

# Chapter 1: Water Basics

## Key Concepts

- Water is integral to life
- Minnesota is a special place for water
- How we treat water affects how well it can meet the needs of living things (including us)
- Water has unusual characteristics
- Water is found in many places and many forms (phases)
- All water is connected through time and space as water cycles from the atmosphere to and through the ground and back to the atmosphere again

WHAT DO YOU CALL the place where two rivers join? Water was so important to some Mdewakanton (med-WAH-ku-tun) Dakota that they named the confluence of the Mississippi and Minnesota rivers *Makoce Cokaya Kin*—the center of the universe.

If you think about it, water is that important to all of us.

Water is above us, below us, around us, inside us. It keeps our bodies and those of other living things alive and functioning properly. It builds and sculpts the nonliving world: Many of the characteristics of Earth's surface—hills, valleys, canyons, mountains, plains—were formed by water. Water shapes weather and climate. It affects where we locate our homes, businesses, and cities. It influences how we work and how we play. Sometimes water moves us from one place to another. Sometimes it stirs our emotions and moves us to the depth of our being. Water itself constantly moves from sky to land to water body to living creature and back again. Figuratively and literally, it permeates our existence.

There are many speculations about how life began. What many—if not all—of them have in common is the presence of water. Water (H<sub>2</sub>O) as a chemical performs a variety of functions inside living things. Water as a component of the environment provides food, shelter, transportation, and more. Without water, life as we know it would not exist.

If water is a big part of life, then nowhere is it more so than in Minnesota. Minnesotans are literally swimming in water! Our state is bordered by the world's

Confluence of Mississippi and Minnesota rivers.



Water is above us,  
below us, around  
us, inside us.

Watercolor by Seth Eastman, Minnesota Historical Society.

largest lake (by surface area), Lake Superior, and contains the headwaters of our continent's most important river, the Mississippi. We are home to 11,842 lakes 10 acres or larger, 69,200 miles of natural streams (90,000 miles of total streams), and six groundwater provinces. Before people began draining them, Minnesota had more than 18 million acres of wetlands, including countless prairie potholes—small, soggy depressions in the landscape that provide valuable habitat for waterfowl and other water-loving animals and plants. The St. Croix was one of the first rivers in the United States to receive a National Wild and Scenic River designation from Congress. We are host to the 72-mile-long Mississippi National River and Recreation Area, the national park running through the Twin Cities metro region that represents the values of the Mississippi River. Voyageurs National Park in Northern Minnesota is the nation's only lake-based national park. Finally, the Boundary Waters Canoe Area Wilderness on the northern border of Minnesota is, perhaps the world's most famous lake-based wilderness area.

Water came from "outer space."

## Where Does Water Come From?

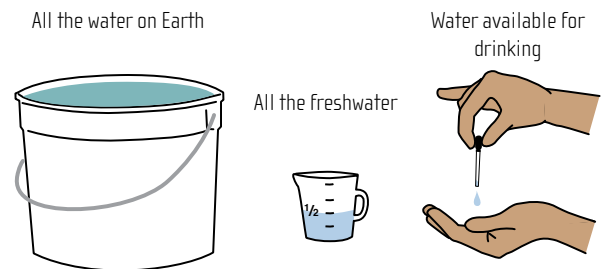
Water came from "outer space." Sound strange? Consider that water exists through much of the known universe. It is made from two of the most common atoms, oxygen and hydrogen. Scientists think it formed during the creation of stars, as heat and rapid movement of materials caused atoms to collide in ways that make them stick together to form molecules. Water is thought to have existed on Earth more than 4 billion years ago. However, scientists are still not sure how so much of it came to be here. It is also possible that water on the surface of the earth was formed by physical processes that occurred as the earth cooled, collisions with water-rich comets or other interstellar objects, and chemical reactions that make water from other molecules.

Although most of our planet is covered with water, only a small amount, 3 percent, is freshwater (water lacking the high salt content of oceans). Because so much fresh water is frozen in glaciers, less than 1 percent is available for human use.



Boundary Waters Canoe Area Wilderness

Explore Minnesota Tourism



Water continues to be formed today by living things. When we extract energy from fats, proteins, and other molecules, we break them down into smaller molecules. One of the molecules they become is water.

Living things also turn water molecules into other kinds of molecules. When plants capture energy from the sun, they store it in chemical bonds made by converting water and carbon dioxide into oxygen and carbohydrates.

Amazingly, and importantly, they are all connected. The snow that falls on a farm field eventually melts and ends up in a lake, river, or aquifer. The water you flush today, a fish may swim in tomorrow. How we treat the water we encounter influences the quality and quantity of water available in other places and for other living things.

