

# Cool It!

*Description: Students make a refrigerator that works without electricity.*

*Learning Objectives: Students will learn about evaporative cooling and how it is used in ancient and modern technology.*

## SCIENCE TOPICS

Transfer of Energy  
Evaporation  
The Water Cycle

## PROCESS SKILLS

Measuring  
Analyzing and  
Presenting Data  
Making Observations

## GRADE LEVEL

6

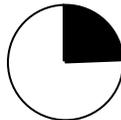
## TIME REQUIRED

### Advance Preparation



**20 minutes**

### Set Up



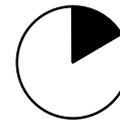
**15 minutes**

### Activity



**1 Hour**

### Clean Up



**10 minutes**

Note: While the experiment takes 1 hour, the bulk of that time is waiting for results. Setting up the experiment requires about 10 minutes and analyzing the results requires about 5 minutes. Since the experiment has a wait time of 45 minutes, plan an activity to fill that space. Many of the optional extensions or cross-curricular extensions fit well into this timeframe.

## SUPPLIES

### Each student or group of students will need:

- 2 large clay pots (flower pots work well)
- 2 clay pots small enough to fit in the larger pots with some space between them
- Sand or fine gravel
- 2 pieces of cloth large enough to cover the large pots (Make sure they're both the same type. Felt, cotton, and canvas work well.)
- 2 small containers with lids that can fit in the small pot (Baby food jars or film canisters work well.)
- Plastic bottles (Water bottles with pop-up lids work well.)

- Water
- 2 small pieces of cardboard or cardstock
- Two thermometers
- Scissors
- Materials to photocopy: Student Background and Student Procedure (1 per group)
- Optional: One or two fans for the class

## ADVANCE PREPARATION

---

- Before doing the activity with the class, follow the procedure to practice the activity.
- Fill water containers (plastic squeeze bottles with a pop top work well to minimize spills).
- Find an area where the pots can sit undisturbed for about an hour (either outside or inside the classroom with a fan directed over them).

## SET UP

---

- Assemble the materials for student use.

## INTRODUCING THE ACTIVITY

---

*Let students speculate before offering answers to any questions. The answers at the right are provided primarily for the teacher's benefit.*

Ask the students the following questions in **bold**. Possible student answers are shown in *italics*.

**What are some of the ways to cool something off?**

*Put it in the refrigerator.*

*Bring it to the North Pole.*

*Put it in a cooler with ice.*

**How did people keep food cool before refrigerators when there was no ice available?**

*Bury it underground.*

*Keep it in shade.*

**How do our bodies cool off on hot days or after strenuous activity?**

*Swimming.*

*By sweating.*

*Going to the mall/movie theatre (being in air conditioning).*

**What happens to sweat or the water on us after swimming that makes it cool us off?**

*The wind blows on it.*

*It evaporates.*

## SCIENCE BACKGROUND

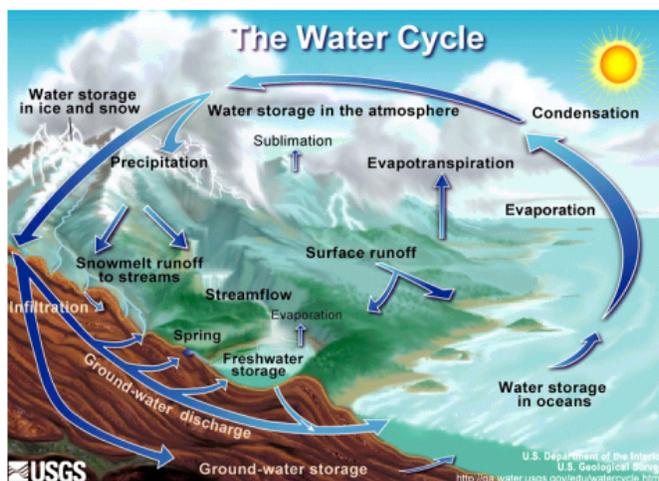
The following is background information on a separate page for students to read before doing the activity or while they are waiting.

### Cool It!

Ever wonder why people sweat? It makes us sticky and smelly, but sweat helps us maintain a constant body temperature by cooling us off when we overheat. It does this through **evaporation**.

Evaporation is the process of a liquid turning into a gas. The opposite of evaporation is **condensation**, the process of a gas turning into a liquid. In nature, evaporation and condensation are key parts of the **water cycle**.

Water evaporates into the atmosphere from all the oceans, rivers, and lakes around the world. The vapor then condenses into clouds and rain, and returns to oceans, rivers and lakes to continue the process.



