FOLLOW THE WATER

Exploration: Then and Now

Grade Level: 6–8

Connections to Curriculum:

Science and Mathematics

Teacher Preparation Time:

60 Minutes

Lesson Duration:

Five 50-Minute Class Periods

(See Pacing Chart for Options)

National Science Education Standards

Science as Inquiry

Physical Science

Life Science

Earth and Space Science

National Council of Teachers of Mathematics Standards

Measurement

Essential Questions

Where is water found?
Why is liquid water important for life?

Lesson Overview

This lesson investigates some of the physical properties of water and the importance of those properties for life on Earth. Students conduct experiments on osmosis, observing the effects that various amounts of salinity have on the transport of water into and out of cells. Students also explore water's movement through different soils, learning about porosity and permeability. Students make observations about the availability and location of water on Earth, the Moon, and Mars.

Background Information

From ancient times, explorers have searched for, found, and then followed water. Early settlements, like Jamestown, were established near water because water is essential for survival. Nearby oceans, bays, and large rivers provided a "highway" for trade and travel. Ports were key points of entry for ships bringing people, goods, and news from home. Most importantly, however, early settlements needed a local source of freshwater.

Water creates an environment that sustains and nurtures plants, animals, and humans. Earth is unique in its abundance of liquid water. About 70 percent of its surface is covered in water. Water is the most fundamental component of Earth's environment and can be found in all three phases: solid, liquid, and gas. The water cycle describes the repetitive pathway of water molecules from Earth's surface to the atmosphere and back again. This system, powered by energy from the Sun, is a continuous exchange of moisture between the oceans, the atmosphere, and the land.

The search for water continues to drive exploration today, even in space exploration beyond Earth. Water ice has been observed in the polar regions of Mars and makes up a large percentage of some of the moons of Jupiter and Saturn. Some scientists believe that water ice may also exist at the poles of Mercury in permanently shadowed areas. According to initial scientific data returned by NASA's Lunar Prospector, water ice may also exist at both the north and south poles of the Moon, again, in permanently shadowed areas. This ice may hold clues to the early history of the Moon and the impacting bodies that bombarded the Earth-Moon system billions of years ago. NASA is planning new missions that may help unlock these clues.

On Earth, liquid water interacts with soil in predictable ways. Scientists think the same may be true elsewhere in the solar system. Tests that determine the soil's acidity on a planet like Mars could indicate what gases formed and later modified the Martian atmosphere. Examination of lunar soil in the Moon's polar regions during future missions could reveal much about the nature and extent of frozen water there.

Besides being a passageway for transportation and helping to shape a planet's environment, water is essential for transporting materials within the human body. The properties of liquid water allow the transport of gasses, nutrients, and hormones that support life as we know it. In many ways, liquid water is vital to life

Instructional Objectives

Students will:

- observe and describe osmosis;
- compare the porosity and permeability of several soil samples;
- observe a soil's water-holding capacity;
- model water dissolving materials as it travels through soil samples;
- make observations about the availability and location of water on Earth, the Moon, and Mars;
- design an investigation to determine how varying amounts of salt in water affects seed germination;
- identify the salinity of unknown solutions based upon observation; and
- compare the differences in challenges faced by 17th-century and 21st-century explorers.

Materials

Students will need journals and class charts in order to organize information throughout this lesson.

Engage

Per class:

- Potato peeler

Per group:

- One potato
- Paper plate
- Freshwater
- Saltwater (dissolve 3–4 tablespoons of salt in 100 milliliters tap water)
- Eyedropper for each liquid

Explore
Per class:

- About 1 liter of sand
- About 1 liter of gravel, any size that is available
- About 1 liter of topsoil
- About 10 tablespoons of rock salt
- Three 2-quart packages of red, purple, or green powdered drink crystals

Per group:

- Two 500-milliliter plastic bottles (recycled soda or water bottles)
- One 5-by-5-centimeter square piece of gauze or cheesecloth
- Rubber band, any size
- 250-milliliter graduated cylinder
- Permanent marker
- Stopwatch or watch with a second hand
- Two water-collecting containers or beakers

Per student:

- "Water Race Data Chart"

Explain
Per student:

- "NASA and Jamestown Follow the Water Chart"

Extend
Per group:

- Presoaked seeds (lima beans or corn)
- Plastic, sealable sandwich bags
- Paper towels
- Transparent tape
- 100-milliliter graduated cylinders
- Metric rulers
- Other materials as requested by students based upon students designing the experiment
- "Experimental Design Chart"

Evaluate
Per group:

- Three samples of *Elodea* (common name, anacharis), freshwater plant found at pet stores in the aquarium section; lettuce may be used as a substitute if *Elodea* is unavailable
- Three solutions marked "A," "B," "C" (freshwater, brackish water, saltwater)
- Three eyedroppers
- Compound microscope (at least 100x magnification)
- Microscope slides
- Cover slips