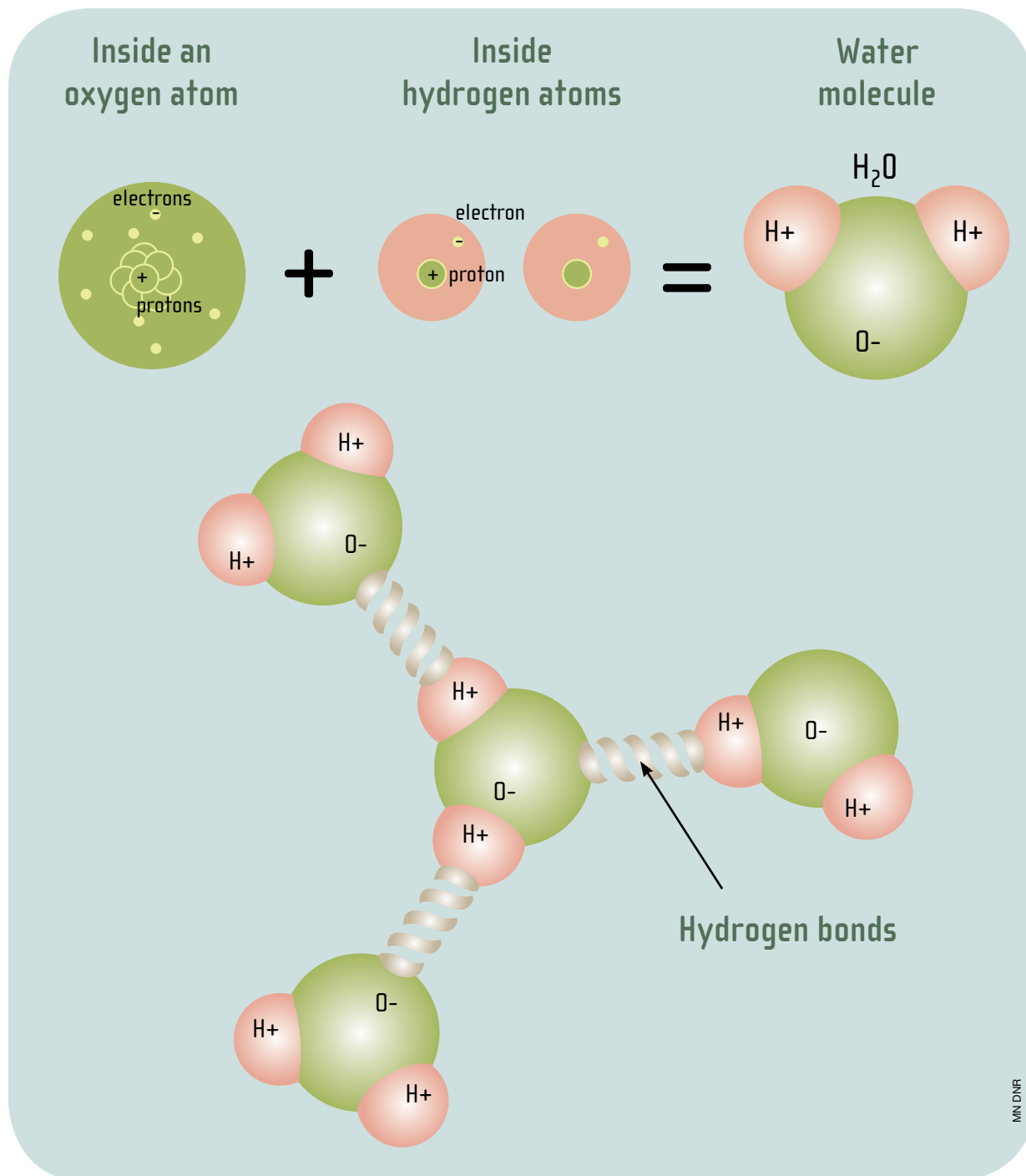
Because water affects all of us—and we all affect it—it's important that we know something about it. What is water? Why is it special? What should we, as fortunate citizens of a water-rich state, do to take care of it? That's what this book is all about.

## How Is Water Unusual?

Water is a common molecule with some very uncommon traits. Its unusual characteristics come from the chemical bond between the hydrogen and oxygen atoms that are found in the water molecule. The oxygen atom shares one of its electrons with each of the two hydrogen atoms. But the oxygen atom also has four electrons it doesn't share, causing the oxygen end of the molecule to be more negatively charged than the rest of the molecule. These unshared electrons *polarize* the

molecule, with the oxygen acting like the negative pole of a magnet and the hydrogen atoms acting like the positive pole of a magnet. The hydrogen atoms from one water molecule then attract the oxygen atoms of another. This attraction, called a **hydrogen bond**, gives water unusual properties. Without these characteristics our planet would be a far different place than it is—and life, if it existed at all, would be far different than life as we know it.

Because of the unusual way in which electrons are distributed around the water molecule, water as a substance has some unusual traits. For instance:



## Three Phases

In the world around us, water exists as a solid, a liquid, or a gas, depending on the temperature and pressure. As a **solid**, molecules are packed together in organized patterns and don't move very much relative to each other; the water is frozen. When energy is added to frozen water in the form of heat, the molecules lose their organized pattern and begin to move around more, and become

a **liquid**. In liquids, the molecules are farther apart and they slide over and around each other. Molecules are even more separated and more active as a **gas**.

