When students have reached the number of paperclips they initially predicted, invite them to pause and make observations about their results. Ask students to make a new prediction and continue to drop paperclips into the cup, counting from where they left off, until the water spills over. Ask students:

- How many paperclips fit into the cup before the water spilled?
- What do you think was holding the water in the cup as the level rose?
- What happened when the cup couldn't hold any more paperclips?
- How did your results compare to your revised prediction?

Part 2
What If?

Ask students to select ONE new variable to test (different-sized cups, different-sized paperclips, plastic-coated paperclips, marbles, beads or pennies). Based on their first observation, students should predict how many objects will fit into the cup before the water spills over.

- Did you get different results with different items?
- What surprised you?
- What new questions do you have?

WRAP-UP

To wrap-up the investigation, bring your students together for a group discussion to help them understand why and how they achieved their results. It is important to share results so that everyone has a clear picture of what happened. To help you facilitate the discussion, review the explanation in "The Why and The How" using the Group Discussion questions as a guide.

Group Discussion
Scientists learn from each other through discussion, and they build upon the work of others to make new discoveries. Just as scientists come to conclusions based on the findings of their experiments, students will now come together as a group to share thier results and make conclusions about the investigations they've conducted. Have students record their final results and the explanation in their journals.

- What were your results?
- Which variables did you test?
- What did you learn about the cohesion of water?

The "Why" and The "How"
Water molecules are attracted to each other and tend to clump together. This is why water drops take the shape of... water drops! Several variables affect the number of drops that will fit on the surface of a penny, such as:

- the size of the straw or water dropper hole;
- the distance between the dropper and the surface of the penny;
- the time allowed between the release of each drop; and
- the condition of the penny (for example, is it clean, oily, dirty, etc.?).

When the amount of water on the surface of the penny becomes too great for the "skin" or surface tension to hold the dome shape, water spills over the rim of the penny.

As paperclips were placed in the cup, the water level began to rise because it was being pushed out of the way and upwards by the paperclips, a property known as **displacement**. When the first few paperclips were placed in the cup and the water rose, the strong cohesive forces at the surface of the water caused it to form a dome shape and kept it from spilling over. However, when too many paperclips were added to the cup, bonds between the molecules at the surface were broken, causing the water to overflow.

Curriculum Match-Up

- Use the same variable ten times and find the average number of drops / paperclips for your results.
- Using the group results from Part One, find the range, the mode and the median.
- Create a small pile of sand or soil and pour water over the pile to observe what the water does once it hits the sand. What does this tell you about how bodies of water are formed?
- Find the ratio between your prediction and your result.
- What percentage of your predictions was correct? What percentage of your predictions was incorrect? Calculate the percentage of your prediction in relationship to your result.
- Create a story using water drops as characters. Tell how water drops are attracted to each other.

TIP
A ratio is a way compare two things. For example if you have 20 dimes and 5 nickels, the ratio of dimes to nickels is 20 to 5, or 20:5.

References
pbskids.org/zoom/activities/sci/dropsonpennies.html
wow.osu.edu/experiments/statesofmatter/psm2/Is_the_Glass_of_Water_Full.pdf

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A Little Drop of Water: Cohesion

Learning Objectives

Students will:

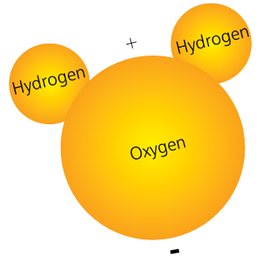
1. Identify and diagram the structure and atoms that form a water molecule.
2. Describe why water forms a dome shape on a flat surface.
3. Test and explain the circumstances that will break the cohesion of water.

Vocabulary Ventures

atom
attraction
cohesion
displacement
hydrogen
meniscus
molecule
oxygen
sphere
surface area
surface tension
teddy bear molecule
variable
water molecule

Have you ever wondered why water forms little beads on the surface of a car after it rains? It has to do with a property of water called cohesion.

Everything on the planet is made of something smaller. The smallest unit of water is called a **molecule**. A molecule is made up of several small particles called **atoms** that are joined by a chemical attraction. In a **water molecule**, two hydrogen atoms with a positive charge are attached to an oxygen atom with a negative charge. When these atoms attach to each other, they form a shape that looks like the head of a teddy bear. That is why the water molecule is known as the **"teddy bear molecule".**



the "teddy bear" molecule


beads of water on glass

Water molecules behave much like a magnet, with a positive end and a negative end. The **oxygen** atom in one molecule of water is attracted to the **hydrogen** atom in another water molecule. This attractive force causes water molecules to be attracted to one another, a property known as cohesion. This is how little drops of water form into a larger pool of water.

The **attraction** between water molecules causes water to pull itself into the shape with the smallest amount of surface area, which is a **sphere**. On a flat surface, water pulls itself into a dome shape called a **meniscus**.