Vocabulary:

adhesion: molecular attraction that holds the surfaces of two substances in contact (e.g., when water molecules are attracted to molecules of other substances)

aquifer: rock or soil through which groundwater moves easily

brackish water: water that is a mixture of freshwater and saltwater; contains less salt than seawater but more salt than freshwater

capillary action: the ability of a substance to draw liquids upwards against the force of gravity

cohesion: the property of a material to stick together (e.g., an attraction of one water molecule to another water molecule)

electrolyte: any of the solutes (i.e., sodium, chloride, potassium) that help maintain hydration of the body as well as muscle and nerve function

estuary: a coastal area or place where freshwater and saltwater mix, such as a bay, salt marsh, or where rivers enter an ocean

groundwater: water that flows or seeps downward and saturates soil or rock, feeding springs and wells; water stored underground in rock crevices and in the pores of geologic materials that make up Earth's crust

isthmus: a narrow strip of land separating two bodies of water and connecting two larger land masses

osmosis: the movement or transport of water molecules across cell membranes due to differences in solute concentration between the inside and outside of the cells

peninsula: a narrow neck of land projecting into a body of water, surrounded by water on three sides

permeability: a material's ability to allow liquid (e.g., water) or gas to flow or pass through it

porosity: percent of a material's total volume that is not occupied by solid particles (e.g., pore space)

semipermeable: partially but not wholly permeable (e.g., allows passage of some but not all materials)

solute: a material that dissolves in another substance, usually a liquid, forming a solution

solvent: a substance that dissolves other substances, forming a solution; water dissolves more substances than any solvent and is known as the "universal solvent"

universal solvent: water dissolves more substances than any solvent and, as such, has been called the "universal solvent"

Suggested Pacing

	Engage	Explore	Explain	Extend	Evaluate	Total
50-minute class periods	**½ class period**	**1 class period**	**½ class period**	**2 class periods (optional)**	**1 class period**	**5 class periods**

Instructional Procedure

Teaching Suggestion: *Prior to beginning this lesson, create a chart that will be displayed throughout the lesson to help organize student learning. Ask the students to create similar charts in their journals. The charts may be formatted as follows, but must be large enough to organize information.*

	EARTH	MOON	MARS
Where is water found?			
Why is liquid water important for life?			

Engage

Finding freshwater is essential for choosing a location for settlement. In 1607, the Jamestown settlers focused on finding a suitable site, complete with freshwater, for their new home. The spot they chose was a peninsula, connected to the mainland by a narrow isthmus and protected on three sides by the James River, the Back River, and Sandy Bay. The river water appeared to be fresh when the settlers first arrived in the spring. However, the settlers did not realize that the lower part of the James River is actually an estuary, a place where saltwater transitions into freshwater thereby creating brackish water.

During the dry summer months, the Jamestown settlers experienced drastic changes in the salinity of the surrounding water. The brackish water became saltier due to warmer temperatures and less rainfall. These seasonal changes, compounded by a serious drought, resulted in little freshwater for the early Jamestown settlers. At times, the water contained 5 times more salt than is safe to drink.

What happens when people drink saltwater or put too much salt into their body?

Taking in a certain amount of salt (sodium chloride) is essential for maintaining good health. One reason for this is that salt helps to maintain the electrolyte balance inside and outside of cells. Cells are surrounded and protected by a structure called a cell membrane that helps regulate materials traveling into and out of the cell. This membrane is semipermeable, meaning that some but not all materials may move through it. Water easily travels through this membrane, but not all solutes dissolved in the water can pass through the membrane. Salt, for example, cannot travel through the cell membrane.

If the environment surrounding the cell becomes too salty or not salty enough, the amount of water stored in the cell may change. If cells are in very salty water, water molecules leave the cell through the membrane. If cells are in water without salt, water molecules move into the cells, increasing the volume of the cells. In either case, the health of the cells may be in jeopardy.

Drinking saltwater would result in water leaving, or dehydrating, the cells. This would drastically shift the location of water in the body, resulting in an imbalance of electrolytes within the body. This could result in a heart attack, increased fluid in the respiratory tract, changes in blood pressure, and seizures.

The movement or transport of water molecules across membranes is called osmosis. Molecules of water tend to move toward the environment that has the most dissolved material or the least amount of water.

The result of osmosis can be seen in the following activity. Students are asked to be careful observers and to make inferences about what they observe. ***PLEASE DO NOT*** **give students any background information about osmosis before doing this activity.**

1. For each group of students, you need to cut a potato in half. To make a flat, stable base for each half, cut the rounded ends (bottom) off each potato. Put the potato halves on a paper plate. Use a potato peeler to bore out a hole 2–3 centimeters across and 3–4 centimeters deep on the flat, cut surface of each half. Be careful ***NOT*** to bore completely through the potato. See Diagram 1.

Diagram 1

2. Ask each group to use an eyedropper to carefully fill the hole in one potato with freshwater. Demonstrate how to fill the hole to make the water level with the top of the potato. Label this potato "A." See Diagram 2.

