Discover Your Changing World with NOAA

National Oceanic and Atmospheric Administration

An Activity Book

The Discover Your Changing World with NOAA Activity Book
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For more information on climate, climate chance science and impacts, data and educational offerings,
please visit: www.climate.gov

Climate Science Literacy is an understanding of your influence on climate and climate's influence on you and society.

Climate Literacy: The Essential Principles of Climate Science

1. The sun is the primary source of energy for Earth's climate system.
2. Climate is regulated by complex interactions among components of the Earth system
3. Life on Earth depends on, is shaped by, and affects climate.
4. Climate varies over space and time through both natural and man-made processes.
5. Our understanding of the climate system is improved through observations, theoretical studies, and modeling.
6. Human activities are impacting the climate system.
7. Climate change will have consequences for the Earth system and human lives.

For more information, see: *www.climate.gov*

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Introduction

How does the sun drive Earth's climate system?

How do the ocean, ice, clouds and atmospheric gases affect the impact of the Sun's energy on the Earth?

How have plants, animals, and humans affected Earth's climate?

How may Earth's changing climate effecting plants, animals and humans?

What tools do scientists use to monitor weather, and how is data from these tools used to forecast weather and climate?

What is a climate-literate person?

He or she understands the principles of the Earth's climate system.

He or she knows how to find and use scientifically accurate information about climate.

He or she is able to make informed and responsible decisions about actions that may affect climate.

These activities will introduce you to Earth's climate system, the factors that drive and change it, the impacts of those changes, and what you can do to continue to explore, understand, and protect our Earth.

Have Fun!

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Activity 1: The Great, Glowing Orb

What You Will Do: Make a Solar Heat Engine*

Big Idea
The Sun is the primary source of energy for Earth's climate system.
(Climate Science Principle 1)

What You Will Need

- Adult partner
- 1 Black plastic trash bag
- 2 Styrofoam cups, 16 oz capacity
- 1 Wood dowel, about 1/4-inch diameter
- 1 Styrofoam freezer tray
- 2 Straight sewing pins
- 1 Plastic lid (from yogurt, margarine or similar container), about 4-inches diameter
- 2 Metal food cans, tops completely removed
- Masking tape
- Scissors
- Hot glue gun (low temperature)
- Metal file
- Ruler
- Drawing compass
- Unsharpened pencil
- Sharp knife
- Gloves for protection while using the knife

* (adapted from Strahl, 2007; *http://www.instructables.com/id/Solar-Thermal-Motor/*)

When we talk about Earth's climate, we are basically talking about the effects of energy from the Sun, and how much of that energy is received at various places on Earth. This energy heats Earth's land, ocean, and atmosphere. Strong winds and large ocean currents are the results of heat moving from warm areas—like the Equator—to colder areas of our planet—like the North and South Poles. So, some of the Sun's heat energy is changed to motion energy. A Solar Heat Engine is a tool we can build that also changes heat energy from the Sun to motion energy.

How It Works

Many plastics shrink when they are heated. This engine uses strips of plastic attached to a flywheel that is mounted on a drum that can rotate on an axle. When one of the plastic strips is exposed to sunlight, it shrinks and pulls the flywheel off-center. This movement causes the drum to rotate. As the drum rotates, another plastic strip is exposed to the sun, and the motion continues. As the strips move into the shadow of the drum, they cool and lengthen again.

How to Do It

[NOTE: This activity should be done with adult supervision.]

1. Lay a garbage bag flat on a large surface (the floor is fine) and cut the bag into strips that are about three inches wide and ten inches long. You need eight strips to make your engine, but you should cut some extra ones for practice.

2. Stretch each of the plastic strips by holding one end in each hand, gripping the plastic tightly between the ends of your fingers and the base of your palm. Slowly stretch the plastic strip, until it is a little more than twice its original length and is about 1" wide. (Photo 1). Some of the strips will probably break because garbage bags aren't perfect, but be patient and work slowly. When you have six stretched plastic strips, cut about two inches off of each end (the parts that you held onto and didn't get stretched).

3. Measure the diameter of the large and small ends of a Styrofoam cup, and use your compass to draw two circles with the small diameter and one circle with the large diameter on the Styrofoam freezer tray. Use a compass instead of just tracing the circles around the cup so that you will know where the exact centers of the circles are. Cut the circles out with a sharp knife. **(Be careful and wear gloves!)**

Photo 1. Stretching the plastic strips.

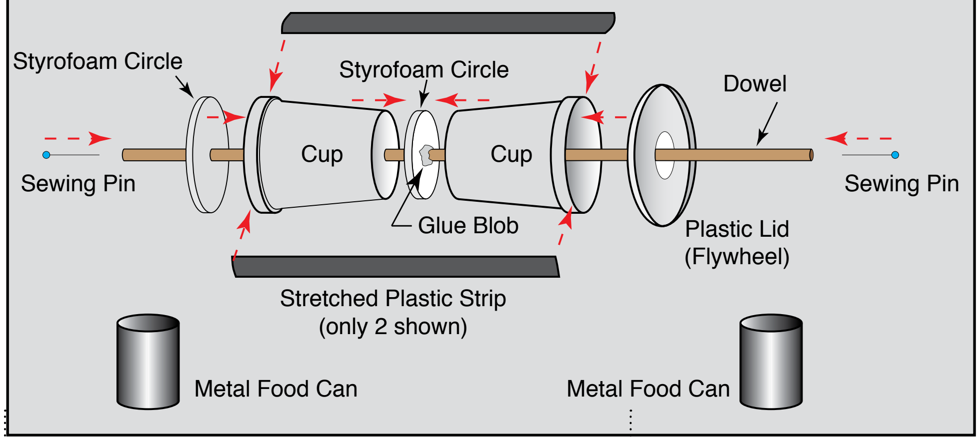
Photo 2.

Photo 3.

4. **Prepare the Fixed Cup Assembly**: Make a hole in the bottom of one Styrofoam cup that is the same diameter as your wood dowel. Make a similar hole in the center of the large Styrofoam circle and in the center of one of the small circles that you cut out in Step 3. Use hot glue to fasten these circles to the large and small ends of the cup. Put the wood dowel through both holes in the cup assembly, and adjust the dowel so that about one inch extends past the large end of the cup (Photo 2). Use hot glue on both ends of the assembly to hold the dowel in place. Add extra hot glue around the dowel at the small end of the cup assembly to form a smooth rounded blob that will provide a pivot point around which the Wobble cup can wobble (Photo 3).

5. **Prepare the Wobble Cup Assembly:** Make a hole in the bottom of the remaining Styrofoam cup that is slightly larger than the diameter of your wood dowel. Be sure the hole is large enough so that the cup can wobble freely on the dowel. Make a similar hole in the center of the small Styrofoam circle that you cut out in Step 3. Use hot glue to fasten the small circle to the small end of the cup (Photo 4).

Figure 1. Exploded view of Solar Heat Engine. Red arrows show direction of assembly.



6. Apply a one-inch line of hot glue along the inside lip of the Wobble Cup Assembly (Photo 5), and place the end of one of the plastic strips on top of the glue. Use an unsharpened pencil to hold the plastic in place until the glue sets. Glue seven more strips around the rim of the cup in the same way. The strips should be evenly spaced around the cup with a gap of about 1/4-inch between the strips (Photo 6).

7. Slide the Wobble Cup Assembly onto the dowel so that the small ends of the Styrofoam cups are close together. Use pieces of masking tape to temporarily hold the Wobble Cup so that it is centered on the dowel (Photo 7). Glue the free ends of the plastic strips onto the Styrofoam circle on the Fixed Cup Assembly. Be sure the strips are taut when you glue them, but should not be stretched so tight that they pull the Wobble Cup off center.

8. Cut a one-inch hole in the center of the plastic lid. **(Be careful and wear gloves!)**Remove the masking tape, and glue the plastic lid onto the large end of the Wobble Cup Assembly. Be sure the hole in the plastic lid is centered on the wood dowel. Stick a sewing pin into each end of the dowel. Your engine is finished!

9. Use a metal file to make a small notch in the rim of each metal can. Space the cans so that you can rest the sewing pin at each end of the dowel into the notch on one of the cans. (Photo 8).Test the balance of your engine by slowly spinning it. If one side seems heavy, stick sewing pins into the Styrofoam circle on the opposite side until it seems balanced.

10. Put your assembled engine in the sun, and watch it spin!

Photo 4.

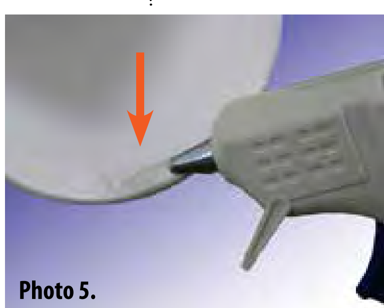


Photo 5.

Photo 6.

Photo 7.

CHALLENGE:
How could you increase the power of this type of solar heat engine?

THINK ABOUT IT:
Would strips made from a white plastic bag work as well as strips made from a black plastic bag? Is it important to consider the principles of heat reflection and heat absorption when choosing the color of plastic strips for this type of heat engine?

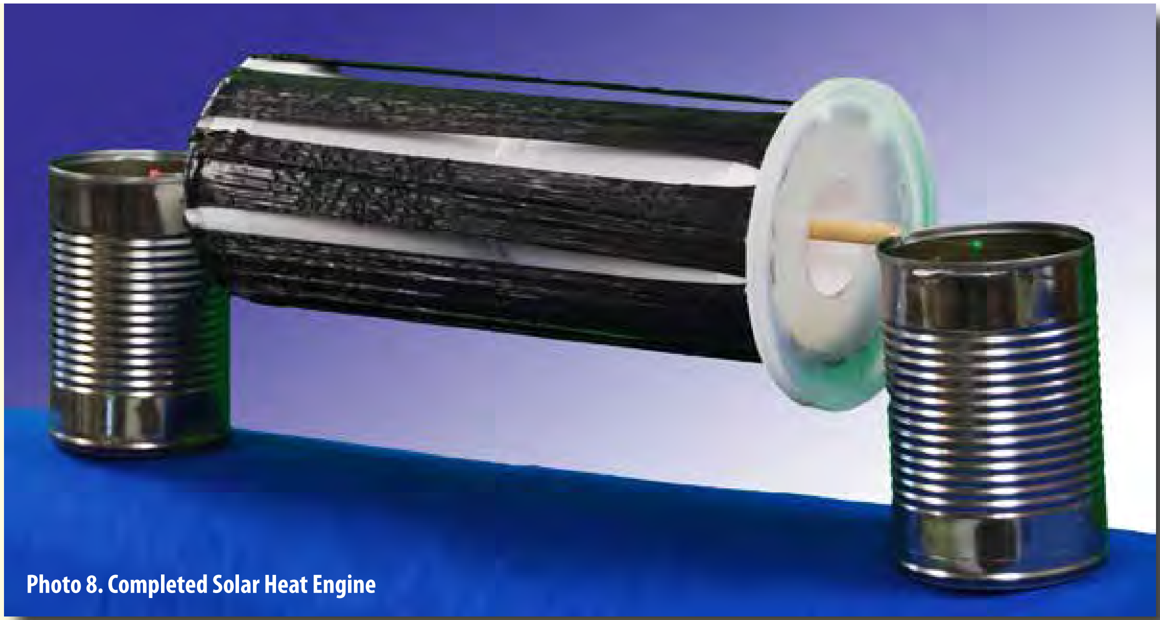


Photo 8. Completed Solar Heat Engine

Your Solar Heat Engine is really just a model, so it isn't powerful enough to do much work; but can you think of any other ways that it could do something useful? Here's one idea: Use a permanent marker to draw a line at one point on the edge of the flywheel (plastic lid). Now you can count the number of revolutions as the Engine spins. You can find out how clouds affect the amount of heat energy that reaches your Engine by counting the number of revolutions in one minute when it is cloudy, and comparing the result to the number of revolutions when there are no clouds. In the same way, you could measure the number of revolutions at different times throughout the day to find the times when the most solar heat energy is received. You could also compare the number of revolutions at different times of the year, but be sure to make your measurements at the same time each day! If you could operate your Solar Heat Engine in two locations at the same time, do you think it would spin faster in Northern Canada or Southern Florida? Hint: Differences in the amount of solar energy that arrives at different latitudes is one of the major controls on climate.

What's Controls Earth's Climate?

Two things happen when sunlight reaches the Earth:

1. Some of the energy is reflected back into space; and
2. Earth's land, ocean, and atmosphere absorb some of the energy and release it as heat.

Earth's overall temperature depends on how much energy is absorbed and how much is released back into space. If the land, ocean, and atmosphere together lose the same amount of energy as they absorb, Earth's energy budget is in balance and its overall average temperature doesn't change. If Earth doesn't release as much energy as it absorbs, its energy budget is not balanced, and our planet will get warmer.

