NATURE Unhooked

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MDC DISCOVER nature SCHOOLS

1 the STRUCTURE and PROPERTIES of Water

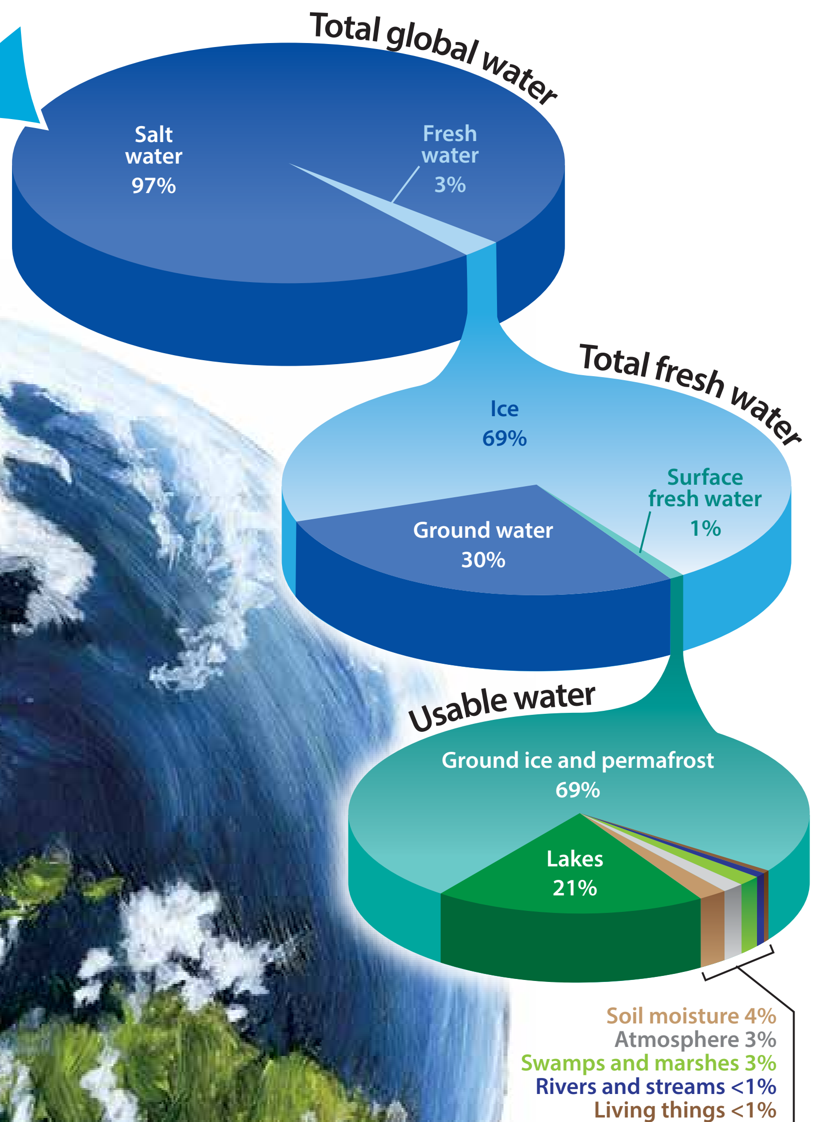
BIG IDEAS

- ➤ Water is a simple molecule.
- ➤ Water's structure gives it distinct properties.
- ➤ Water's properties are important for life.

Earth is called the Blue Planet. There are many other blue planets hurtling around the universe, but none are blue for the same reason as Earth. The planet we call home is painted blue by the water of its oceans, rivers, clouds, and ice. In fact, water covers more than 70 percent of Earth's surface. And it's this water — one of the universe's simplest substances — that makes life possible on our careening ball of rock. In this chapter we'll learn how a water molecule's simple structure gives it unique properties that are necessary for life.

Water, water everywhere? It depends.

Earth contains 1,355,000,000,000,000,000,000 liters of water. Although that sounds like a lot, only a small percentage is available to living things.



Did you know? Scientists have found evidence that 30 to 50 percent of the water on our planet is older than the Earth itself.

Did you know?

Water molecules are really small! Each is only about 0.0000003 of a millimeter wide. It would take more than 60 million water molecules lined up side-by-side to stretch across a penny.

Water is a simple molecule.