## TEACHER DEMONSTRATION

You may want to model the activity by creating your own clay pot refrigerator. Having a pre-made example available to show students what the final model looks like is helpful.

The *Cloud Jar* activity listed in the optional extensions also works well as a demonstration.

## CLASSROOM ACTIVITY

*Students should work in groups of two or four.*

Each group will assemble two pots—one control and one test. Monitor students to make sure they pour water into the sand of only the test pots. The control pots should remain dry. Also, make certain they have covered the test pot with a wet cloth and the control pot with a dry cloth.

Students will see a greater change in temperatures if they do not uncover the pots during the wait period. Removing the cloth is the equivalent of leaving the refrigerator door open. They may notice that the temperature in the control pot has dropped a small amount. This is due to a small amount of moisture already in the clay and sand.

If you decide to run the experiment for a longer period of time, you may need to add more water to the sand in the test pot.

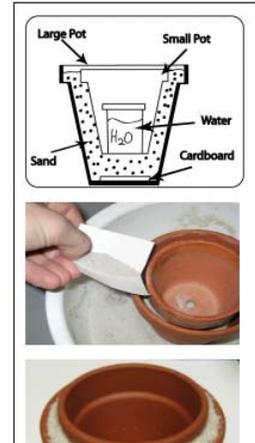
### Student Procedure: Cool It!

#### 1 Prepare the coolers.

- Cover the holes in the bottom of the large pots with the small pieces of cardboard.
- Fill the bottom of the large pots with a layer of sand.
- Put the small pots into the center of the large pots.
- Fill the space between the small and large pots with sand. A creased piece of cardboard makes a nice scoop.

#### 2 Prepare the samples.

- Fill both small containers with room temperature water.
- Use the thermometers to measure the starting temperature of the water. Record the temperatures.
- Secure the lids on the small containers and place one into each small pot.



## CLASS DISCUSSION

*Ask for student observations. Let students guide the discussion and present their hypotheses before discussing explanations.*

Ask the students the following questions in **bold**. Possible student answers are shown in *italics*.

### **Which pot-in-pot cooled the water more? Why?**

*The wet cloth and sand allowed evaporation to cool off the pot-in-pot.*

*The control pot was dry, could not be cooled by evaporation.*

### **Why was it important to have the pots in a dry, windy place or in front of the fan?**

*The wind helps increase the amount of evaporation from the wet sand.*

### **In what types of climates would this technology be most useful?**

*Arid climates such as deserts have the driest air. Dry air can evaporate more water.*

### **How might changes in evaporation affect the planet's climate?**

*It would affect the amount of moisture in the air, altering the water cycle.*

*More or less evaporation would cause water in oceans, rivers, or lakes to become cooler or warmer.*

## **EXPLANATION**

*In-depth background information for teachers and interested students.*

### **Evaporation—The Fundamental Principle of Clay Pot Refrigerators**

Matter can exist in three states, solid, liquid, and gas. Evaporation is the process of a liquid changing into a gas. Fast-moving molecules near the surface of a liquid have enough kinetic energy to escape the liquid, evaporating into a gaseous state. (A similar process can happen when going from a solid state directly into a gas. This process is called sublimation. In sublimation the solid never passes through the liquid state before it becomes a gas. Dry ice is an example of carbon dioxide sublimating from a solid into a gas.)

Higher temperatures give molecules more energy and make evaporation easier. When the fast-moving molecules escape a liquid and evaporate, the molecules left behind are the ones with less energy. The liquid cools off because the most energetic molecules leave. This process is called evaporative cooling.

Condensation, when a gas turns into a liquid, is the opposite of evaporation. This occurs when a vapor is cooled. The molecules in the gas slow down and form droplets of liquid. When this happens, a small amount of heat is transferred from the new droplets of liquid to their surroundings.

The water cycle is a continuous process of evaporation and condensation in the Earth's waterways and atmosphere. Water (mostly from the tropical oceans) evaporates into the atmosphere, where it condenses to form clouds and rain. This process helps regulate the Earth's climate and creates a circulation in the atmosphere and ocean currents.

### **History and Refrigeration**

Refrigeration helps people keep food safer and helps food last for longer periods of time. Since ancient times, people have used ice and snow to keep food cool. The "icebox" was exactly that, a wooden box with a metal lining and a place to store a large block of ice. Block ice was a major export of New England through the late 19<sup>th</sup> century. But in areas where block ice was unavailable, a different method needed to be developed. Ancient Egyptians and Indians used evaporative cooling from clay pots as far back as 1000 BCE. By leaving the pots

outside on cold nights and keeping them wet, they could actually make ice in the desert. Romans also used evaporative cooling by forcing slaves to fan clay jugs to keep them cool.