Climate is not the same as weather. Weather describes the temperature, precipitation, and other conditions of Earth's atmosphere at a specific place. Climate lis the result of the long-term average of conditions in the atmosphere, ocean, and ice sheets and sea ice. These conditions are described by statistics, such as means and extremes. Here are some easy ways to remember the difference:

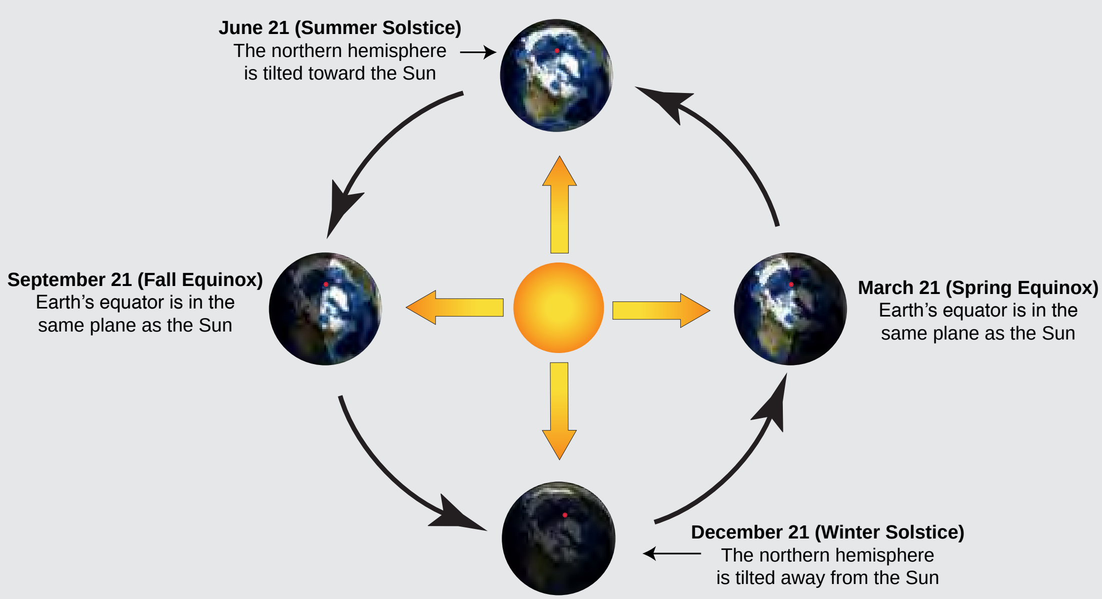
- "Climate is what you expect; weather is what you get." (Robert Heinlein)
- "Climate lasts all the time, weather lasts only a few days." (Mark Twain)
- Weather tells you what to wear on any given day; climate tells you what wardrobe to have.

We know that different places on Earth have different climates (think about Antarctica and the deserts of the Middle East, for example). Since Earth's overall climate is caused by energy from the Sun, places with warmer climates must receive more of the Sun's energy than places with colder climates. The amount of energy that a particular place on Earth receives from the Sun depends upon several things.

We also know that Earth moves! It moves through space, following a path around the Sun that is called an orbit. If you tie a rubber ball onto a piece of string and whirl the ball in a circle, the path of the ball's motion is an orbit. The time needed for Earth to travel one complete orbit around the Sun is how we define the length of a year.

First, Earth is shaped like a ball. The most direct sunlight is received at the equator (the equator is an imaginary line that goes around the Earth halfway between the North and South Poles). The area around the equator is very warm. Places located at high latitudes (far from the equator) receive less direct sunlight than places at low latitudes (close to the equator), so high latitudes have colder climates.

Second, as Earth moves around the Sun through the year, different parts of it receive more direct sunlight and have longer days and shorter nights than others. This is because Earth's axis (an imaginary line that goes through the Earth from the North Pole to the South Pole) is tilted compared to the plane of Earth's orbit. The changing amounts of sunlight cause Earth's seasons. During June, Earth's northern hemisphere is tilted toward the Sun. The day that the northern hemisphere points most directly toward the Sun (on or around June 21) is called the summer solstice. During December, Earth's northern hemisphere is tilted away from the Sun. The day that the northern hemisphere points most directly away from the sun (on or about December 21) is called the winter solstice. When the apparent position of the Sun is halfway between the summer and winter solstices, every place on Earth receives equal periods of day and night (remember, the Sun does not actually move; it is Earth that moves around the Sun). This happens on March 21 and September 21, which are called the spring equinox and fall equinox.



Earth's orbit around the Sun. The illustration shows how Earth would look if you were looking at it from a location beyond Earth's orbital plane. The red dots show the approximate location of the North Pole,which is off center because Earth's axis is not perpendicular to its orbital plane. Note that this illustration is not to scale, because the Sun is actually MUCH larger than Earth! (Image credit: Mel Goodwin, LuAnn Dahlman)

Third, the amount of energy produced by the Sun also changes slightly over time,. Over the past 30 years, the Sun's energy output has changed very slightly; sometimes increasing a little, sometimes decreasing a little. There is no evidence that recent changes in the Sun's energy output have caused much change in Earth's average temperature.

Fourth, over thousands of years, the motions of Earth's rotation on its axis and its orbit around the Sun change very slightly. These gradual changes cause the amount of sunlight received by different parts of Earth to change as well. When less sunlight is received in the northern hemisphere, snow and ice can accumulate there. Then, Earth's average temperature drops and we have ice ages. When more sunlight is received, the average temperature increases and we have warmer periods between the ice ages. For the last one million years, changes in Earth's rotation and orbit have happened in cycles that are about 100,000 years long.

Activity 2: The Climate Team

What You Will Do: Make a Solar Cooker

Big Idea

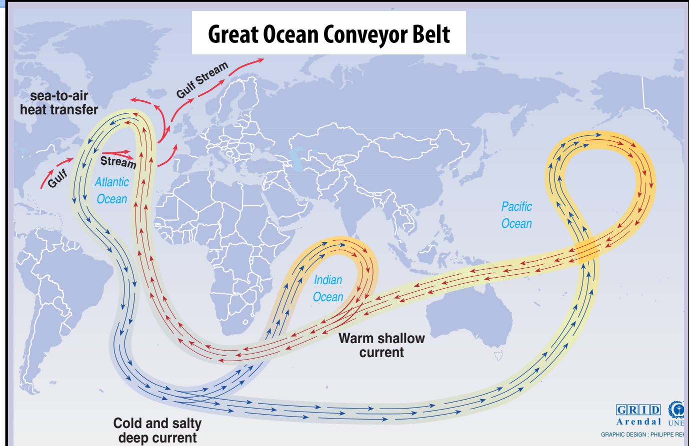
Climate is regulated by complex interactions among components of the Earth system. (Climate Science Principle 2)

What You Will Need

- Adult partner
- 1 – Cardboard about 22 in x 10 in
- 1 – Cardboard about 57 in x 45 in (from a large appliance carton or mirror box)
- Aluminum foil, about 18 square feet
- White glue
- Foam paint brush, about 2 inches wide
- Measuring cup, at least 2 oz capacity
- Paper or plastic cup, about 8 oz capacity
- Duct tape
- Black pot, 1 or 2 quart capacity (buy an inexpensive aluminum pot from a local thrift store and paint the outside with flat black paint)
- Metal ruler or straightedge
- Knife for cutting cardboard (safety box cutters and safety utility knives have a built-in shield to protect fingers)
- Gloves for protection while using the knife (hardware stores and home centers have cut-resistant gloves)
- Sunglasses and oven mitts for protection while using your Solar Cooker
- Rice

We can think of Earth's ocean, atmosphere, clouds, ice, land, plants and animals as the Climate Team, because they all affect climate. The climate at a particular place on Earth depends upon how members of the Climate Team work together.

The ocean is one of the Climate Team's power players. One reason is that the ocean is very large and covers 70% of Earth's surface. Another reason is that water has a high heat capacity, which means it takes a lot of heat to change the temperature of water. Raising the temperature of one kilogram of water by one degree requires more than three times as much heat energy as raising the temperature of one kilogram of air by one degree. The ocean absorbs large amounts of heat energy from the Sun, and ocean currents move this energy from one place on Earth to another. The ocean's major current systems are sometimes called the "global conveyor belt," and the heat that they carry has a large impact on climate.



The Global Conveyor Belt is caused mainly when seawater in the Norwegian Sea is cooled and sinks into the deep ocean. The sinking process can slow down or even stop if large amounts of freshwater enter the Norwegian Sea from unusual rainfall, snow, runoff, or melting ice. Changes in the Global Conveyor Belt can cause climate changes in Europe and other areas of Earth's Ocean (United Nations Environment Programme and World Meteorological Organization, 1996; *http://maps.grida.no/library/files/storage/31new.pdf*).

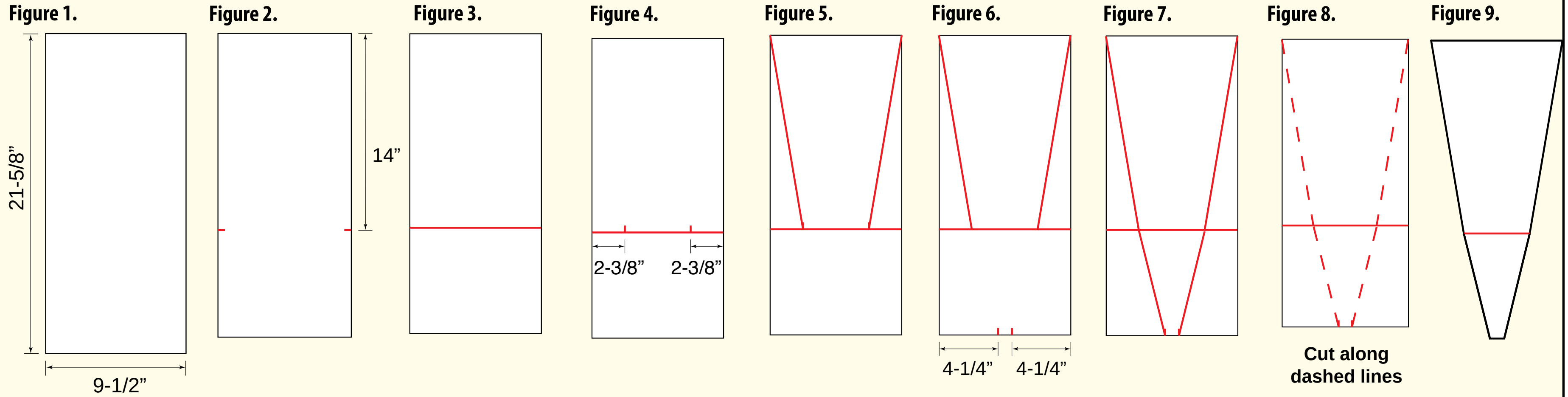
The atmosphere is another one of the Climate Team's power players, and it exchanges heat with the ocean. Water from the ocean enters the atmosphere when it evaporates, and returns to the ocean as rain or snow. When water evaporates it absorbs heat, and when it precipitates as rain or snow it releases heat. Movement of water vapor in the atmosphere is another way that heat can be transferred from one place to another. The atmosphere also absorbs and reflects energy from the Sun. The amount of solar energy that is absorbed or reflected depends on the gases that make up the atmosphere. The ways that different gases affect Earth's climate is discussed more in Activity 6, *I Didn't Do It, Did I?*.

How It Works

Solar cooking is an easy, safe, and convenient way to cook food without using fuel. These benefits are particularly important for people who live in places where fuel is scarce or expensive. Besides cooking food, solar energy can be used to purify drinking water by boiling it, and avoid waterborne diseases that kill many people every year.

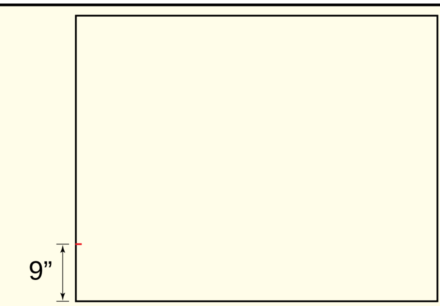
The basic principle of solar cookers is when sunlight strikes a dark-colored object, the object absorbs some of the energy in the sunlight and converts it to heat. This causes the object to become hot. Solar cookers use shiny surfaces to reflect sunlight onto a dark pot to increase the amount of heat energy that the pot receives. These reflectors may be flat panels, boxes, or curved surfaces (see Want to Do More for sources of different solar cooker designs). Dark, shallow, thin metal pots with dark, tight-fitting lids are the best containers for solar cooking. Some solar cookers use a clear plastic bag around the pot to trap heat and still allow sunlight to strike the pot.

Figures 1 - 9: Steps to make a pattern for the solar cooker.