Most molecules the size of a water molecule are a gas at temperatures commonly found on Earth. But because of their hydrogen bonds, water molecules have more of a tendency to stick together than do these other molecules. As a result, water exists as a liquid and a solid as well as a gas at everyday temperatures on our planet.

...water exists as a liquid and a solid as well as a gas at everyday temperatures on our planet.



MN DNR



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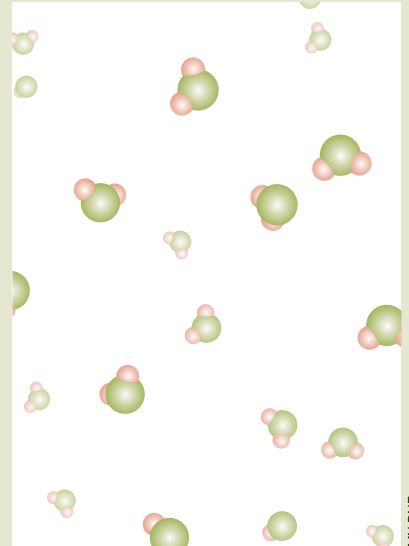
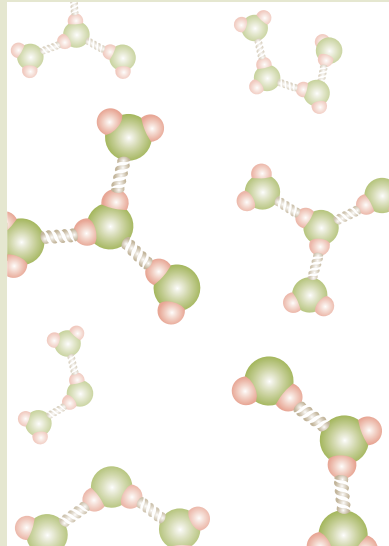
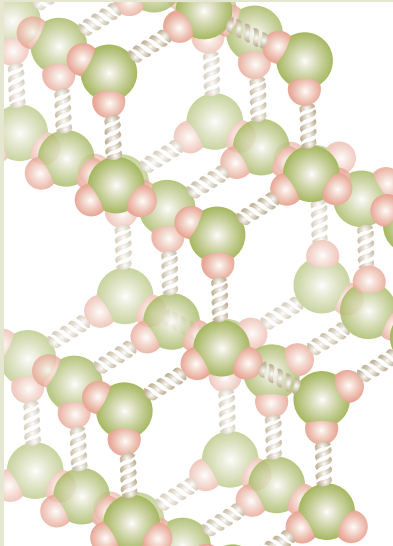


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Solid

Liquid

Gas



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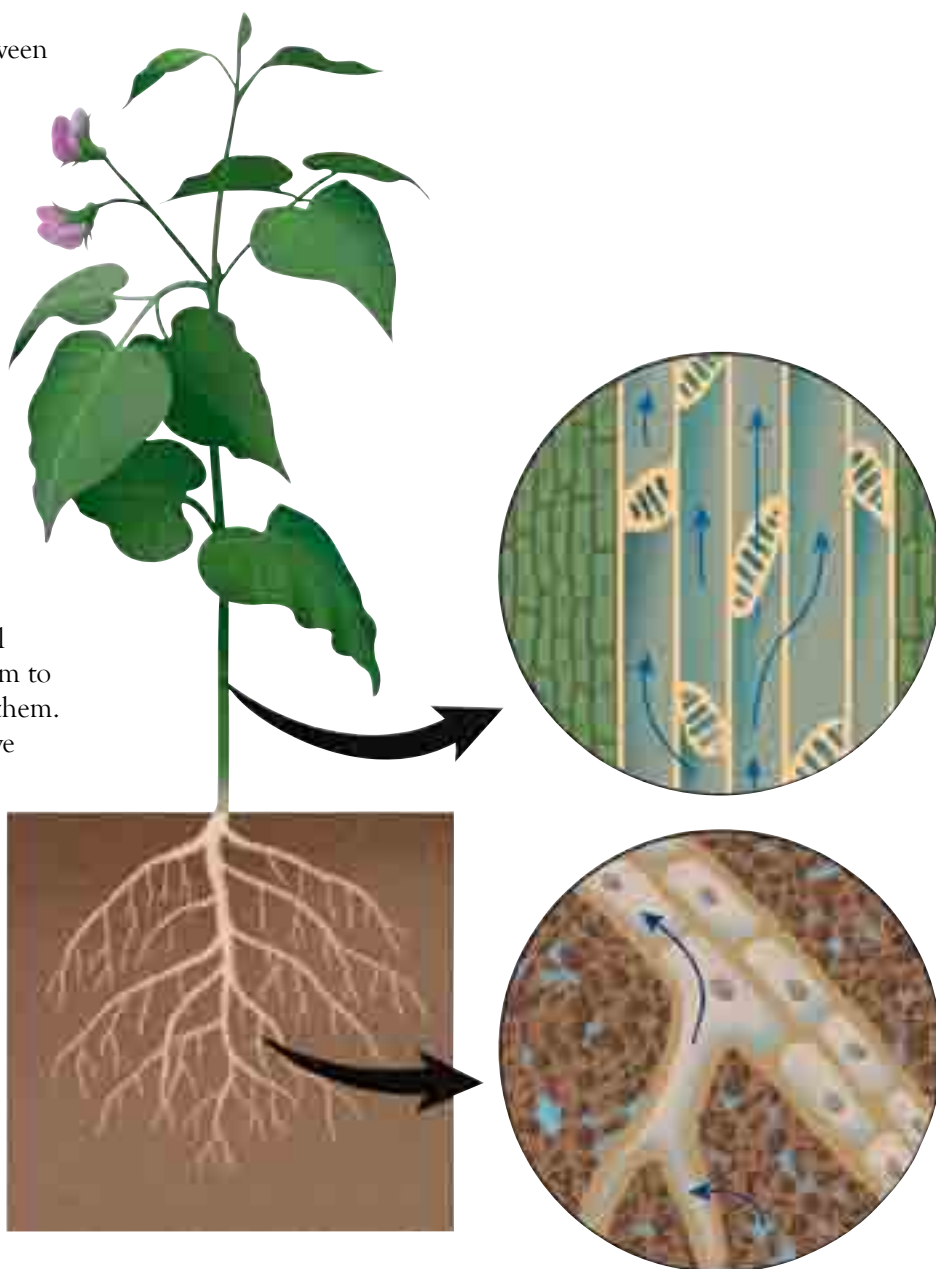
## Clingy Molecules

