Fifth Edition

YOU BE THE CHEMIST™

ACTIVITY GUIDES

Hands-on Science
for Grade K-8 Students

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Chemistry of Life & Earth Sciences

Background

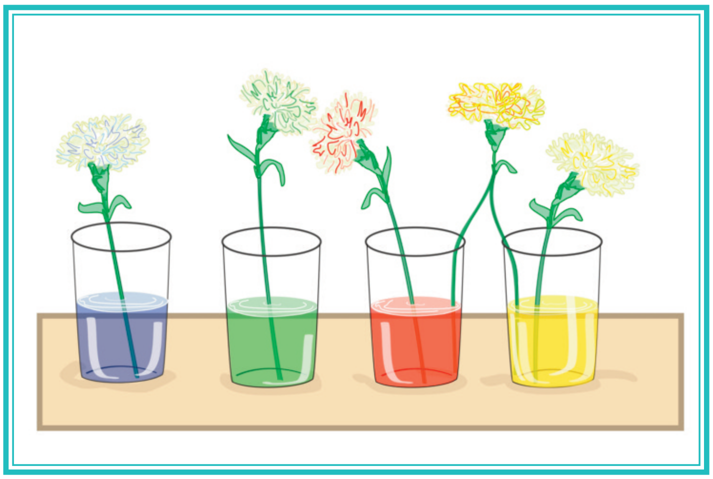
Activity Guides:

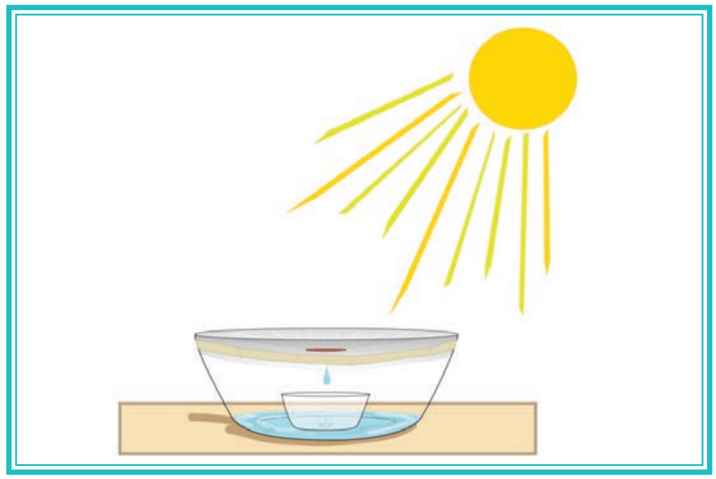
BLUBBER IN SEA MAMMALS | CAPILLARY CARNATIONS | IRON IN CEREAL | HOLD THE SALT | DEW DROPS

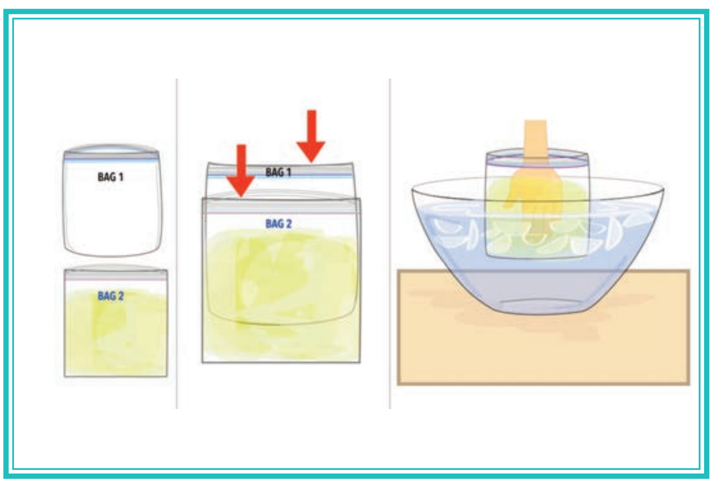
Chemistry of Life & Earth Sciences

Chemistry is the basis of all life. Everything from our environment, the weather, the food we eat, to how our bodies work depends on chemistry! By studying chemistry, we can better understand how the world works. In this section, students explore activities that explicitly connect chemistry to their natural world.

Let's try some activities so you can experience the chemistry of life and earth sciences in action!







Blubber in Sea Mammals

Section **THE CHEMISTRY OF LIFE & EARTH SCIENCES**

Estimated Time Setup: 10 minutes; Procedure: 10-15 minutes

OVERVIEW

Experience how a layer of fat keeps animals warm even in the coldest climates!

In this activity, students explore how an insulator like fat keeps the body warm. They test how well a layer of vegetable shortening – which mimics animal fat – protects their hands from icy water. Students will also measure and compare temperatures with and without the layer of fat to show the difference that it makes.

INQUIRY QUESTIONS

Getting Started:
- How have animals adapted to stay warm in cold climates?

Learning More:
- What internal and external structures allow animals to maintain body temperature?

Diving Deeper:
- What are the physical and chemical properties of fats and how do they help regulate body temperature?
- What are the properties of insulators, and how do they reduce thermal energy transfer?

CONTENT TOPICS

This activity covers the following content topics: energy, energy transfer, thermal energy, heat, insulators, chemistry in the human body, animal adaptations, temperature regulation, properties of fat and blubber

This activity can be extended to discuss: climate change, conservation of energy

NGSS CONNECTIONS

This activity can be used to achieve the following Performance Expectations of the Next Generation Science Standards:
- **2-PS1-2:** Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.
- **3-LS3-2:** Use evidence to support the explanation that traits can be influenced by the environment.
- **5-PS1-3:** Make observations and measurements to identify materials based on their properties.

MATERIALS

For one setup:
- 3 sealable quart or gallon size plastic bags
- Large bowl or bucket
- Water
- Ice
- Solid vegetable shortening
- Thermometer

ACTIVITY NOTES

This activity is good for:
- Pairs
- Small groups
- Large groups
- Demonstrations

Safety Tips and Reminders:
- Vegetable shortening can be messy. For younger students, an adult should prepare the setup in advance. For older students, they should wear gloves and ensure they do not get the shortening on their clothing since it may be hard to remove.
- Review the Safety First section in the Resource Guide for additional information

Fun Fact #1

"Cold-blooded" animals do not maintain a constant internal body temperature. Their body temperature is close to whatever the temperature is in their environment. Most animals besides mammals and birds are cold blooded, including reptiles, fish, snakes, and more! You might see cold blooded animals basking in the sun to warm up on a cool day, or hiding in the shade or water on a hot day to stay cool.

ENGAGE

Use the following ideas to engage your students in learning about chemistry of life and Earth sciences:

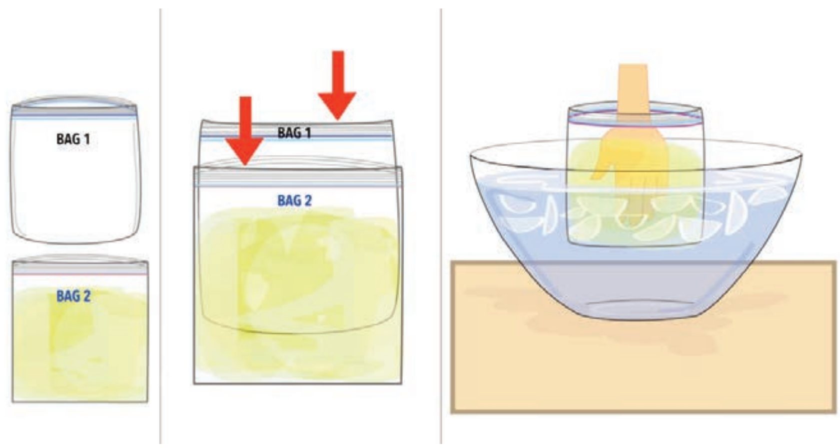
- Show students pictures of animals from both warm and cold climates. What similarities and differences do they note? Can they guess the climate in which each animal lives? They can explore some of the differences they see in this experiment!
- To introduce insulators, see if students can make a list of items in their lives that keep things cold or hot. Examples include travel coffee mugs, thermoses, refrigerators, the walls and insulation in a home, clothing, and more! How many can they think of? What materials or characteristics describe these items?
- Present students with various materials that could act as insulators, including things like cloths, vegetable shortening, wood, metals – whatever you have accessible! Which do they think will effectively keep something at the same temperature? Where might they have seen an example of this material used as an insulator?
- Discuss how people regulate body temperature to cool off or warm up. Ask students to think of a time when they felt very warm, maybe after playing outside on a hot day. How did their body respond? What do they remember? What about on a very cold day? What adaptations on our bodies or modifications to our environment do we make? Write down ideas as students say them, separating them into two categories without labeling them: physical adaptations (i.e. shivering, sweating, fat) and environmental modifications (i.e. turning on heat or air conditioning, putting on warm or cooler clothes, moving into the shade). After a long list has been compiled, can they label the categories?