Diagram 2

3. Ask each group to fill the hole in the other potato with saltwater. Label this potato "B."
4. Ask students to make drawings of each set-up in their journals and to predict what they expect to see in 10 minutes.
5. After 10 minutes, ask students to record their observations.
6. Discuss the following questions as a class.
   - Describe the differences that you see between the two potatoes. Don't limit your descriptions to just the hole filled with water. *(The hole with the freshwater seems to lose water as water is carried into the potato's cells. The hole with the saltwater fills and overflows. Water from the potato cells is transported out of the potato.)*
   - What do you think caused the movement of the water? *(Water moving across the cell membrane due to differences in solute concentration between the inside and outside of the cell is called osmosis. The cell membrane is a semipermeable membrane that allows water to move through it. Salts and some other dissolved substances cannot travel through the membrane.)*
   - For the potato with the freshwater, where do you think the water has traveled? *(The water has moved from the hole into the potato's cells.)*
   - For the potato with the saltwater, what is the source of the extra water? *(The water is moving out of the potato's cells.)*
   - Compare your cells with the potato cells. How are they alike and different? *(Both the plant cells and human cells [animal cells] have semipermeable cell membranes. Plant cells also have a cell wall that makes the cells more rigid.)*
   - How does this experiment model what happened to the Jamestown settlers when they drank brackish water with high levels of salt? *(In a*

simple way, the potato and the saltwater demonstrate what happened to the Jamestown settlers when they drank salty water. Just as water travels from the potato cells into the salty water, water in the cells of the Jamestown settlers traveled out of the cells, dehydrating the cells. For the Jamestown settlers, this shifted the location of water in their bodies, resulting in an imbalance of electrolytes within the body. Many settlers died as a direct result of drinking the saltwater.)

7. Ask students to add any information to the class/student charts created at the beginning of this study to help answer the question, “Why is liquid water important for life?”

Explore

From space, Earth has been described as a “blue marble.” It looks like the watery planet that it is. Liquid water is a vital substance that sets Earth apart from the rest of the planets. Without water, plants, animals, and people would die. Although water covers approximately 70 percent of Earth’s surface, usable water is not as abundant as one might think.

Based upon statistics from the U.S. Geological Survey, about 97 percent of Earth’s water is saltwater, resulting in only about 3 percent freshwater on Earth. When you take a close look at Earth’s freshwater, about 69 percent of the freshwater is locked up in glaciers and icecaps and about 30 percent of Earth’s freshwater is stored in groundwater, which leaves less than 1 percent found as easily accessible surface water.

Groundwater is the largest single source of freshwater available for human use. It fills pores or open spaces in soils and rocks, creating aquifers. An aquifer may be a layer of gravel or sand, a layer of sandstone or other rock, or some other material with holes or pores that can store water underground.

A soil’s texture helps determine how much water the soil can hold, or the soil’s water-holding capacity. Based upon the relative proportions of different-sized particles, soil texture can be classified as sand, silt, and clay, with sand being the largest particles and clay the smallest. When soil is a combination of all three textures, it is referred to as a loam, a more complicated soil textural class. The soil at Jamestown is sandy loam, a mixture of more than 50 percent sand with varying amounts of clay and silt.

Sandy soil has larger pores and a low water-holding capacity, allowing water to drain more quickly than clay and silt soils. The sandy loam proved to be a problem for the Jamestown settlers, since a soil’s water-holding capacity is a measure of how much water might be stored for plants or human use.

A soil’s porosity describes the amount of open space, or pores, in the soil. A soil’s permeability measures how water flows through the soil. The porosity and permeability of the soil, coupled with gravity, affects how much water is stored as groundwater.

Water is the only chemical compound naturally found on Earth's surface in all three physical states—as a solid, liquid, and gas. Liquid water is called the "universal solvent," as it can dissolve more materials than any other liquid.

Liquid water, like rain, dissolves some carbon dioxide and other gases as it falls through the atmosphere. Although people may think rainwater is freshwater, carbon dioxide mixed with water sometimes creates a mild carbonic acid. Rainwater may weather and erode rock, dissolving some materials such as salts and other minerals.

When water travels through sand, soil, and gravel, it dissolves some of the substances in those materials. Salt is one material easily dissolved as water travels through soil and earth materials. This is one reason that the majority of water on Earth is salty.

When ocean water evaporates or sea ice is formed, the salinity of the ocean increases. Water vapor and ice are basically salt-free. An increase in salinity is counterbalanced by the addition of freshwater from rivers, rain and snow, and melting ice.

This activity challenges students to observe the movement of water as it "races" through different soil samples. They will look for evidence that water has dissolved materials and will gain a better understanding of how water is stored as groundwater.

1. Before beginning this experiment:
   - Gather two 500-milliliter (16.9-fluid-ounce) plastic bottles for each group. For consistency, use the same style of bottle for all groups. Cut off the base of one bottle to make the container for the soil column. Cut the top off of the spout of the other bottle to make the water collector. See Diagram 1.

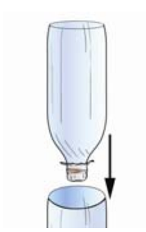


Diagram 1

   - Gather three different soil samples: sand, gravel, and topsoil. You will need enough of each soil sample to make two soil-test columns. See Diagram 2.

Sand Gravel Topsoil

Diagram 2

2. Show the students how to place a piece of gauze or cheesecloth over the spout of the bottle, securing the cloth with a rubber band.
3. Ask students to use a graduated cylinder to measure 50 milliliters of water and how to pour the water into the collecting bottle. Demonstrate how to mark the water level of the 50 milliliters of water on the outside of the bottle.
4. Once the water level is marked, ask students to empty the water out of the bottle. Students will use this line for the finish line of the water race.