With the rise of electric appliances, the icebox and clay pot coolers became obsolete in most of the world. The exception is areas where there is no ice or electricity available. The American Amish have used this principle to create water coolers that work without electricity, and, in 2002, a man named Mohammed Bah Abba won a Rolex Award for Enterprise for re-introducing pot-in-pot technology to farming communities in Nigeria. The pot-in-pot system allows farmers to store their produce for weeks before selling or consuming it.

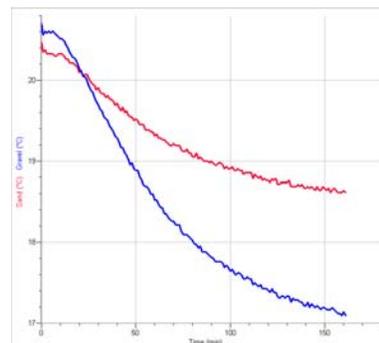
## OPTIONAL EXTENSIONS

### Extension A—Scientific Inquiry Variations

There are many variables your students can explore to improve upon the design of the pot-in-pot.

#### Procedure:

- Increase the time of the experiment to several hours. Take temperature readings every 30 minutes to track the changes over time.
- Gravel, rice, or another medium can be used instead of sand. Students can also experiment with different types of pots or cloths.
- Soak the small pots in water overnight. Try the experiment without the large pots or sand.
- Vary the position or speed of the fan to determine the effect wind has on temperature, or conduct the experiment outside and collect data on different weather conditions.
- Use electronic probes to record the temperatures throughout the experiments. The graph at right was produced using a Vernier LabPro and stainless steel temperature probes.



*Sand vs. Gravel over 3 hours*

### Extension B—Making a Sling Psychrometer

A sling psychrometer is a device with two thermometers. One dry-bulb thermometer gives the air temperature, while one wet-bulb thermometer shows how much evaporative cooling can take place. By entering the data collected with this instrument and a barometer into an equation, meteorologists can determine the relative humidity. See Student Procedure Extension B.

**Each student or group of students will need:**

- Two classroom thermometers
- String or twine, about 36" long
- A small piece of cardboard or folded paper
- An elastic band
- A small piece of cloth, a piece of cotton t-shirt works well
- A few drops of water
- Materials to photocopy: Master A, Student Procedure Extension B

**Extension C—Cloud Jar**

This demonstrates how water vapor in the air condenses around small particles to form clouds.

**You will need:**

- A wide-mouth glass jar, about one gallon (large pickle jars or water jugs work well)
- A rubber or latex cleaning or dishwashing glove
- A book of matches
- A few tablespoons of water



**Procedure:**

- Pour a bit of water into the jar, so that the bottom is just covered.
- Place the glove so that its fingers are inside the jar, then stretch the open end over the jar's opening.
- Reach into the glove and pull it in and out several times (keeping it stretched over the mouth of the jar) to show that there is no visible change.
- Remove the glove, drop a lit match into the jar then replace the glove. The match will burn out.
- When you pull the glove out, it will fill the jar with fog. The fog will disperse when you release the glove back into the jar.



**Explanation:** The jar is filled with a small amount of invisible water vapor. When the glove is pulled outward, the volume increases and the air inside expands. Expansion uses up some thermal energy and slows down the molecules moving inside the jar, cooling the air. This causes the water vapor to condense. The small amount of smoke from the match gives the vapor tiny particles to condense on, creating visible fog. Pushing the glove back in decreases the volume and increases the temperature, causing the water droplets to evaporate and become invisible again.

## CROSS-CURRICULAR CONNECTIONS

<b>SUBJECT</b>	<b>Activity</b>
<b>VISUAL ARTS</b>	Draw a picture or diagram of a Water Cycle.
<b>CREATIVE WRITING</b>	Write a journal entry from the point of view of a Sub-Saharan farmer who uses pot-in-pot refrigeration.
<b>MATHEMATICS</b>	Make a graph illustrating the data collected in the experiment.
<b>DRAMA</b>	Create a short play demonstrating the value of a pot-in-pot refrigerator to rural farmers.
<b>SOCIAL STUDIES</b>	Collect news about the conflict in Darfur, where the refrigerators are commonly used.  Research the way local native people preserved food before electricity.

## RESOURCES

<http://www.noaa.gov/>

The webpage of the National Oceanic & Atmospheric Administration gives information on local atmospheric conditions such as humidity, barometric pressure, and wind speed.

