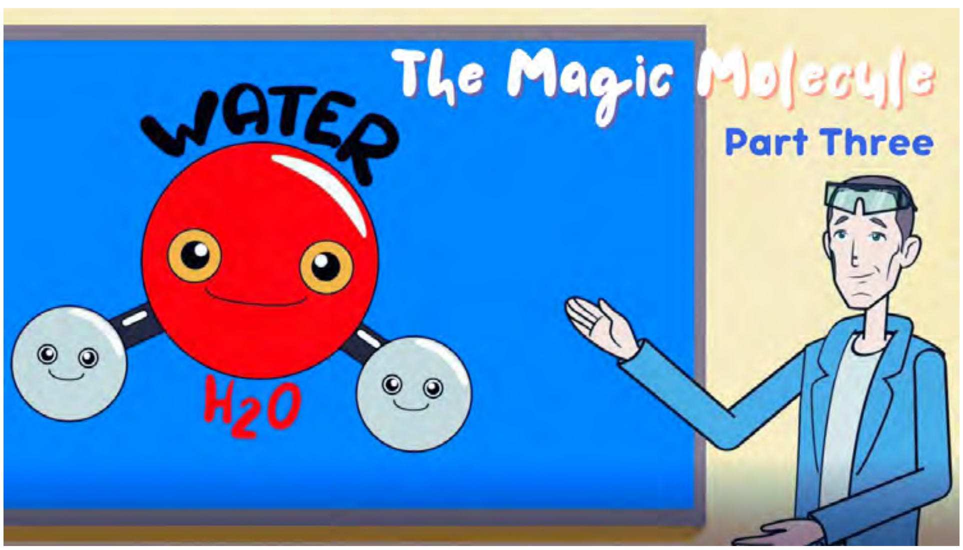
Video Six Lesson Plan

The Magic Molecule – Part 3



This lesson plan is a product of the CO_2 Learning Center project and the CO_2 Coalition

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A note about our lesson plans:

Our CO_2 Learning Center lesson plans all have the same format, which includes learning standards from the Next Generation Science Standards (NGSS), student learning objectives, background information on the science concepts covered in the book or video, suggested activities including labs to enrich the lesson and reinforce use of the scientific method, and formative and summative questions.

This lesson plan was created by the CO_2 Coalition's Senior Education Advisor Sharon Camp, Ph.D. Analytical Chemistry; B.S., Geology, using Next Generation Science Standards (NGSS).

The NGSS are the standards on which most public-school systems have based their curriculum. We do not necessarily endorse the NGSS but have included the relevant standards for circumstances in which a teacher is required to use them. The lesson plans contain everything that a teacher might be required to submit in a formal lesson plan to a school administrator or science department head.

Understanding NGSS:

LS: Life Science

PS: Physical Science

ES: Earth Science

1-5 indicates standard for grade level (1-first grade, 2-second grade, 3-third grade, 4-fourth grade, 5-fifth grade)

Please note that only the parts of the outline that are relevant to this lesson have been included. If LS1.C *and* PS3.D *(example from this lesson) are shown, these NGSS segments were included as relevant to this lesson for Life Science and Physical Science.*