See the Elaborate section of this activity for more ideas to engage your students.

EXPLORE

Procedure:

1. Fill the bucket or bowl with ice and water.
2. Fill a plastic bag halfway with vegetable shortening.
3. Take a second plastic bag and turn it inside out. Place it inside the bag with shortening and connect the two seams. This should allow a student to put their hand in the now double-walled bag without touching the shortening directly. (If this is too messy, try sealing the two bags together with a layer of duct tape along the top.)
4. Have a student place one hand in an empty plastic bag, and the other in the double-walled shortening bag. Place both hands with the bags over them into the ice water for a few seconds.
5. Take the temperature of the inside of each bag by placing the bulb of the thermometer at the bottom of the bags one at a time. Wait a few minutes and record the temperature. Repeat for the other bag.



DATA COLLECTION & ANALYSIS

Analyze and discuss the results of this activity using the following questions:

- Describe the appearance of the vegetable shortening. What physical properties do you notice?
- Describe the feeling inside each bag. Are they the same or different? How?
- Record the temperature (in °C) for each bag. Does this support what you noticed when you put your hands in the bags?

EXPLAIN

What's happening in this Activity?

First review the Chemistry of Life & Earth Sciences Background section to gain a deeper understanding of the scientific principles behind this activity.

Around the world, animals are challenged with harsh living conditions in their environment: extreme heat, cold, wind, natural disasters, and more. Over thousands of years, animals have adapted to these conditions and are more likely to survive, grow, and reproduce to make the next generation.

Mammals and birds are referred to as **warm-blooded** animals, which means they can keep their body temperature stable. For example, human body temperature is around 98.6 °F or 37 °C. Whether it is a hot summer day, or a cold winter night, your body works to maintain a constant internal temperature. Other warm-blooded animals' normal body temperatures range from 97-105 °F depending on the species.

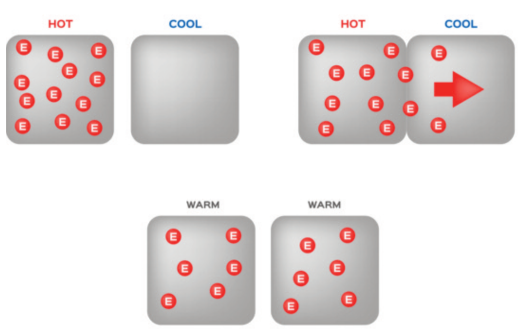
Warm-blooded animals use a variety of techniques to maintain constant body temperature even when their environment is cold or hot. To cool the body, animals can seek out the shade, reduce their activity during the daytime, or swim in water or mud. Animals that live in hot climates also have adaptations to their bodies that help them stay cool, such as the ability to sweat or pant, and features like big ears and long limbs covered in blood vessels that allow excess heat to escape into the surroundings.

Warm-blooded animals that live in cold climates have many ways to increase their body temperature to maintain a constant internal temperature. They might exhibit behaviors like huddling in groups, taking shelter, or even hibernating so they skip the coldest months. In addition to acting in certain ways, the bodies of animals in cold climates have adapted over the course of many generations. Cold climate animals might exhibit adaptations like being able to shiver to keep their muscles warm, fluff their feathers to trap warm air near the body, or contracting the muscles around their hair follicles to stand the hair up and create a protective barrier – which is why we see goosebumps! These animals might also have thick fur, extra layers of insulating fat, and shorter limbs and ears so less heat escapes the body.

There are many types of fat: some found in animals and some found in plants. Fats can be solids or liquids, are insoluble in water, and are often good **insulators**, meaning they slow the passage of heat. To understand how insulators work, we first need to understand energy, temperature, and heat.

Temperature measures the average speed of particles in a substance. When particles move faster, the temperature is higher. When particles move slower, the temperature is lower.

Energy is the capacity to do work or produce heat, and comes in many different forms, including light, sound, electricity, chemical bonds, motion, and thermal energy. **Heat** is the transfer of energy from a higher temperature region (faster particles) to a lower temperature region (slower particles). The rate of heat transfer is affected by many factors, including material thickness, physical properties, and more .



EXPLAIN continued

How does this relate to animals living in different climates? If an animal is in a cold environment, their body will be warmer than their surroundings. Heat will naturally be transferred from the warm animal to the cool environment, meaning that over time the animal's temperature will decrease.

One way that animals maintain their internal body temperature is by slowing down this process of heat transfer. While heat transfer cannot be entirely stopped, layers of fats drastically reduce heat transfer because they are good insulators and heat does not move well within and through them. In humans, we use insulators like down jackets, wool sweaters, and other clothing reduce heat flow. Animals that live in cold climates have layers of fat and **blubber** (thick fat with many blood vessels found in sea animals) beneath their skin. They can act as a source of stored energy, a thermal insulator, and padding around organs. Fats and blubber are typically found over muscles and contain molecules like proteins and water. The thickness, structure, and composition vary across species and even within individuals.

In this activity, vegetable shortening is used to represent fat or blubber in the body. Vegetable shortening is a solid fat made from vegetable oils. Like other fats, it is a great insulator! When you put your hand in the shortening bag and then in the water, your hand stays warm and you likely do not feel the icy cold water in the bowl surrounding you. This is because the heat from your hands very slowly moves into the shortening, and energy transfer is low.

Conversely, if you put your hand in the empty plastic bag and into the ice water bath, you immediately feel cold as the heat (thermal energy) from your hand rapidly moves into the ice water. When you feel cold, thermal energy (heat) is moving from your body to the environment. If an animal that does not have enough insulation from fat, blubber, fur, or hair (or clothing, in humans!), it might lose too much thermal energy to the environment. If an animal's body temperature gets too low, it loses the ability to perform normal body functions, which is why fat and blubber are so important to animals around the world!

Differentiation for Younger or More Advanced Students

You can differentiate this activity for students of different grade levels by focusing on the concepts outlined below.

GETTING STARTED	DIVING DEEPER
For younger students, emphasize the following concepts: • Animals have different adaptations that help them to survive the environments in which they live. • There are many ways animals can regulate their body temperature, either by changing their behavior or over many generations through changing structures both inside and outside their bodies.	**For more advanced students, emphasize the following concepts:** • Fats have specific uses because of their unique chemical and physical properties. • Insulators, such as fat or blubber, reduce heat transfer between animals and their environment.

Fun Fact #2

Camels live in some of the hottest climates on Earth – and carry around up to 80 pounds of fat just in the humps on their backs! Why? Fat is stored energy and water. Camels can survive for up to seven days with no water, and three weeks with no food by breaking down the fat in their humps. When the humps are depleted they will look deflated and sag to one side, but after some food and drink they will regrow and be ready to use again!

Notes

ELABORATE

Elaborate on your students' new ideas and encourage them to apply them to different situations. The section below provides some alternative methods, modifications, and extensions for this activity.

- Compile temperature data from all groups in the class and plot them on a graph or create a table. There should be two sets of temperature data: one for the plastic bag, and one for the bag with the vegetable shortening. Can students find the average, median, or range of each data set? What does this data show? What conclusions can students draw from this data?
- Extend this into an exploration of physical adaptations in humans. How do people regulate body temperature to cool off or warm up? What adaptations on our bodies or modifications to our environment do we make?
- Does insulation thickness matter? Try the experiment with a variety of setups and record the estimated thickness of the vegetable shortening in each. Plot the results of thickness versus temperature after the bags have been in the ice water bath for some time. What is the thinnest this layer can be to be effective? Check back an hour later. Have the temperatures changed?
- See how long the insulation works. Set up the experiment and check the temperature over the next few hours until the water becomes room temperature. Plot the temperatures on a graph (temperature versus time for each setup). How did the temperature of each bag change over time? How long did the shortening work as an effective insulator?
- Does an insulator also protect from the heat? Try the experiment again but use hot water instead of ice water. (Be careful to not let students put their hands in water that is too hot!) Are the results the same?
- Have students develop their own insulator using the Engineering Design Process. Their task can be to keep an ice cube from melting on a hot day, or any other challenge you can think up. To adjust the level of difficulty, change the groupings, materials, time for each step, or any other part of the process. Success can be defined in a number of ways, including how long the device maintained temperature, which used the least or cheapest materials, etc.
- What other insulators could be used in the glove? Students can try things like soil, sand, flour, cotton balls, air – anything they can think of! They can set up multiple stations around the room and measure the temperature over time to see which insulator works best.
- Connect this activity to matter and energy cycles through ecosystems. How do animals build a storage of fat or blubber? What types of food do they eat? Where do they fall within the food web?
- This is a great topic to start a unit on adaptations, evolution, and other life science content areas!
- Students might have heard that with climate change and the melting sea ice, polar bears and other arctic animals have less opportunities for hunting prey. Without a constant food supply in the months leading up to the frigid winters, they might not be able to build up enough fat stores to keep them warm. Lead a discussion about where polar bears get their food and how they hunt, then transition into this activity to learn the impact that a thick layer of fat has on keeping heat in the body.