The hydrogen bonds that form between water molecules cause the water molecules to cling to each other (called **cohesion**) and to other things (called **adhesion**).

Cohesion and adhesion are responsible for many of the traits we observe in liquid water. They help it move through the environment. They help it carry out physiological processes inside animals, plants, and other living things. They help raindrops form and rivers flow.

When the forces of cohesion and adhesion work together in a small space, they create something called **capillary action**. As adhesion causes water molecules to cling to the material forming the space, cohesion causes them to pull other water molecules along with them. Together, the forces cause water to move into spaces that don't have water. Capillary action helps water travel up the stem of a plant. It also helps water move through soil.

The tendency of water molecules to cling to each other also creates a phenomenon known as **surface tension**. Because molecules at the surface of a body of water only have other molecules on three sides to interact with, the attraction is even stronger. As a result, water acts like it has a skin on it. Surface tension is why you can fill a glass of water past the top without having it spill over the sides.



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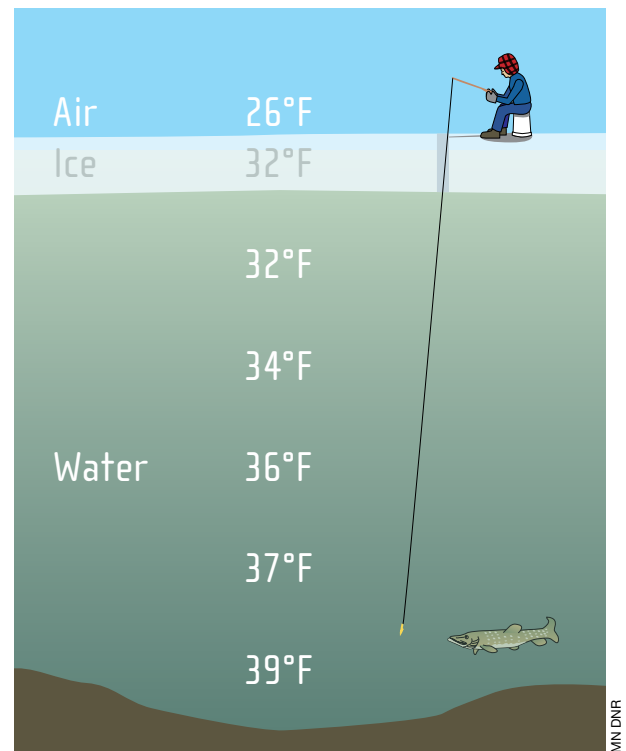
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**Walking on Water.** An insect known as a water strider takes advantage of water's unique properties to literally walk on water. Surface tension gives it a tougher-than-your-usual-water surface to walk on. Tiny air bubbles trapped in microscopic hairs on its legs repel the water and help it "float" on top rather than sink.

## Density Differences

For most substances, the solid phase is heavier than the liquid phase, because the molecules are packed together more closely. Surprisingly, this is not true for water. That's because, as liquid water molecules cool down, the pushing and pulling of their hydrogen and oxygen components cause them to line up in a lacy pattern with lots of space in between. As a result, water expands when it freezes. Instead of a tightly packed mass, water molecules forming their corresponding solid—ice—end up in a lightweight lattice pattern that is less dense than the liquid from which it formed. The molecules take up more space than they did in the liquid form, and ice is “lighter” than water, allowing it to float on water.

This property of water is very important to things that live in lakes. Water is most dense at about 39° F which means that colder, denser water sinks to the bottom of a lake. If ice didn't float and cold, dense water didn't sink, the water at the interface with cold air would freeze in winter and sink to the bottom. Eventually, the whole lake would be frozen. But because solid water is lighter than liquid water, ice stays on the top of the water. That allows fish and other water animals and plants to stay alive 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 between rocks, it helps to break them apart. This is part of the process by which soil forms.