Lesson Plan: Video Six

Grades K-8

Student Learning Goals

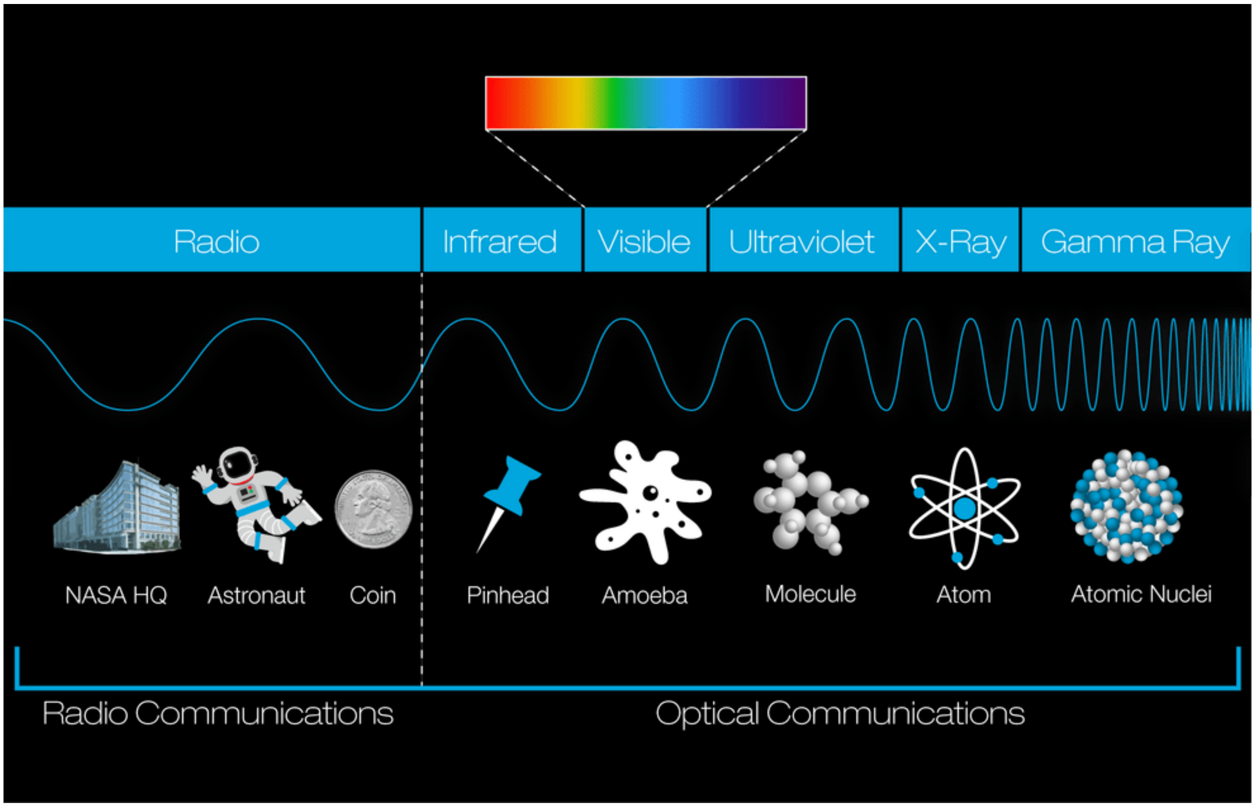
After watching the video, students will be able to:

- Define electromagnetic radiation and give three examples.
- Explain what thermal radiation is.
- Explain how energy flows from the Earth's surface to water vapor molecules by conduction.
- Explain how convection transfers heat from the Earth's surface to higher elevations.
- Explain how water vapor heats the air during the day.
- Explain why water vapor slows down cooling at night.
- Explain how the evaporation of water over oceans can drive convection in the atmosphere.

Background Information

The properties of water that were discussed in Videos 4 and 5 are necessary to understand the lesson from Video 6.

The sun is the source of almost all the energy on the surface of Earth. This energy travels through space in the form of waves and is known as electromagnetic radiation. Just as visible light occurs as a spectrum that is most easily seen as a rainbow, all forms of radiation from the sun occur on a spectrum.[1]



Source: https://www.nasa.gov/directorates/somd/space-communications-navigation-program/spectrum-overview/

The Earth's atmosphere blocks most of the wavelengths, but most radio waves and all visible light rays pass through. Energies below ultraviolet radiation wavelengths are harmless to humans, whereas energies with ultraviolet wavelengths and above cause damage to tissues and can cause cancer or even death.

Infrared radiation, also known as thermal energy, is part of the electromagnetic spectrum. Special cameras have been developed that are used to take thermal photographs and for night vision goggles. People and other living things give off infrared radiation, as well as buildings or other objects that release heat.

Source: David Skinner, CC BY 2.0 <https://creativecommons.org/licenses/by/2.0>, via Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Leicester_Square,_London,_in_Thermal_Infrared_(27652936141).jpg

Notice in the picture above that the dog, the man, the trees, the pavement, the buildings, the other people and the bench they are sitting on all are visible because all of them give off heat or thermal energy. Not only do our bodies give off thermal radiation because of our metabolism, but they can also absorb visible heat from the sun, which warms us.

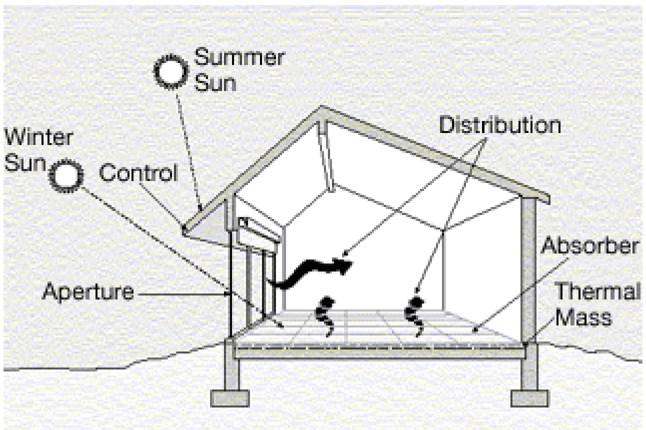
As discussed in a previous lesson, energy can be transferred in three ways: conduction, convection, and radiation.[2] The movement of energy through space is called radiation, and this is how the energy gets from the sun to the Earth. Dark colors absorb all frequencies of light and will warm faster than light colors, which will reflect most or all the frequencies. This is why dark colors warm us better in the winter than light colors.