Notes

CHEMISTRY IN ACTION

Share the following real-world connections with your students to demonstrate how chemistry is all around us.

Real-World Applications

The earth's atmosphere is a collection of gases that act as effective insulators! They trap energy from the sun and keeps it from escaping into space, which is called the Greenhouse Effect. Over time, humans have put excess greenhouse gases – such as carbon dioxide, methane, and nitrous oxide – into the atmosphere, meaning more heat is trapped within our atmosphere than in recent years, which can lead to climate change .

Many animals with hair, fur, or feathers stay warm by trapping air close to their skin. The air acts as an insulator and barrier against the cold.

Gases tend to be good insulators because particles are spread far apart, which makes it hard for energy to be transferred. Even better than having gas as an insulator, is to have a vacuum with no particles at all! This is why so many insulated bottles and mugs have a vacuum insulated layer, which keeps your drinks the same temperature for many hours .

Thermal insulators are used in buildings – such as your home or school – to reduce energy transfer. When the air conditioning is turned on inside, your home or school will stay cool compared to the outside temperature. Likewise, when the heat is turned on, it will remain warmer inside. Without insulation, the temperature inside your home or school would be about equal to the temperature outdoors—which may not be very comfortable and wastes a lot of energy and money!

Careers in Chemistry

- Animals aren't the only ones that have to stay warm to survive – plants are at risk of freezing, too! Farmers use greenhouses to keep crops warm, protected, and productive in cold climates. Farmers and agriculture scientists design greenhouses from a variety of insulating materials – including things like bubble wrap! – to create the perfect climate that allows in light but traps heat, which allows their crops to thrive.
- Divers have to find ways to maintain their body temperatures in the water. Even water that is 90 °F over a short time can cause heat loss since it is lower than body temperature! Divers can protect themselves by wearing special gear that keeps heat from escaping. For example, divers often wear hoods and a full-body wetsuit, which traps air and a layer of water that is warmed by body heat and acts as an insulator during dives.

EVALUATE

- Now that students know more about thermal energy transfer, behaviors, and adaptations, provide them with a variety of images of animals from climates around the world. Can they explain at least three adaptations or behaviors they see in each image and how it relates to concepts like temperature, energy, heat, insulators, and more?
- Ask students to draw a diagram that shows thermal energy movement with and without the shortening glove, including what direction thermal energy is flowing. Their pictures should be labeled and they should be able to explain their thinking to a peer.
- Have students take a tour of their community: where do they see examples of insulators? What materials are these insulators made of? Where do they see examples of things that should maybe have an insulator do but not? What type of insulator might work best in each example? Students should take photos, videos, draw, or write their ideas, then present them to the class the next day.
- Fat (animal and plant) and blubber have had many different uses in modern and ancient societies due to their unique physical and chemical properties. Task students with researching one modern and one ancient use for fat or blubber and sharing their findings with the class.

Capillary Carnations

Section **THE CHEMISTRY OF LIFE & EARTH SCIENCES**

Estimated Time Setup: 5-10 minutes; Procedure: 24 hours

OVERVIEW

Place white flowers in colored water and watch as the flower petals transform!

In this activity, students learn how plants move water and nutrients from the external environment into their roots, stems, leaves, and flowers. Students place white flowers in water dyed with food coloring, and over the course of a day the flower petals turn the same color as the dyed water!

INQUIRY QUESTIONS

Getting Started:

- What does a plant need to survive, and where does a plant find these things?

Learning More:

- What are the structures in a plant that enable it to get water and nutrients?

Diving Deeper:

- How does capillary action allow water to move from the soil up to the leaves of a plant?

CONTENT TOPICS

This activity covers the following content topics: properties of matter, properties of water, surface tension, adhesion, cohesion, plant structure and function, transpiration, capillary action

This activity can be extended to discuss: pressure, agriculture, irrigation, plant lifecycle, photosynthesis

NGSS CONNECTIONS

This activity can be used to achieve the following Performance Expectations of the Next Generation Science Standards:

- 4-LS1-1: Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.
- MS-PS1-1: Develop models to describe the atomic composition of simple molecules and extended structures.

MATERIALS

For one setup:

- White flower (see "Elaborate" section for other materials you can substitute)
- Clear cups
- Water
- Food coloring
- Scissor or knife

Optional materials:

- Bounty® paper towels

ACTIVITY NOTES

This activity is good for:

- Demonstrations
- Large groups

Safety Tips and Reminders:

- Food coloring can stain clothes and skin. Students should wear gloves and smocks, or an adult can help with coloring the water.
- Review the Safety First section in the Resource Guide for additional information

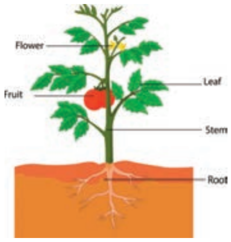
Fun Fact **#1**

The oldest known flowering plant is Monteschia vidalii, which was found fossilized in Spain and is estimated to have lived 130-124 million years ago!

ENGAGE

Use the following ideas to engage your students in learning about the chemistry of life & Earth science:

- This activity fits well after or alongside a study of the parts of a plant!



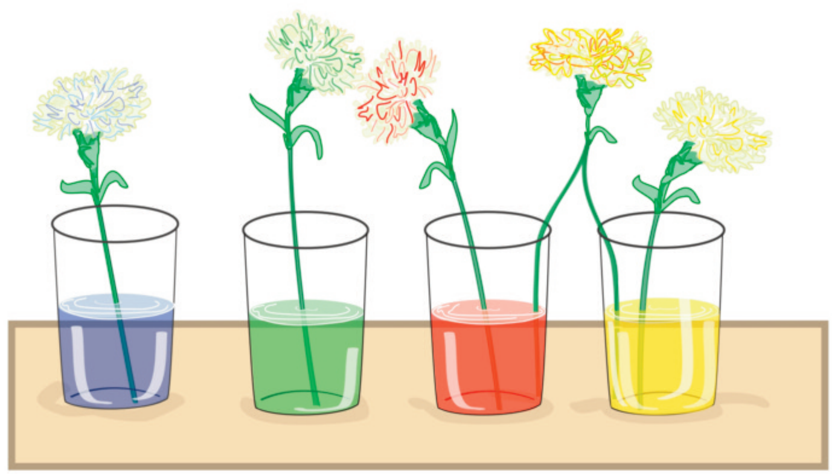
- Start with a discussion about what plants need to survive and grow. What do they need from their environment? How do these things get from the external environment into the plant itself? Where have students seen these processes?
- Take students outside and ask them to examine a plant of their choosing. What structures do they see? What might these structures do for the plant? They can draw a picture and write their ideas. Once inside the classroom, provide an example of a flower with intact roots so they can see the entire plant structure. This can lead into a discussion about the function of each plant part and how it relates to the ability of a plant to grow, survive, and reproduce.
- Show students examples of dyed flowers from a local shop. How do they think those colors and patterns were made?
- Before the experiment, take a Bounty® paper towel and hold the bottom of it in a cup of water. Have the students watch as water rises up the paper towel. Ask your students if they know how this is possible. Discuss how water can rise up against the force of gravity. Most will know that the water is being absorbed by the paper towel, but they may not know that it is because of capillary action. The water adheres to the fibers in the paper towel and climbs up the paper towel, pulling other water molecules upward as well because of cohesion.

See the Elaborate section of this activity for more ideas to engage your students.

EXPLORE

Procedure:

1. Fill a cup hallway with water
2. Add 20-30 drops food coloring
3. Cut two inches from the bottom of the flower's stem
4. Place the flowers in the colored water
5. Wait several hours, or until the next day, then observe the results



DATA COLLECTION & ANALYSIS

Analyze and discuss the results of this activity using the following questions:

- Examine the flower structures closely. What do you notice about the stem? The petals? The leaves? Write your observations.
- Draw a picture of the flower at the start of the experiment and make a prediction as to what you think will happen!
- Draw a picture or take photos at the middle and end of the experiment. What changes do you notice?
- At the end of the experiment, closely examine the bottom of the stem again. Use a hand lens to look closer. What do you see? Does this help to explain what happened to the flower?

EXPLAIN

Notes

What's happening in this Activity?

First review the Chemistry of Life & Earth Sciences Background section to gain a deeper understanding of the scientific principles behind this activity.

