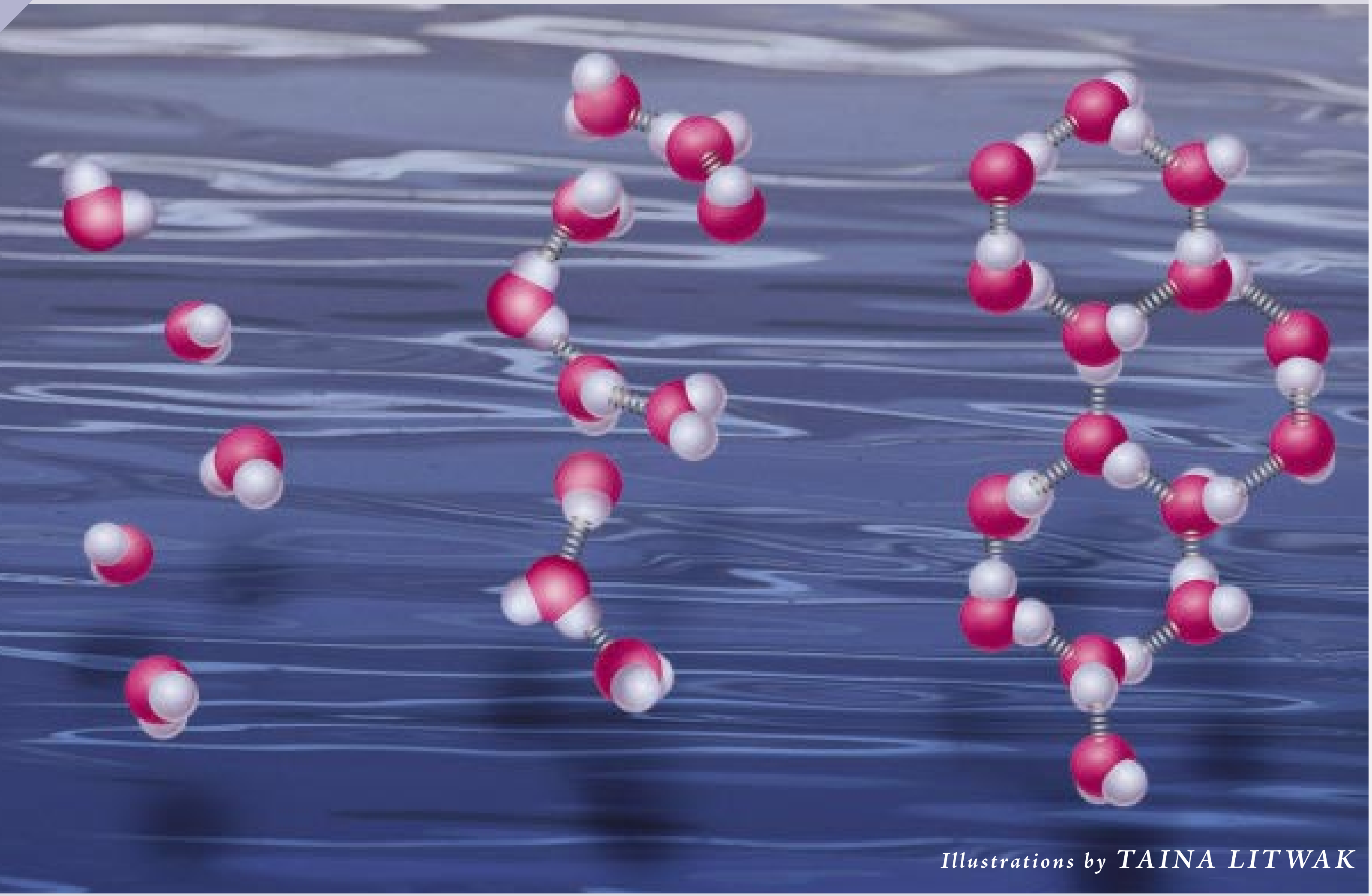
Young Naturalists

the Wonder of Water

Without this common substance's uncommon traits, life as we know it would not exist.