CAUTION:

- **Be sure to wear sunglasses whenever you work with aluminum foil outside in the sun.**
- **Wear oven mitts when removing pots and pans from your solar cooker! When the sun is shining they can become too hot to touch in one or two minutes!**
- **Tips for Safe Cutting: Sharp is safe, because a dull knife can slip off the cardboard rather than cut into it easily. Always use a cutting board to protect the blade of the knife and help keep it sharp. Keep your fingers away from the path of the blade as you cut. Begin with a light scoring cut to guide the blade for additional cuts. Several light cuts make it easier to control the blade. Never force the blade through materials being cut, because it increases the chances of an uncontrolled slip.**



How to Do It

1. Cut a pattern for your solar cooker from the 22 in x 10 in piece of cardboard.
   a. Place the cardboard on a flat surface and cut it to measure 21-5/8 in by 9-1/2 (Figure 1).
   b. Make a mark 14 inches from the top of the cardboard along each side (Figure 2). Draw a line between these marks (Figure 3).
   c. Make a mark 2-3/8 inches from the sides of the cardboard on the line drawn in Step 1b (Figure 4).
   d. Draw a line from the top corners of the card-board to the marks made in Step 1c (Figure 5).
   e. Make a mark 4-1/4 inches from the sides of the cardboard along the bottom (Figure 6).
   f. Draw a line from the marks made in Step 1c to the marks made in Step 1e (Figure 7).
   g. Put the cardboard on a cutting board or several layers of scrap cardboard. Cut along the lines drawn in Steps 1d and 1f (Figure 8). Use a metal ruler or straightedge to keep the cuts straight. **(Be careful and wear gloves!)**
   h. Your pattern should look like Figure 9.

2. Lay out the Reflector for your solar cooker on the 57 in x 45 in piece of cardboard.
   a. Place the cardboard on a flat surface. Make a mark 9 inches from the bottom along the left side of the cardboard (Figure 10).
   b. Place your pattern on the cardboard, and make two marks as shown in Figure 11.
   c. Draw a line around the outside of your pattern, then remove the pattern (Figure 12).
   d. Draw a line between the two marked points (Figure 13).
   e. Use your pattern to draw another outline beneath the outline drawn in Step 2c. Be sure to make the two marks (Step 2b) and draw a line between these points (Step 2d) as before. Now your layout should resemble Figure 14.

Figure 11.

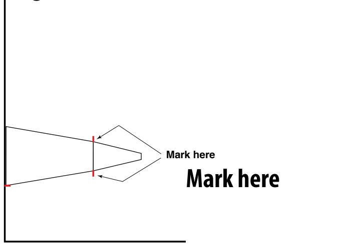


Figure 12.

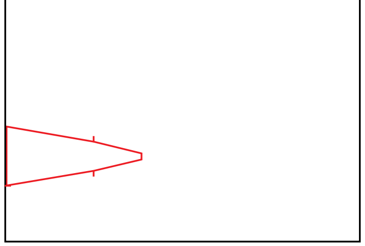


Figure 13.

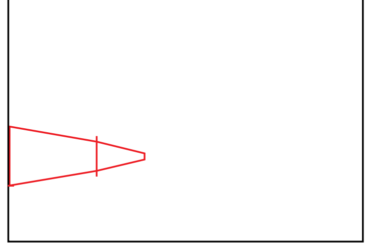


Figure 14.

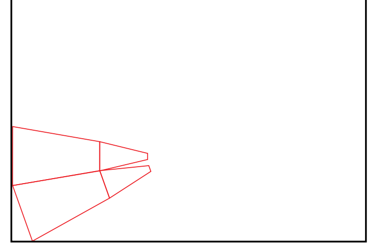


Figure 15.

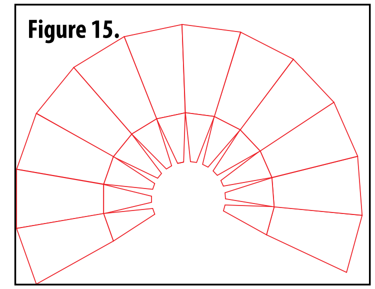


Figure 16.

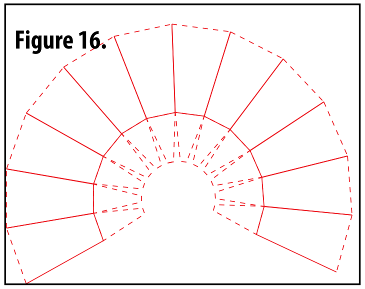


Figure 17

f. Use your pattern to draw ten more outlines as shown in Figure 15. Be sure to make the two marks (Step 2b) and draw a line between them (Step 2d) on each outline.

g. Put the cardboard on a cutting board or several layers of scrap cardboard. Cut the Reflector out along the DASHED lines shown in Figure 16). Use a metal ruler or straightedge to keep the cuts straight. **(Be careful and wear gloves!)**

3. Fold the Reflector along the SOLID lines shown in Figure 16. Use a metal ruler or straightedge to keep the folds straight. You may also use the edge of a table or countertop to help make straight folds.

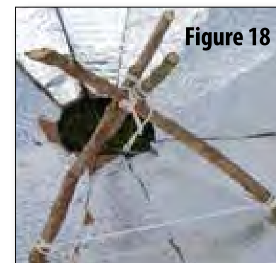
4. Mix 2 oz of white glue with 2 oz water in a paper or plastic cup. Use a foam paint brush to spread the glue mixture over the surface of the Reflector, then put strips of aluminum foil onto the Reflector to completely cover the surface. Allow the glue to dry.

5. Bring the small triangles together and hold them in place with duct tape on the cardboard side of the reflector (Figure 17). Do not put tape on the aluminum foil side! Bring the long edges of the Reflector together and hold them in place with more duct tape. Your reflector is finished!

6. It's time to test your Solar Cooker. A good first test is to cook some rice. Put 1/2-cup of rice into your black pot, add 1 cup of water, and place the lid on the pot. Set your Reflector on a flat surface so that it is resting on one or two of the small triangles closest to the center, and pointing toward the Sun. Put some bricks or rocks around the outside of the Reflector to keep it steady and to stop any wind from blowing it around.

Your Reflector is designed to have the approximate shape of a parabola. Parabolas are useful because their shape can focus the energy of sunlight onto a specific spot. The location of this spot depends upon the dimensions of the parabola. The focal point of your Reflector should be about six inches from the small hole at the back of the Reflector. This means that you will need some way to hold your pot in this position. A tripod (Figure 18) is a good choice, because it won't prevent reflected sun rays from reaching the sides and bottom of the pot. You can make a tripod from three sticks and a piece of heavy string. Search the Internet for "tripod lashing" (or ask a Boy or Girl Scout) to find directions for tying the sticks together to make a tripod.

Figure 18



Put your tripod inside the Reflector, put the pot on top of the tripod, and wait (Figure 19). Rice ordinarily takes about 20 minutes to cook on top of a stove, but your Solar Cooker will probably need at least twice as much time. Check your rice after 40 minutes. If it needs more time, put the lid back on, check to be sure the Reflector is still pointed toward the Sun, and wait another 30 minutes. For long cooking times, you need to adjust the Reflector position every now and then as the position of the Sun changes in the sky.

7. Once your rice is cooked, try an experiment:

a. Put about two cups of rice in the pot without water. Cover the pot, place the lid on top, put the pot on the tripod in your Solar Cooker, and leave it in the Sun for ten minutes.

b. Check the temperature of the rice with a


Figure 19

thermometer (be careful, the pot will be hot!) and record your measurement.

c. Empty out the rice, and put two cups of water into the pot. Place the lid on top, put the pot on the tripod in your Solar Cooker, and leave it in the Sun for ten minutes.

d. Check the temperature, and record your measurement.

e. Can you explain your results? [Hint: remember the discussion of heat capacity at the beginnning of this Activity]. If land and water both receive the same amount of sunlight, which will absorb more solar energy?

8. You can cook many different types of food in your Solar Cooker! For some ideas and recipes, check out *http://www.solarovens.org/recipes/*. Remember you can also use covered black baking pans for foods such as cookies.

What About Other Members of the Climate Team?

Climate-prediction scientists know there are many other players on the Climate Team. These scientists often call the Climate Team players "climate forcings" because they can force Earth's climate to change, usually by affecting the amount of solar energy that enters and leaves Earth's atmosphere.

Some climate forcings affect solar energy entering the atmosphere as well as the energy from Earth that escapes back into space. Clouds are an example, because dense, low-lying clouds reflect sunlight back into space before it can reach Earth's surface. On the other hand, high, thin clouds have the opposite effect. These clouds allow incoming sunshine to pass through the atmosphere but trap heat that would escape back into space if the clouds were not present.

Clouds are often affected by airborne particles called aerosols. These are tiny liquid and solid particles that are injected into the atmosphere by natural processes such as ocean spray, volcanoes, and forest fires. Human activities such as burning fuels for cooking, heat, transportation, and electricity can also send aerosols into the atmosphere. Different aerosols have different effects on Earth's climate. Light-colored aerosols reflect sunlight back into space and have a cooling effect. Dark-colored aerosols absorb solar energy and make the atmosphere warmer. Sometimes, aerosols increase cloud formation, but dark aerosols like the soot from forest fires can reduce cloudiness. These kinds of opposite effects are one of the reasons that climate prediction is a complicated job!

Ice and snow can act as climate forcings because they also reflect solar energy away from Earth's surface. The ability of a surface to reflect radiation is called albedo (pronounced al-BEE-dough). When increased air temperatures cause ice and snow to melt, the surface underneath (such as soil) may be much darker. When this happens, the newly-exposed surface will absorb more energy from sunlight than was absorbed by the ice and snow. Absorption of additional energy raises the surface temperature, and causes even more melting. This is an example of positive feedback loops that can amplify the effects of a single change. The water from melting ice and snow can cause changes in major ocean currents, which in turn can lead to rapid changes in climate in regions far away from the places where the melting actually happened. The players on the climate team influence each other, which means that a significant change to one part of Earth's climate system can have effects on the entire system.

Plants and animals continuously move certain gases in and out of the atmosphere. Carbon dioxide is one of these gases that is also an important climate forcing. The effect of plants, animals, and carbon dioxide is discussed more in Activity 6.

Want to Do More?

For information about other solar cooker designs, see *http://www.solarcookers.org/index.html*. This is the Solar Cookers International website dedicated to spreading solar cooking awareness and skills worldwide, particularly in areas with plentiful sunshine and diminishing sources of cooking fuel.

Image on Page 8 is from: United Nations Environment Programme and World Meteorological Organization. 1996. Internet: *http://www.grida.no/publications/vg/climate/page/3085.aspx*; data from Climate Change 1995 – Impacts, adaptations and mitigation of climate change: Scientific-Technical Analyses. Contribution of Working Group 2 to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cartographer/Designer: Philippe Rekacewicz, UNEP/GRID-Arendal. Cambridge University Press.

Activity 3: Climate Is Our Friend...Isn't It?

What You Will Do: Make an Extinction Polyhedron

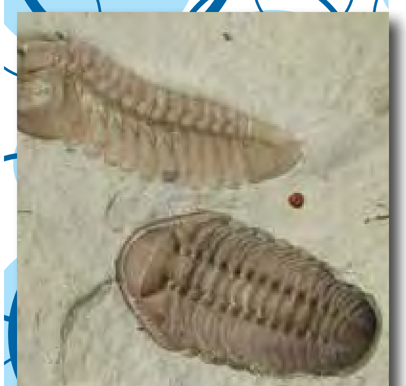
Big Idea

Life on Earth depends on, is shaped by, and affects climate.

(Climate Science Principle 3)

What You Will Need

- Stiff paper or cover stock; size depends upon how large you want your polyhedron to be (see How to Do It, Step 3)
- Scissors
- Pen or pencil
- Glue
- Art supplies (if you want to make your own illustrations; see How to Do It, Step 1)
- Computer with Internet access or library resources



Trilobite *Kainops invius*.
Image courtesy Wikipedia.

We know that Earth's climate affects everything that lives on our planet; but can living things affect climate? The answer is "Yes!" Life on Earth has a major effect on heat-trapping gases in the atmosphere. The presence of these gases allows Earth's environment to have liquid water and enough warmth to support many different kinds of living organisms. During Earth's history, these organisms—including microbes, plants, and animals and humans—have significantly changed the chemical makeup of the atmosphere.

One of the reasons there are so many different kinds of organisms is that different locations on Earth have different climates, which means that they have different conditions of temperature, precipitation, humidity, and sunlight. Individual organisms require a certain range of these conditions; polar bears, for example, cannot survive in the tropical jungle. If living organisms are exposed to climate conditions outside their normal range they must adapt to the new condition or migrate to a different location. Otherwise, these organisms will die.