On the surface of water, the attraction between water molecules is very strong. This strong attraction creates an invisible "skin" on the surface of the water that helps hold it together. This property of water is known as **surface tension**.


drops on a penny

Time Needed to Conduct Investigations

Investigation 1: This investigation has two parts.
Organize and set up materials: 10 minutes
Introduce the lesson: 5 minutes
Conduct the investigation: 20 minutes
Student journaling/group reflection: 10 minutes
Total estimated time: 45 minutes

Investigation 2: This investigation has two parts.
Organize and set up materials: 10 minutes
Introduce the lesson: 10 minutes
Conduct the investigation: 20 minutes
Student journaling/group reflection: 10 – 15 minutes
Total estimated time: 50 – 55 minutes

Investigation 1: Drops on a Penny

Materials

For groups of one or two
Student journals and writing tools

Introduction to Cohesion
Build a Water Molecule
- Different types of marshmallows: multi-colored or large and small
- Toothpicks

INVESTIGATION 1
Part 1
- 9 oz cup of water
- Eyedropper or straw
- Paper towel
- Penny
- Sponges for clean-up

Part 2
- Assortment of new, old, shiny, dirty and discolored pennies
- Two ½ liter water bottles filled with tap water
- Other liquids to serve as **variables**: Soapy water, salt water, white vinegar, Karo syrup, baby oil, isopropyl alcohol, seltzer water
- Waxed paper
- Paper towel
- Aluminum foil
- Wood block or cardboard

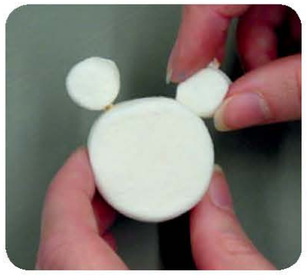
INVESTIGATION 2

Part 1
- ½ liter water bottle
- 9 oz clear hard plastic tumbler
- Boxes of small metal paperclips, 100 - 150
- Paper towels
- Sponges for clean-up

Part 2
- 12 oz clear plastic cup
- 3 oz paper cup
- Boxes of large metal paperclips
- Boxes of plastic-coated paperclips
- Bags of marbles
- Hundreds of pennies
- Different liquids

Introduction to Cohesion
Build a Water Molecule

Discuss the make-up of water molecules and the difference between atoms and molecules with students. Have them diagram pictures of water molecules in their student journals and create a model of a water molecule using different colored marshmallows (or different shaped marshmallows) and toothpicks. Review any relevant concepts/vocabulary from the background information.



marshmallow model of water molecule

TIP
Gather all necessary materials prior to the start of the activity. Students can help prepare salty and soapy water solutions.

Part 1
How Many?

GET READY!

1. Break your students into groups of two.
2. Explain to students that they will be doing an experiment to investigate why water forms into droplets.
3. Ask students to make some hypotheses (educated guesses) as to why water behaves in this way.
4. Provide students with an eyedropper (or a straw) and a penny.
5. Have students place their pennies "heads up" on a piece of paper towel on a flat surface.
6. Before they start, have students practice using the eyedropper by making drops of water in the cup.

PREDICT

Ask students to predict how many drops of water will fit on the head of the penny before it spills over. Ask them to explain why they made that prediction. Students should record their predictions in their student journals.

TIP
Have students be careful not to shake the table. Students can help prepare salty and soapy water solutions.

OBSERVE

Ask students to begin by placing one drop of water at a time on the head of the penny, counting drops as they go. Encourage them to make some observations, such as:
- What is happening to the drops as you place them on the penny?
- How do the drops move?
- What shape are the drops taking on the penny?
- How does the water look from the top? From the side? Invite students to diagram what they see in their journals.
- Does the way you drop the water affect your outcome? Allow students to practice different dropping techniques and observe the results.

When students have reached the number of drops they initially predicted, invite them to pause and make observations about their results. Ask students to make a new prediction and continue to place drops on the penny, counting from where they left off, until the water spills over. Ask students:
- How many drops fit on the surface of the penny?
- What do you think was holding the water on the penny?
- What happened when the penny couldn't hold any more drops on its surface?
- How did your results compare to your revised prediction?

Part 2
What If?

Ask students to share questions that might have come up during the investigation. Do they have any other questions they would like to explore?

Explain that when we change one aspect of an experiment to see how it affects our results, this change is known as a **variable**. If we repeat the experiment and change just one variable, will we get the same results? Distribute additional materials and allow students to select ONE new variable to test at a time. Some possibilities are:
- What if we used soapy water? Salty water? Cold water? Hot water? A different coin?

Feel free to try these investigations, or take suggestions from your students. Encourage students to share their questions and results with the class and record them in their student journals.

Investigation 2: Filled to the Brim

meniscus on cup

Part 1
What Happens?

GET READY!

Explain to students that they will conduct another experiment to explore the cohesive properties of water. Review any relevant concepts/vocabulary from previous investigations.

1. Have students place a cup on top of a paper towel and fill the cup to the very top with water, until it almost spills over.
2. Gather the paperclips and explain to the students that they will be placing the items into the cups of water.

PREDICT

Ask students to make predictions. What will happen as they start placing paperclips in the cup? How many paperclips will the cup hold before the water spills over?

OBSERVE

Invite the students to slowly begin placing paperclips in each cup, and make the following observations:
- What is happening to the water? Why do you think this is happening?
- What shape is the water taking in the cup?
- How does the water look from the top? From the side? Invite students to also diagram what they see in their student journals.
- Why do you think the water is taking that shape?
- What happened when too many paperclips were placed in the cup?
- Why did this happen?