**Snowflakes' Six Sides.** Water molecules have three atoms. Snowflakes have six points. That's no coincidence. The shape of water molecules and their unusual properties are the reason snowflakes are shaped the way they are.

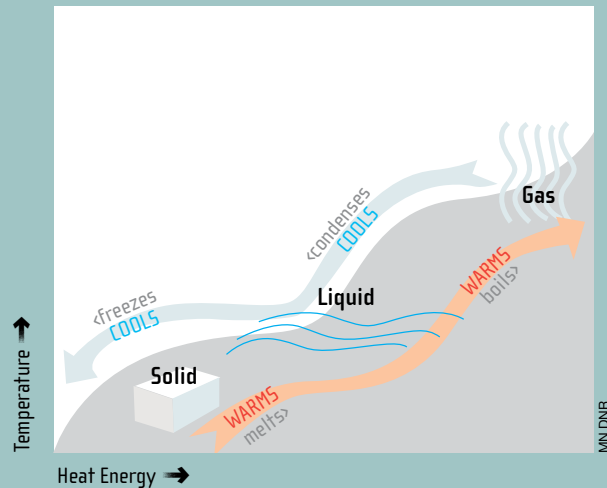
Snowflakes start when a molecule of water freezes onto a tiny bit of dust in the atmosphere. Other molecules of water eventually freeze to that molecule, with oxygen ends attracted to hydrogens and vice versa. The result of the pattern of attraction is a lattice made up of six-sided rings, the same shape as honeycomb. As more and more water molecules join the crowd, the shape becomes a hexagonal prism. At a certain size (relative to the size of the individual water molecules) the whole structure becomes so unwieldy that it starts to grow arms instead of just adding more



to the prism shape. As the arms add arms, the distinctive snowflake shape emerges.

The ultimate size and shape of each snowflake is related to the temperature and humidity of the air in which it forms. Scientists are still learning about the physics behind this relationship.

**Truly Sublime.** Water undergoes a number of familiar phase changes: melting, freezing, evaporating, condensing. Two less familiar changes are **sublimation** and **deposition**. Sublimation is the process by which water molecules move directly from the solid (ice) phase to the gaseous phase. On cold winter days when the sun shines, large amounts of snow and ice may be lost to this process. Deposition, the opposite of sublimation, occurs when gaseous water becomes a solid without going through the liquid phase. Snowflakes and frost crystals are both products of the deposition process.



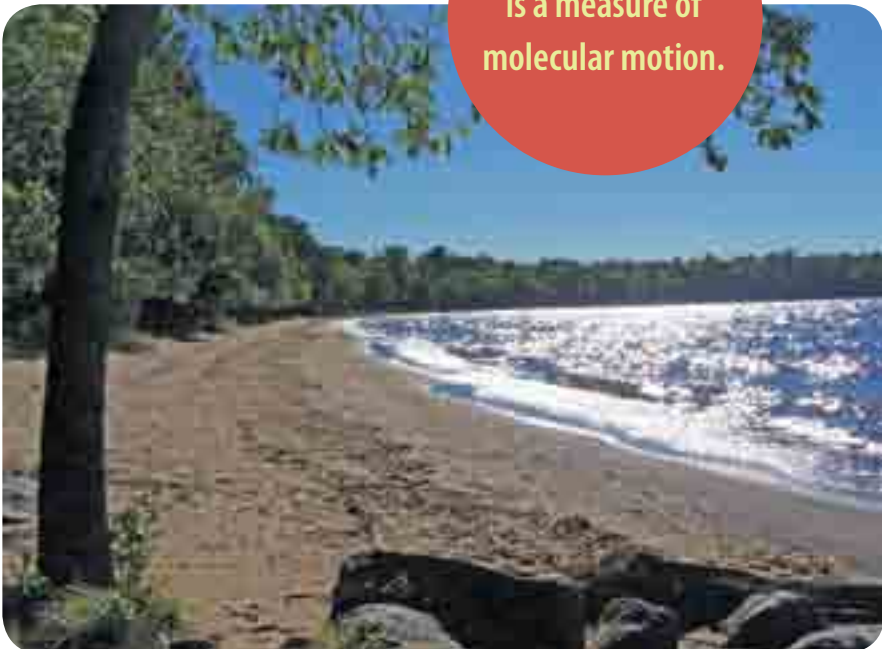
## Heat Holder

Temperature is a measure of molecular motion. When you add energy in the form of heat to a liquid, the molecules move around more and the temperature goes up. In liquid water, the hydrogen bonds keep the molecules from moving around as much as they otherwise would. As a result, water has a high **specific heat capacity**—you need to add a relatively large amount of heat energy to water in order to cause the temperature to increase. Think of the difference between the water and the sand at a beach. When the sun shines on it, sand becomes very hot. But the water stays cool.

Every kind of substance requires energy to change from a solid to a liquid and from a liquid to a gas. Because of its hydrogen bonds, water takes more energy than most substances to change from one form to another. Water takes a lot of heat energy to turn from solid to liquid (**heat of fusion**) or from liquid to gas (**heat of vaporization**).