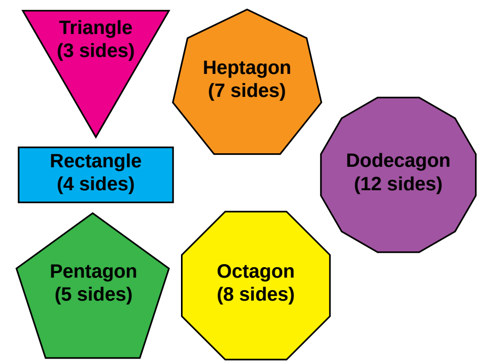
Fossils are any remains, traces, or imprints of a plant or animal that has been preserved in a rock. Some fossils are formed when the remains of an organism are replaced by minerals that keep the organism's shape. Another way fossils are formed is when an organism's remains make an imprint in a soft substance such as clay or mud that later hardens into a rock. Fossils can also be things that were made by an organism, such as footprints in mud. Fossils provide important information about organisms that were alive at various times in Earth's history. Many kinds of organisms are now extinct, which means none of them are alive today. Dinosaurs are a good example of extinct organisms, and there are millions of others. Information from fossils shows that at certain times in Earth's history, many different kinds of organisms became extinct at about the same time. When this happens, we say that a "mass extinction event" has occurred. The cause of most mass extinction events involved some type of climate change.

How to Do It

Polygons are 2-dimensional shapes that are made of straight lines in which the lines connect together to form an enclosed space (Figure 1).

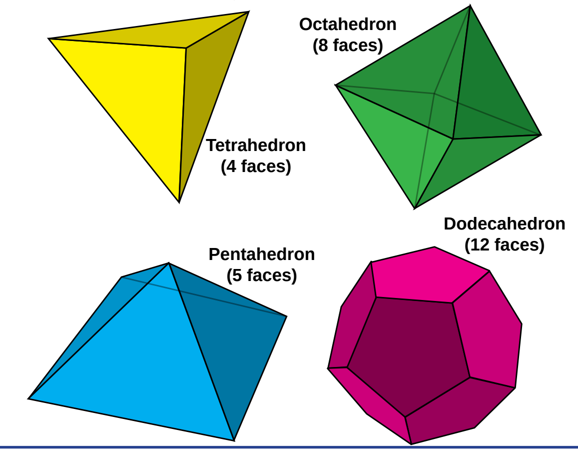
Polyhedrons are three-dimensional shapes that are made of polygons (Figure 2).

Figure 1.
Examples of Polygons



Polyhedrons are easy to make, interesting to look at, and are a great way to present and discuss information. This activity uses polyhedrons to show information about some extinct organisms, and how their extinction may have been related to climate change. First, you need to get the information together, then you can construct your Extinction Polyhedron!

Figure 2. Examples of Polyhedrons

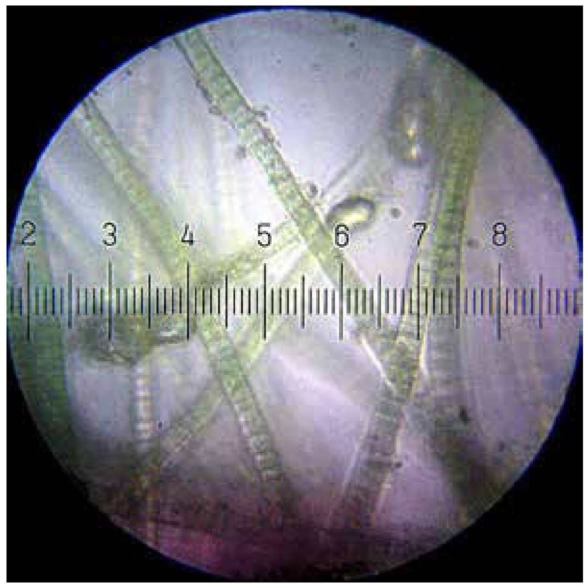


1. Use the Internet or library resources to find pictures of seven extinct organisms that look interesting or that have interesting stories (or both). You may be able to download or copy pictures directly from the sources you use, or to use these pictures as a guide for illustrations that you make yourself. When you have selected the organisms to use for your Extinction Polyhedron, Find out some interesting facts about each organism, such as when and where they lived, what they ate, when and why they became extinct, etc. Here are some suggestions:

NOTE: There are MANY other examples of extinct organisms. In fact, more than 99% of all the species that have ever lived on Earth are now extinct.

Anomalocaris	Trilobite
Placoderms	Smilodon
Ammonoid	Arthropleura
Mammuthus primigenius	Opabinia
	Pelycosaur
Wiwaxia	Archaeocyathid
Blastoid	Pterosaur

2. Let's add one more organism to the seven you selected in Step 1. Cyanobacteria have been a very important part of life on Earth, and actually caused one of the biggest extinctions in Earth's history! Can you find out how? Individual cyanobacteria are too small to see without a microscope, but many of these organisms produce much larger structures that are easily visible. You could also use a photograph made with a microscope or an illustration you prepare yourself for the Extinction Polyhedron.



Cynobacteria through a microscope. Image courtesy Wikipedia.

3. Decide how large you want your Extinction Polyhedron to be. The pattern in Figure 3 will produce a polyhedron with eight sides (an octahedron). Each side has the shape of a triangle whose sides are about 1-3/4 long. If you want a larger Extinction Polyhedron, use a copying machine to enlarge Figure 3, or lay it out yourself with a ruler. Cut out the pattern along the solid lines, and trace the pattern onto stiff paper (such as cover stock or construction paper). Cut the pattern out of the stiff paper, and fold along all of the dotted lines. Do not fold the pattern into its final shape yet, because it is much easier to attach pictures while the pattern is flat.

4. Cut the eight pictures so that each one will fit on one of the sides of the octahedron, then glue the pictures into place.

5. Fold the pattern with the glued-on pictures along the dotted lines, and attach the tabs to the inside of the polyhedron with tape or glue. Your Extinction Polyhedron is finished!

Some Things You Can Do With Your Extinction Polyhedron

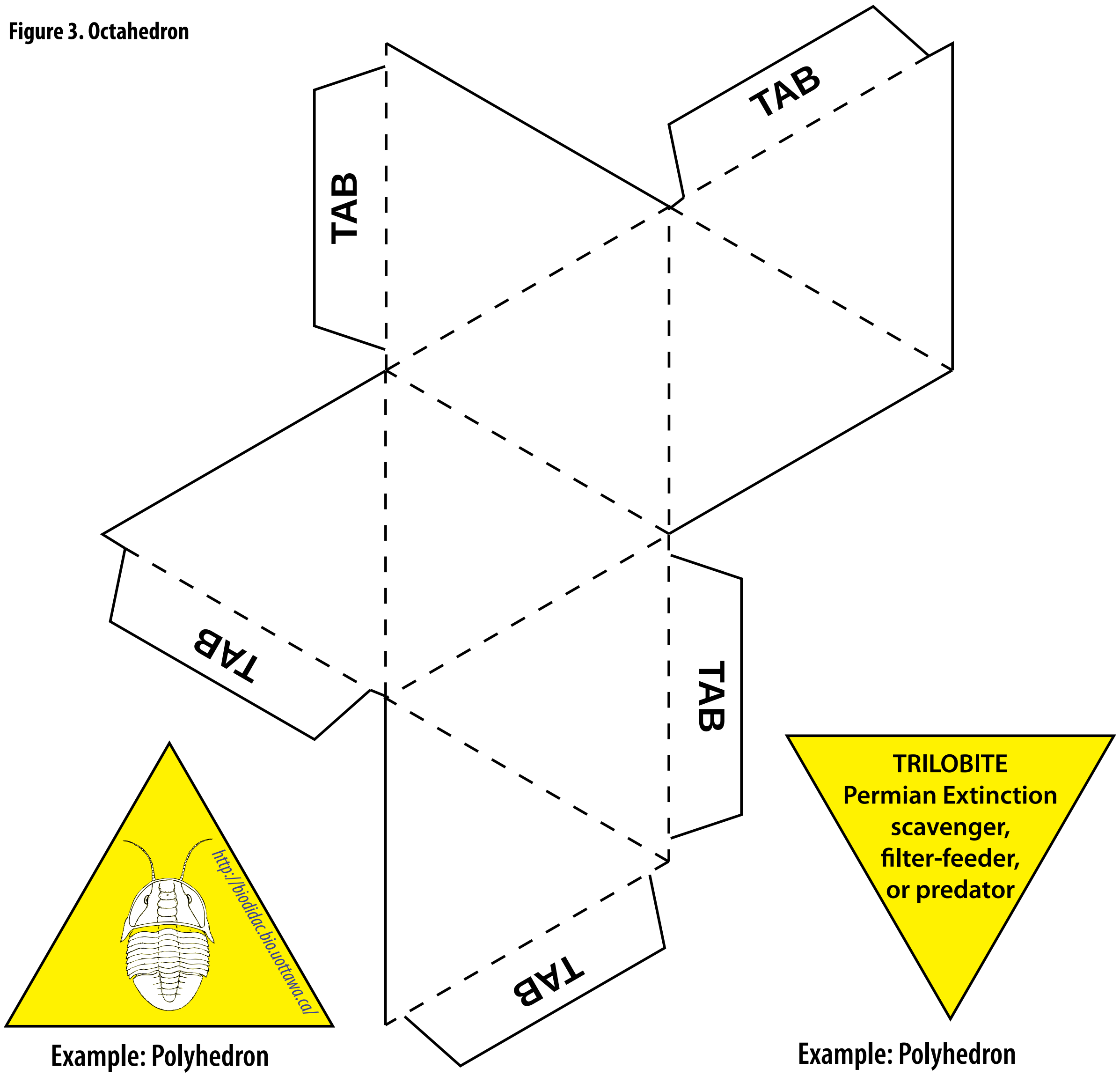
Here are a few ideas. You can probably think of many others!

The main purpose of an Extinction Polyhedron is to present information about extinct organisms and why they became extinct. If you put your Extinction Polyhedron on a table in a room where people are present, someone will probably pick it up for a closer look. When this happens, ask the person if they recognize any of the organisms shown in the pictures. This is one way to start a conversation about extinctions and why they happen.

Another thing you can do is to make several additional Extinction Polyhedrons, and hang them onto wires or sticks to form a mobile. If you want to make something besides octahedrons, there are many Web sites that have patterns and directions for making other shapes.

You can also make up games that use Extinction Polyhedrons. For example, you could have one polyhedron with pictures, and another polyhedron with the organisms' names written on the sides.

Figure 3. Octahedron



Example: Polyhedron face with picture

Example: Polyhedron face with facts

Player #1 drops the picture polyhedron onto a table, then turns the polyhedron over so that Player #2 can see the picture that was face down when the polyhedron landed on the table. Player #2 must turn the polyhedron with written names so that the correct name for the organism is face up. If you make more than one set of name polygons, several players can compete to see who can be the first to turn up the correct name.

Why are they extinct?

When you were gathering information about your selected organisms in Step 1, you probably noticed several things about mass extinctions. First, these events have happened many times throughout Earth's history. One of the first mass extinctions happened about 2,400 million years ago when bacteria called cyanobacteria produced large amounts of oxygen that dramatically changed Earth's atmosphere. Before this happened, Earth's atmosphere contained very little oxygen, and most living organisms were adapted to live without oxygen. An oxygen-rich atmosphere caused most of these organisms to become extinct. This mass extinction is called the Oxygen Revolution, the Oxygen Catastrophe, the Oxygen Crisis, or the Great Oxidation. This is a case in which one form of life caused the extinction of other forms of life. It is also a good example of how mass extinctions make it possible for new species to appear.

Other major mass extinctions (sometimes called "The Big Ones") include:

- The Cambrian Extinction, about 499 million years ago, when about 30% of living groups became extinct;

- The Ordovician Extinction, about 443 million years ago, when an estimated 60% of all genera became extinct;
- The Devonian Extinction, about 345 million years ago, when about 70% of all known species became extinct;
- The Permian Extinction, about 250 million years ago, when an estimated 96% of all marine species became extinct and 70% of terrestrial vertebrate species became extinct;
- The Triassic Extinction, about 200 million years ago, when about half of all known species became extinct; and
- The Cretaceous Extinction, about 65 million years ago, when dinosaurs along with 85% of all known species became extinct.

There are usually several theories about the cause of most mass extinctions. For example, the Cambrian Extinction has been linked to sharp decreases of oxygen in Earth's atmosphere along with increased levels of hydrogen sulfide. The reason for these changes is not known. The Ordovician Extinction happened when Earth's climate cooled, causing large amounts of water to be trapped in glaciers. This reduced the level of Earth's ocean, which was where most organisms lived at this time. Global cooling has also been suggested as a possible cause of the Devonian Extinction, and may have been the result of decreased carbon dioxide in the atmosphere. An asteroid impact is another suggestion, which is also believed to have been responsible for the Cretaceous Extinction. Large asteroid impacts may have a direct effect on Earth's climate, since large amounts of dust and soot in the atmosphere following such impacts can result in global cooling. It is important to remember that mass extinctions may have more than one cause, and that some extinction events happened when several things went wrong at about the same time.

