microbes by reducing their exposure to attack by disinfectants. Microbial attachment to particulate material has been considered to aid in microbe survival. Fortunately, traditional water treatment processes have the ability to effectively remove turbidity when operated properly. (Source: EPA)

Measuring turbidity

State-of-the-art turbidity meters (left-side picture) in rivers to provide an instantaneous turbidity picture shows a closeup of the meter. The large reads shining a reading how to the contains a measure water, by holes) and a temperature gauge (the metal rod). are beginning to be installed reading. The right-side tube is the turbidity sensor; it turbidity in the river by light into the water and much light is reflected back sensor. The smaller tube conductivity sensor to electrical conductance of the which is strongly influenced dissolved solids (the two
Your nose knows about vapor pressure

Vapor pressure

The equilibrium pressure, in a closed container, between molecules moving between the liquid and gaseous phases.

So, what do turnip greens, your nose, and vapor pressure have in common? To try to explain vapor pressure to you, maybe the best place to start is your nose. Assuming that the gentleman in this picture does not care for the smell of turnip greens, he is adjusting the vapor pressure to help keep the smell down (sorry, no thermostat-like device really exists that would actually allow you to adjust the vapor pressure for your whole house, but it would be handy, right?). The vapor pressure of liquids helps to determine the extent to which molecules in the liquid stay as liquid or escape into the air as gas or vapor.

As far as your nose is concerned, when you boil water to cook a delicious pot of turnip greens, the added heat in the pot energizes the water molecules so that some of them escape into the kitchen air as gas. Indirectly, the smell of turnips will escape into the air, too, which is why you smell that turnip aroma when you boil them in water. The added heat raises the normal vapor pressure of water, with the result being water vapor wafting through the kitchen, and with it, the smell of turnips.

The example above is a little deceptive as when water boils water vapor is released, but not necessarily "turnip vapor". But, the higher heat and agitation of boiling water helps to break down molecules in the turnips and those are released as particles into the air with the water vapor. So, you're not really smelling the water vapor, but you are smelling tiny bits of turnips. The same concept does hold true for various liquids, and here vapor pressure does explain why you smell some liquids more readily than others.
An explanation of vapor pressure

Vapor pressure is constant when there is an equilibrium of water molecules moving between the liquid phase and the gaseous phase, in a closed container.

The vapor pressure of a liquid is the point at which equilibrium pressure is reached, in a closed container, between molecules leaving the liquid and going into the gaseous phase and molecules leaving the gaseous phase and entering the liquid phase. Note the mention of a "closed container". In an open container, the molecules in the gaseous phase will just fly off and an equilibrium would not be reached, as many fewer gaseous molecules would be re-entering the liquid phase. Also note that at equilibrium the movement of molecules between liquid and gas does not stop, but the number of molecules in the gaseous phase stays the same—there is always movement between phases. So, at equilibrium there is a certain concentration of molecules in the gaseous phase; the pressure the gas is exerting is the vapor pressure. As for vapor pressure being higher at higher temperatures, when the temperature of a liquid is raised, the added energy in the liquid gives the molecules more energy and they have greater ability to escape the liquid phase and go into the gaseous phase.

Turnip greens in a hurry

If you wanted to cook your turnip greens quicker you would want the water temperature to be higher. But, in an open container, water boils at 212°F (at sea level), and if you continue to heat the water you will release more molecules as water vapor but the temperature of the water won't go higher than 212°. Now, this assumes you live at sea level, since as the higher your kitchen is above sea level, the lower the air pressure pushing down on the water in the pot of turnip greens, and the lower the vapor pressure, and thus, the water will boil at a lower temperature. That is why it takes longer to cook food at higher altitudes.

The point is, in an open container once water reaches the boiling point it will not get hotter. You can use vapor pressure to "trick" your turnip greens, though, by using a closed container to cook in—known as a pressure cooker. Pressure cookers have lids that can be secured to the pot which prevents steam from escaping the pot, which raises the pressure of the vapor inside the container. There is a pressure-release valve on the top of the pot to prevent pressures from getting so high that the pot explodes (although there are many instances of the valve malfunctioning with the disastrous effect being a pot that literally explodes). We mentioned that with a higher vapor pressure higher water temperatures can be reached, meaning that in a
pressure cooker the vapor pressure is much higher and thus, the water doesn't boil until it reaches a higher temperature, which cooks the food faster.