This ability to absorb heat helps protect Earth from extreme temperature changes from night to day and summer to winter. It keeps the temperature of the oceans relatively constant and the temperature of lakes from swinging as widely as do air temperatures from season to season.

Temperature  
is a measure of  
molecular motion.



## Super Solvent

Because water molecules have partly positive and negative ends, they attract other kinds of molecules. As a result, it's easy for many other substances to dissolve in water. Water dissolves more substances than any other liquid. In fact, scientists call water the “universal **solvent**.” That's

good news when we think about water carrying needed substances through our bodies, or nutrients to plants and animals that need them. It's not so good when water dissolves polluting chemicals and spreads them from one place to another.

Water dissolves more substances than any other liquid.

## Buoyancy

Another property that affects living things' interaction with water is **buoyancy**—the upward force a liquid exerts on an object that is immersed in it, counteracting the downward force of gravity. Because of buoyancy, ducks, people, logs, fish, air-filled boats, and other objects less dense than water are able to float in it.

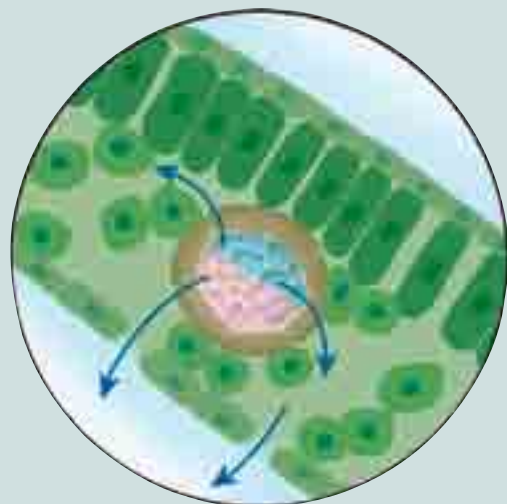


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**The Inside Story.** Water plays an important role in helping living things, including you and me, stay alive. For example:

- Adult humans are typically 50 to 60 percent water. Our blood plasma is about 90 percent water. It carries oxygen-bearing cells, immune cells, fats, and other molecules around our bodies.
- In vascular plants, water carries nutrients from the roots to the leaves and food from the leaves to the rest of the plant.
- Water in plant cells makes them rigid, allowing them to stand upright.
- Water is one of the ingredients plants use to make sugar from sunlight.
- Water in the form of urine helps transport toxins out of animals' bodies.
- Fish and other animals that live in water can extract oxygen gas dissolved in the water.

Water and sunlight enter the plant—sugar is made by the plant and oxygen is released.



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# The Water Cycle

Water's ability to exist in solid, liquid, and gas phases at temperatures we experience on Earth means it moves from place to place and phase to phase. The journey water takes as it travels from one place to another across our state and around the globe is called the **water cycle**.

Imagine yourself a water droplet, falling from the sky onto the head of a squirrel gathering nuts in a park in a small town in northern Minnesota. You trickle down its forehead, onto its nose, then drip off the tip onto the grass at its feet.