Radiation from the sun also warms the surface of the Earth, and so objects on the Earth, such as rocks, plants, and soil, give off thermal energy. This heat energy is transferred to the air and water vapor above it by conduction, which is the transfer of heat by direct contact. Heat always moves from the warmer object into the colder object, so the warmer Earth will transfer thermal energy into the water vapor molecules. As the air and water vapor warm, the air will expand and become less dense. When this happens, the air will move upward because it is less dense than the cooler air above it. The thermal energy from the warm air then is transferred to the cooler air above it through a process called convection. Convection is the movement of a fluid caused by convection currents, which are defined as currents that form when a less dense fluid rises through a denser fluid. Lava lamps do a great job of demonstrating this concept.

Source: https://commons.wikimedia.org/wiki/File:Lava_lamp_blk.jpg

Water vapor, because it can absorb thermal energy, will get warmer and then transfer that warmth to the molecules around it. This process warms the air near the Earth's surface. Warm air is less dense than cool air and rises. Cool air, further away from the Earth's surface, is denser and falls. This rising and falling is called convection. Gases, however, do not act in the same way as solids and liquids when it comes to absorbing thermal radiation. Interestingly, the ability of a molecule to absorb thermal radiation depends on the symmetry of the molecule, and whether its symmetry can be changed by absorbing light from the sun. If the symmetry cannot be changed, as with nitrogen and oxygen, the molecule will not absorb energy. If the symmetry can be changed, such as with water and carbon dioxide, the molecule will be able to absorb energy. An excellent discussion of this property is discussed at the Athenas KSU website.[3] Water vapor absorbs thermal radiation from land sources through conduction and then transfers the energy to the rest of the air through convection. Water vapor can also absorb energy directly from the sun's light.

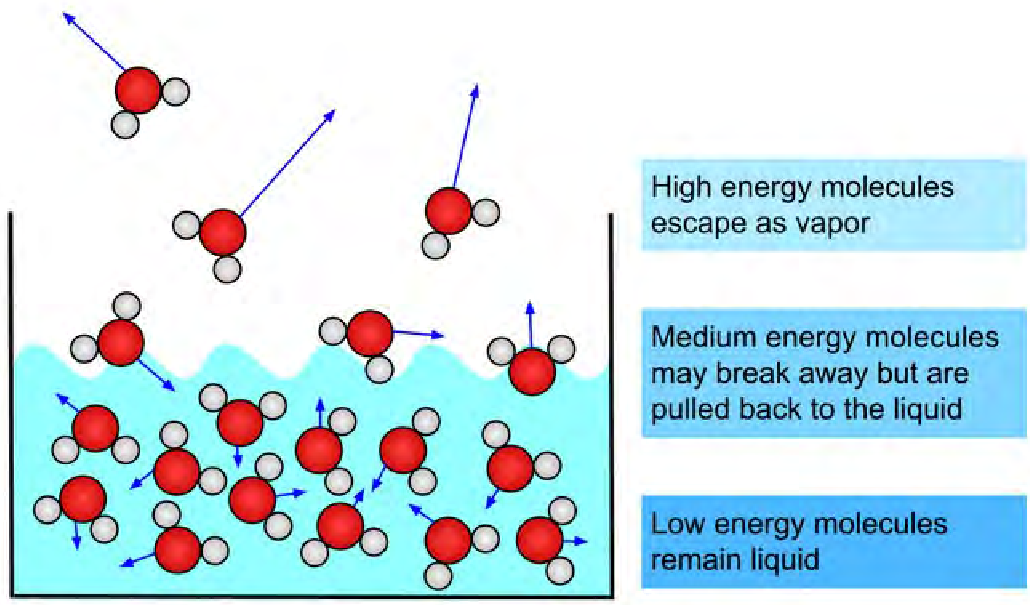
At night, the ground reradiates the heat it absorbed during the day back into the air. This can be easily experienced by simply touching concrete, rocks, or other solid objects after the sun goes down. They will still be warm to the touch and warmer than the surrounding air. (Remember heat is also called infrared or thermal radiation.) In fact, this principle is frequently used by architects when they are designing buildings with passive solar heating. The floor or a wall that gets sunlight from a south-facing window will warm during the day and release that heat, which warms the air, at night.[4]



Source: https://commons.wikimedia.org/wiki/File:Illust_passive_solar_d1.gif, http://www.eere.energy.gov, Public domain, via Wikimedia Commons