<http://www.srh.noaa.gov/elp/wxcalc/wxcalc.html>

Students can enter their sling psychrometer data into a weather calculator to find relative humidity.

[http://www.rolexawards.com/laureates/laureate-6-bah\\_abba.html](http://www.rolexawards.com/laureates/laureate-6-bah_abba.html)

<http://www.scienceinafrica.co.za/2004/september/refrigeration.htm>

Articles about the re-introduction of pot-in-pot refrigerators in Sub-Saharan Africa.

<http://www.piec.com/page3.htm>

A company that produces “swamp coolers” describes how they harness evaporative cooling.

## GLOSSARY

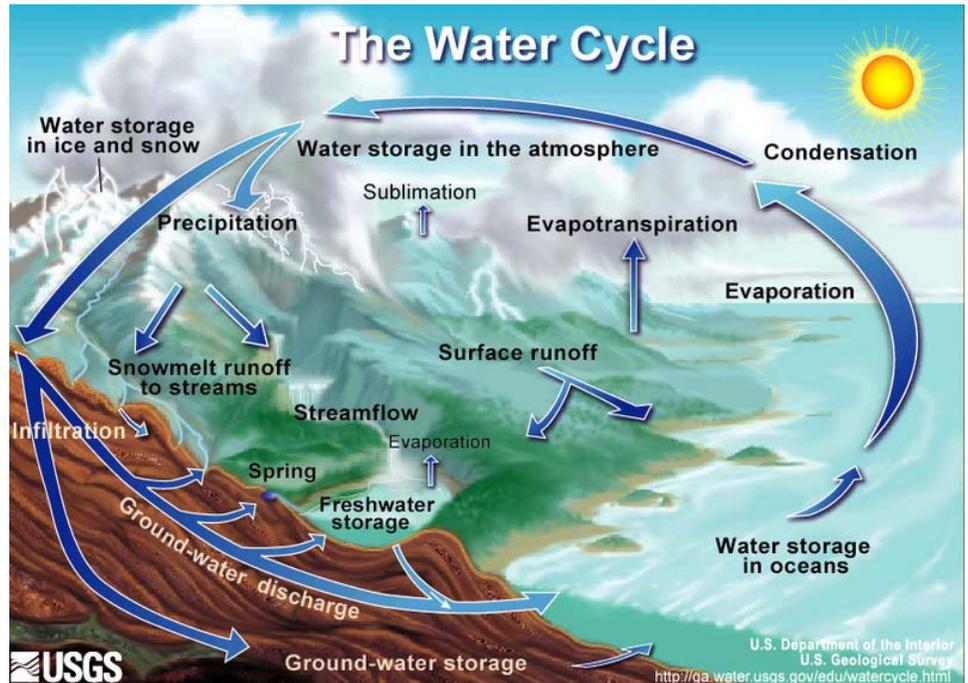
---

- Arid:** A very dry region, like a desert.
- BCE:** Before Common Era. The Common Era (CE), sometimes known as the Current Era, is the period of measured time beginning with the year 1 to the present.
- Condensation:** The process of a vapor becoming a liquid.
- Dew point:** The temperature at which water will condense on a slick surface, indicating 100% relative humidity, or saturation. Dry-bulb and wet-bulb temperatures will be equal.
- Energy:** How much work it takes to do something.
- Evaporation:** The process of a liquid becoming a vapor.
- Evaporative cooling:** A process where heat is removed from an object by the evaporation of a liquid.
- Dry-bulb temperature:** The ambient air temperature taken with a thermometer.
- Humidity, Relative:** The percentage of water vapor in the air compared to how much water the air could hold. A relative humidity of 100% means the air is saturated and can hold no more water vapor.
- Perspiration:** The process of secreting a saline fluid through sweat glands, which serves as a method of excretion and temperature regulation.
- Precipitation:** The process of water falling to the earth in the form of rain, sleet, snow, or hail.
- Pot-in-pot refrigerators:** An evaporative cooling technology used for thousands of years.
- Saturation:** When something is filled to capacity. In meteorology, air is saturated when the relative humidity is 100%. Evaporation can no longer take place.
- Water cycle:** The natural cycle of evaporation, condensation, and precipitation that creates most of Earth's weather.
- Wet-bulb temperature:** The lowest temperature air can reach through evaporative cooling, measured using a psychrometer.

# Cool It!

Ever wonder why people sweat? It makes us sticky and smelly, but sweat helps us maintain a constant body temperature by cooling us off when we overheat. Sweat does this through **evaporation**.