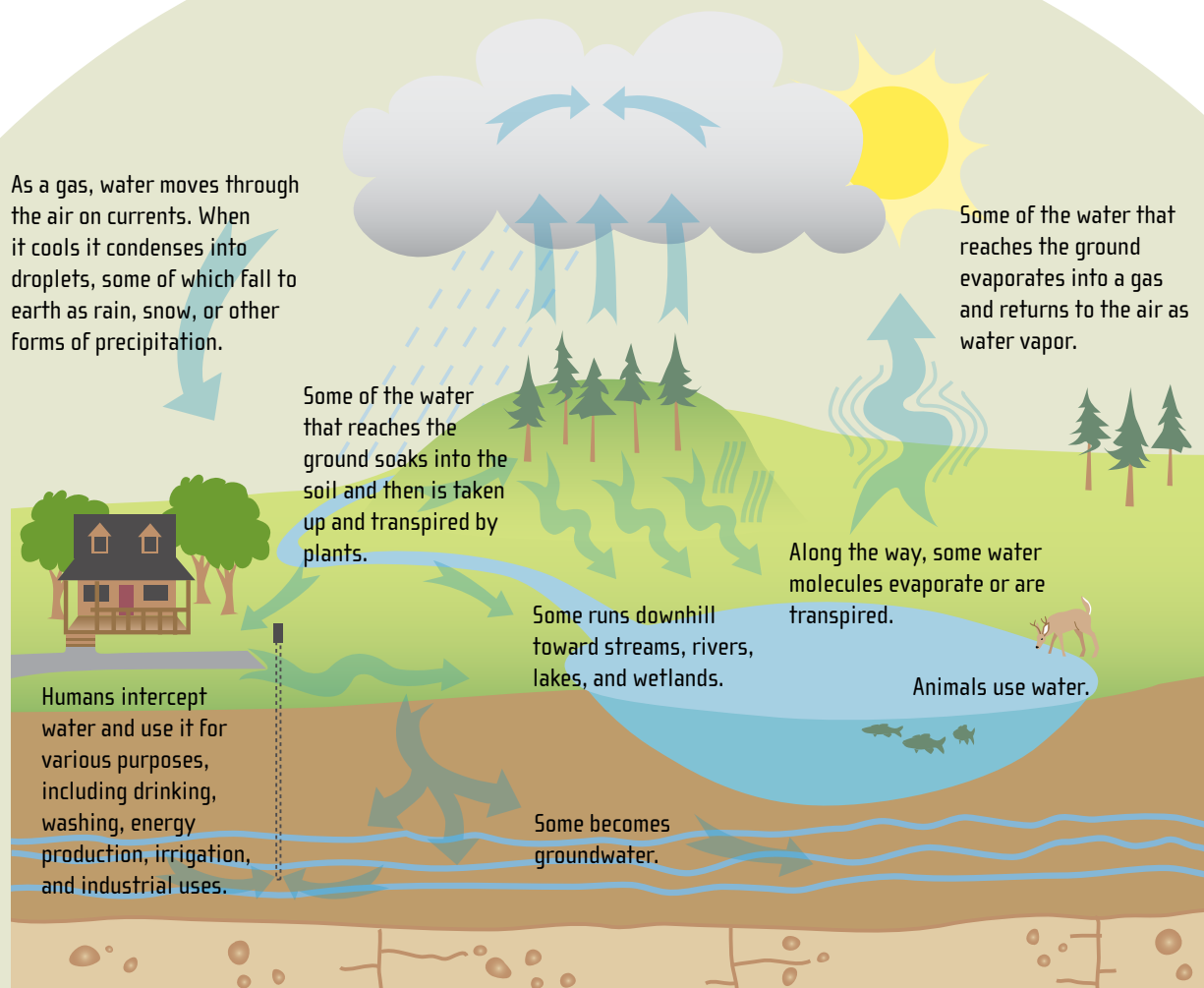
Then what? Perhaps you slip through the grass and soak into the soil, traveling downward until you meet the body of water that permeates soil and rock below. Perhaps you are sucked up by a plant root, travel up the stem and are transpired back into the air as vapor. Perhaps you run off the grass into the street, into the storm sewer, into a nearby creek that empties into a larger creek that empties into the Mississippi River, which empties into the Gulf of Mexico—if you don't first get evaporated by the heat of the beating sun, or removed by a water

intake for a power plant or city water system, or sucked in by a fish or frog, or splashed onto shore. In Minnesota, the amount of precipitation that becomes **runoff** ranges from about 20 inches per year along the steep slopes of the North Shore of Lake Superior to only 2 inches in the flat, absorbent western part of the state.

In the water cycle, the possibilities truly are endless. Unless the water molecule itself is broken and rebuilt into something else along the way, it eventually, invariably, ends up back in the sky—and then back on land, and, back in the water, and back in the sky again. This process could take a matter of hours, or thousands of years.

When it rains or snows, water soaks into the ground and fills up lakes, rivers, and oceans. Plants continually absorb water. Eventually the same water will evaporate back into the sky, becoming clouds. As the clouds grow thicker, they will again release water as rain or snow back down to the ground.

In the next chapter, we'll look at the various components of the water cycle in Minnesota and how water moves among them.



C A R E E R P R O F I L E

**Kristine VanWilgen-Hammitt**  
**Science Teacher,**  
**Bemidji High School**  
**Bemidji**



Lakes, snow, and students are a big part of Kristine VanWilgen-Hammitt’s work day. She teaches environmental science, biology, and exercise science at Bemidji High School.

VanWilgen-Hammitt’s environmental science class includes units on water quality and bioindicators. She and her students study principles of fisheries management and lake management in spring. In winter, they learn about snow and water purification, and study the effect of road salt on water quality. Along with teaching, VanWilgen-Hammitt also adapts curriculum for special education and gifted students to ensure each student is challenged and learning.

To VanWilgen-Hammitt, being a teacher is much more than knowing and passing along information. Every day she thinks about what each student needs to learn most. “The thing I love about teaching is that every day is different,” she says.

VanWilgen-Hammitt encourages young people who are interested in teaching as a career to volunteer at a variety of places—science centers, youth organizations, community education classes, on the field or track. That will help them learn what it’s like to work with students and decide whether it’s right for them.

**Related careers:**  
**college professor,**  
**environmental educator,**  
**naturalist**



## Suggested Project WET Activities & Minnesota Connections

EL = elementary

MS= middle school

HS=high school

### Water is essential for all life to exist

Let's Even Things Out (solutions, osmosis) EL, MS, HS

Thirsty Plants (transpiration, water cycle) MS

### Water connects all Earth systems

Imagine!\* (water cycle) EL, MS - Water cycle script modified for Minnesota geography.

The Incredible Journey\* (water cycle) EL, MS - Water cycle dice are available for the three major Minnesota watersheds with local place names.

Old Water\* (Age of water, geology) EL, MS – Timeline of history of Minnesota's water.