Water vapor in the air will reduce the rate of cooling because water vapor will reradiate the heat it absorbed during the day. (Water will absorb and radiate heat at the same time, but during the day the rate of absorption is greater than the rate at which the heat is reradiated. This rate is reversed at night.) The reradiated heat will slow heat loss, which is why areas that are humid stay warmer at night than areas that are dry, such as the desert. For example, two cities in the US that are about the same size are Marietta, GA and Carson City, NV. Marietta is located in a humid subtropical climate, whereas Carson City is located in a desert climate. During August 2023, when the absolute amount of water vapor in the air in both cities would be at its highest, Marietta averaged a daily high of 92°F and a low of 68°, which is a difference of 24°. Carson City had an average daily high of 87°F and a low of 57°F, which is a difference of 30°. The smaller difference between daytime and nighttime average temperatures was in the humid subtropical climate, where the high amount of water in the air reradiated more heat back to the ground than did the dry air of the high desert.[5]

Water at the ocean's surface evaporates. When the sun is high, especially in the summer in the northern hemisphere, the water molecules located on the surface absorb enough energy from the sun that they can break the surface tension and escape into the air. Because these molecules have absorbed energy, they are warmer than the air, and some of their thermal energy makes surrounding air molecules move faster, thus raising their temperature. Then the warmer air rises, forming a convection current.



Source: Hawesthoughts, CC0, via Wikimedia Commons,
https://commons.wikimedia.org/wiki/File:Evaporation.svg

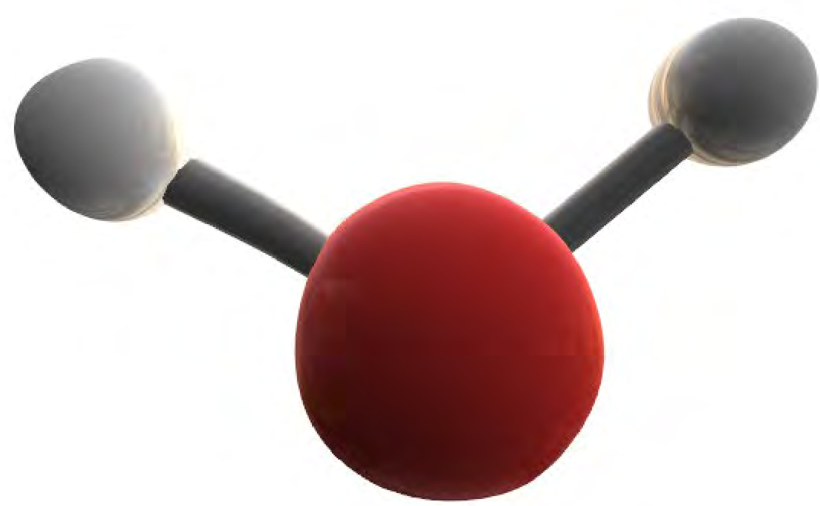
References

1. https://www.nasa.gov/directorates/somd/space-communications-navigation-program/spectrum-overview/
2. https://www.khanacademy.org/science/physics/thermodynamics/specific-heat-and-heat-transfer/v/thermal-conduction-convection-and-radiation
3. https://athenas.ksu.edu/climate-change/the-science-of-climate-change/greenhouse-effect/why-are-some-gases-called-greenhouse-gases#professional-development-for-educators
4. https://www.energy.gov/energysaver/passive-solar-homes
5. https://weather.com/weather/monthly/l/b9d90749e21fb6481956f6de70c26897159677dd8741075ba6be83da4e2e6e73

Suggested Activities

1. **Using Manipulatives as Models for Molecules:** It is often very useful to use models to represent molecules and how they can break apart and the elements be put back together to form different molecules. This can be easily accomplished by using beads, Legos or other items that connect interchangeably. For older students, using a separate color block for

each element can work well, or a molecular modeling kit can be used. If you prefer, you can use Styrofoam balls to represent the shape of the molecule more accurately. Find or paint balls in different colors to represent the elements and fasten them together with toothpicks. Have the students form CO_2 and H_2O molecules, then break them apart and recombine the elements to form glucose, which shows how carbon dioxide and water is used by the plant to make food. Glucose is a complicated molecule whose atoms are connected to form a circle. There are many pictures of models online that you can use for reference. For younger students, you may want to build a molecule model that they can look at.