Illustrations by TAINA LITWAK

By MARY HOFF

It's solid as a rock, but light enough to float. It's a gas that turns to liquid when it touches cold air. In liquid form, it defies gravity. It's one of the strangest chemical compounds ever discovered. Yet it's the most common substance on Earth. It's found on every continent in the world. It's in the sky, in the oceans, in your back yard, in your house—even in you. It's weird, wonderful water.

Water is almost everywhere, so we're pretty used to it. In fact, you might think of it as a little boring. But it's not. Due to some chemical quirks of nature, water behaves differently than other substances. And that makes all the difference in the world. Plants and animals depend on water's odd traits to carry out the everyday business of living. If water weren't so strange, life as we know it would not exist.

As a gas (left), liquid (center), or solid (right), water molecules have special properties that make them behave in wonderful ways.

Amazing Molecule

Why is water weird? It's the way it's put together.

Rocks, plants, animals, air, and other things in the world around us are made up of tiny bits of stuff called *atoms*. There are more than 100 kinds of atoms. Some are familiar: oxygen, gold, helium. Others you may never have heard of: molybdenum, cesium, scandium, antimony.

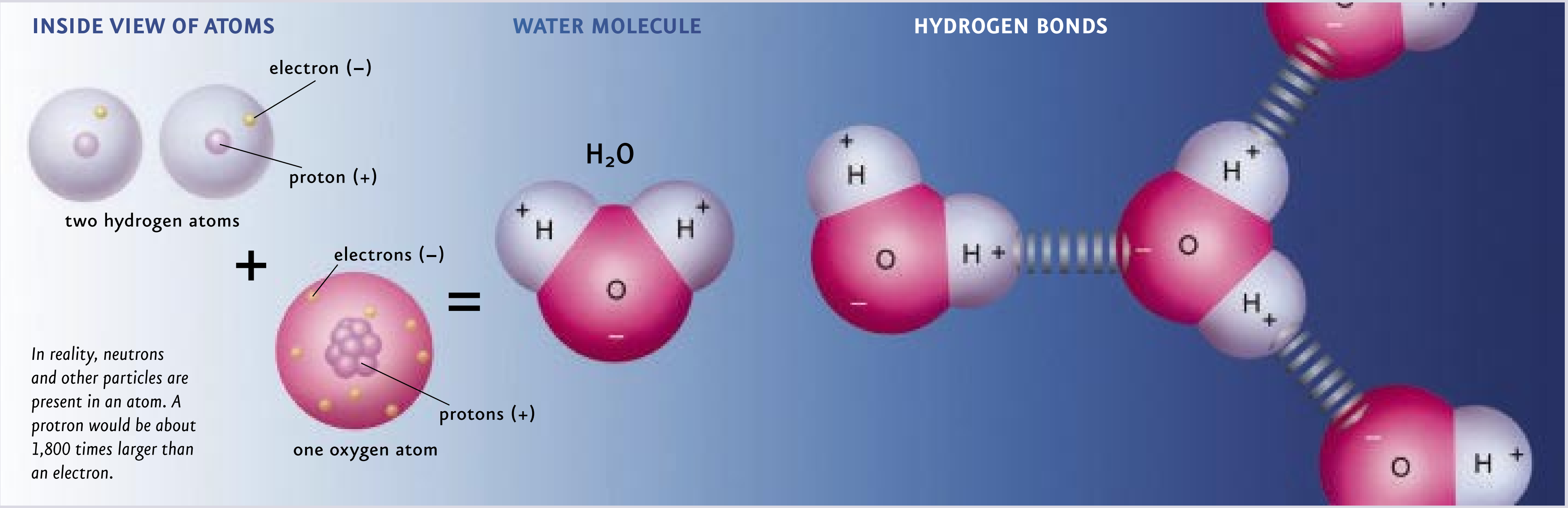
Atoms are made up of still smaller bits of stuff called *protons, neutrons,* and *electrons*. Sometimes atoms share electrons. When they do, atoms stick together like friends holding hands.