Poetic Precipitation (condensation, precipitation) EL, MS

The Thunderstorm (weather, precipitation) EL, MS, HS

Water Models (water cycle) EL, MS

Wet Vacation (climate, tourism) MS

### Water has unique physical and chemical characteristics

Adventures in Density (density) EL, MS, HS

H<sub>2</sub>Olympics (cohesion, adhesion) EL, MS

Hangin' Together (polarity) EL, MS, HS

Is There Water on Zork? EL, MS, HS (water properties, inquiry, experimental design)

Molecules in Motion (states of water) EL, MS

Water Match\* (states of water) EL - game cards have pictures of Minnesota water in different states.

What's the Solution? (solutions, solvents) EL, MS

\* Some Project WET Activities have Minnesota adaptations posted online for Minnesota Project WET Educators in the trained teacher page at <http://www.mndnr.gov/projectwet>. Additional adaptations will be added when possible.

## Classroom Connections

**Water Connections:** Have students each think of a Minnesota-related object—any object—and write it down or draw a picture of it. After they have made their choices, have them brainstorm (and research, as appropriate for your circumstances) how water has affected that object, and how that object might affect water.

**Water Stories:** Water is a common theme in literature. Has your class read a book or short story set in Minnesota? How was water part of the story—in concrete or metaphorical terms? See some examples at [www.mndnr.gov/projectwet/waterways](http://www.mndnr.gov/projectwet/waterways).

**Map Scavenger Hunt:** Minnesota is all about water! Our state’s name comes from a Dakota term meaning “sky-tinted water.” Hand out state highway maps, and challenge students to find as many communities as they can with water-related names.

**Water Poetry:** Invite students to imagine where the water inside them has been. Have them draw pictures or write a story or poem that illustrates their imaginings.

**Where is Water Droplet?** Invite younger students to build a story together of the adventures of a water droplet. Hold a cutout of a water droplet in your hand, and start the story by describing the fall of a water droplet named Drip from the sky during a rainstorm. Pass the cutout to a student, and invite him or her to describe what happened next. Keep passing the cutout until everyone has had a chance to add to the story. Does Drip go into animals or plants and out again? Does Drip end up back in the air? At the bottom of a lake? There is no end to the places a drop called Drip can go!

**Frozen Cars:** Explore with very young students how water behaves differently under different circumstances by freezing small toy cars into a few of inches of water in two identical containers. Remove the car-ice blocks from the containers and put them side by side in a larger container. Add salt to one of the blocks. Talk about what might happen. Give students the opportunity to return to the display over the course of the day so they can observe melting in action.

## Out and About

**Scavenger Hunt:** Take students on a water scavenger hunt or a winter water scavenger hunt. Go on a 30-minute hike outside your school. Have each record any water they see. When you get back, list all of your “finds” on the board. How many were solid? Liquid? Gas? Don’t forget to include clouds, squirrels, frosty breath, blades of grass, and other less visible sources of water as well as puddles, holding ponds, and streams.

**Water Properties:** Use the book, *A Drop of Water: A Book of Science and Wonder* by Walter Wick to have students see pictures of different states and properties of water in action. Challenge students to re-create demonstrations of the same properties. If you have access to cameras, have your students take pictures of water properties or different states of water outside and create a presentation to share with their classmates.



## A few excellent resources:

1. *A Drop of Water: A Book of Science and Wonder* by Walter Wick (1997). This book pairs amazing photos and descriptions of water properties like evaporation, condensation, surface tension.
2. *Water Dance* by Thomas Locker (2002). Beautifully illustrated picture book describing the water cycle with more in-depth information on the last two pages.
3. *The Snowflake: A Water Cycle Story* by Neil Waldman (2003). Another great water cycle picture book, focused on winter and snow.
4. SnowCrystals.com website. <http://www.its.caltech.edu/~atomic/snowcrystals/> An excellent website with photos, activities and snowflake physics descriptions.
5. *Snowflake Bentley* by Jacqueline Briggs Martin (1998). A Caldecott Award Winning picture book that shares the story of the first person to photograph a single snow crystal in 1885, Wilson A. Bentley.
6. Minnesota State Climatology Office website. <http://climate.umn.edu/> offers current climate conditions, historical data (like monthly precipitation totals), “create your own” climate calendars, and many more facts about climate throughout the state.
7. *The Urban Water Cycle*, MN Department of Health and Hamline University’s Center for Global Environmental Education. <http://www.health.state.mn.us/divs/eh/water/urbancycle/index.html> An online student program with videos, diagrams, maps and games for students to investigate how our drinking water, wastewater and stormwater systems work. Also includes supporting classroom curriculum for teachers.
8. *The Story of Snow* by Mark Cassino and Jon Nelson (2009). This book investigates how snow crystals form, what shapes they can take and other exploration of the science of snow.

## Want More? See [www.mndnr.gov/projectwet](http://www.mndnr.gov/projectwet) for resources and information:

Academic standards correlations to Project WET Activities  
 Educational materials/classroom resources for Project WET teachers  
 Out and About—field trip ideas  
 Citizen science/service learning opportunities  
 Useful websites  
 Suggested books