Both plants and animals have specific needs that must be met for them to survive. For animals like humans, we need food, water, air, and more. Similarly, plants need food and water to survive. But without being able to move to get the nourishment they need, how can a plant survive? And where do their water and nutrients come from?

One of the most important things plants need to survive is water. Plants can absorb some water through their leaves, but most of the water a plant gets is through the soil using its roots. The soil also contains nutrients the plant needs, which are often dissolved in this water. But how does a plant bring water from the soil all the way up to the branches, leaves, and flowers?

The secret lies within the properties of water and the microscopic structures inside the plant. As we know from the Surface Tension Activity Guides, water has properties similar to other liquids, but also some properties that are unique. Like other liquids, water particles exhibit cohesion. **Cohesion** is the attractive force between two like particles in a liquid. In a sample of water, each H_2O molecule is attracted to the other H_2O molecules nearby, making them tend to stick together. **Surface tension** is a property of liquids that describes the attraction of liquid molecules at the surface. Molecules at the surface of the liquid are more strongly attracted to one another than molecules in the liquid. This brings the surface molecules closer together and creates a surface "film." As a result, moving an object through the surface of a liquid is more difficult than moving the object when it is completely submerged in the liquid.

Another property of liquids is **adhesion**, which is the attractive force between two unlike particles. For example, a water molecule (H_2O) is attracted to the tissue of a plant, which is made of different molecules. Water molecules not only stick together – especially at the water's surface – but they also stick to other surrounding molecules, even if they are different.

A final property of liquids that explains how water moves through a plant is capillarity, or **capillary action**. Capillary action is the movement of liquid upwards through a narrow tube and against the downward force of gravity. Capillary action is possible due to adhesion and cohesion. Plant tissues attract water molecules through adhesion. When one molecule moves, the water molecules around it follow because they stick together due to cohesion. Adhesion between water and the plant tissue and cohesion between water molecules pull the water molecules up from the roots all the way through the furthest leaves and flowers on the plant.

The structure inside a plant that carries water and dissolved nutrients up from the soil is called the **xylem**. The xylem runs vertically like a long tube from the bottom to the top of a plant, and also provides structural support to keep the plant upright. You can think of it like a hose: when water is running through it the hose is stiff and can maintain its shape, but when the water is off the hose is deflated. Similarly, a plant that does not have enough water in the xylem will appear wilted, and when it has enough water the plant will stand upright again .

In this activity, we can watch water moving through a plant by first dyeing the water. The petals change color because water moves from the space surrounding the plant and into the roots or stem, and then all the way up to the petals through the processes of adhesion, cohesion, and capillary action.

EXPLAIN continued

But how does water get all the way to the top of the plant – especially in trees hundreds of feet tall? The process that pulls the water to the top of the plant is called **transpiration**. This is when water evaporates from the plant leaves, and as it evaporates it creates suction pressure in its place. It is almost like sucking water through a straw: as the sun heats the earth, its energy warms plant leaves. Liquid water in the leaves evaporates into a gas, exits the plant, and goes into the air. The loss of water from the leaves creates a kind of vacuum, pulling up more water to replace what was lost. This water is pulled up through the xylem, from the roots, and originally from the soil itself!

Differentiation for Younger or More Advanced Students

You can differentiate this activity for students of different grade levels by focusing on the concepts outlined below.

GETTING STARTED

For younger students, emphasize the following concepts:

- Plants need water to survive.
- Plants get water from the soil using their roots and stems.
- Plants have internal structures to transport water and nutrients.

DIVING DEEPER

For more advanced students, emphasize the following concepts:

- Plants have internal structures called xylems, which are tubes that transport water throughout the system.
- Capillary action helps water move through a plant using the forces of adhesion and cohesion (surface tension).

ELABORATE

Elaborate on your students' new ideas and encourage them to apply them to different situations. The section below provides some alternative methods, modifications, and extensions for this activity.

- Try an array of colors by setting up multiple carnations in water dyed different colors.
- Don't have carnations? This experiment can be done with many plants, such as other flowers, cabbage leaves, stalks of celery, or lettuce. Try different examples and see what works best!
- Does the concentration of food coloring or the color of the dye matter? Try the experiment with different amounts of food coloring, or with different colors, to see which works the best. Be sure to only test one variable at a time!
- To dye one carnation's petals two different colors, use a knife or scissor to split the stem lengthwise into two halves until it is around 2-3 inches from the top of the stem. Place each half of the stem in a separate colored water solution (you might have to tape the stems to the cups to keep them in place). Or, after you cut the stem in half, put one half in plain water and the other in colored water.
- Ask students how they would add a control to the experiment. What part of the procedure would they change? Would it still be placed in water? Should they still add food coloring?
- How quickly does water move through a plant? If you are able to do frequent checks, set up a timer and note when you first see color in the petals. Or, set up a camera and record a video or take pictures throughout the next few days. Are there other factors that affect how quickly water moves through a plant? See if it varies based on stem length, thickness, the type of flower or plant, and more!
- After the experiment, cut the stems and see if students can find the xylems (hint: they should be colored!). A hand lens might help, and if you take a thin enough cross-section you can examine it under a microscope.
- Will other colored liquids work for this experiment? Try juices or different types of dyes and see what works the best!
- Watch the CEF staff demonstrate this experiment here (and be sure to watch until the end!).

CHEMISTRY IN ACTION

Share the following real-world connections with your students to demonstrate how chemistry is all around us.

Real-World Applications

Capillary action explains why we often water the roots of a plant, not the leaves. The leaves can take in some water, but the roots and stems are the best vehicles to get water into a plant.

Some plants that might appear to have plain, simple designs to the human eye actually have elaborate markings that can only been seen on the ultraviolet light spectrum. Many insects that act as pollinators can see ultraviolet light, and plants use these designs to attract pollinators to their flowers!

Careers in Chemistry

- Over certain holidays flowers are dyed unusual, bright colors. Florists have a number of techniques and dyes to help them safely color flowers in exciting new ways.
- Irrigation systems need to efficiently deliver just enough water to plants so they can grow, but not drown. It is also important to not waste any water and use only what is needed. There are hundreds of ways to build and design irrigation systems, many of which funnel water right to the base of a plant so it can be taken up by the roots, instead of losing it to the air through evaporation.

Notes

EVALUATE

- Ask students to draw a picture of a flower and indicate using arrows how water moves through the plant. Can they label each place the water goes? For more advanced learners: can they label the parts?
- Have students conduct a writing exercise about what they learned in this experiment. They could create a poem, comic, series of social media posts, or write a story about what processes are occurring within the plant.
- Is there anything similar about the ways that plants get water and the way that humans get water? Have students do some research on their own to learn about the system humans use to transport nutrients.

Fun Fact #2

The largest single flower in the world is Rafflesia arnoldii, which is a rare flower found in Indonesia. The flower bloom can be up to three feet across and weigh 15 pounds! This plant is also a parasite, so instead of getting its own water and nutrients, it grows attached to other plants and steals what it needs from its host. This flower also emits a foul odor that people claim smells like rotting meat, which attracts pollinators like flies .

Dew Drops

Section **THE CHEMISTRY OF LIFE & EARTH SCIENCES**

Estimated Time Setup: 5-10 minutes; Procedure: 15-20 minutes

OVERVIEW

Make condensation appear both on the inside and outside of a glass.

In this activity, students fill a jar first with hot water, then cold water. Depending on the temperature of the water, condensation – in the form of beads of water or fog – will appear either on the inside or outside of the glass. This activity demonstrates water changing states based on temperature and explains why we see drops of dew outside in the morning!

MATERIALS

For one setup:

- Clear glass jar with lid
- Ice
- Hot and cold water

INQUIRY QUESTIONS

Getting Started:

- What are the states of matter and how do we describe them?

Learning More:

- How can matter change between states, and what are these processes called?

Diving Deeper:

- How does energy and particle motion relate to states of matter and changes in states of matter?

CONTENT TOPICS

This activity covers the following content topics: states of matter, physical changes, condensation, vaporization, atomic structure, energy, temperature, heat

This activity can be extended to discuss: water collection methods, sublimation, deposition, photosynthesis, plant structure and functions, animal behavior, dew point, weather, climate, intermolecular attraction, hydrogen bonding

NGSS CONNECTIONS

This activity can be used to achieve the following Performance Expectations of the Next Generation Science Standards:

- **2-PS1-4:** Construct an argument with evidence that some changes caused by heating or cooling can be reversed and some cannot.
- **5-PS1-1:** Develop a model to describe that matter is made of particles too small to be seen.
- **MS-PS1-4:** Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

ACTIVITY NOTES

This activity is good for:

- Pairs
- Small groups
- Large groups
- Demonstrations

Safety Tips & Reminders:

- If you are having trouble getting the experiment to work, try it in a humid environment like a kitchen or bathroom.
- Do not use boiling hot water for this activity, as it can melt the plastic cup.
- Review the Safety First section in the Resource Guide for additional information

Fun Fact #1

Dew can be a powerful resource for farming in arid climates. If the dew can be trapped and collected, it can be used to water plants and even as drinking water!