A group of stuck-together atoms is called a *molecule*. Just as there are many kinds of atoms, there are many kinds of molecules. Water molecules are made up of three atoms: two hydrogen atoms (symbolized by H_2) and one oxygen atom (symbolized by O). That's why we call water H_2O.

When hydrogen and oxygen atoms join together to form water, oxygen shares one of its electrons with each of the hydrogen atoms. But it also has electrons it doesn't share. This makes the oxygen part of a water molecule act like the negative (–) pole of a magnet and the hydrogen parts act like the positive (+) pole of a magnet.

So what? Well, just as the + end of one magnet attracts the – end of another, the Hs from one water molecule attract the Os of others. This attraction, called a *hydrogen bond*, makes water molecules do some very strange things. Turn the page to see!

TRY THIS: Water molecules are a lot like mini magnets. Take two magnets and try to stick the + end of one to the – end of the other. What happens? Try to stick the + ends of the two magnets together. What happens then?



Atoms contain protons, which have a positive (+) charge, and electrons, which have a negative (–) charge. When an oxygen atom joins with two hydrogen atoms to make a water molecule, it shares an electron with each. But it also has electrons it doesn't share. As a result, the water molecule has + and – poles, like a magnet. These poles attract each other, forming weak links called *hydrogen bonds*.

Three Phases

Water, like other substances, can exist in three forms or *phases:* solid, liquid, or gas. As temperatures go up, water changes from solid to liquid to gas.

In a solid, molecules are packed and stacked together in organized patterns and don't move relative to each other. In a liquid, the molecules are farther apart and they move around. In a gas, molecules are even farther apart and more active.

Most molecules about the size of a water molecule, such as carbon dioxide, exist only as gases at temperatures we commonly find on Earth. Because of their hydrogen bonds, water molecules stick together more than other molecules do. As a result, water exists as a liquid and a solid as well as a gas at everyday temperatures. That's why on a warm winter day you can splash in a puddle, slip on ice, and breathe air with water molecules in it all at the same time!

Water's ability to exist in all three forms of matter at temperatures common on Earth helps it move from one place to another. As a gas, it flies through the air. When it cools, it turns to liquid and falls as

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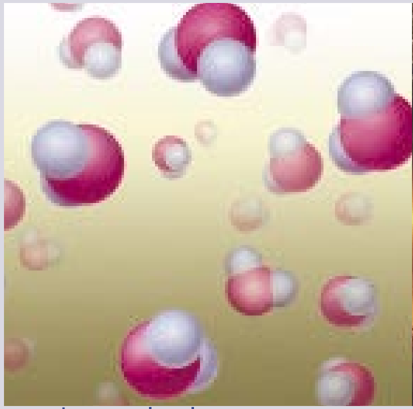
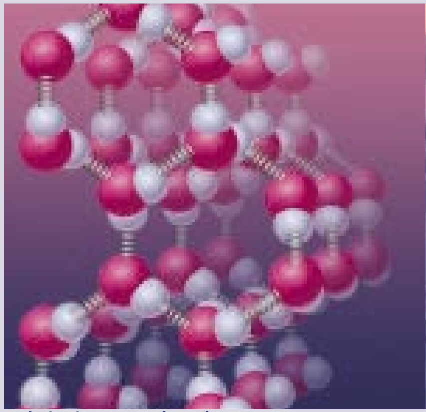

gas-phase molecules


morning fog


liquid-phase molecules


dew drops


solid phase molecules


ice ridge on a lake

PHOTOGRAPHS BY RICHARD HAMILTON SMITH

rain or snow. As a liquid, it soaks into the ground or runs downhill, forming streams and rivers that carry it to lakes and eventually to the sea. Along the way, some water molecules evaporate (turn to gas) and travel back through the air again.

This movement of water is called the *water cycle.* The water cycle helps make water available to all creatures, wherever they live.

TRY THIS: With a grown-up's help, heat a cup of water in a pan on the stove. Watch what happens to the water as it warms. What is in the bubbles that form? When the water starts to boil, hold a cool plate about 10 inches above the pan. What happens to the plate? Why?