Water Race Data Chart **Student Handout**

Predictions:
Water will flow slowest through: ____________
Water will flow fastest through: ____________
The material that will hold the most water is ____________
Materials in the soil that will dissolve might be ____________

Provide an explanation or rationale for your predictions:

Water Race Data

Material	Trial 1	Trial 2	Trial 3
Sand			
Gravel			
Topsoil			

Water Race Data Chart

5. Give each group a small sample of each soil. Ask students to create their own chart to make and record observations about the sand, gravel, and topsoil. Explain that the sand sample is most like the soil found at Jamestown.
6. Ask students to make the following predictions:
   - Which material do you think will allow water to pass through the quickest and which will be the slowest?
   - Which material will "hold" the most water?
   - Which materials might dissolve in the water?
7. Each group will "race" water through one soil sample. Arrange for each sample to be tested by two different groups. For example, if you are working with six groups, two groups will test sand, two groups will test gravel, and two groups will test topsoil.
8. Demonstrate how to fill the soil column with about 16 centimeters of the soil sample. Measure from the mouth of the bottle. Discuss the importance of accurately measuring the soil column and the need for each group to be consistent with this measurement.
9. Help students fill their group's soil column and support the soil column in the water-collecting bottle.
10. Ask students to measure 250 milliliters of water using a graduated cylinder.
11. Once all groups are ready for the race, ask students to record their predictions for how long they think it will take 50 milliliters of the 250 milliliters of water to travel through the soil column.
12. Each group should have a student timer to start the "race" and should stop timing when 50 milliliters of water has been collected in the water-collecting bottle.

13. Have students continue to collect water until no more water passes through the column.

14. Ask students to make the following observations about the water:

- How much water traveled through the soil sample? *(Answers will vary, but more water will travel through the material that has the greater permeability. Permeability is a measure of how water flows through the pores in a material.)*
- What happened to the water that was not collected in the water-collecting bottle? *(Water is stored in pores within the soil. This is how groundwater is stored. About 30 percent of Earth's freshwater is stored as groundwater.)*
- Describe the water that has been collected. What materials did the water pick up as it traveled through the sample? *(Depending on the soil sample, the collected water may be muddy or cloudy. Materials in the soil may have been dissolved by the water. The water may also have picked up and carried small soil particles as it traveled through the sample.)*
- How could you test to find out if the water picked up materials that you cannot see? *(Water is the universal solvent, which means that it dissolves many materials. Materials from the soil that cannot be seen have probably dissolved in the water. It may be possible to recover these materials by evaporating the water. Dissolved materials are left behind when water evaporates.)*
- Which soil sample "won the race?" What comparisons can you make about the texture of the soil sample that allowed water to pass through the quickest? *(Water will travel more quickly through the sample with the largest and greatest number of pores. In most instances, the gravel allows the water to pass through the quickest. The gravel usually has the greatest porosity and most permeability because it has the most pores. The pores are connected to allow water to flow through them.)*

15. As a class, make comparisons between the three soil samples by comparing the data.

16. Ask students to collect and label the water from the water-collecting bottle. They will compare this first sample to the sample collected in the next trial.

17. Ask students to measure another 250 milliliters of water to run this race again and repeat the experiment.

18. The soil column now contains some stored water. Use these questions to help guide the discussion of how this might affect the second race.

- Do you expect the same material to allow water to pass through the quickest and the slowest? How do you think stored groundwater will affect the speed that the water travels through the soil?
- Will the same material "hold" the most water if it already contains some stored groundwater?

19. Run the race again. Compare the results of the second trial to the first trial.

20. Ask students what they think might happen if water was poured into soil that was already saturated with groundwater. Ask students how they might test their predictions.

21. Ask students to compare the second sample of collected water to the first sample. Is there any difference in the clarity of the two samples? *(In some instances, the second sample will look cleaner than the first sample. Materials that easily dissolve or are carried by the water may have been carried by the first sample of water.)*
22. Cover the top of half of the soil columns with 2–3 tablespoons of rock salt.
23. Cover the top of the other half of the soil columns with one package of purple, green, or red powdered drink crystals. Choose a color that will be the most obvious once it dissolves and travels through the column of soil.
24. Ask students to predict what will happen when another 250 milliliters of water is poured through the soil column. Discuss the reasons for their predictions and what evidence they expect to see to support their predictions. *(The water will dissolve the salt and powdered drink crystals. As the dissolved material travels through the soil, some of the water carrying the dissolved material will be stored as groundwater. Some of the water carrying the dissolved material will travel through the soil. Dissolved salt in water will not be visible. Dissolved drink crystals will color the water.)*
25. Compare what the students observe to their predictions. Ask students what they might do to "prove" that salt was dissolved in the water and carried through the soil sample? *(Students may suggest evaporating the collected water to retrieve the salt.)*
26. Discuss these questions with the students:

- How does this last trial compare to what happens in the "real world"? *(When water travels through sand, soil, and gravel, it dissolves some of the substances in those materials. Salt is one material easily dissolved as water travels through soil and earth materials. This is one reason that the majority of water on Earth is salty.)*
- What impact might salting icy roads have on the surrounding environment? *(As observed in this lesson, salt is easily dissolved in water. Dissolved salt in water may be stored as groundwater and mix with freshwater supplies.)*
- Why is it important to follow directions regarding quantity when applying fertilizers to plants? *(Many fertilizers are easily dissolved in water. Fertilizers dissolved in water may be stored as groundwater or travel through groundwater to sources of fresh surface water.)*

27. Ask students to add any information to the class/student charts created at the beginning of this study to help answer the question, "Where is water found?"