It is also important to remember that living organisms can affect climate, and have probably helped cause some mass extinction events. Large land plants that covered Earth's landscape for the first time during the Devonian Period may have caused decreased carbon dioxide in the atmosphere during the Devonian Extinction.

This painting by Donald E. Davis depicts an asteroid slamming into tropical, shallow seas of the sulfur-rich Yucatan Peninsula in what is today southeast Mexico. The aftermath of this immense asteroid collision, which occurred approximately 65 million years ago, is believed to have caused the extinction of the dinosaurs and many other species on Earth. The impact spewed hundreds of billions of tons of sulfur into the atmosphere, producing a worldwide blackout and freezing temperatures which persisted for at least a decade. Shown in this painting are pterodactyls, flying reptiles with wingspans of up to 50 feet, gliding above low tropical clouds. Image courtesy NASA/JPL-Caltech.

Today, human activities have significant influence on species extinctions. Habitat destruction and over-harvesting directly affect some species, and many others are harmed by activities such as pollution and introducing exotic species that interfere with natural ecosystem processes. The effect of human activities on Earth's climate system is explored in Activity 6, "I Didn't Do It … Did I?"

Want to Do More?

Visit NOAA's Paleoclimatology Web site (*http://www.oar.noaa.gov/climate/t_paleo.html*) for information and image collections about many topics related to climate change during Earth's history.

Big Idea

Climate varies in space and time through both natural and man-made processes.

(Climate Science Principle 4)

What You Will Need

- Adult partner
- 1 – Multimeter capable of measuring volts, milliamps, and ohms (such as Extech MN35)
- 1 – 9 volt battery
- 1 – Battery snap (such as Radio Shack 270-324)
- 1 – Resistor, 10K ohm, 1/2 watt (such as Radio Shack 271-1126)
- 1 – Thermistor, 10K ohm (such as Digi-Key 490-4660)
- 2 – Clear glass jar, beakers or plastic cups, about 250 ml (8 oz) capacity
- 1 – Wire strippers
- 1 – Thermometer (such as Forestry Suppliers #89323; you may want to order two of these, since you will use them again for Activity 6; these thermometers have an aluminum case which makes them useful for field investigations as well as in your laboratory)
- Speaker wire, 24 gauge, about 1 m (3 ft) (such as Radio Shack 278-1301)
- Liquid electrical tape (from a boating supply store or hardware store)
- Conductive Glue (keyword search "wire glue" to find suppliers; if you or your partner know how to solder, you can use solder and a soldering iron instead of conductive glue)
- Needle-nose pliers
- Ice
- Hot water

Activity 4: Climate, Weather...What's the Difference?

What You Will Do: Make an Electronic Temperature Sensor

Weather describes what is happening in the atmosphere over a short period of time (days or hours) at a specific place. Weather descriptions include temperature, humidity, winds, cloudiness, and atmospheric pressure. Climate is the average of these weather conditions over many years. The National Weather Service uses 30 years of weather measurements to calculate the average climate for a city, state, or region. An easy way to summarize the difference is "climate is what you expect; weather is what you get," or "weather tells us what kinds of clothes to wear, climate tells us what kinds of clothes to buy."

When scientists talk about climate change, they mean that there has been a significant change in the average or extreme (or both) climate conditions, and that this change has continued over a long period of time. We all know that climate conditions (air temperature, precipitation, and wind) change with the seasons. There are also natural cycles such as El Niño that cause climate conditions to be different from year-to-year. These differences are part of natural climate variability, but they are not the same as climate change.

Earth's climate has changed many times in the past, and is changing now. Studies of tree rings show that Earth's average temperature is now as warm or warmer than it has been for at least the past 1,300 years. Scientific weather observations from around the world show that average temperatures have increased rapidly during the past 50 years, especially in the Arctic region. In the past, climate change has happened over periods of decades to thousands of years. It is very unusual to have a rapid temperature change in only 50 years, because few natural processes affect climate this quickly. The rapid rate of 20th century warming, and the increase above the millenium baseline in the absence of natural forcing, are consistent with the warming caused by increased greenhouse gases. One way that this is happening is that human activities are adding carbon dioxide to the atmosphere much more rapidly than natural processes can remove it. You'll find out more about how carbon dioxide affects climate in Activity 6.

How It Works

An electric current is the flow of electrons through a conductor such as a wire. An electric circuit is a path for an electric current. One way to imagine an electric current is to think of water flowing through a pipe. The voltage of an electric current is the force of the current, similar to the pressure of the water in the pipe flowing through the imaginary pipe. As you may have guessed, voltage is measured in volts.

Resistance is a force that opposes the flow of an electric current. You can think of resistance as a valve or obstruction in the imaginary pipe. Resistance is measured in ohms; the more ohms, the higher the resistance. Resistors are electronic components that resist the flow of electric currents.

A thermistor is a type of resistor whose resistance changes when the temperature changes. When a thermistor is in an electric circuit, the voltage of the electric current changes when the thermistor's resistance changes. We can measure the voltage of this type of circuit, and use this measurement to find the temperature of the thermistor. Compared to liquid-filled thermometers, thermistors are less expensive, more rugged, and do not require someone to look directly at them to get a temperature measurement. Because of these advantages, thermistors are used in cooking appliances, indoor/outdoor thermometers, doctors' offices, fire alarms, refrigerators, wind turbines, weather balloons, aircraft, space vehicles, industrial facilities, and many other places where temperature measurement or control is needed.

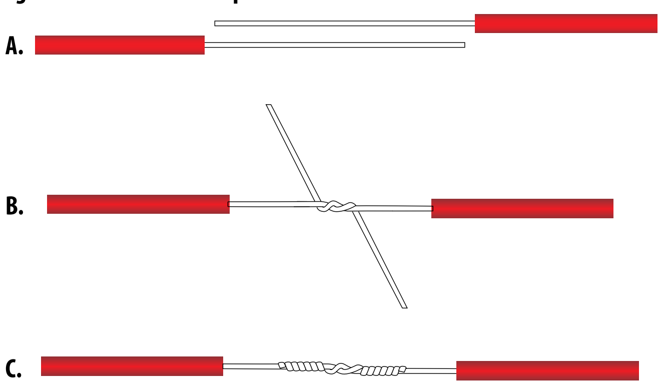
How to Do It

1. Remove about 2 cm (1 in) of the insulation from both ends of the two wires in the speaker cable, and also from the two wires of the battery snap. Twist the strands of each wire so that they are tightly wrapped (Figure 1).

Figure 1.

2. Connect the wires from one end of the speaker cable to the wires coming from the thermistor. Use a Western Union splice as shown in Figure 2.
3. Use a Western Union splice to connect one of the wires from the other end of the speaker cable to one of the wires coming from the resistor (it doesn't matter which wire).
4. Use a Western Union splice to connect the other wire from the speaker cable to one of the wires from the battery snap (it doesn't matter which one).
5. Use a Western Union splice to connect the other wire from the battery snap to the remaining wire coming from the resistor. This completes the thermistor circuit, which should resemble Figure 3.
6. Brush a small amount of conductive glue onto each of the splices, and allow the glue to dry (or solder these splices).
7. Brush liquid electrical tape onto the thermistor splices so that all of the bare wires are covered (Figure 4).
8. Set your multimeter to measure volts. Set the voltage range on your multimeter to at least 10 volts (check the instructions that came with your meter for exactly how to do this). Check the voltage of your battery by touching the positive lead from the meter to the positive terminal of the battery, and the negative lead from the meter to the negative terminal of the battery.
9. Connect the 9-volt battery to the battery snap. Touch one of the multimeter leads to one wire of the resistor, and touch the other multimeter lead to the other resistor wire. If the voltage reading is negative, reverse the multimeter leads. Your Electronic Temperature Sensor is finished!
10. Now you need to calibrate your Electronic Temperature Sensor to so that you can use voltage measurements to find the temperature of the thermistor. Put some ice in one of the glass jar (or beaker or plastic cup), and add water so that the container is almost full.

Figure 2. Western Union splice.



The Western Union Splice. Bring ends of wires to be spliced together so that the ends are pointing in opposite directions (A). Twist each wire 3/4 of a turn in opposite directions (B). Turn the ends so they are at right angles to the wires being spliced, and twist each end to form at least five more turns spaced as tightly as possible (C). It is easier to make these twists with a pair of needle-nose pliers. Cut off the ends and twist them close to the center wire.

Figure 3.

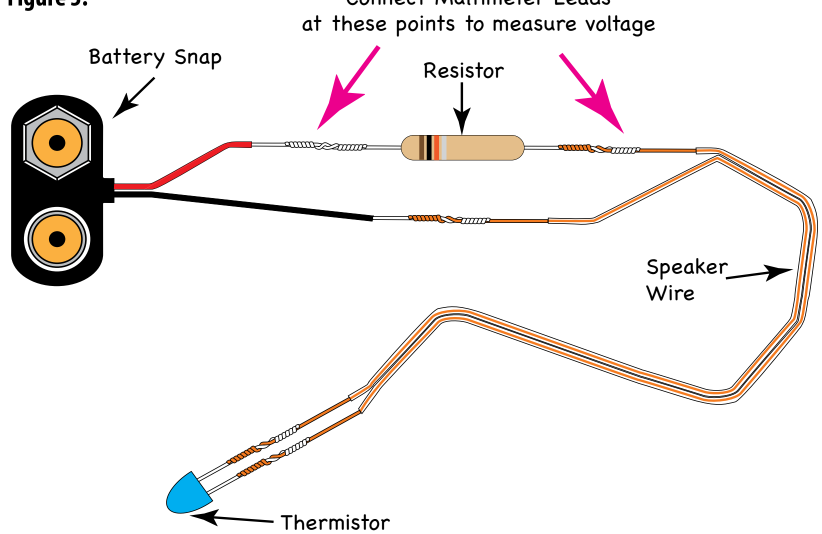
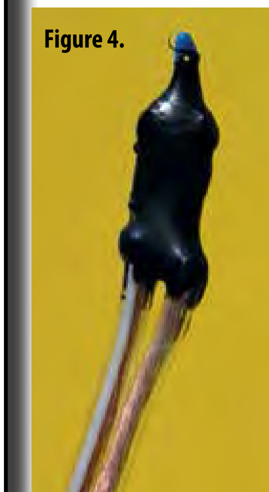


Figure 4.



11. Put some hot water in the other container, and put the thermistor into the water. Wait about ten seconds, then measure the voltage as in Step 9. Check the temperature of the water with the thermometer, and record the voltage and temperature in the Calibration Table.

12. Reduce the temperature of the water from Step 11 by adding a small amount of cold water. Put the thermistor into the water, wait about ten seconds, then measure the voltage and check the temperature of the water. Record the voltage and temperature in the Calibration Table. Repeat this step until you have at least eight different readings. The highest temperature should be around 80° C, and the lowest should be near 0° C.

13. Graph the data from the Calibration Table with temperature on the vertical axis (y-axis) and voltage on the horizontal axis (x-axis). Now you can use this graph to find the temperature that corresponds to any voltage reading from your Electronic Temperature Sensor.

Calibration Table

Voltage	Temperature

Want to Do More?

The University Corporation for Atmospheric Research Web site has links to interactives, simulations, games, and virtual labs about weather and climate: *https://spark.ucar.edu/interactives* and *https://spark.ucar.edu/activities*

Using Your Temperature Sensor

Your temperature sensor is useful when you want to record a series of temperature measurements from the same place over a long period of time, and to measure temperature in places that can't be reached with a liquid-filled thermometer. Here are three ideas (you can probably think of many more!):

Your Daily Weather

Climate is the average of weather conditions over many years, but regular weather measurements are needed to calculate this average. Measurements of air temperature along with other weather observations help improve weather predictions, and also help us understand how current weather conditions compare to climate averages. To investigate local temperature conditions with your temperature sensor, talk with your adult partner to select a sheltered location on a north-facing wall, which provides some protection from rain and direct sunlight. Install the sensor 1.2 to 1.8 m (about 4 to 6 ft) above ground, and try to make temperature measurements at the same time each day. Record your measurements in a notebook along with other observations about the weather at the time the measurements were made, such as rain conditions, cloud cover, wind, and barometric pressure (see Activity 5, "How Do We Know" for more weather instruments). For more about weather, climate, and temperature measurements and ideas for analyzing your data, see *http://globe.gov/sda/tg/maxmin.pdf*.

Explore a Microclimate

Microclimates are places whose climate is different from the surrounding area. They may be very small or as large as lakes or cities. Air temperatures over large bodies of water can be less extreme than temperatures over nearby land areas. Cities are often warmer than surrounding areas with fewer humans. Microclimates may also exist in valleys, where the bottom of a valley may be much colder than the slopes. Smaller microclimates are also found in home gardens where buildings, fences, rocks, raised beds, paved surfaces, and other features can change wind conditions, water flow, and sun exposure. Some microclimates are deliberately created to provide conditions needed by garden plants, and also to improve energy efficiency of buildings. See if you can find microclimates near your own home, and use your temperature sensor to compare their temperature with the temperature of nearby locations. Make daytime and nighttime measurements to see whether the microclimate effect changes with the time of day. Can you design a microclimate that might improve the energy efficiency of your home? Try a Web search on "energy efficiency" and "microclimate" for some ideas.