**Water, the Universal Solvent**

Water is capable of dissolving a variety of different substances, which is why it is such a good solvent. In fact, water is called the "universal solvent" because it dissolves more substances than any other liquid. This is important to every living thing on earth. It means that wherever water goes, either through the air, the ground, or through our bodies, it takes along valuable chemicals, minerals, and nutrients.

It is water's chemical composition and physical attributes that make it such an excellent solvent. Water molecules have a polar arrangement of oxygen and hydrogen atoms—one side (hydrogen) has a positive electrical charge and the other side (oxygen) had a negative charge. This allows the water molecule to become attracted to many other different types of molecules. Water can become so heavily attracted to a different compound, like salt (NaCl), that it can disrupt the attractive forces that hold the sodium and chloride in the salt compound together and, thus, dissolves it.

**Our kidneys and water make a great pair**

Our own kidneys and water's solvent properties make a great pair in keeping us alive and healthy. The kidneys are responsible for filtering out substances that enter our bodies from the foods and drinks we consume. But, the kidneys have got to get rid of these substances after they accumulate them. That is where water helps out; being such a great solvent, water washing through the kidneys dissolves these substances and sends them on the way out of our bodies.

**Why salt dissolves in water**

At the molecular level, salt dissolves in water due to electrical charges and due to the fact that both water and salt compounds are polar, with positive and negative charges on opposite sides in the molecule. The bonds in salt compounds are called ionic because they both have an electrical charge—the chloride ion is negatively charged and the sodium ion is positively charged. Likewise, a water molecule is ionic in nature, but the bond is called covalent, with two hydrogen atoms both situating themselves with their positive charge on one side of the oxygen atom, which has a negative charge. When salt is mixed with water, the salt dissolves because the covalent bonds of water are stronger than the ionic bonds in the salt molecules.
The positively-charged side of the water molecules are attracted to the negatively-charged chloride ions and the negatively-charged side of the water molecules are attracted to the positively-charged sodium ions. Essentially, a tug-of-war ensues with the water molecules winning the match. Water molecules pull the sodium and chloride ions apart, breaking the ionic bond that held them together. After the salt compounds are pulled apart, the sodium and chloride atoms are surrounded by water molecules, as this diagram shows. Once this happens, the salt is dissolved, resulting in a homogeneous solution.

Electrical Conductivity and Water

You're never too old to learn something new. All my life I've heard that water and electricity make a dangerous pair together. And pretty much all of the time that is true—mixing water and electricity, be it from a lightning bolt or electrical socket in the house, is a very dangerous thing to do. But what I learned from researching this topic was that pure water is actually an excellent insulator and does not conduct electricity. Water that would be considered "pure" would be distilled water (water condensed from steam) and deionized water (used in laboratories), although even water of this purity can contain ions.

But in our real lives, we normally do not come across any pure water. If you read our article about water being the "universal solvent" you know that water can dissolve more things than just about any other liquid. Water is a most excellent solvent. It doesn't matter if the water comes out of your kitchen faucet, is in a swimming pool or dog dish, comes out of the ground or falls from the sky, the water will contain significant amounts of dissolved substances, minerals, and chemicals. These things are the solutes dissolved in water. Don't worry, though—if you swallow a snowflake, it won't hurt you; it may even contain some nice minerals your body needs to stay healthy.

Free ions in water conduct electricity

Fish shocking to collect biological samples. One hydrologist is using a backpack electro-fisher to stun the fish. Water quits being an excellent insulator once it starts dissolving substances around it. Salts, such as common table salt (NaCl) is the one we know best. In chemical terms, salts are ionic compounds composed of cations (positively charged ions) and anions (negatively charged ions). In solution, these ions essentially cancel each other out so that the solution is electrically neutral (without a net charge). Even a small amount of ions in a water solution makes it able to conduct electricity (so definitely don't add salt to your "lightning-storm" bath water.). Once water contains these ions it will conduct electricity, such as from a lightning
bolt or a wire from the wall socket, as the electricity from the source will seek out oppositely-charged ions in the water. Too bad if there is a human body in the way.

Interestingly, if the water contains very large amounts of solutes and ions, then the water becomes such an efficient conductor of electricity that an electrical current may essentially ignore a human body in the water and stick to the better pathway to conduct itself—the masses of ions in the water. That is why the danger of electrocution in sea water is less than it would be in bath water.

Lucky for us hydrologists here at the U.S. Geological Survey (USGS), water flowing in streams contains extensive amounts of dissolved salts. Otherwise, these two USGS hydrologists might be out of a job. Many water studies include investigating the fish that live in streams, and one way to collect fish for scientific study is to shoot an electrical current through the water to shock the fish for scientific study is to shoot an electrical current through the water to shock the fish ("zap 'em and bag 'em").