Teaching Suggestion: *Connect this lesson to NASA's hunt for water beyond Earth. Water ice has been observed in the polar regions of Mars and makes up a large percentage of some of the moons of Jupiter and Saturn. Some scientists believe that water ice may also exist at the poles of Mercury and the Moon in permanently shadowed areas.*

In 2002, the Mars Odyssey spacecraft found evidence of large amounts of water ice buried in a thin layer of soil around the Martian poles. Scientists estimate that high concentrations of ice, perhaps as much as 80 percent by volume, may be within half a meter of the surface. Permafrost on Mars is another place that may contain large amounts of frozen water. The Martian permafrost may be several kilometers thick and as much as half of this layer could be water ice.

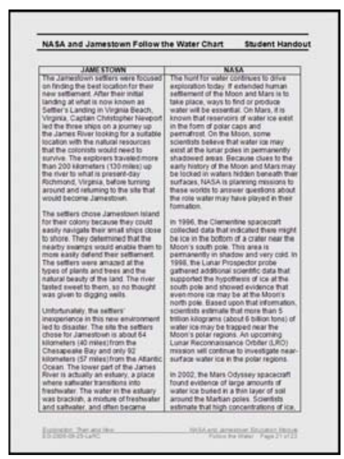
Freeze some of the soil samples to create dirt/water icicles. Ask students to investigate the water content of frozen soil samples by examining the frozen samples. Based upon their observations, ask students to identify which sample may be most like the frozen ice scientists expect to find near the north pole of Mars.

You may want to show the 60-second NASA KSNN™ (Kids Science News Network) video, "Where can NASA find water on Mars?" found at http://ksnn.larc.nasa.gov/webtext.cfm?unit=phoenix. You will also find an expanded version of this activity and more explanations about water on Mars on this site.

Explain

Exploration is often guided by searching for and following water. Early settlements, like Jamestown, were established near water because water is essential for survival.

The search for water continues to drive exploration today, even in space exploration beyond Earth. Water ice has been observed in the polar regions of Mars and makes up a large percentage of some of the moons of Jupiter and Saturn. Some scientists believe that water ice may also exist at the poles of Mercury and the Moon in permanently shadowed areas.



NASA and Jamestown Follow the Water Chart **Student Handout**

JAMESTOWN	NASA
The Jamestown settlers were focused on finding the best location for their new settlement. After their initial landing at what is now known as Settler's Landing in Virginia Beach, Virginia, Captain Christopher Newport led the three ships on a journey up the James River looking for a suitable location with the natural resources that the colonists would need to survive. The explorers traveled more than 200 kilometers (130 miles) up the river to what is present-day Richmond, Virginia, before turning around and returning to the site that would become Jamestown. The settlers chose Jamestown Island for their colony because they could easily navigate their small ships close to shore. They determined that the nearby swamps would enable them to more easily defend their settlement. The settlers were amazed at the types of plants and trees and the natural beauty of the land. The river tasted sweet to them, so no thought was given to digging wells. Unfortunately, the settlers' inexperience in this new environment led to disaster. The site the settlers chose for Jamestown is about 64 kilometers (40 miles) from the Chesapeake Bay and only 92 kilometers (57 miles) from the Atlantic Ocean. The lower part of the James River is actually an estuary, a place where saltwater transitions into freshwater. The water in the estuary was brackish, a mixture of freshwater and saltwater, and often became	The hunt for water continues to drive exploration today. If extended human settlement of the Moon and Mars is to take place, ways to find or produce water will be essential. On Mars, it is known that reservoirs of water ice exist in the form of polar caps and permafrost. On the Moon, some scientists believe that water ice may exist at the lunar poles in permanently shadowed areas. Because clues to the early history of the Moon and Mars may be locked in waters hidden beneath their surfaces, NASA is planning missions to these worlds to answer questions about the role water may have played in their formation. In 1996, the Clementine spacecraft collected data that indicated there might be ice in the bottom of a crater near the Moon's south pole. This area is permanently in shadow and very cold. In 1998, the Lunar Prospector probe gathered additional scientific data that supported the hypothesis of ice at the south pole and showed evidence that even more ice may be at the Moon's north pole. Based upon that information, scientists estimate that more than 5 trillion kilograms (about 6 billion tons) of water ice may be trapped near the Moon's polar regions. An upcoming Lunar Reconnaissance Orbiter (LRO) mission will continue to investigate near-surface water ice in the polar regions. In 2002, the Mars Odyssey spacecraft found evidence of large amounts of water ice buried in a thin layer of soil around the Martian poles. Scientists estimate that high concentrations of ice.

NASA and Jamestown
Follow the Water Chart

1. Ask students to read the "NASA and Jamestown Follow the Water Chart**"** to find out more about why water is important to settlement and how water has long influenced exploration.
2. Discuss key ideas from the reading.
3. Help students add any information to the class/student charts created at the beginning of this study to help answer the questions, "Where is water found?" and "Why is liquid water important for life?"

Extend

The **Engage**, **Explore**, and **Explain** activities look at some of the reasons water is important for life. The demonstrated water processes deal with liquid water. As observed in the **Engage** activity, liquid water transports or carries some materials into and out of cells. Liquid water dissolves some substances as it travels through different soil samples, as demonstrated in the **Explore** activity. Human's need for freshwater was discussed in the **Explain** reading.