Investigate Water Quality

Your temperature sensor makes it easy to measure water temperature, and temperature is one of the most important characteristics of aquatic ecosystems. Temperature affects the biological activity of most species, and some species have very specific temperature requirements. Water temperature also affects dissolved oxygen levels and pH. High water temperatures can contribute to outbreaks of bacteria, harmful algae, and submerged aquatic vegetation. Talk with your adult partner about nearby water bodies that might be interesting to investigate. For more information about this kind of investigation, see *http://archive.senseit.org/files/Addon_Water_quality_and_temperature.pdf*.

Activity 5: How Do We Know?

What You Will Do: Make additional weather sensors; set up a home weather station

Big Idea

Our understanding of the climate system is improved through observations, theoretical studies, and modeling.

(Climate Science Principle 5)

What You Will Need*

Wind Vane Materials

Adult partner
1 – Broomstick or long wooden dowel, about 1 inch diameter
1 – Aluminum baking dish, about 6 x 9 inches
1 – Wood stick, about 3/4 inch square and 12 inches long
1 – Nail, about 1 inch long
1 – Metal washer with a hole slightly larger than the nail
Duct tape
Small saw or serrated knife
Scissors strong enough to cut the aluminum baking dish
Ruler or tape measure
Silicone or other glue that will stick to aluminum
Leather gloves
(Optional) Hand drill, and small drill bit slightly larger than the nail

Barometer Materials

1 – Ruler, about 30 cm (12 in)
1 – Clear drinking glass, glass jar, or other container with sides tall enough to support the ruler
1 – Clear plastic drinking straw or piece of clear plastic tubing, about 30 cm (12 in) long
Clear tape
Modeling clay or chewing gum
(Optional) Food coloring, your choice of color

Rain Gauge Materials

- Straight-sided glass or plastic container, with a diameter of about two inches or less (such as an olive jar)
- Coat hanger or wire bent to make a holding rack (see Figure 4)
- Measuring spoons: One teaspoon and 1/4 teaspoon
- Hammer and nails to secure the rack
- Felt tip marker

We all know that weather can change quickly, sometimes in only a few minutes. Climate also varies, but over longer periods of time. You may have heard someone say, "Expert weather forecasters can't accurately predict what the weather will be next week; how can anyone possibly know what the climate will be years from now?"

The answer is that forecasting climate is not the same as forecasting weather. Local weather predictions are based on natural processes that are more random and by their nature are difficult to precisely predict. Earth's climate systems, though, obey the basic physical laws that operate throughout the Universe. For example, when a planet's atmosphere traps heat, the planet's surface tends to become warmer. This means that the behavior of the climate system can be understood and predicted by careful scientific studies. Environmental observations are the foundation for these studies. Instruments carried on satellites, ships, buoys, weather stations, and other platforms can gather information about many pieces of the present climate system. Information about past climates can be found in natural records such as tree rings, ice cores, and layers of sediment, as well as in historical documents and local knowledge.


Image courtesy NOAA

This information can be combined with theories about climate to construct computer models that make predictions about what the climate will be when the ocean and atmosphere have certain characteristics. Comparing these predictions with knowledge about actual climate when these characteristics exist allows scientists to improve the computer models and make additional observations and experiments to make better predictions about future climate conditions.

A lot of research has been done about Earth's climate system, and climate prediction models continue to improve. Today's climate models are able to reproduce the average global temperature changes that occurred in the 20th century when they include all of the known natural and human-caused factors that affect climate. This gives us additional confidence that predictions about future climate conditions provide accurate information that will help societies decide how to prepare for the impacts of climate change.

* Scientists use many different instruments to make measurements that help predict weather and climate; but only a few instruments are needed to set up a Home Weather Station that can help you make your own weather predictions. You need to be able to measure temperature, wind speed, wind direction, and atmospheric pressure. You already know how to make an instrument for measuring temperature from Activity 4. Table 1 lists some clues that will help you estimate wind speed. To complete your Home Weather Station, you need a wind vane to measure wind direction, and a barometer to measure atmospheric pressure.

How It Works

Weather Vane: Winds are named according to the direction from which the wind is blowing, so a "north wind" is blowing from the north. The head of the Weather Vane will point to the direction from which the wind is blowing.

Beaufort Scale

Table 1
In 1805, Sir Francis Beaufort invented a scale from 0 – 12 for estimating wind speed based on features that can easily be observed.
Sailors still use the Beaufort scale, but professional weather forecasters usually report wind speed in miles per hour or kilometers per hour.
(source: *http://www.srh.noaa.gov/jetstream/ocean/beaufort_max.htm#beaufort*)

Beaufort Scale No.	Wind Speed (km/hr)	Wind Speed (mi/hr)	Forecast Term	Observations: Sea	Observations: Land
0	0-1	0-1	Calm	Sea surface smooth	Smoke rises vertically
1	1-5	1-3	Light	Sea surface rippled	Smoke drift indicates wind direction, wind vanes do not move
2	6-11	4-7	Light	Small wavelets, crests have glassy appearance but do not break	Wind felt on face, leaves rustle, wind vanes begin to move
3	12-19	8-12	Gentle	Large wavelets, crests begin to break	Leaves constantly moving, light flags extended
4	20-28	13-18	Moderate	Small waves, numerous whitecaps	Leaves, and loose paper lifted, small tree branches move
5	29-38	19-24	Fresh	Moderate waves, many whitecaps	Small trees in leaf begin to sway
6	39-49	25-31	Strong	Larger waves, whitecaps common, some spray	Larger branches moving, whistling in wires, umbrella use difficult
7	50-61	32-38	Strong	Sea heaps up, white foam streaks off breakers	Whole trees moving, resistance felt walking against wind
8	62-74	39-46	Gale	Moderately high (18-25 ft) waves, foam blown in streaks	Twigs breaking off trees, walking difficult
9	75-88	47-54	Gale	High waves (23-32 ft), dense streaks of foam	Slight structural damage may occur, slate blows off roofs
10	89-102	55-63	Whole Gale	Very high waves (29-41 ft) with overhanging crests, sea white with foam	Trees broken or uprooted, considerable structural damage
11	103-117	64-72	Whole Gale	Exceptionally high (37-52 ft) waves, foam covers sea	Extensive damage
12	118-132	72-82	Hurricane	Air filled with foam, waves over 45 ft, sea completely white	Countryside devastated

Barometer: The water level in the barometer tube will rise and fall as atmospheric pressure changes. When atmospheric pressure increases, air presses on the surface of the water in the container causing the height of the water in the tube to rise. When atmospheric pressure decreases, there is less pressure on the surface of the water in the container so the height of the water in the tube falls. Decreasing atmospheric pressure usually indicates that a low-pressure area is approaching, and this often brings clouds and rain. Increasing atmospheric pressure often indicates fair weather.

How to Do It

Make the Wind Vane

Be careful of the sharp edges on the pieces of cut aluminum! Use gloves to protect your hands until the edges are taped.

1. Use the saw or serrated knife to cut a notch about 1/2-inch deep into each end of the wood stick. The notches should be parallel (Figure 1).

2. Rotate the stick so that the two slots are vertical. Use the ruler or tape measure to find the exact center of the wood stick. Mark this spot on the upper surface of the stick, and drive a nail through the marked spot. Be careful: if the nail is too big, the stick will probably split. To avoid this, drill a hole slightly larger than the nail through the marked spot. You may need your adult partner to help with the drilling.

3. Cut the head and tail pieces of the Weather Vane from the aluminum baking dish using Figure 2 as a guide. **Be Careful—The Edges Are Sharp!** Use duct tape to cover the sharp edges.

Figure 1. Wind Vane Assembly

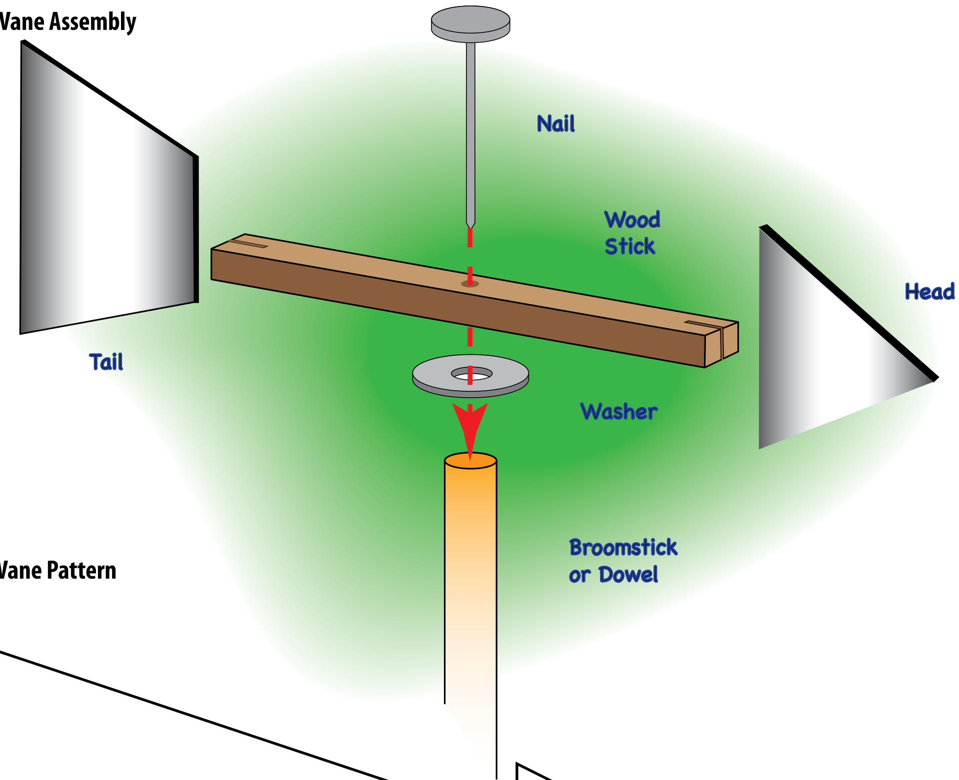
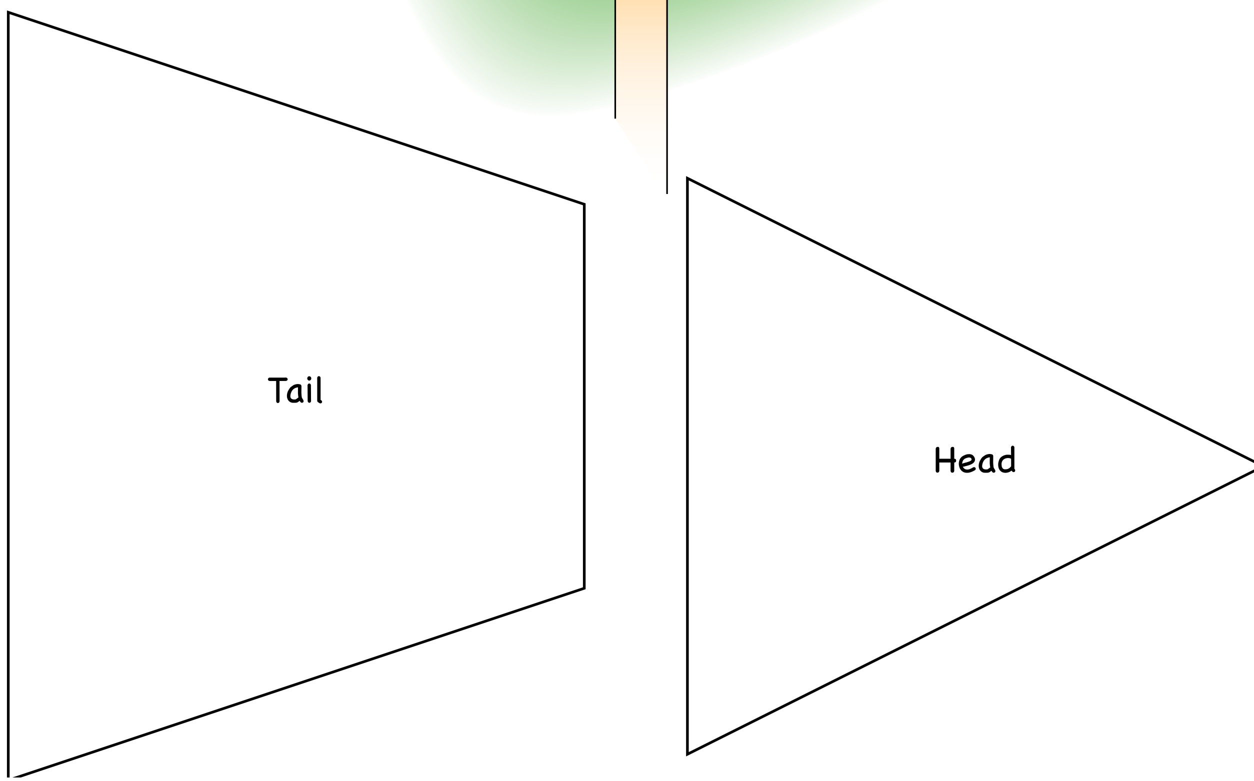


Figure 2. Wind Vane Pattern



4. Fit the head piece into one of the slots in the wood stick and fit the tail piece into the other slot. Glue the head and tail pieces into place and allow the glue to dry.