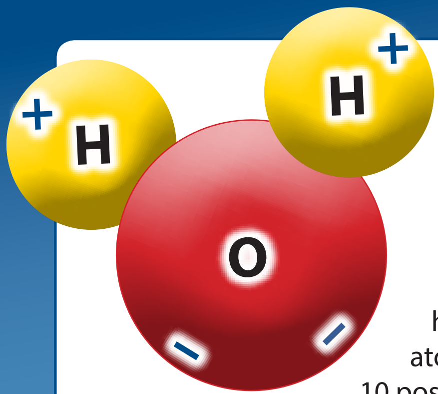
All matter — both living and nonliving — is made of **atoms**. Atoms bond with other atoms to form **molecules**. Some molecules are made of just two atoms. Other molecules are made of thousands of atoms. Water is made of three atoms: two hydrogen atoms and one oxygen atom (H_2O). The atoms are held together by strong bonds that are hard to break.

Like all molecules, water is a pure substance with distinct properties. One of its properties is its shape. Water's atoms are arranged in such a way that they look like a teddy bear's head. The angle between the hydrogen atoms (teddy bear's ears) and the oxygen atom (teddy bear's head) is always in this configuration. Every molecule of water — in the streams and oceans of the world, in raindrops and dewdrops, in our bloodstream and in the fog of air we exhale on a cold day — looks like this.

One molecule of water (just those three atoms) is the smallest unit of water you can obtain. If you break the molecule apart, it stops being water and instead becomes hydrogen and oxygen — two substances with properties that are quite different from those of water.

Did you know?

Water is the most abundant ingredient in living things, usually making up 60 to 75 percent of an organism's weight. The average 12-year-old has nearly 70 pounds of water sloshing inside his or her body.



Water's structure gives it distinct properties.

Atoms are composed of smaller particles. **Protons** have a positive charge (+). **Electrons** have a negative charge (–). Protons stay in the nucleus at the center of the atom. Electrons zip around the nucleus like swarms of bees. Water's two hydrogen atoms each contain one proton and one electron. Water's oxygen atom has eight protons and eight electrons. Thus, a water molecule contains 10 positively charged protons and 10 negatively charged electrons.

In some molecules, the protons and electrons are evenly distributed throughout the molecule. But water is different. Because oxygen has eight protons, it has a greater ability to pull electrons away from the hydrogen atoms. (Remember, opposite charges attract.) So, the electrons in a water molecule tend to swarm around the oxygen atom more often than the hydrogen atoms. Because electrons are negative, the oxygen end of a water molecule (teddy bear's chin) has a slight negative charge, and the hydrogen ends (teddy bear's ears) have a slight positive charge. A molecule such as water, in which the charges aren't evenly distributed, is called a **polar molecule**. (Think of a battery or a magnet that has positive and negative poles.) It's this polarity that gives water many of its distinct properties.

Water's properties are important for life.

COHESION

Opposites attract — it's an undeniable fact of physics and cheesy romance novels — and water is no different. The positively charged hydrogen ends of a water molecule are attracted to negatively charged oxygen ends on nearby water molecules. This causes water molecules to stick to each other. Chemists call the points where they stick together **hydrogen bonds**.

The attraction of one molecule to another molecule of the same kind is called **cohesion**. Cohesion explains why raindrops are round and why water beads up on a freshly waxed car. Cohesion produces surface tension, which explains why water striders can skim across a pond's surface without sinking and why doing a belly flop off the high dive hurts so much. More importantly, cohesion (along with adhesion, which we'll learn about next) plays an important role in moving water and other substances throughout the bodies of living things.

Cohesion allows water to form a dome over this penny.

ADHESION

Adhesion is the attraction between two different kinds of molecules. If you've ever noticed dewdrops clinging to a leaf, you've seen adhesion in action. Adhesion is also responsible for the slight curve you see when you pour water into a graduated cylinder. The water is attracted to the glass at the sides of the cylinder and curves downward at the center. (Because of adhesion, you should always read the volume measurement at the bottom of the curve.)