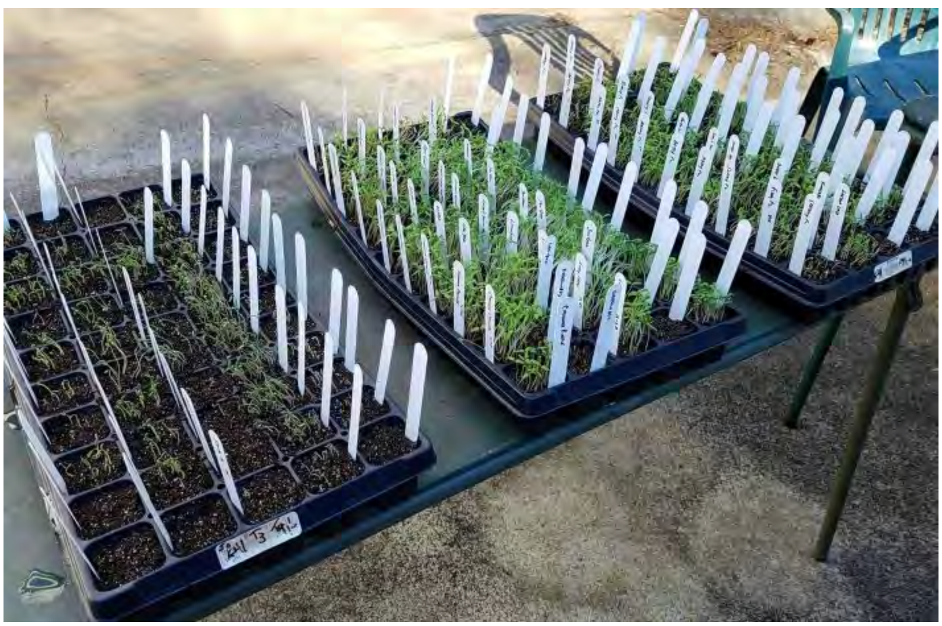
Source: Chemitorium, CC0, via Wikimedia Commons,
https://commons.wikimedia.org/wiki/File:Water_Molecule_3D_X_3.jpg

2. **Demonstrating that Plants Need Sunlight:** The easiest way to demonstrate the necessity of sunlight for plants is to grow seeds in a closed closet versus seeds grown in sunlight. Mung beans or lima beans sold in a garden store will germinate very quickly. The beans could be shallowly planted in a small pot or many seeds in a seed starting tray, or they could simply be put in a plastic bag with a damp paper towel. Each student can keep a daily log of observations to note differences in appearance and growth rate.

Materials: Seeds (mung bean or pole bean seeds germinate quickly and are large and easy to see; buy seed packets and not dried beans from the grocery store for best results), small pots or a seed starting tray, soilless seed starting medium or plastic bags with damp paper towels, popsicle sticks or other materials to label the plants with the student's name, a sunny windowsill or grow light, a dark closet or cabinet, journals for the students.

Procedure: *Students should hypothesize first what they expect to happen, and then see if their observations support or disprove their hypothesis.* Plants need sunlight to produce chlorophyll, so the seeds in the closet should have no pigment while the seeds in the light should have green shoots and leaves. If you want to allow the plants to grow for a longer period, pots would be better to use than plastic bags.

For seed starting tray: Each student should plant at least nine seeds (three per cell using three cells. When they start growing, leave the strongest seedling and remove the other two). If there is enough room, let each student have seeds in both the sun and the darkness. If not, split the class in half and let one half use sun and the other use darkness. The plants in the sun will act as the control group, and the seeds in darkness are the experimental group. First, make sure the seed starting mix is damp. If not, put the mix in a large bucket and add water until the soil is moist but not wet. This will ensure that the soil will absorb the water later when the seeds need water. Fill the cells three quarters of the way full, then have the students place their seeds carefully on the top and label the cells with their names using popsicle sticks or plant labels. Then go back and just barely put soil over the top of the seeds. (If they are planted too deeply, they will take longer to germinate or may not germinate at all.) Water carefully from the top with a spray bottle until the soil is moist but not soaking wet. Then put the seeds in either the sun or the closet. If a sunny window is not available, a grow light can be used. Grow lights have the specific wavelengths of light, primarily red, that are essential for photosynthesis and should be used instead of another kind of light.



Source: Photo: Craig LeHoullier, https://joegardener.com/podcast/037-starting-seeds-indoors-pt-1/

For plastic bags: Each student should have a plastic bag (or two, depending on whether they have seeds in both sun and darkness) with their name labeled on it. Each student also needs one paper towel per bag (use a high-quality absorbent paper towel). The towels should be completely wetted, squeezed dry (gently so that they don't break), folded, and placed inside the plastic bag. Take the seeds and place them carefully on top of the paper towel, seal the bag, and place it in either the sun or darkness. This method allows the students to see the development of the roots and shoots; however, the plant's development is not the focus of this activity necessarily.