5. Attach the Weather Vane to the broomstick or dowel, by placing the washer on one end of the dowel and hammering the nail through the wooden stick into the dowel. Be sure the stick still moves freely around the nail.

6. Mount your Weather Vane outside where there are no nearby obstructions to block the wind. Try to get the dowel as high as you can while still keeping it steady and secure.

Make the Barometer

1. Tape the plastic straw or plastic tubing to the ruler so that one end is lined up with the "1 cm" ("1/2-inch") mark on the ruler.

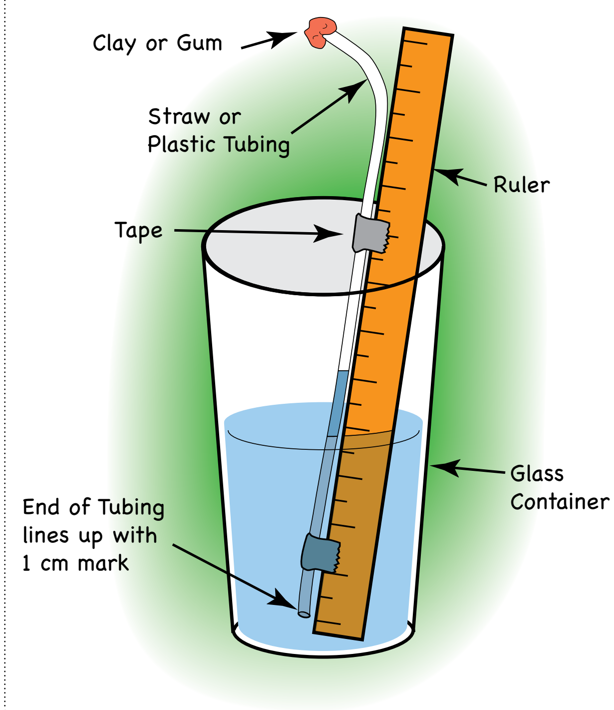
2. Stand the ruler-tubing assembly upright in the glass (or other container), and tape the assembly to the top of the container.

3. Fill the container about 3/4-full of water. If you want colored water, first mix food coloring with the water in another container.

4. Use the modeling clay or chewing gum (you'll have to chew it until it is soft enough) to plug the end of the straw or plastic tubing near the top of the ruler.

5. Carefully pour out some of the water so the container is about half full. Be sure the lower end of the straw or tubing stays beneath the water surface while you do this! When you are finished, the water in the straw or tube should be higher than the water in the container. Your barometer is now finished. Since barometers are sensitive to minor changes in weather conditions, keep your barometer indoors for greatest accuracy. (See Figure 3 for finished barometer.) The water level in the tube will rise and fall as atmospheric pressure changes. When atmospheric pressure increases, air presses on the surface of the water in the container causing the height of the water in the tube to rise. When atmospheric pressure decreases, there is less pressure on the surface of the water in the container, so he height of the water in the tube falls. Decreasing atmospheric pressure usually indicates that a low pressure area is approaching, and this often brings clouds and rain. Increasing atmospheric pressure often indicates fair weather.

Figure 3. Barometer



Sample Weather Journal Data Form

Date	Time	Temperature	Barometric Pressure		Wind		Precipitation		Other Events
			Instrument	NWS	Speed	Direction	Type	Amount	

Keep a daily record of outside temperature, barometric pressure, wind speed, wind direction, and recent precipitation or other significant weather events. When you record barometric pressure, record the height of the water in the barometer tube (using the scale on the ruler), as well as barometric pressure reported by a local office of the National Weather Service. That way, you will know how readings from your Home Weather Station barometer compare to measurements from barometers used by professional weather forecasters.

Make the Rain Gauge

1. Rain gauges measure the amount of rainfall in cubic inches. So your first task is to make a scale for your container that shows how many cubic inches of water are in the container. One cubic inch of water is about 3 1/4 teaspoons, so you can draw the scale on your container by measuring 3 1/4 teaspoons of water to your container, then drawing a short line at the level of the water. If you look closely, the top of the water will seem to be slightly curved and thickened. Draw your line so that it matches the bottom of the curved surface (which is called a meniscus). This line corresponds to a rainfall of one inch.

2. Add another 3 1/4 teaspoons of water to the container and draw another line. The second line corresponds to a rainfall of two inches.

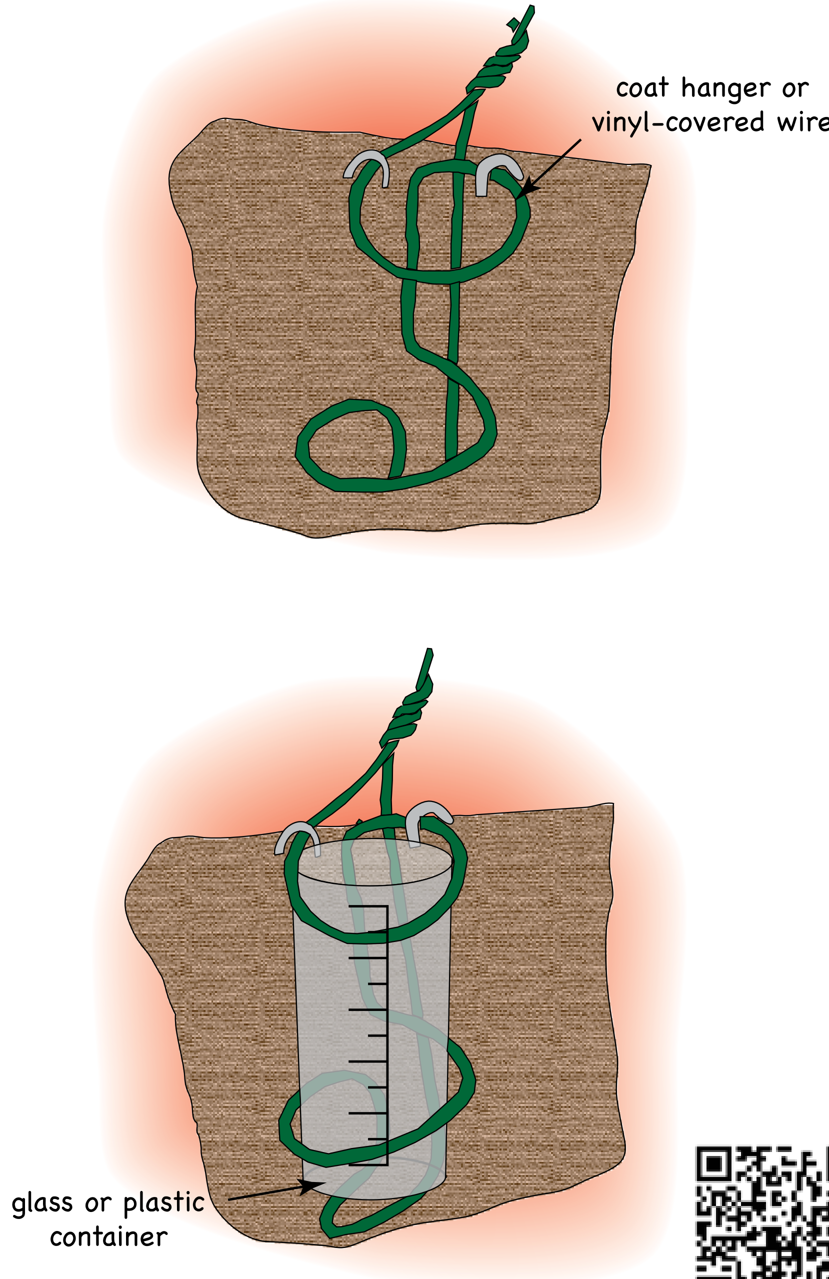
3. Repeat Step 2 until you have at least five marks on the container. This will be enough for most rain events; but you may want to add another line or two, just in case!

4. Find a location for your rain gauge where there is nothing overhead (such as trees or a building roof) that could direct water into or away from your gauge. The edge of a fence away from buildings is often a good spot. Another possibility is to attach your rain gauge to a broomstick driven into the ground in an open area. Be sure to record rainfall soon after a rain event to avoid false readings caused by evaporation.

Empty your gauge after each reading, and you are ready for the next event!

This activity is adapted from "Build Your Own Weather Station" by the Educational Technology Programs Team at the Franklin Institute, Philadelphia, PA (*http://www.fi.edu/weather/todo/todo.html*).

Figure 4. Rain Gauge



Activity 6: I Didn't Do It...Did I?

What You Will Do: Make Your Own Greenhouse Effect (adapted from Lambert, Cottongim, and Leard, 2009)

Big Idea

Human activities are impacting the climate system.

(Climate Science Principle 6)

What You Will Need

- Adult Partner
- 1 – Scratch awl or icepick
- 3 – Clear plastic drinking water bottles, about 500 ml (1 pt) capacity
- 1 – Vinyl tubing, about 3 mm (1/8 in) inside diameter, about 60 cm (2 ft) long (tubing for aquarium air systems works well)
- 2 – Thermometers (such as Forestry Suppliers #89323; these thermometers have an aluminum case which makes them useful for field investigations as well as in your laboratory)
- Modeling clay (the kind that doesn't harden, not the kind you bake)
- White vinegar, about 250 ml (1 c)
- Baking soda, about 40 g (2 tablespoons)
- Funnel
- Safety glasses
- Felt tip marker
- Heat lamp (if you don't have a sunny location)

More than 90% of climate scientists agree that Earth's average global temperature has increased since 1950, and the cause of this increase is human activities. These scientists also agree that most of the temperature increase is due to burning fossil fuels, which has increased the levels of greenhouse gases like carbon dioxide in Earth's atmosphere.

Two things happen when sunlight reaches Earth:

1. The land, ocean, and atmosphere absorb some of the sunlight's energy; and
2. They return some of this energy back into space.

Earth's atmosphere is a mixture of many gases. The most abundant are nitrogen (about 78% of the total atmosphere) and oxygen (about 21% of the total atmosphere). Other gases are present in much smaller quantities, yet are still very important for life on Earth, because they trap some heat in the atmosphere and prevent it from escaping to outer space. Heat-trapping gases are called greenhouse gases, and include water vapor, carbon dioxide, and methane. If the amount of greenhouse gases in the atmosphere increases, then more heat is trapped and Earth becomes warmer (for a short animation about how this works see *http://epa.gov/climatechange/kids/basics/index.html*).

Since the Industrial Revolution, widespread burning of fossil fuels has increased the concentration of greenhouse gases, mostly carbon dioxide, in Earth's atmosphere, and Earth's average temperature has increased. Other human activities have also changed Earth's atmosphere, as well as its land and ocean. Climate change caused by human activities is making it difficult for some species to survive. Scientists predict that there may also be positive benefits from climate change, such as longer growing seasons in some areas and less ice to interfere with ships passing through the Arctic Ocean. Overall, though, climate change is expected to produce more problems than benefits.

How It Works

Heat-trapping gases in Earth's atmosphere are called "greenhouse gases" because they reduce the amount of heat that is lost to outer space, but this is not actually the way a greenhouse works. It is hot inside a greenhouse because the glass allows objects inside to absorb heat from sunlight and prevents wind from carrying heat away. Greenhouse gases trap heat in the atmosphere, but do not form an actual barrier like glass in a greenhouse. Ozone is also a greenhouse gas, but holes in the ozone layer have nothing to do with global warming.

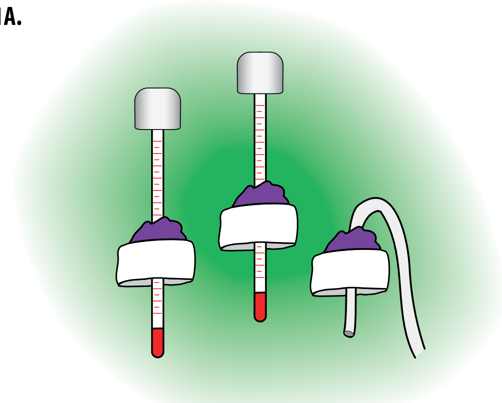
How to Do It

1. Read through all of these steps before you start!

2. Ask your adult partner to use the scratch awl to punch a hole in the caps of the drinking water bottles. The holes in two of the caps should be just large enough to fit the thermometers, and the hole in the third cap should be just large enough to fit the plastic tubing. Ask your partner to also punch a hole in the side of one of the drinking water bottles about 25 mm (1 in) from the top. Label this bottle "CO_2" with the felt tip marker.