Missouri's tallest oak tree stretches 150 feet into the sky. Plants as tall as this need good plumbing. How else could they get water from their roots to the top of their branches? A plant's plumbing is composed of a series of dead cells that form tiny tubes. Adhesion draws water up into these tiny tubes. As the water molecules move upward, they tug — because of cohesion — at the molecules they're attached to. In this way, water is pulled up through the tubes from the roots to the leaves.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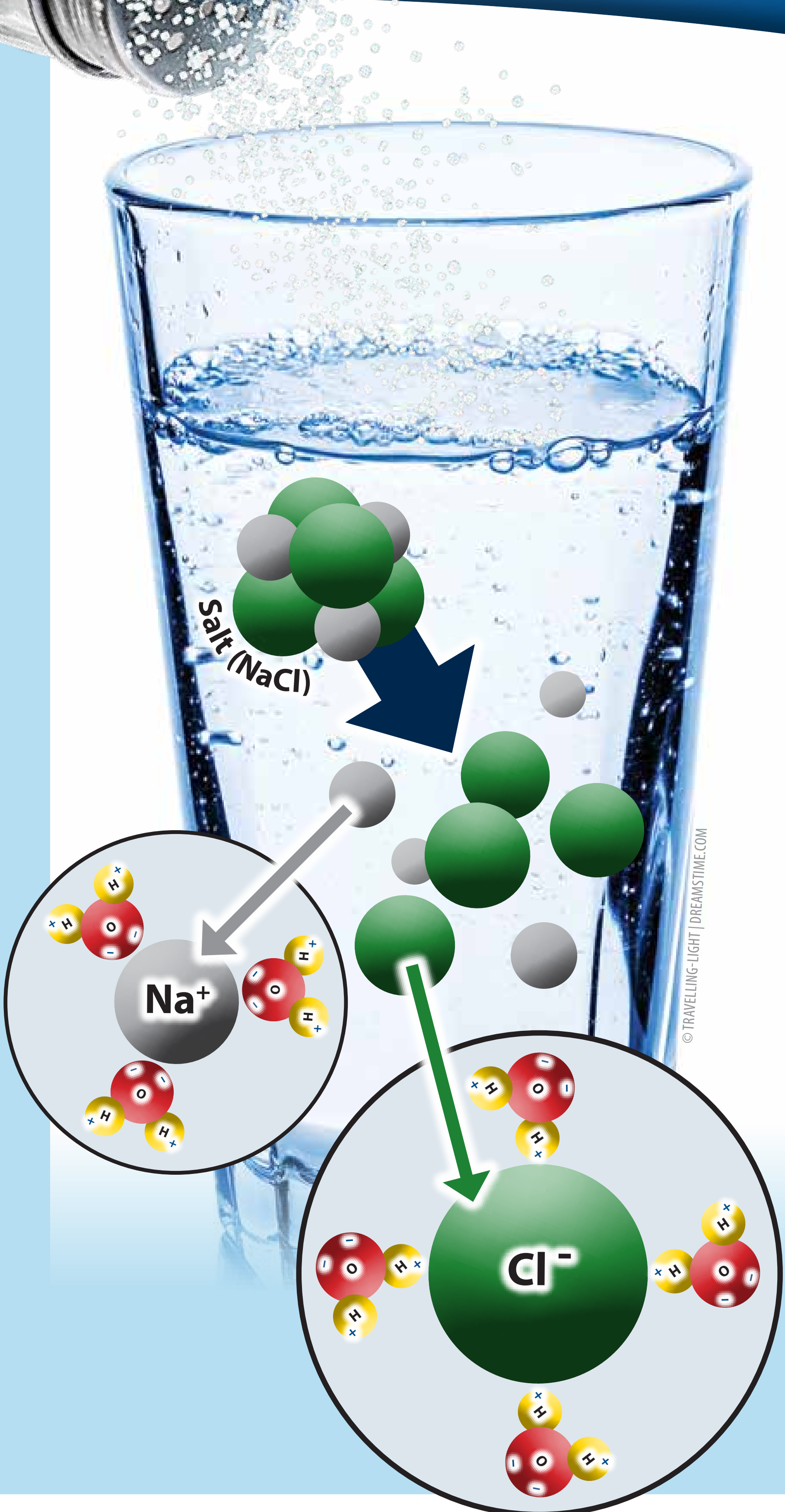
THE UNIVERSAL SOLVENT

Because water is a polar molecule, it is able to attract and pull apart other polar molecules. For example, when table salt, which is made of sodium and chlorine atoms, is mixed into water, the negative ends of the water molecules are attracted to the positively charged sodium atoms, and the positive ends of the water molecules are attracted to the negatively charged chlorine atoms. This causes the sodium and chlorine atoms to separate and dissolve in water.

When a substance dissolves in another substance it forms a **solution**. The **solute** is the substance that dissolves. The **solvent** is the substance that does the dissolving. Many substances dissolve in water. That's why water is called the universal solvent.

Water's knack for dissolving things makes it an excellent vehicle for moving molecules into, out of, and inside living things. Many of life's most important molecules — including sugars, amino acids, and proteins — dissolve in water. Water transports these molecules into and out of cells. On a larger scale, the blood pulsing through your veins and arteries is about 92 percent water. This water helps transport oxygen and nutrients to cells and also helps carry away wastes, such as carbon dioxide. Sweat and urine, both of which are mostly water, play roles in removing wastes from our bodies.