Sticky Liquid

EDWARD TSANG

Hydrogen bonds make water a sticky liquid. Water molecules stick to each other—a force called *cohesion*. They also stick to other things—a force called *adhesion*.

TRY THIS: You can watch liquid water molecules cling to each other at the surface, where water meets the air. Fill a glass to the very top with water. Carefully add more water, drop by drop. Eventually the water will form a dome above the rim of the glass!

Cohesion and adhesion help water soak into things. They help water soak into the ground so plants and animals can use it. They help water soften hard, dry acorns so they can grow into new oak trees. They help water carry out the processes in your body that keep you alive.

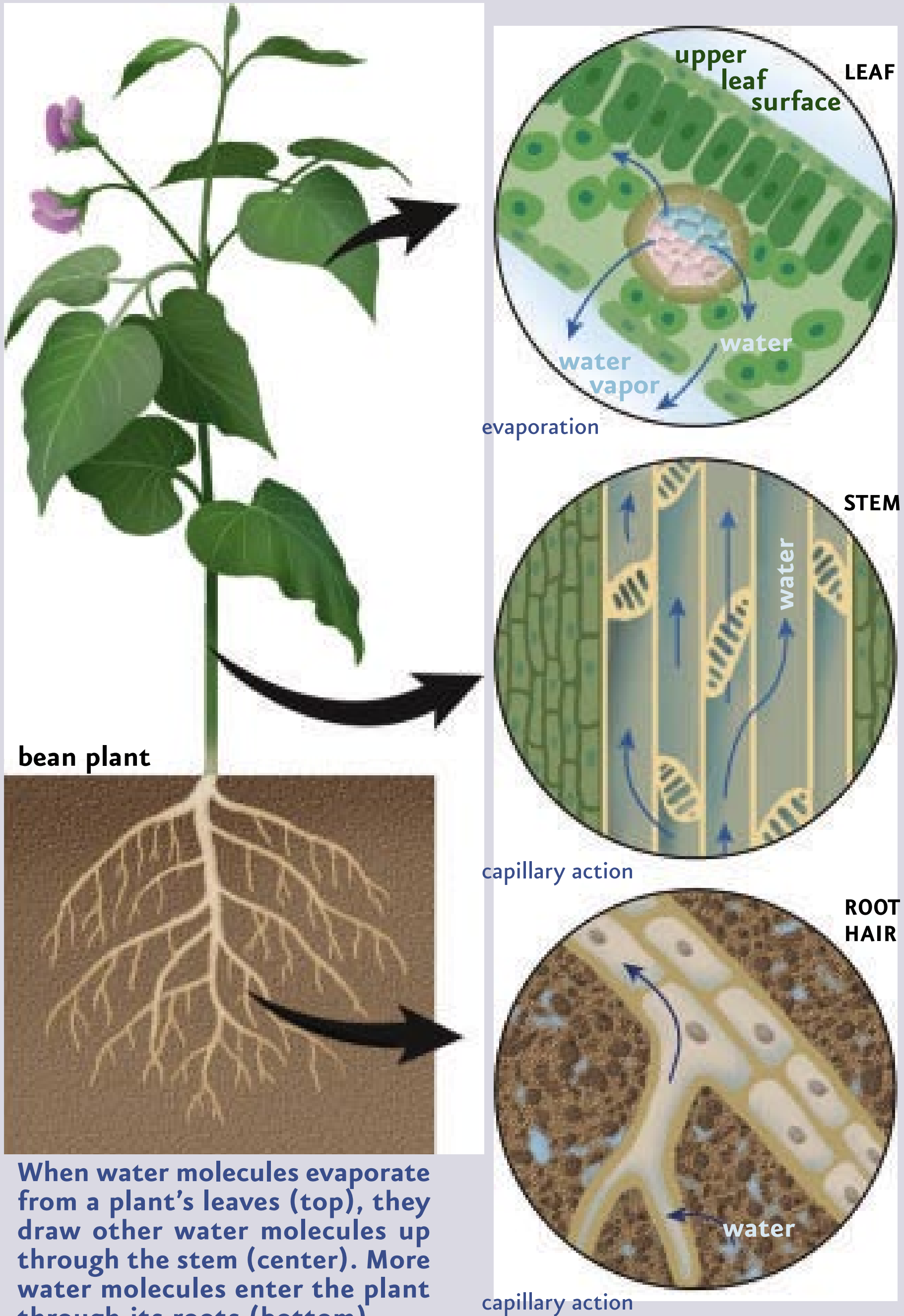
Cohesion and adhesion also help water travel against gravity! When a water molecule turns from liquid to gas, it rises into the air. As it does, the hydrogen bonds cause it to pull other molecules in the liquid water along as well, much as the leader in a long line of kids holding hands pulls the others when he or she moves. So when gas water molecules rise into the air, they pull liquid water molecules behind them. This pulling, called *capillary action*, allows liquid water to move against gravity.