Evapotranspiration - The Water Cycle

Evapotranspiration is the sum of evaporation from the land surface plus transpiration from plants. Precipitation is the source of all water.

What is evapotranspiration?

If you search for the definition of evapotranspiration, you will find that it varies. In general, evapotranspiration is the sum of evaporation and transpiration. Some definitions include evaporation from surface-water bodies, even the oceans. But, since we have a Web page just about evaporation, our definition of evapotranspiration will not include evaporation from surface water. Here, evapotranspiration is defined as the water lost to the atmosphere from the ground surface, evaporation from the capillary fringe of the groundwater table, and the transpiration of groundwater by plants whose roots tap the capillary fringe of the groundwater table. The banner at the top of this page offers an even more simple definition.

The transpiration aspect of evapotranspiration is essentially evaporation of water from plant leaves. Studies have revealed that transpiration accounts for about 10 percent of the moisture in the atmosphere, with oceans, seas, and other bodies of water (lakes, rivers, streams) providing nearly 90 percent, and a tiny amount coming from sublimation (ice changing into water vapor without first becoming liquid).
Transpiration: The release of water from plant leaves

After a plastic bag is wrapped around part of a plant, the inside of the bag becomes misty with transpired water vapor. Just as you release water vapor when you breathe, plants do, too – although the term "transpire" is more appropriate than "breathe." This picture shows water vapor transpired from plant leaves after a plastic bag has been tied around the stem for about an hour. If the bag had been wrapped around the soil below it, too, then even more water vapor would have been released, as water also evaporates from the soil.

Plants put down roots into the soil to draw water and nutrients up into the stems and leaves. Some of this water is returned to the air by transpiration. Transpiration rates vary widely depending on weather conditions, such as temperature, humidity, sunlight availability and intensity, precipitation, soil type and saturation, wind, and land slope. During dry periods, transpiration can contribute to the loss of moisture in the upper soil zone, which can have an effect on vegetation and food-crop fields.

How much water do plants transpire?

Plant transpiration is pretty much an invisible process. Since the water is evaporating from the leaf surfaces, you don't just go out and see the leaves "breathing". Just because you can't see the water doesn't mean it is not being put into the air, though. One way to visualize transpiration is to put a plastic bag around some plant leaves. As this picture shows, transpired water will condense on the inside of the bag. During a growing season, a leaf will transpire many times more water than its own weight. An acre of corn gives off about 3,000-4,000 gallons (11,400-15,100 liters) of water each day, and a large oak tree can transpire 40,000 gallons (151,000 liters) per year.

Atmospheric factors affecting transpiration

The amount of water that plants transpire varies greatly geographically and over time. There are a number of factors that determine transpiration rates:

- **Temperature**: Transpiration rates go up as the temperature goes up, especially during the growing season, when the air is warmer due to stronger sunlight and warmer air masses. Higher temperatures cause the plant cells which control the openings (stoma) where water is released to the atmosphere to open, whereas colder temperatures cause the openings to close.
- **Relative humidity**: As the relative humidity of the air surrounding the plant rises the transpiration rate falls. It is easier for water to evaporate into dryer air than into more saturated air.
- **Wind and air movement**: Increased movement of the air around a plant will result in a higher transpiration rate. Wind will move the air around, with the result that the more
saturated air close to the leaf is replaced by drier air.

- **Soil-moisture availability**: When moisture is lacking, plants can begin to senesce (premature ageing, which can result in leaf loss) and transpire less water.
- **Type of plant**: Plants transpire water at different rates. Some plants which grow in arid regions, such as cacti and succulents, conserve precious water by transpiring less water than other plants.

**Transpiration and groundwater**

In many places, the top layer of the soil where plant roots are located is above the water table and thus is often wet to some extent, but is not totally saturated, as is soil below the water table. The soil above the water table gets wet when it rains as water infiltrates into it from the surface, but it will dry out without additional precipitation. Since the water table is usually below the depth of the plant roots, the plants are dependent on water supplied by precipitation. As this diagram shows, in places where the water table is near the land surface, such as next to lakes and oceans, plant roots can penetrate into the saturated zone below the water table, allowing the plants to transpire water directly from the groundwater system. Here, transpiration of groundwater commonly results in a drawdown of the water table much like the effect of a pumped well (cone of depression—the dotted line surrounding the plant roots in the diagram).