ENGAGE

Use the following ideas to engage your students in learning about the chemistry of life and Earth sciences::

- If it is early enough in the day, take students outside to a grassy area. Why do they think the grass is wet if it did not rain? Where does the moisture come from? Why do we only see it in the morning? If you are meeting with students later in the day, you can start by asking them if they have noticed this phenomenon or show pictures of it to spark their memories and a discussion.
- To engage prior learning, start with The Moving Molecule Stomp Activity Guide to show how particle motion changes between states and as energy changes occur.
- Show pictures of common example of condensation, such as beads of water on containers left outside, water pooling on a table around a glass of ice water or fogged up mirrors and windows. When have students noticed these phenomena in everyday life? Can they explain what is happening ?

See the Elaborate section of this activity for more ideas to engage your students.

EXPLORE

Procedure:

1. Fill jar halfway with hot water.
2. Put a lid on the jar, then place it on a table and observe.
3. Next, pour the water out of the jar and dry completely.
4. Fill jar halfway with cold water and ice cubes.
5. Put a lid on the jar, then place it on a table and observe.

DATA COLLECTION & ANALYSIS

Analyze and discuss the results of this activity using the following questions:

- Draw diagrams of water as a solid, liquid, and gas. What does each look like and what is different? At which temperature would you find each example?
- Make a prediction: what will happen when you fill the jar with hot water? What about ice water? Why?
- Draw a picture and describe what you see when the jar is filled with hot water and when the jar is filled with ice water. Is each similar or different from your predictions?

Notes

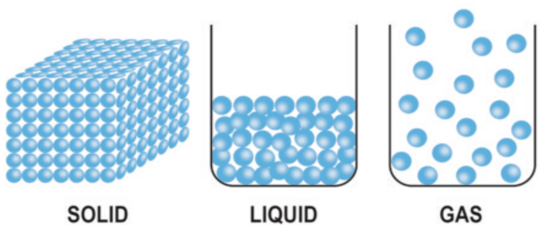
EXPLAIN

What's happening in this Activity?

First review the Chemistry of Life & Earth Sciences Background section to gain a deeper understanding of the scientific principles behind this activity.

All matter on earth exists in three forms: solid, liquid, or gas. Each state of matter has its own properties:

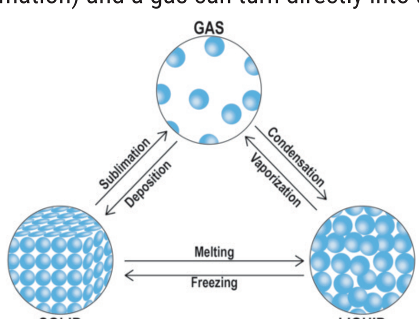
- **Solids** have defined shape and volume. In a solid, particles are vibrating in place and at their lowest energy state. Examples of solids are ice cubes, wood, and steel.
- **Liquids** have a defined volume but no defined shape; they take the shape of the container they are in. In a liquid, molecules have more energy than in a solid, they move faster, and flow around one another. Examples of liquids are water, juice, and oil.
- **Gases** do not have a defined volume or shape. Gas particles have more energy than particles in a liquid, and they move in all directions at high speed. Examples of gases are oxygen, helium, and water vapor.



Matter can change from one state to another when it gains or loses energy. For example, when water molecules (comprised of two hydrogen atoms and an oxygen atom – H_2O) have the least amount of energy and are at a low temperature, they are a solid: ice. As more energy is added to the ice – for example, if the ice is heated – the molecules gain energy and move more freely. Once the molecules have enough energy to break free of the bonds holding them tightly in solid form, the ice becomes liquid, which we know as water. If more heat is added, the liquid water eventually turns to gaseous water vapor, which we call steam. Water easily moves between states from a solid, to a liquid, and finally to a gas as heat is added and the H_2O molecules gain energy to move more freely, faster, and further from one another.

The reverse process of a gas becoming a liquid and then a solid is also possible. As energy is removed, such as through cooling processes like refrigeration or freezing, the H2O molecules slow down and move closer together. When water vapor gas is cooled it becomes liquid water, and if the liquid water is cooled further it becomes solid ice once more.

There is a specific name given to each phase change. When a solid becomes a liquid we call it melting, and when a liquid becomes a gas that is evaporation (also known as either boiling or vaporization). For the reverse processes, when a gas becomes a liquid that is condensation, and when a liquid becomes a solid that is freezing. In rare cases, a solid can directly into a gas (sublimation) and a gas can turn directly into a solid (deposition).



Notes

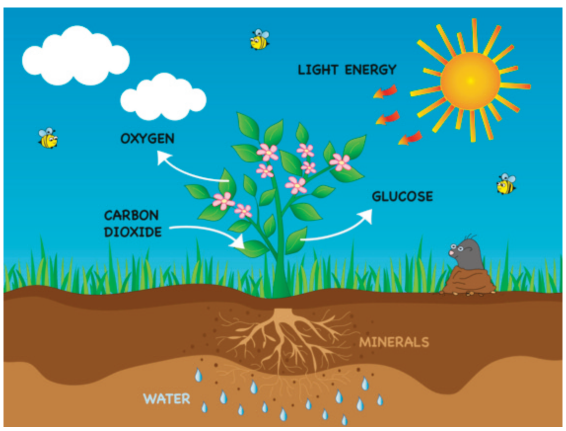
EXPLAIN continued

In this activity, when there is hot water in the jar, the inside of the glass fogs up. This happens because the hot water releases water vapor (steam) and warms the water vapor already in the air in the glass. Those warm water vapor molecules move around the inside of the jar, and when they touch the room-temperature glass they get colder and condense from a gas to a liquid. As the water vapor condenses, it loses energy to the colder glass. The fog you see in the jar is the liquid water droplets forming as water vapor cools.

In the next phase, ice water is put into the jar. This time, you will see droplets of water forming on the outside of the jar. The ice water inside the jar cools the glass, so when warmer water molecules in the air touch the glass they condense into liquid on the outside of the cup.

If you are an early riser, you have likely experienced this phenomenon already! When the sun goes down at night and the environment cools, water vapor in the air condenses into liquid. We see this in the morning as **dew** on surfaces outside. If you live in an area that gets cold, you will see this as **frost**. As the sun comes up and provides energy through heat, the dew usually evaporates and becomes water vapor in the air, and the frost usually melts.

In places that do not get a lot of rain, the formation of dew is important because it allows plants and animals to access liquid water they need to survive. For example, in desert climates plants are known to use fog or dew as sources of water for **photosynthesis**, which is the chemical process that a plant uses to make sugars .



Differentiation for Younger or More Advanced Students

You can differentiate this activity for students of different grade levels by focusing on the concepts outlined below.

GETTING STARTED	DIVING DEEPER
For younger students, emphasize the following concepts: • Matter exists in three states: solid, liquid, and gas. • Each state of matter has its own properties. • Matter can change between the states due to changes in energy, such as heat.	**For more advanced students, emphasize the following concepts:** • Particles in each state of matter behave differently. • As energy is added or removed from a system, matter changes state as particles gain or lose energy.

ELABORATE

Elaborate on your students' new ideas and encourage them to apply them to different situations. The section below provides some alternative methods, modifications, and extensions for this activity.

- Set up the activity with the hot water and ice water jars at the same time so students can compare the results side-by-side
- Try the experiment with different containers: metal cans, plastic bottles, paper cups – whatever you can find! Which worked best and why?
- Connect this experiment to learning about other types of moisture that are found in the environment, including humidity, rain, snow, sleet, glaze, hail, clouds, and much more!

Fun Fact #2

Rain occurs when water vapor in the air condenses from a gas, back into a liquid form, and leaves the atmosphere, returning to the surface of the Earth in a process known as the water cycle.

CHEMISTRY IN ACTION

Share the following real-world connections with your students to demonstrate how chemistry is all around us.

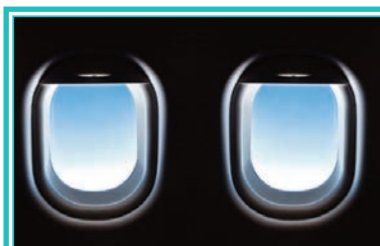
Real-World Applications

Have you ever blown air onto a mirror or window to fog it up? When you do this, water vapor on your breath is condensing on the cool mirror or window surface! The same process happens in homes and buildings. On cold days water droplets might form on the inside of the windows, and on warm days if the air conditioning is water droplets might form on the outside.