Have the students write in their journals what their procedure was (as is age appropriate), including a drawing of what they saw. Let the students observe their seeds or seedlings and record their observations daily. This could continue for as long as 10 days, depending on germination rates (seeds will germinate more quickly in warmth, so a heating pad for seed starting could be used to speed up the process). After the data has been collected, let the students draw conclusions that directly respond to their hypothesis (whether or not sunlight is critical for the development of plants).

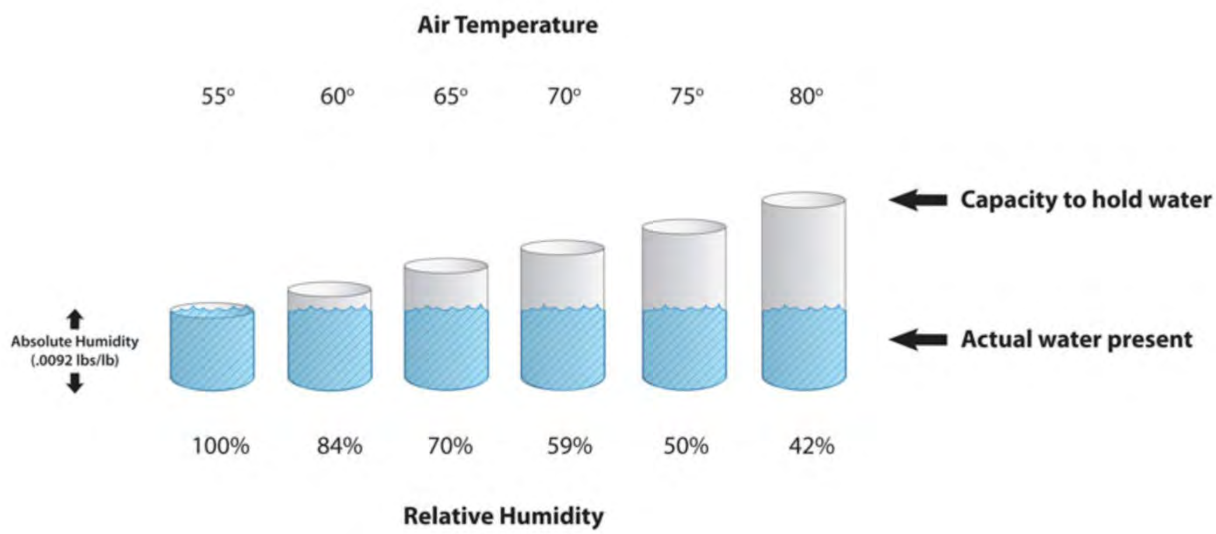
Source: https://www.mombrite.com/growing-beans-in-a-bag/

Sources: https://joegardener.com/podcast/037-starting-seeds-indoors-pt-1/
https://www.mombrite.com/growing-beans-in-a-bag/

3. **Comparing Temperatures:** Weather Underground (https://www.wunderground.com/) has archived temperature data that can be used to compare high and low temperatures for cities. In the US, Death Valley, CA is located in a desert climate and Yankeetown, FL is located in a tropical climate. Both cities have about the same population.

   Given the information provided in this lesson plan, it should be possible to write a hypothesis concerning how the high and low temperatures might be the same or different. After writing the hypothesis, go to Weather Underground and record the temperature data for daily high and low temperatures for four months (spring, summer, fall and winter), and determine the average high and low temperature for each city for each of the four months and compare. If desired, the averages can be plotted on a graph. Was the hypothesis supported? Why is it better to get averages for four months than to get the average for just a few days? If the hypothesis wasn't supported, why not? Was there an experimental error (math, etc.)?

4. **Absolute vs. Relative humidity:** Absolute humidity is a measurement of the actual amount of water vapor in a sample of air. It is not measured directly, but rather is calculated from other existing conditions such as temperature and the vapor pressure of water. Relative humidity is the amount of water in the air compared to how much water vapor it can hold at that temperature. Because air molecules move closer together as they cool, there is less space for water molecules to fit in. Air at higher temperatures can hold more water than air at lower temperatures. Whereas absolute humidity is measured in mass of water/volume of air, relative humidity is measured in percentages. If the relative humidity is 50%, that means that only half as much water is in the air as it can actually hold. A relative humidity of 100% means that no more water vapor can fit in the air, so it will condense out in the form of rain or fog.



Source: https://ceresgs.com/how-do-i-control-humidity-in-my-greenhouse/

Relative humidity can be easily measured by comparing the temperature measured by a dry thermometer with the temperature measured by a wet thermometer at the same time. These are called the dry bulb and wet bulb measurements.