This activity challenges students to design and implement an experiment to discover how seed germination is affected by varying amounts of salt in water. One important food for the early Jamestown settlers was corn. Scientists are studying which plants to grow in a spacecraft for long-duration missions in space. Researchers believe that some of the best plants for a long mission are soy, peanuts, potatoes, tomatoes, beans, green leafy vegetables, and wheat.

Seed germination and crop growth were affected as the water source for the Jamestown settlers became saltier. At first, the Jamestown settlers thought the water in their new home was fresh and sweet tasting. But the brackish water became saltier and saltier as seasonal temperatures became warmer and there was less rainfall.

How much salt is usually found in brackish and ocean water?

The amount of salt or salinity in saltwater is measured by looking at the concentration of salt in the water. This is usually described by comparing the amount of salt in 1,000 grams of water. One gram of salt in 999 grams of water would have the salinity of 1 part per thousand, or 1 ppt.

Freshwater is usually less than 0.5 ppt. Water with salinity ranging from 0.5 ppt and 17 ppt is called brackish. Estuaries, places where fresh river water merges with the ocean water, are examples of brackish water.

The average salinity of ocean water is 35 ppt. This amount may vary between 32 and 37 ppt, affected by rainfall, evaporation, river runoff, ice formation, and climate. By this measurement, ocean water is about 3.5 percent salt. About 90 percent of this is sodium chloride, or table salt. The other dissolved salts include: magnesium, sulfur, calcium, and potassium.

Experimental Design Chart — Student Handout

Question:	"Can adding salt to water affect seed germination?"
Hypothesis: What do you think will happen?	
Independent variable: What are you purposefully changing or varying?	
Dependent variable: What will change because of the independent variable?	
Control: What usually happens?	
Trials: How will you run more than one test?	
Constants: Make a list of all factors that must stay the same.	
Materials: What materials are needed?	
Procedure: What will you do?	
Observation and Data: Create a chart to record your observations and measurements.	
Analysis/Results: Give specific details about your observations and measurements.	
Conclusions: Examine your hypothesis and state whether it was accepted or rejected based on your results. Summarize your findings and explain what was learned. Generate further research questions.	
What do you wonder now?	

Experimental Design Chart

1. Challenge the students to work as teams to design an experiment to answer this question, "Can adding salt to water affect seed germination?"
2. Use the experimental design chart and these questions to help students develop this experiment:

- What might be the independent variable for this experiment? *(The amount of salt in the water.)*
- What is the dependent variable for this experiment? *(Seed germination)*
- What is the control for this experiment? *(Water without salt. This might be distilled water.)*
- How can you simulate fresh, brackish, and ocean water? *(Freshwater is usually less than 0.5 ppt. Water with salinity ranging from 0.5 ppt and 17 ppt is called brackish. The average salinity of ocean water is 35 ppt. This amount may vary between 32 and 37 ppt. Students can mix these solutions in 2-liter bottles. For example, ocean water [35 ppt] can be created by mixing 35 grams of salt with 965 grams of distilled water. One gram of water equals 1 milliliter of water, so you will mix 35 grams of salt with 965 milliliters of distilled water.)*
- How can the class work together to gather more data? *(Students may work as teams, with each team setting up one control test and one or two experimental tests.)*
- How can the class work together to double check each group's results? *(Experimental tests may be assigned to more than one team so that each test solution is assessed more than once.)*
- What materials are available for this experiment? *(Review available materials with the class. You may want to pre-soak seeds for the students to speed up the germination. Dried lima beans from the grocery store work well. Corn seeds could be used to draw a connection to the Jamestown settlers, but seed corn needs to be purchased from gardening or feed stores.)*
- How will you design your experiment so that you can easily observe germination? *(You may allow your students to design this experiment, making it an open inquiry. Or, you may want to make this a guided inquiry and offer suggestions for ways to design this experiment. One protocol for experimental design would be for students to use sealable plastic sandwich bags and paper towels as the germinating bags. A paper towel, when folded into quarters, fits inside the plastic bag. Transparent tape holds the seeds across the middle of the paper towel. Students pour water into the bag to create a pool of liquid about 1 centimeter deep along the bottom of the bag. The edge of the paper towel should hang into the water solution. The plastic bags can be taped to a window or hung on a line along a window. See Diagram 1.*

Diagram 1

The water will travel through the paper towel through capillary action. If students have not observed capillary action before, this gives them a chance to see how water climbs up the paper towel against the downward pull of gravity. In nature, capillary action helps water travel to the highest branches and leaves in a tree. Two properties of water, its cohesion and adhesion, work together in capillary action. Adhesion describes water's attraction to other materials. Water moves through some small-diameter tubes due to its attraction to the molecules that make up those tubes. Cohesion describes a water molecule's attraction to other water molecules. Water molecules pull each other along through the narrow tubes in the paper towel.

As a class, students will decide which group will test brackish or salt water. Each group should set up a second germinating bag using freshwater as a control. Four to 5 seeds should be placed inside each bag.

Students should make daily qualitative [describing changes in the seed] and quantitative [measuring the roots] observations.)