Evaporation is the process of a liquid turning into a gas. The opposite of evaporation is **condensation**, the process of a gas turning into a liquid. In nature, evaporation and condensation are key parts of the **water cycle**. Water evaporates into the atmosphere from all of the oceans, rivers, and lakes around the world. The vapor then condenses into clouds and rain and returns to oceans, rivers, and lakes to continue the process.



Evaporation depends on several factors: surface area, temperature, humidity, and wind.

- A greater surface area means there are more water molecules able to escape into the air. A wide, shallow puddle will evaporate faster than the same amount of water in a narrow, deep puddle.
- High temperatures mean molecules have more **energy**, so evaporation occurs more quickly.
- Humidity is the measure of water already in the air. If the air is already saturated with moisture, there is no room for more to evaporate.
- Wind or moving air keeps the humidity low and allows more evaporation

Most mammals, including people, use **perspiration**, or sweat, to help keep the right body temperature. This is how we cool down when we are hot or have exercised. If an animal has sweat glands, the skin will produce sweat if the animal's temperature rises above normal. The sweat evaporates, cooling the animal. It takes energy to change a liquid into a gas. The energy is in the form of heat. During evaporation, the molecules at the surface "bounce away" into the atmosphere. When they do, they take some of the heat (energy) with them,

leaving the skin a little cooler. This process is called **evaporative cooling**. Even animals that don't sweat can use evaporative cooling by getting wet. Animals that don't sweat can get wet by going into a swamp or a river. Some animals hang their wet tongue out of their mouth to help them cool down.

People also use evaporative cooling as a technology. Archaeological evidence shows Ancient Egyptians, Indians, and Romans used the evaporation of water from clay pots to keep food and drinks cool as far back as 1000 BCE. On cold desert nights it was even possible to freeze small amounts of water. Clay **pot-in-pot refrigerators** are still used today by many farmers in Sub-Saharan Africa.

Many modern buildings also use "swamp coolers" instead of air conditioning. By circulating air through wet "dripping pads," air temperature can drop by about 20 degrees through evaporative cooling. These devices are especially popular in **arid** regions such as the American Southwest because they are energy efficient and add a small amount of moisture to the dry air.

# Student Procedure: Cool It!

## 1 Prepare the coolers.

- Cut a piece of cardboard about 2 in. by 2 in.
- Cover the holes in the bottom of the large pots with the small pieces of cardboard.
- Fill the bottom of the large pots with a layer of sand.
- Put the small pots into the center of the large pots.
- Fill the space between the small and large pots with sand. A creased piece of cardboard makes a nice scoop.

## 2 Prepare the samples.

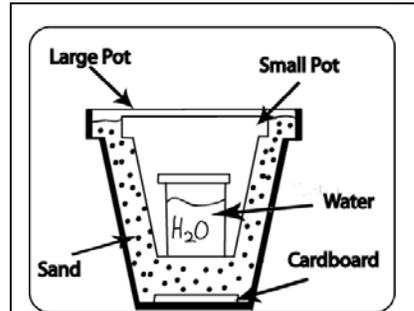
- Fill both small containers with room temperature water.
- Use the thermometers to measure the starting temperature of the water. Record the temperatures.
- Tightly place the lids on the small containers and place one into each small pot.

## 3 Conduct the experiment.

- Label one pot-in-pot “control.”
- Label the second pot-in-pot “test.”
- Cut two cloth pieces large enough to cover the tops of the larger pots. Use the same kind of cloth for both.
- Control Pot—cover with a dry piece of cloth.
- Test Pot—carefully pour water into the sand until it is very wet. Some water may leak out of the bottom. Cover with a wet piece of cloth.
- Place both pots in a dry and windy place. If it is raining or humid outside, this could be in the classroom with a fan.
- Wait 45 minutes.

## 4 Analyze the results.

- Measure the temperatures of the water in your test and control pots.
- Compare the change in water temperature in each.





# Student Procedure:

## Extension B

- 1 Tie the two thermometers together back-to-back with one end of the string.**
  - Make sure the knot is secure.
- 2 Place a piece of cardboard or a folded piece of paper between the two thermometers.**
  - Use an elastic band to hold it in place.
- 3 Carefully slide a small piece of cloth under the bulb of one thermometer.**
- 4 Begin the experiment.**
  - Record the starting temperature on each thermometer.
  - Wet the piece of cloth so that it is damp.
  - Avoid wetting the other thermometer.
- 5 Swing that thing!**
  - Find an area with a few feet of clear space around you.
  - Hold the end of the string securely.
  - Slowly begin swinging the thermometers in a circular motion—but not too fast!
- 6 After about a minute, STOP!**
  - Record the change in temperature on each thermometer.
  - Compare the two.