Have you ever followed the path of an airplane through the sky by watching its trail? These trails are a type of cloud called a cirrus cloud. They are formed when jet exhaust from the plane encounters cold air in the sky, condenses into water droplets, and then freezes to form ice crystals.

Careers in Chemistry

- Car manufacturers have to build systems that quickly and efficiently remove moisture from car windows, since they can impair a driver's vision on the road. Car defrosters perform a variety of functions: some warm the window to evaporate moisture and remove ice, others pass dehumidified cold air that can absorb moisture from the windows.
- Sick of your cold drinks "sweating" on your tables? Double-walled cups have been designed to keep the outside of the cup at room temperature, so no condensation forms. The double wall also acts as an insulator, which keeps your hands from getting too cold or hot while enjoying your drink!
- Have you ever been on a plane and noticed the tiny "breather hole" in the window? Aerospace engineers and window manufactures have included this feature has a number of purposes: it equalizes the pressure between the cabin and the air gap between the window panes, and it also releases moisture to keep your view free of frost or fog!



EVALUATE

- Provide a scenario to students: they come home and notice that there is a glass of room-temperature water on the table, and it is sitting in a small pool of water. What do they think happened? Why? Which part of the experiment is similar to this scenario?
- Explore where condensation forms in the local community. Ask students to keep a science journal for the week and note every instance of condensation they see in their environment, either in human made or natural objects. At the end of the week they can share their findings with the class. Did anything surprise them? Where was condensation frequently found? Where was it never found? Why do they think that is?
- Can students draw the three states of water and name the processes of changing between states? See how far they can get from memory, and provide clues as needed. For more advanced learners: can they draw how particles are arranged and show their motion? Where is energy being added, and where is it being removed?

Fun Fact #3

When you take a hot shower, the mirror or bathroom window usually gets foggy. The "fog" is actually condensed water vapor.

Hold the Salt

Section **THE CHEMISTRY OF LIFE & EARTH SCIENCES**

Estimated Time Setup: 10 minutes; Procedure: 4+ hours

OVERVIEW

Transform saltwater into pure drinking water using knowledge of separation techniques, states of matter, and physical changes.

In this activity, students create their own solar sill: a low-cost device that can be used to purify water. Through their understanding of how water can change from liquid to gas and back again, and how mixtures can be separated through the process of distillation, students engineer their own solution to the problem of dirty drinking water.

INQUIRY QUESTIONS

Getting Started:

- Where do we find fresh water on Earth, and how is this water used by humans, and other plants and animals? What are the problems with other sources of water that make them unusable?

Learning More:

- What physical or chemical properties can be used to separate a saltwater solution into water and salt?

Diving Deeper:

- How can a sample of saltwater be purified into fresh water through distillation?

CONTENT TOPICS

This activity covers the following content topics: states of matter, physical changes, condensation, vaporization, mixtures, solution, separation techniques, distillation, desalinization

This activity can be extended to discuss: human impact on the environment, fresh water scarcity, water purification methods, water cycle, precipitation, pollution, physical properties, intermolecular attraction, solutions

NGSS CONNECTIONS

This activity can be used to achieve the following Performance Expectations of the Next Generation Science Standards:

- **K-PS3-1:** Make observations to determine the effect of sunlight on Earth's surface.
- **2-PS1-4:** Construct an argument with evidence that some changes caused by heating or cooling can be reserved and some cannot.
- **MS-PS1-4:** Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.
- **MS-ESS2-4:** Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.

MATERIALS

For one setup:

- Large bowl
- Heavy glass cup (shorter than the bowl)
- Teaspoon
- Clear plastic food wrap
- 1 coin
- Clear cellophane tape
- Food coloring - blue
- Spoon
- Water
- 3 tablespoons table salt
- Ruler

Optional materials:

- Dry erase marker

ACTIVITY NOTES

This activity is good for:

- Small groups
- Large groups
- Demonstrations

Safety Tips & Reminders:

- Even though the product of this experiment is clean water, we do not recommend drinking it since the equipment might not be sterilized beforehand.
- Review the Safety First section in the Resource Guide for additional information

Fun Fact #1

About 6,800 gallons of water are required to grow a day's worth of food for a family of four!

ENGAGE

Use the following ideas to engage your students in learning about the chemistry of life and Earth sciences::

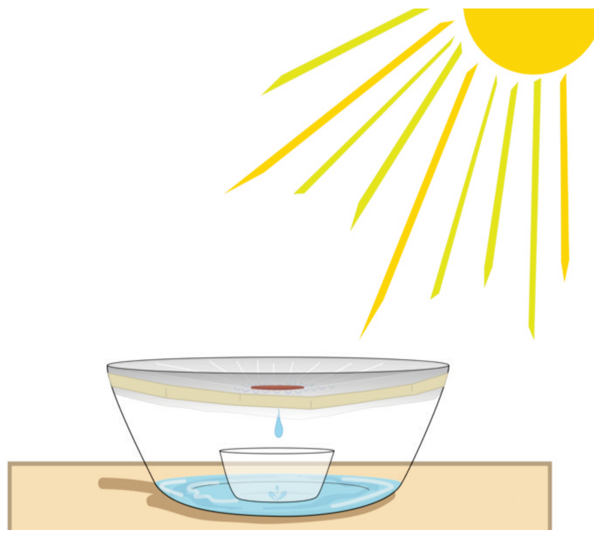
- Start with a problem: how would students get fresh water if they were stranded at sea and surrounded by only salt water? Or what if they were lost in the desert? Students can brainstorm strategies in groups and share with the class before trying the activity.
- Make this activity into an engineering task! Pose the problem of how to make pure water from saltwater, and provide the materials listed here, along with any others you have available to add more of a challenge and diversity to the solutions. Lead students through the Engineering Design Process to ensure they tackle the problem like a real-life engineer would.
- Begin the lesson with a deep dive into the challenge of humans' high demand for freshwater, including local activities and industries that require this resource (i.e. farming, drinking, plumbing in homes, etc.). Discuss how water is unequally distributed around the world, largely inaccessible, expensive to source, energy-intensive to clean, and how pollution makes even our natural freshwater systems unusable at times. Students can conduct their own local research into this problem, and this activity can be used as an example of a simple, low-cost way to get pure water.
- This activity can be connected to learning about the water cycle, since this is a small, simple way to represent the processes of vaporization and condensation in a closed system.

See the Elaborate section of this activity for more ideas to engage your students.

EXPLORE

Procedure:

1. Pour water into a bowl to a depth of around 5 cm. Either write down the depth or mark it on the bowl using tape or a dry erase marker.
2. Add 10 drops of blue food coloring and 2-3 teaspoons of salt. Mix until the salt dissolves.
3. Place the glass cup in the center of the bowl with the opening facing up, so the base is in the blue saltwater solution. (If the cup floats try to find a heavier cup or put something in the cup to weigh it down.)
4. Loosely cover the bowl with plastic wrap and tape it to the side of the bowl securely so no air can get in or out. The plastic wrap should not be pulled tight, but should sag slightly in the middle.
5. Place a coin on top of the plastic wrap, directly over the cup.
6. Put the bowl on a flat surface in a warm place, like near a windowsill, outside, or under a heat lamp.
7. Wait at least 4 hours, then observe the height of the water and see if there is anything in the cup.
8. Remove the plastic wrap and lift the cup out of the bowl to observe the results.



DATA COLLECTION & ANALYSIS

Analyze and discuss the results of this activity using the following questions:

- Describe the problem posed in this activity.
- Brainstorm some ways you might solve the problem posed in this activity. Draw or describe your thinking and solutions.
- Using the materials supplied, discuss with your group how you could build a device that would transform saltwater into pure water. After coming to a consensus, draw your idea and label the parts and their purpose. Or, if your educator has shown you one way to do this, describe how you think it will work.
- After a few hours or the next day, describe what you notice in the device that was built. Did you successfully make pure water? How do you know? If not, what might have gone wrong?
- Describe or draw how you think water is made from saltwater in this experiment.

EXPLAIN

What's happening in this Activity?

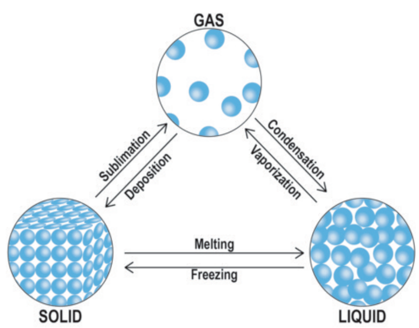
First review the Chemistry of Life & Earth Sciences Background section to gain a deeper understanding of the scientific principles behind this activity.