Capillary action is very important in nature. It makes it possible for water to travel from the roots of plants to the tips of their leaves—even to the tops of towering trees!

The stickiness of the hydrogen bonds also causes liquid water to form a kind of "skin"—called *surface tension*—where it meets the air. This skin allows insects called *water striders* to walk across the surface of a pond.

TRY THIS: Put 10 drops of red food coloring into one cup of water. Cut the bottom end off of a rib of celery (use one that still has leaves on top) and put the rib, cut end down, into the water. Leave it there for a day. What happens to the colored water?

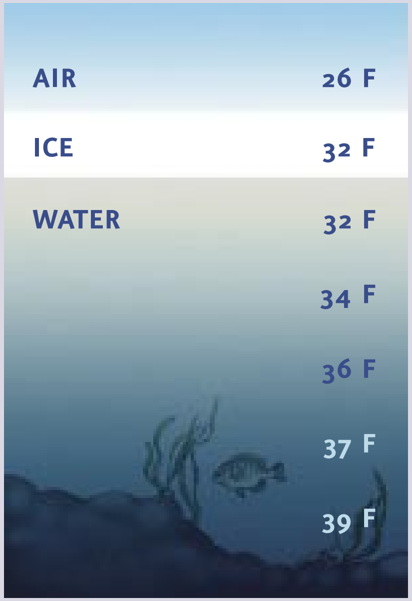
HOW WATER MOVES THROUGH A PLANT



When water molecules evaporate from a plant's leaves (top), they draw other water molecules up through the stem (center). More water molecules enter the plant through its roots (bottom).

KENNETH G. LIBBRECHT, SNOWCRYSTALS.COM

SNOW CRYSTALS are formed when water vapor condenses directly into ice. The most dramatic patterns are formed at 5 F (-15 C). The six-pointed shape is a result of hydrogen bonding.



WATER IS MOST DENSE at about 39 F (4 C). As it cools, the molecules line up to make a lacy crystal, ice. The spaces between molecules in ice crystals make ice less dense than cold water, so it floats.

Light Solid

For most substances, the solid form is denser than the liquid form. But not for water! As water molecules move together to form ice, the pushing and pulling of – and + ends cause them to line up in a lacy pattern with lots of empty spaces in between. As a result, water expands when it freezes.

The empty space trapped in ice makes ice less dense than water. This is very important for creatures that live in lakes. If ice didn't float, then in winter the water at the top of the lake, near the cold air, would freeze and sink to the bottom. Eventually, the whole lake would be frozen.

But because solid water is less dense than liquid water, ice stays on top of the water. That gives fish and other water animals and plants a place to live through the winter.

The fact that water expands when it freezes also accounts for many of the changes in the world around us. When water freezes in cracks in rocks, the ice helps to break the rock apart. This is part of the process by which soil forms.

TRY THIS: Fill an empty, clean jar halfway with water. Draw a line to mark the water level. Freeze (uncovered) overnight. Where is the surface of the ice compared to the water level? What happened as the water froze?