- How will you organize and sort data? Be sure to include both words and pictures to record what you observe. *(A variety of data charts could be developed.)*

3. Help students analyze their data and draw conclusions from this experiment. These questions may help guide this discussion:

- Which liquid would you choose for the best germination?
- What might you infer from this experiment about the effect salting icy roads may have on the environment?
- How does this experiment depict some of the experiences of the early Jamestown settlers?
- What does this experiment reveal about the importance of freshwater for life and future explorations?

Evaluate

Choose one or more of the following activities to assess student understanding.

1. Evaluate the students' charts. Look for an increase in understanding of where water can be found and why liquid water is important for life.
2. Evaluate the student-designed experiments from the **Extend** section that answer the question, "Can adding salt to water affect seed germination?"
3. Ask students to work in groups to solve the mystery of the "Case of the Salty Water."
   - Give each group 3 small samples of Elodea. Elodea is a green freshwater plant. If Elodea is unavailable, you may substitute lettuce.
   - Give each group 3 "unknown" solutions marked "A," "B," and "C." One solution is actually freshwater, one solution is brackish water, and one solution is saltwater.
   - Give students access to microscopes, microscope slides, cover slips, and eyedroppers.
   - Challenge the students to use these materials to make a "case" for which solution is freshwater, which is brackish, and which is saltwater.
   - Students should be able to apply what they have learned about osmosis to solve this mystery. When placed in saltwater, the water inside the Elodea cells will move out of the cell. This loss of water will cause the cells to shrink and become limp. Under the microscope, students will see the cytoplasm shrink and pull away from the cell wall.
4. Ask students to write a paragraph to respond to one of the following journal prompts.

Journal Prompt 1: Where is water found? Organize your writing by thinking about answers to these questions:

- Where is water found on Earth?
- Where is water stored on Earth?
- Where has evidence of water been found in the solar system?
- What role does finding water play in past, present, and future exploration?

Journal Prompt 2: Why is liquid water important for life? Organize your writing by thinking about answers to these questions:

- How does water transport or carry materials?
- What can liquid water do that cannot be done by water as a solid or gas?
- Why was liquid water important for the Jamestown settlers?
- Why does NASA search for water on the Moon and Mars?

Additional NASA Resources

Sections of this lesson were adapted from existing NASA educational products. These additional NASA resources may extend student understanding about where water can be found and why liquid water is important for life.

Living Off the Land: Water Filtration Challenge
Students learn about the importance of an Environmental Control and Life Support System (ECLSS) through this Engineering Design Challenge. They design, build, test, and measure the performance of a water filtration device. Based upon collected data, students work to improve their filtration design.
http://edc.nasa.gov/challenge.html#lotl

Mars Exploration
Have your students take a look at images from Mars and then become detectives as they look for clues that indicate the past or present presence of water.
http://mars.jpl.nasa.gov/follow/index.html

Mars Global Surveyor
Read more about recent images taken by the Mars Orbiter Camera on NASA's Mars Global Surveyor that suggest that water still flows in brief spurts on Mars.
http://marsprogram.jpl.nasa.gov/mgs/newsroom/20061206b.html

NASA's Earth Observatory
Learn more about NASA's satellite missions that help us explore Earth and uncover new information about weather, the water cycle, and the presence of water on the planet.
http://earthobservatory.nasa.gov

Phoenix: The Search for Water
Help your students learn about Phoenix, the new lander planned for the next mission to Mars.
http://www.nasa.gov/missions/solarsystem/phoenix_water.html

Designed for Grades 3–5
The NASA SCI Files™ "The Case of the Wacky Water Cycle"
Visit this site to understand that water is a limited resource and to demonstrate where usable water can be found on Earth.
http://scifiles.larc.nasa.gov/docs/guides/Water_Cycle.pdf

NASA KSNN™ "Why does ice float in my drink?"
Have you ever wondered why ice floats but other solid materials don't? Visit this site to learn about one of water's essential properties.
http://ksnn.larc.nasa.gov/webtext.cfm?unit=Density#

Water Race Data Chart Student Handout

Predictions:
Water will flow slowest through: ___________________________________
Water will flow fastest through: _____________________________________
The material that will hold the most water is _________________________
Materials in the soil that will dissolve might be ______________________

Provide an explanation or rationale for your predictions:

___

___

___

___

___

Water Race Data

Material	**Trial 1**	**Trial 2**	**Trial 3**
Sand			
Gravel			
Topsoil			

Experimental Design Chart — Student Handout

Question:	"Can adding salt to water affect seed germination?"
Hypothesis: What do you think will happen?	
Independent variable: What are you purposefully changing or varying?	
Dependent variable: What will change because of the independent variable?	
Control: What usually happens?	
Trials: How will you run more than one test?	
Constants: Make a list of all factors that must stay the same.	
Materials: What materials are needed?	
Procedure: What will you do?	
Observation and Data: Create a chart to record your observations and measurements.	
Analysis/Results: Give specific details about your observations and measurements.	
Conclusions: Examine your hypothesis and state whether it was accepted or rejected based on your results. Summarize your findings and explain what was learned. Generate further research questions.	
What do you wonder now?	