Materials: Two Celsius thermometers with a temperature range between -5^o to 50^o, be marked in 1^o increments, and be alcohol filled. These thermometers can be found on Amazon (https://www.amazon.com/Laboratory-Thermometer-305MM-Scientific-Home/dp/B01ND4CARX/ref=sr_1_3?crid=FYNB9WE7YM6I&keywords=celsius+thermometer+science&qid=1702497314&sprefix=celcius+thermometer%2Caps%2C1005&sr=8-3); gauze, solid piece of wood or Styrofoam for mounting; rubber band or heavy thread; small fan; lab notebook.

Procedure: First, attach the two thermometers side by side on the board or stiff piece of Styrofoam. Make sure to fasten the thermometers securely so that they do not fall off the board and break. Next, attach a piece of gauze to one of the thermometers using the thread. Be sure to put enough gauze around the bulb of the thermometer so that it is completely covered. Wet the gauze thoroughly with water; this will be the “wet” bulb. Or, if using the wet-dry bulb hygrometer, add water to the well under the wet bulb.

In order to calculate the relative humidity, air needs to be moving over the thermometers. Set up the fan so that it is blowing directly on both thermometers. Then take readings on the thermometers at regular intervals, perhaps every 30 seconds. The dry thermometer temperature should remain the same, but the wet-bulb thermometer's temperature should decrease with time. When the wet-bulb temperature remains constant, record the two temperatures.

Once both the wet and dry temperatures have been determined, use the chart below to determine the relative humidity.

Dry Bulb Temperature (°C)	Temperature Difference (dry bulb – wet bulb, °C)									
	1	2	3	4	5	6	7	8	9	10
10	88	77	66	55	44	34	24	15	6	–
11	89	78	67	56	46	36	27	18	9	–
12	89	78	68	58	48	39	29	21	12	–
13	89	79	69	59	50	41	32	22	15	7
14	90	79	70	60	51	42	34	25	18	10
15	90	81	71	61	53	44	36	27	20	13
16	90	81	71	63	54	46	38	30	23	15
17	90	81	72	64	55	47	40	32	25	18
18	91	82	73	65	57	49	41	34	27	20
19	91	82	74	65	58	50	43	36	29	22
20	91	83	74	67	59	53	46	39	32	26
21	91	83	75	67	60	53	46	39	32	26
22	91	83	76	68	61	54	47	40	34	28
23	92	84	76	69	62	55	48	42	36	30
24	92	84	77	69	62	56	49	43	37	31
25	92	84	77	70	63	57	50	44	39	33

Source: Miami Museum of Science, 2000

If an online calculator is used, the barometric pressure is needed. This air pressure can be found by using https://www.wunderground.com/.

Critical Thinking: How would the relative humidity change in the bathroom while taking a shower? Devise a hypothesis and test it. Does using the fan (if present) in the bathroom affect the relative humidity during a shower? How could this be determined? Would the relative humidity change when a storm front moves through? Devise a hypothesis to answer this question and test it. How does relative humidity change from month to month? Devise a hypothesis and design an experiment to answer this question.

Source: https://www.sciencebuddies.org/science-fair-projects/project-ideas/Weather_p011/weather-atmosphere/make-your-own-psychrometer

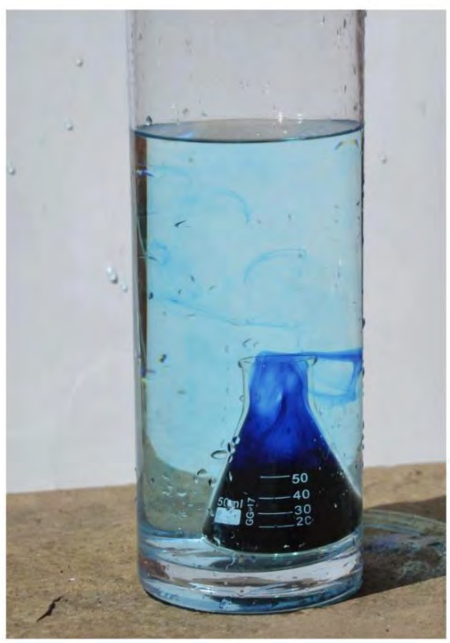
5. **Demonstrate that hot water rises but cold water doesn't:** Warm fluids, such as water and air, get less dense when they warm. When they are less dense than the fluid above them, they will rise while the denser fluid falls back down. This circular movement is called a convection current and occurs when there is uneven heating of a fluid (usually coming from the bottom). A lava lamp is an easy way to demonstrate a convection current, but how can a convection current in water be demonstrated? This is the focus of this activity.

Materials: tall clear glass or vase, small clear glass or other container that fits inside the larger one, hot water, cold water, red and blue food coloring.