Heat Holder

Temperature is a measure of how much molecules are moving around. When you heat a liquid, the molecules move around more and the temperature goes up. But hydrogen bonds make it harder for molecules to move. As a result you can add a lot of heat to water, but the temperature only goes up a little bit. We say water has a high *heat capacity.*

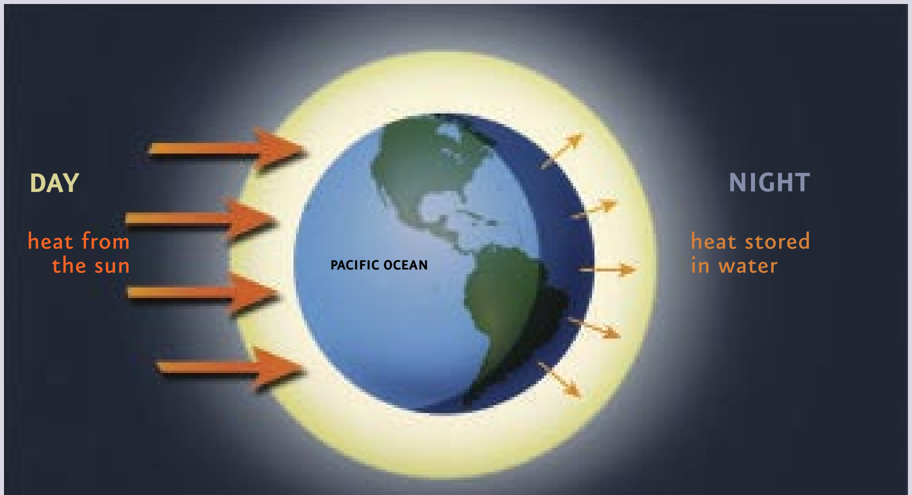
Every kind of molecule requires energy to change from a solid to a liquid and from a liquid to a gas. Because it takes extra energy to break hydrogen bonds, water takes more energy than most substances to change from one form to another. That means water soaks up a lot of heat energy as it turns from ice to liquid or from liquid to gas.

TRY THIS: Place two pie tins in a sunny spot. Fill one with water and leave the other empty. After an hour, carefully touch the two pie tins. Which is hotter? Why?

What good does this do to the rest of the world? A lot! Water's ability to absorb heat helps protect Earth from wild temperature swings from night to day and summer to winter. It keeps ocean temperatures fairly constant, so creatures that live there have a relatively stable environment.

Water's ability to soak up heat as it changes from one form to another helps keep you cool too. When your sweat evaporates, it draws heat from your body. Dogs, rabbits, birds, and other animals cool off by holding their mouths open and letting the water inside evaporate. Turkey vultures pee on their legs when they are hot. As the water evaporates, it cools them off.

WATER GAINS HEAT from the sun during daytime and releases it after dark. This helps keep air temperatures from changing wildly from night to day.



Dynamic Dissolver

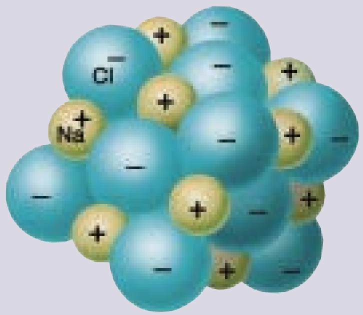
Just as a magnet attracts iron, water molecules attract other kinds of molecules. When other kinds of molecules hang out among water molecules, we say they *dissolve* in water. Sugar, salt, soap, powdered drink mixes, lollipops, and many more things dissolve in water. In fact, water dissolves more substances than any other liquid. Scientists call water the *universal solvent.*

What does that mean for living things? It means water can carry stuff from one place to another. Rivers and streams carry nitrogen and phosphorus, which plants need to grow. They also carry pollutants, which can harm living things. Water carries nutrients from plants' roots to their leaves. It carries food through an animal's bloodstream to nourish its cells.

If all of the water on Earth disappeared today, life would disappear. Next time you get a drink or splash in a puddle, take a moment to celebrate water's amazing traits and the hugely important role it plays in our world.

TRY THIS: Put a teaspoon of sugar into a jar of vegetable oil. Put another teaspoon of sugar into a jar of water. Stir them. What happens?

Table salt is made of sodium (Na) and chlorine (Cl) atoms that act like the + and - ends of a magnet. Because water has + and - parts too, salt dissolves easily in water.



salt dissolved in water