JAMESTOWN	NASA
The Jamestown settlers were focused on finding the best location for their new settlement. After their initial landing at what is now known as Settler's Landing in Virginia Beach, Virginia, Captain Christopher Newport led the three ships on a journey up the James River looking for a suitable location with the natural resources that the colonists would need to survive. The explorers traveled more than 200 kilometers (130 miles) up the river to what is present-day Richmond, Virginia, before turning around and returning to the site that would become Jamestown. The settlers chose Jamestown Island for their colony because they could easily navigate their small ships close to shore. They determined that the nearby swamps would enable them to more easily defend their settlement. The settlers were amazed at the types of plants and trees and the natural beauty of the land. The river tasted sweet to them, so no thought was given to digging wells. Unfortunately, the settlers' inexperience in this new environment led to disaster. The site the settlers chose for Jamestown is about 64 kilometers (40 miles) from the Chesapeake Bay and only 92 kilometers (57 miles) from the Atlantic Ocean. The lower part of the James River is actually an estuary, a place where saltwater transitions into freshwater. The water in the estuary was brackish, a mixture of freshwater and saltwater, and often became	The hunt for water continues to drive exploration today. If extended human settlement of the Moon and Mars is to take place, ways to find or produce water will be essential. On Mars, it is known that reservoirs of water ice exist in the form of polar caps and permafrost. On the Moon, some scientists believe that water ice may exist at the lunar poles in permanently shadowed areas. Because clues to the early history of the Moon and Mars may be locked in waters hidden beneath their surfaces, NASA is planning missions to these worlds to answer questions about the role water may have played in their formation. In 1996, the Clementine spacecraft collected data that indicated there might be ice in the bottom of a crater near the Moon's south pole. This area is permanently in shadow and very cold. In 1998, the Lunar Prospector probe gathered additional scientific data that supported the hypothesis of ice at the south pole and showed evidence that even more ice may be at the Moon's north pole. Based upon that information, scientists estimate that more than 5 trillion kilograms (about 6 billion tons) of water ice may be trapped near the Moon's polar regions. An upcoming Lunar Reconnaissance Orbiter (LRO) mission will continue to investigate near-surface water ice in the polar regions. In 2002, the Mars Odyssey spacecraft found evidence of large amounts of water ice buried in a thin layer of soil around the Martian poles. Scientists estimate that high concentrations of ice,

stagnant. The seasons also played an important role in the quality of the James River water. In early spring, melting mountain snows provided enough freshwater run-off to push the brackish water back toward the ocean. Later, temperatures warmed and water evaporation increased. Drought conditions resulted in less freshwater run-off and saltier water once again moved up the river. By the summer months, the brackish water around Jamestown contained up to 5 times more salt than is safe to drink.

Unfortunately for the settlers, they arrived at the onset of a severe 7-year drought that began in 1606. Even the shallow wells that were dug during the second year of the settlement became contaminated as saltwater from the James River seeped into them when freshwater supplies dwindled. By May 1610, according to one settler's account, only 60 of the nearly 500 settlers who had been at Jamestown were still alive. Some historians believe the startling number of deaths from disease in the early years may have been caused by the settlement's placement along the James River. Eventually, as the settlers learned more about their new environment and as weather conditions improved, they were able to locate nearby freshwater sources and dig freshwater wells on Jamestown Island.

Despite the initial hardships caused by the brackish water of the James River, the river proved to be an invaluable source of food for the settlers and an important part of their

perhaps as much as 80 percent by volume, may be within half a meter of the surface. Permafrost on Mars is another place that may contain large amounts of frozen water. The Martian permafrost may be several kilometers thick. As much as half of this layer could be ice.

Images taken in 2004 and 2005 by the Mars Orbiter Camera on NASA's Mars Global Surveyor revealed bright new deposits seen in two gullies on Mars that suggest water might have carried sediment through them sometime during the past 7 years. If this proves to be signs of present-day water-related activity on Mars, it may lead to the discovery of aquifers or melting permafrost.

These observations suggest that water still flows occasionally on the surface of Mars. The atmosphere of Mars is so thin and the temperature so cold that liquid water cannot persist at the surface. It would rapidly evaporate or freeze. Researchers propose that water could remain liquid long enough, after breaking out from an underground source, to carry debris downslope before totally freezing. The two fresh deposits are each several hundred meters long.

The lighter color of the deposits could be from surface frost continuously replenished by ice within the body of the deposit. Another possibility is a salty crust, which would be a sign of water's effects in concentrating the salts.

Since 2000, the Mars Global Surveyor has discovered tens of thousands of gullies on slopes inside craters and other depressions on Mars. To look for

lifeline back to England. Fish of many varieties, especially sturgeon, became a staple food supply for the settlers. Oysters, crabs, and other aquatic animals were also an essential part of the settlers' diet. In addition to providing a food source, the James River was the settlers' "interstate highway" for travel, exploration, and trade routes to the surrounding Powhatan Indian town sites. It was also part of the "water bridge" connecting Jamestown to England via the Chesapeake Bay and the Atlantic Ocean. Being the only avenue of communication between the settlers and England, this water route was vital for the eventual survival and expansion of the Virginia colony.	changes that might indicate a present-day flow of water, the camera team repeatedly imaged hundreds of the sites. More about images taken by the Mars Orbiter Camera may be learned by listening to a short podcast of an interview with Dr. Michael Malin, the principal investigator for the Mars Orbiter Camera on NASA's Mars Global Surveyor, found at *http://www.nasa.gov/multimedia/podcasting/jpl-mgs-20061206.html*. NASA will continue to look for evidence of water during Moon and Mars missions, not only to search for clues about the past but in preparation for possible future lunar and Martian settlements.