Procedure: First ask the student(s) to describe what will happen when warmer water is placed inside cooler water. First, fill the large container almost to the top with very cold water; the colder the better. Next, fill the small container with very warm, but not boiling, water and add a few drops of red food coloring. Carefully put the small container in the cold water in the large container and watch what happens.

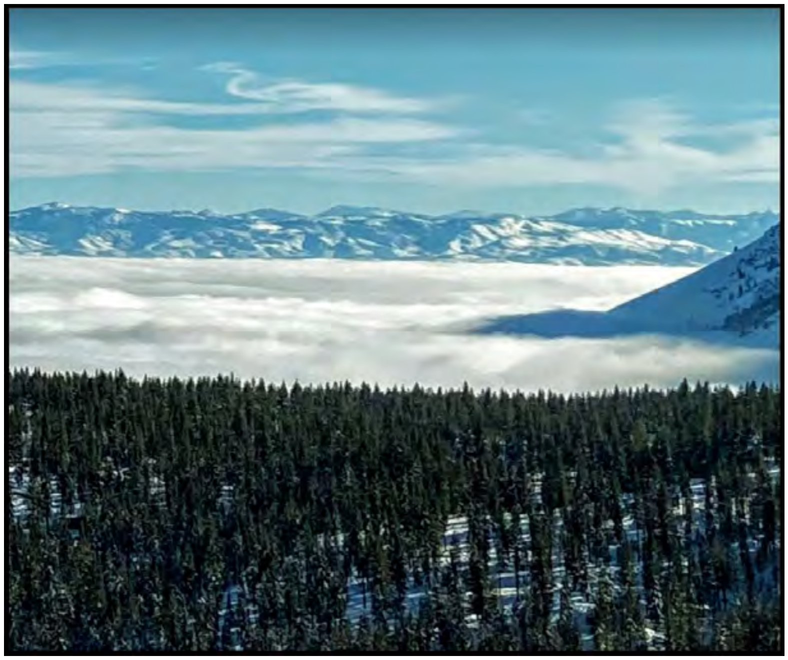
At first, the warm water will rise to the top of the container, and then it will cool and sink downward. The upward and then downward motion is convection. Eventually all of the water in the container will reach the same temperature. (Why? What is a way to keep the convection current moving?)

What would happen if the small container also had cold water? Ask the student(s) to explain what they expect. Refill the large container with very cold water, but this time put cold water in the small container also and add a few drops of blue food coloring. Put the small container in the large container and watch what happens.



The water from the small container does not move upward. Why?

Without convection, heat cannot be transferred from lower elevations to higher elevations. This occurs in nature during a temperature inversion. In this case, colder, denser air stays near the surface of the Earth. This frequently occurs in a valley where the mountains or hills prevent the air from spreading out. Research question: how do temperature inversions form and what are the consequences for air quality near the ground?



Temperature inversion in Carson Valley, NV. Source: Sharon Camp

Source: https://www.science-sparks.com/convection-currents-made-easy/

Formative and Summative Assessments

1. What is electromagnetic radiation? What are three examples?
2. Define thermal radiation. What is another term that can be used instead?
3. How does thermal energy at the Earth's surface get transferred to air molecules?
4. How does the warm air near the Earth's surface transfer that thermal energy to air higher in the atmosphere?
5. How does water vapor warm the other air molecules around it during the day?
6. How does water vapor slow down cooling of the air around it at night?
7. How does the evaporation of water over the ocean drive convection of the air?

Next Generation Science Standards (NGSS) Learning Objectives:

K-PS3-1. Make observations to determine the effect of sunlight on Earth's surface.

PS3.B: Conservation of Energy and Energy Transfer

Sunlight warms Earth's surface.

4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents. [*Assessment Boundary: Assessment does not include quantitative measurements of energy.]*

PS3.A: Definitions of Energy

Energy can be moved from place to place by moving objects or through sound, light, or electric currents.

PS3.B: Conservation of Energy and Energy Transfer

Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.

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.

PS3.A: Definitions of Energy

The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. (secondary)

The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system's material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material. (secondary)

MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

PS3.A: Definitions of Energy

Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.

PS3.B: Conservation of Energy and Energy Transfer

Energy is spontaneously transferred out of hotter regions or objects and into colder ones.

MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

PS4.B: Electromagnetic Radiation

When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (MS-PS4-2)

Source: https://www.nextgenscience.org

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What is the CO_2 Coalition?

The CO_2 Coalition was established in 2015 as a 501(c)(3) for the purpose of educating thought leaders, policymakers and the public about the important contribution made by carbon dioxide to our lives and the economy.

The CO_2 Coalition is a group of the top scientists, engineers and energy experts who study and report on the important contribution made by carbon dioxide to our lives and the economy.

Learn more at CO2Coalition.org and CO2LearningCenter.com.