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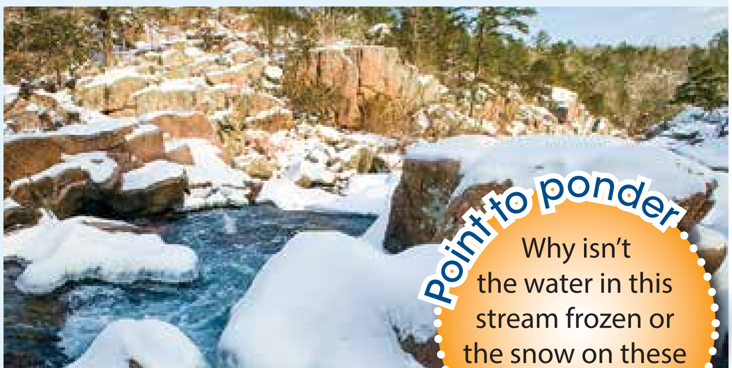
Did you know?

Most substances shrink as they get colder. Water is weird. It expands when it freezes. That's why soda cans explode when you leave them in the freezer.

HIGH HEAT CAPACITY



Point to ponder

Why isn't the water in this stream frozen or the snow on these rocks melted?

Molecules are constantly in motion, as jittery as your little brother after eating Halloween candy all night. Even the molecules in your desk are jiggling in place. **Temperature** is a measure of how much the molecules are moving. The more wildly a substance's molecules are moving, the higher its temperature.

Like hip hop music at a dance party, energy causes molecules to move more. Heat is a form of energy. As heat is added to a substance, its molecules move more rapidly and spread out to occupy more space. This is why substances usually expand when heated and shrink when cooled.

But water's molecules don't want to let go of each other. The hydrogen bonds that connect one water molecule to another are strong. It takes a lot of energy to break these bonds apart so that water's molecules can start dancing. Because of these bonds, water can absorb a lot of heat before its temperature increases. In other words, water has a high **heat capacity**.

Water's high heat capacity makes it vital to living things. Many of the chemical reactions that occur inside cells happen in only a narrow range of temperatures. Water, because of its high heat capacity, moderates temperatures inside organisms so that the reactions can proceed. On a much larger scale, water in the oceans and in the atmosphere helps moderate Earth's temperatures so that life can exist.

DENSITY

Water can exist in three states: solid, liquid, and gas. In a **gas**, molecules are spread widely apart and moving wildly about. The molecules come into contact with each other only when two molecules happen to collide in their wanderings. In a **liquid**, molecules are constantly in contact with each other but still move about freely. In a **solid**, molecules are packed tightly together and, though they may jiggle in place, don't move about freely.

Density is a measurement of how much matter is packed into a specific space. To find an object's density, you divide its mass by its volume (D = M/V). It makes sense, then, that lots of molecules packed into a small space have a higher density than a few molecules packed into a large space. So in most substances, solids are more dense than liquids.

Water is weird. When water freezes, the hydrogen bonds joining the molecules lengthen. This pushes the molecules farther apart and makes solid water less dense than liquid water. This is important for aquatic organisms. When a lake freezes, the ice forms first on the surface (not from the bottom up). This creates an insulating layer over the liquid water below, which provides living space for aquatic organisms until the ice melts.

Bald eagle

KEEP Discovering

The substances that are dissolved in water influence what lives there. For an illustration of this, grab a dip net, a pair of tweezers, and an ice cube tray and head to your local stream. There, find a riffle and a pool. Riffles are shallow, fast-moving stretches where water splashes over rocks. Pools are calmer, deeper stretches.

Use the dip net to strain up aquatic invertebrates (animals without a backbone) that live in the riffle. (You may need to drag the net through the gravel at the bottom.) Use forceps to gently pluck the invertebrates out of the net and place them in one end of an ice cube tray filled with water. Fill the other end of the tray with invertebrates captured from a pool.

Now take a close look at the critters in each end of the tray. Do they look alike?

The answer has something to do with water's role as a universal solvent. Oxygen dissolves in water. When water splashes over the rocks in a riffle, water molecules grab oxygen molecules from the air and hang on to them. Because of this, water in a riffle contains more dissolved oxygen than water in a pool. And, the organisms that live in a riffle need more oxygen than those that live in a pool.

MAKE THE Connection

On Christmas Eve 1988, a 2-foot-wide steel pipeline burst near Vienna, Missouri, spewing more than 860,000 gallons of crude oil into the Gasconade River. Within 24 hours, a slick of oil 15 miles long and more than a foot thick in places had turned the Gasconade's clear green water deathly black. As crews struggled to contain the spill, the Gasconade carried the oil into the Missouri River, where traces reached St. Louis within the week. The spill became the worst inland oil disaster in U.S. history, and it cost the Shell Oil Company $22 million in fines, environmental cleanup, and court costs.

Oil, being a nonpolar substance, does not dissolve in water. Given what you know about how water's polarity makes it a good solvent, do you think it is easier to clean up polar substances or nonpolar substances? Explain your answer.

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