Plants and animals need fresh water to survive, but in many places fresh water is not easily available. Around 72% of the earth is covered in water, but 97% of that water is in our oceans. Ocean water is not pure water. It is mixed with many different substances, some of which—for example, salt—are unsafe to drink. We need some salt in out diet, but too much salt can dehydrate our cells and damage our kidneys and blood cells. To make ocean water safe to drink, we must purify it to remove the salt and other unsafe materials. Water in lakes, streams, and other bodies of water are also often mixed with unhealthy materials, and have to be treated to get clean, fresh water.

The combination of water and salt is a mixture. A **mixture** is two substances that are physically combined. The parts of a mixture retain their own properties, so they can be separated from one another based on differences in their physical or chemical properties. In this mixture, the solid salt is dissolved in the liquid water. Salt is very **soluble** in water, meaning that a lot of salt can be added to water and it will easily dissolve.

Distillation is the process by which a liquid is isolated based on its **boiling point**, which is the temperature at which it turns from a liquid to a gas. The phrase "distilled water" comes from this separation technique. As an example, when a mixture of water and other impurities – like salt – is heated, the liquid water will easily boil. As the water turns from liquid to gas, the water vapor gas produced is funneled through a tube. The tube then cools the water vapor, and it **condenses** back to liquid water in a separate container. With the water boiled and condensed into another container, eventually the only material left in the original container will be the solid impurities .

Water turns from liquid to gas at 100 °C. Salt takes a huge amount of energy to turn into a gas, and only does so at 1,413 °C! This means that if we take a solution of saltwater and let it warm in the sunlight, the water should easily vaporize over time and turn to gas, and the salt will remain behind. (Hint: remember phase changes between states of matter from the previous activity, Dew Drops!)



Now that we understand how pure water can vaporize from a solution, we have to find a way to turn the water back into a liquid again so it can be used. We seal our contraption so no water vapor escapes. When then water vapor touches the cool plastic wrap, it condenses into liquid water once more. Since the plastic wrap is weighed down in the middle over the cup, the water drops are directed right into the cup, where they can be collected and used!

Why is the water in the cup clear and not colored blue like it was originally? Food coloring also has a higher boiling point than water so more energy is needed to make it into a gas. Therefore, the water collected in this experiment should be pure H_2O – with no salt or coloring!

Notes

EXPLAIN continued

Any method that removes the salt from water is called **desalinization**. Desalinization is important for making pure water for human to use and drink. The contraption built in this experiment is a solar still. A solar still uses energy from the sun to heat and evaporate water, and then cools and collects the purified water vapor as a liquid. There are many types of solar stills and they are used around the world as a simple, low-cost way to obtain **potable** (drinkable) water.

Differentiation for Younger or More Advanced Students

You can differentiate this activity for students of different grade levels by focusing on the concepts outlined below.

GETTING STARTED	DIVING DEEPER
For younger students, emphasize the following concepts: • Matter can be found in three states: solid, liquid, or gas. As temperature changes, matter can change between these states. • A mixture can be separated into its components through different techniques.	**For more advanced students, emphasize the following concepts:** • A substance undergoes each phase change at a specific temperature, and substances can be identified based on these temperatures. • Distillation is a technique that separates liquids based on their boiling points.

ELABORATE

Elaborate on your students' new ideas and encourage them to apply them to different situations. The section below provides some alternative methods, modifications, and extensions for this activity.

- Does the type of bowl used affect the results? Try the experiment with a metal, glass, and plastic bowl. Which worked best? Why?
- Does the location of your experiment affect the results? What if it was done on concrete? Grass? Outdoors? Indoors? See where you get the best results!
- Can you distill water out of other solutions? Try juice, sodas, or anything else that contains water.
- As recommended in the Engage section, you can pose this as an engineering problem for students to solve. Alternatively, if they do the experiment first, see if they can optimize the design to get the most water in a 24-hour period.
- Lead a discussion about the real-world feasibility of using this type of device to purify water. What are the limitations? What are the benefits? Would this be something that could be adopted in your community? Why or why not?

Fun Fact #2

By 2025, the United Nations projects that 2/3 of the world's population will face water scarcity. Finding inexpensive, simple ways to produce and clean fresh water for a growing population is important.

CHEMISTRY IN ACTION

Share the following real-world connections with your students to demonstrate how chemistry is all around us.

Real-World Applications

On a very small scale, this activity also demonstrates how water moves through its natural cycle. Processes like condensation and evaporation happen on a large scale, along with other complex phenomena which cause the weather and earth formations we see in the world around us .

Solar stills can be used on land and in the water to get water through natural processes of evaporation and condensation.

Careers in Chemistry

- Food chemists perform distillation on a massive scale to ensure they are working with the purest, safest products, and also to isolate specific liquids from a mixture. When oil is refined, it also goes through a process of distillation to separate the crude oil into its components for use .
- Techniques like the one used in this experiment are useful in areas of the world without infrastructure for plumbing, sufficient rainfall to provide drinking water, or dependable power sources. Low-tech ways to get clean water and food are also useful for people who do adventure sports or travel to remote areas of the world. There are many companies that sell inexpensive products to generate portable water using the power of the sun.

Notes

EVALUATE

- What changes in state occurred during this experiment and how? Ask students to write a report of what happened in this experiment using their new vocabulary words, such as evaporation, condensation, liquid, gas, desalinization, mixture, and more!
- There are many solar still designs, and even more devices for desalinization. Task students with researching a desalinization device either on their own or in pairs. What are the pros and cons of the system? How does it purify water? Where can we find it? Is it sustainable?
- If students are familiar with other separation techniques (hint: check out the Separations Techniques Activity Guide set!), provide a complex mixture for them to separate. What techniques would they use? Is a perfect separation possible? Students can write or draw their solutions, or test them out.

Iron in Cereal

Section **THE CHEMISTRY OF LIFE & EARTH SCIENCES**

Estimated Time Setup: 5 minutes; Procedure: 5-10 minutes

OVERVIEW

Separate iron from iron-enriched foods using a magnet!

In this activity, students learn about an essential part of our diet: iron. Through a simple separation process, they extract iron from cereal using a magnet. They can learn about the properties of metals and why some metals are intentionally added to foods to help us live healthier lives.

INQUIRY QUESTIONS

Getting Started:
- What things are added to our foods to make us healthier?

Learning More:
- What is the role of iron in our diets and where can we find iron-rich foods?

Diving Deeper:
- What body processes use iron and how?

CONTENT TOPICS

This activity covers the following content topics: properties of matter, elements, compounds, mixtures, forces, magnetism, food chemistry, chemistry of the human body, health, properties of metals

This activity can be extended to discuss: anemia, sickle cell disease, circulatory system, nutrition, periodic table of elements, hemoglobin

NGSS CONNECTIONS

This activity can be used to achieve the following Performance Expectations of the Next Generation Science Standards:
- K-LS1-1. Use observations to describe patterns of what plants and animals (including humans) need to survive.
- 5-PS1-3. Make observations and measurements to identify materials based on their properties.
- MS-LS1-7. Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.

MATERIALS

For one setup:
- Breakfast cereal with high iron content
- Bowl
- Large spoon
- Strong magnet or magnetic wand
- Plastic bag with zipper (quart size or larger)
- Water

ACTIVITY NOTES

This activity is good for:
- Pairs
- Small groups
- Large groups
- Demonstrations

Safety Tips & Reminders:
- Review the Safety First section in the Resource Guide for additional information

Fun Fact **#1**

Iron-rich hemoglobin gives blood its red color. But not all animals have red blood! Octopuses have blue blood from copper-rich hemocyanin – which is their version of hemoglobin. Some fish have clear blood, and skinks (a type of lizard) have green blood !

ENGAGE

Use the following ideas to engage your students in learning about the chemistry of life and Earth sciences::

- Provide examples of several foods that are "enriched with iron" or something similar. Ask students if they know what this means, and why we might want extra iron in our food. Can they name anything else that iron is used for? Is it safe to eat? What do they know about this topic already?
- Cut out nutrition labels and lead a discussion about the items on the labels that students might not be familiar with. How many of the things listed on the nutrition label can they find on the periodic table?
- Start with a deep dive into iron: what do students know about iron already? Where is iron found on the periodic table? What is it used for? How much iron is recommended in our diets each day? Do they know the foods that contain iron?
- Explore a case study about a student who is feeling tired and has low energy. Provide students with some clues to figure out what might be wrong with the student. They can examine the student's diet, behavior, exercise routines, home life, etc. and try to pinpoint what might be wrong. They should be able to narrow it down to anemia, which is due to low iron in the diet. You can then explore this activity to learn about foods that are enriched with iron, and foods that naturally have iron.

See the Elaborate section of this activity for more ideas to engage your students.

EXPLORE

Procedure:

1. In a bowl, crush 2 cups of cereal using your hands or a large spoon.
2. Pour the crushed cereal into a plastic bag.
3. Fill the plastic bag with water to about 1 inch below the seal, then seal the bag.
4. Wait a few minutes for the cereal to soften.
5. Gently shake the bag for a few minutes.
6. Hold the magnet in the palm of your hand and place the bag horizontally on top. (Or, work in pairs and have one person hold the magnet while the other places the bag on top.)
7. Gently swirl the bag for 30 seconds with the magnet still underneath it.
8. With the magnet still pressed to the bag, gently turn the bag over so the magnet is now on top.
9. Look closely and record your observations.

DATA COLLECTION & ANALYSIS

Analyze and discuss the results of this activity using the following questions:

- Look closely at the cereal at the start of the experiment. What physical properties do you notice? Can you see the iron?
- Based on the nutrition label, how much iron would you expect to find in a serving of cereal? Make an estimate of how much you will find in this experiment.
- Carefully remove the iron from the bag using the magnet. Weigh the iron and record your results. Compare these results to the amount of iron in each serving of cereal.
- At the end of the activity, describe what you see. Draw a picture of the iron. What physical properties do you notice?

EXPLAIN

What's happening in this Activity?

First review the Chemistry of Life & Earth Sciences Background section to gain a deeper understanding of the scientific principles behind this activity.

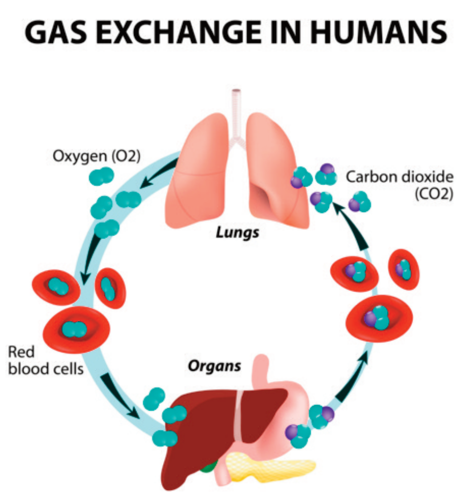
Humans need a variety of vitamins, minerals, and elements in our diet to stay healthy. One such essential piece of our diet is iron. Iron, Fe, is element 26 on the periodic table of elements:

An **element** is a pure substance that cannot be broken down any further. Elements are the building blocks for all the matter in our world. Over half of the elements, includes iron, are metals. **Metals** are grouped together because they have many properties in common, like those below. **Non-metal** elements also have a specific set of properties, as shown in the table below:

Metals	Non-Metals
Shiny	Not shiny
Good conductor of heat	Poor conductor of heat
Good conductor of electricity	Poor conductor of electricity
Malleable	Not malleable
Ductile	Not ductile

Iron is also one of the most abundant metals on Earth. About 5.6% of the earth's crust is made of iron, and the core of the earth is molten (liquid) iron. We use iron to make magnets, pots, pans, steel, and for many engineering and manufacturing processes.

Humans also need iron in our daily diet, and the average human naturally contains around four grams of iron! Iron is used by the protein **hemoglobin**, which is in our red blood cells. Hemoglobin transports oxygen (O_2) around the body, first picking it up from the air we breathe into our lungs, and then transporting it to the tissues and organs around the body. Hemoglobin picks carbon dioxide (CO_2) up in the body, then returns it to the lungs where we exhale it out as waste .



Iron is also needed for a variety of other body processes, including enzyme reactions, protein synthesis, and more. Humans need around 10-18 milligrams of iron each day. Without enough iron in the body, we cannot effectively transport oxygen and maintain dozens of other essential body functions. Many foods naturally contain iron, such as dark leafy greens, egg yolks, and red meat. Some foods have iron added in, such as certain cereals and grains. Eating vitamin C along with iron-rich foods helps the body to absorb as much iron as possible.

EXPLAIN continued

Since iron-enriched foods are **mixtures**, the parts of the mixture can be separated using their different properties. The pure iron in cereal is magnetic, meaning it is attracted to magnets. **Magnetism** is a force that can either pull objects together or push them apart, even if the objects aren't touching. Only some metals are magnetic, including iron, nickel, and cobalt. Since the iron is magnetic, but the other parts of the cereal are not, we can remove the iron using its attraction to another magnet. To learn more about magnetism, check out the Forces & Interactions Activity Guide section.

Differentiation for Younger or More Advanced Students

You can differentiate this activity for students of different grade levels by focusing on the concepts outlined below.

GETTING STARTED	DIVING DEEPER
For younger students, emphasize the following concepts: • Humans need a variety of elements, vitamins, and minerals in our food to stay healthy. • Iron can be found in many foods naturally and is added to some cereals and grains. • Iron is an element and a metal.	**For more advanced students, emphasize the following concepts:** • Iron is needed to help transport oxygen around the body. • Iron is an essential part of hemoglobin, which is the protein that carried oxygen and carbon dioxide in red blood cells. • Iron can be separated from foods it is added into through magnetism.

Notes

ELABORATE

Elaborate on your students' new ideas and encourage them to apply them to different situations. The section below provides some alternative methods, modifications, and extensions for this activity.

- Having trouble getting results? Try using a stronger magnet, crush the cereal into finer pieces using a blender first, or find a cereal that has 100% the daily recommended serving of iron per cup!
- This experiment can also be done without a bag. Instead, crush the cereal and add water to a large bowl. Attach the magnet to the end of a ruler, rod, or use a magnetic wand. Dip the magnet into the mixture and move it slowly back and forth. Then remove the magnet, gently dip it into a cup or bowl of clean water to wash away any cereal pieces, then observe.
- If there is iron in cereal, is the cereal itself magnetic? Try passing a magnet over the cereal before crushing it. Does this work? Why or why not? (Hint: think of how small the pieces of iron are and how big and heavy the flakes are!)
- Which cereal has the most iron? Test a variety of cereals or grains – or any other foods that claim to be enriched with iron. Which sample has the most iron? Are your results reflected in the nutritional label? Be sure to control for as many variables as possible, such as using the same amount of cereal and water.
- Weigh your results to determine exactly how much iron you extracted! Or, before the experiment have each student make an estimate as to the amount of iron they will be able to extract per serving size based on the nutrition label.
- If you have access to a blender, try using that to break up the cereal. With finer cereal particles you might be able to extract more iron from.

CHEMISTRY IN ACTION

Share the following real-world connections with your students to demonstrate how chemistry is all around us.

Real-World Applications

Many iron-rich foods are meats or animal products, so people on vegetarian or vegan diets need to make sure they get enough iron from other sources, such as other iron-rich foods or by taking supplement iron and vitamin C, which helps the body absorb iron. Without enough iron in the body, a person can't carry oxygen to parts of the body that need it, making them excessively tired and short of breath. This is called anemia. Luckily this condition can be easily avoided by eating iron-rich foods or taking supplemental iron and vitamin C.

The iron added to our food is different from the iron found in things like nails. The iron in your breakfast cereal is food-grade iron, which is a form of iron that can be readily absorbed by the body and is safe for consumption.

Iron metal is formed inside the core of stars in space. When a star creates iron, it uses so much energy that the star begins to implode. When the star eventually collapses and explodes, iron is scattered into space and eventually forms meteorites that fall down to planets like Earth.

Careers in Chemistry

- Pharmacists are tasked with developing dietary supplements for important things like iron. They must make sure supplements can be easily administered, are at proper dosages, and can be easily absorbed by the body without any negative side effects.
- Nutritionists make recommendations based on data and experiments about how much iron people need to consume. These recommendations depend on someone's age, sex, lifestyle, diet, and many other factors. Nutritionists also need to be the experts on which foods contain which nutrients so they can advise their patients .
- Part of a food chemist's job is make their products healthier, such as by adding in substances like iron that are necessary for a healthy diet.

EVALUATE

- Ask students to make a list of things they notice are added to their food to keep them healthy. They can look at food packaging at home, in the local grocery store, or online. Are there common items they notice added to certain products? If they don't know what each of these items does or what they look like, create a research project so they can learn more and share their findings with their peers.
- Task students with determining how much cereal they would have to eat each day to get the daily recommended amount of iron. First have them look up the recommendations, then using the nutrition label or the results from their experiment, how much cereal would they have to eat to satisfy that requirement? They should show their thinking and calculations.
- Where else is iron found in our world – especially in our food? Ask students to bring in samples of different foods they think might be enriched with iron and try the experiment again in groups. They can record their results as a class and see what patterns they observe.
- Have students research other nutrients commonly added to food and present their results to their peers, including how much of the nutrient humans need each day, in what food products it can be found naturally or as an additive, and what happens if we do not get enough (or too much!) of this nutrient. See if students can think of ways to separate different kinds of nutrients from food using physical properties.