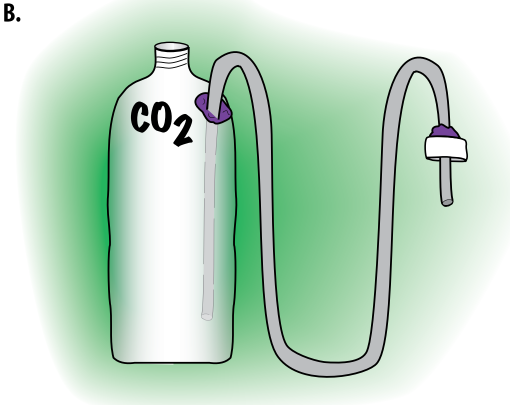
3. Put the thermometers and plastic tubing into the caps, and make a tight seal using modeling clay. The thermometers should extend about 40 mm (1.5 in) below their caps, and the tubing should extend about 25 mm (1 in) below its cap (Figure 1A).

Figure 1A.



4. Poke the free end of the plastic tubing into the hole in the side of the drinking water bottle so about 25 mm of the tubing is inside the bottle. Make a tight seal using modeling clay (Figure 1B).

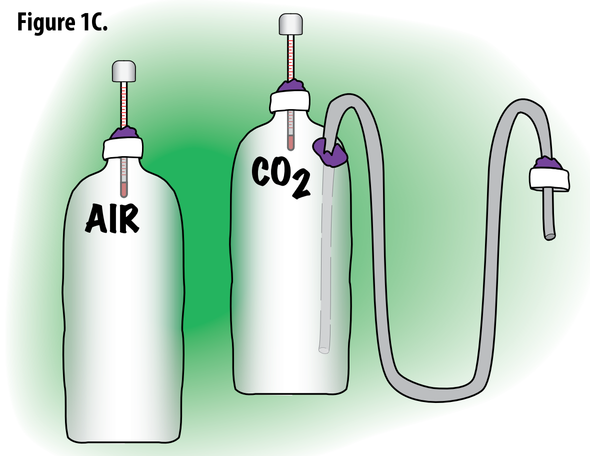
Figure 1B.



5. Put one of the caps with a thermometer onto one of the bottles that does not have the plastic tubing attached. Screw the cap on snugly. Label this bottle "Air" with the felt tip marker.

6. Put the other cap with a thermometer onto the "CO_2" bottle. Screw the cap on enough to keep it attached to the bottle, but loose enough so that air can escape if you squeeze the bottle (Figure 1C).

Figure 1C.



7. Use the funnel to place about 40 g (2 tablespoons) of baking soda in the unlabeled water bottle.

8. Get ready, because now you have to work fast. Pour about 60 ml (2 oz) of vinegar into the bottle with the baking soda, and QUICKLY fasten the cap with the tubing to the bottle. The easiest way to do this is to have one person pour the vinegar while the other person holds the bottle in one hand and the cap in the other hand. As soon as the vinegar is in the bottle, bring the cap and bottle together and twist the BOTTLE to make the seal. The mixture in the bottle will foam up vigorously, then gradually calm down. The bubbles are carbon dioxide gas, which will flow through the plastic tubing to the bottle with the hole in the side (Figure 2).

Gently swirl the bottle to move the vinegar around, and you should be able to stir up some more bubbles. When no more bubbles appear, remove the bottle from the cap, pour another 60 ml (2 oz) of vinegar into the bottle, and quickly replace the cap. Repeat this process until you have

Figure 2.

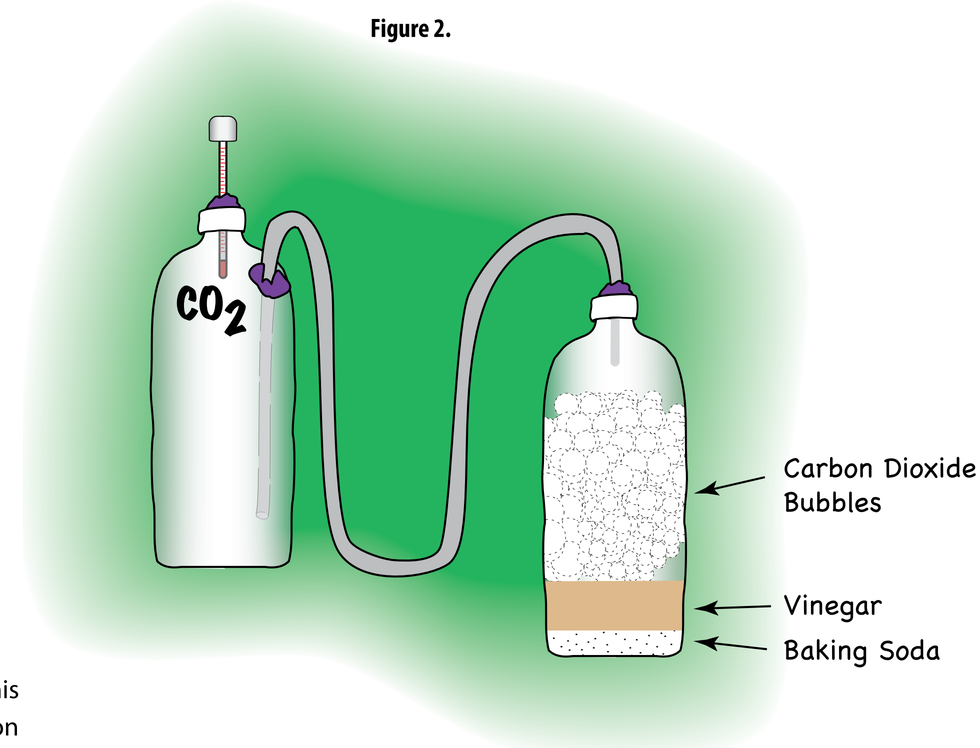


Table 1. Record Your Data

Temperature (°C)

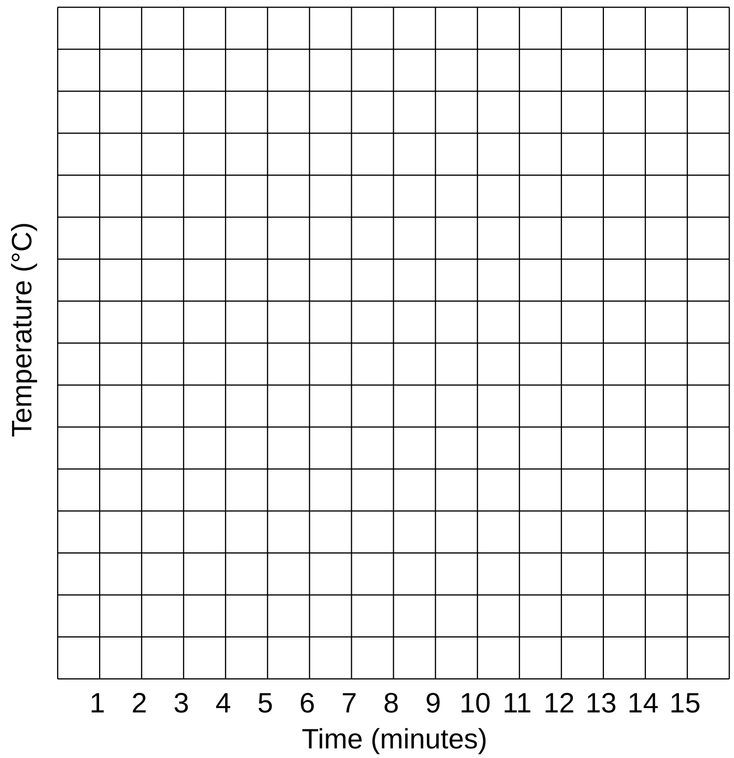
Time (min):	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Air																
CO_2																

added about 250 ml (1 c) of vinegar to the bottle. You should notice that the baking soda is gradually disappearing.

9. Remove the plastic tubing from the side of the bottle with the hole, and quickly seal the hole with modeling clay. Tighten the cap on the bottle.
10. Place both bottles in the sun, or near a heat lamp. Immediately record the temperature of both thermometers in the left column (labeled "0") of Table 1. Record the temperature every minute for 15 minutes. It doesn't matter if the two thermometers have different readings at the beginning, because the important thing is how quickly and how much the temperature changes in each bottle.

11. When you have recorded data for 15 minutes, construct a graph of these data. Your data should show that temperature increased in both bottles; but the temperature changed most quickly in the bottle with carbon dioxide, and the total temperature increase was greater in this bottle as well. Both bottles had a greenhouse effect, but adding carbon dioxide increased this effect; just as carbon dioxide added to the atmosphere by human activities has increased the greenhouse effect on Earth!

Graph 1. Graph Your Data



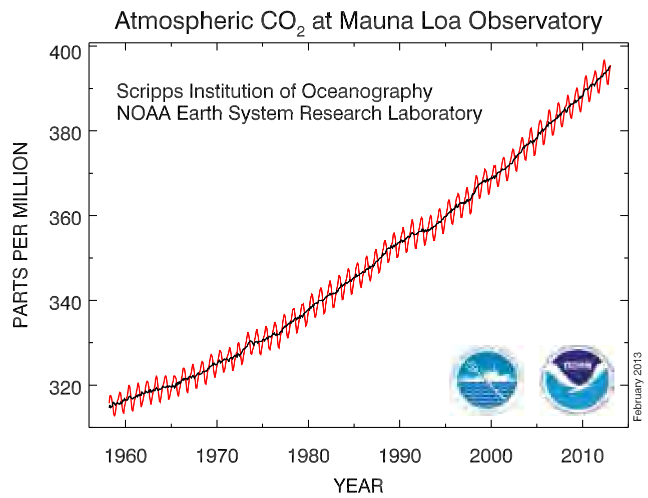
Note to Adult Partners

Lambert, Cottongim, and Leard (2009) describe an alternative method for this demonstration using dry ice to supply carbon dioxide. This may be somewhat quicker than the baking soda/vinegar method described here, but introduces additional hazards. If you want to use this method, be sure that your young partner understands the dangers of severe cold, and NEVER put dry ice and water into a sealed container. Closed plastic bottles containing dry ice and water can easily explode, creating dangerous shrapnel that can seriously injure anyone nearby.

Dry Ice can be DANGEROUS!!!

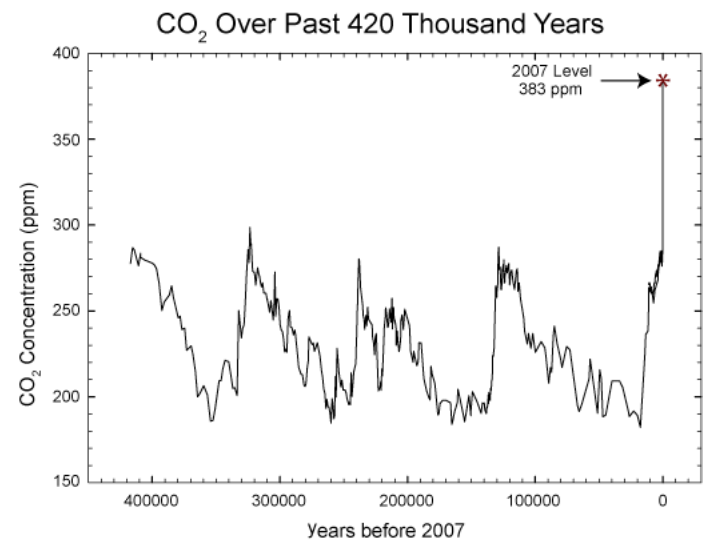
Lambert, J., Cottongim, L, & Leard, C. (2009). Investigating the greenhouse effect *Oceanography*. Published activity. (*http://www.oceanography.org/hands-on/activities/lambert_hands-on.pdf*)

Graph 2. Measurements of carbon dioxide in the atmosphere at the Mauna Loa Observatory since 1957.



http://www.esrl.noaa.gov/gmd/ccgg/trends/

Graph 3. Atmospheric carbon dioxide concentrations over the last 420,000 years.



http://scrippsco2.ucsd.edu/program_history/keeling_curve_lessons_4.html

More About Carbon Dioxide

Here are two famous graphs. Graph 2 shows measurements of carbon dioxide in the atmosphere at the Mauna Loa Observatory that began in 1957. This graph shows annual variations in carbon dioxide concentration caused by changing growth rates of plants during the seasons of the Northern Hemisphere, and also shows a steady increase in atmospheric carbon dioxide that has continued every year since the measurements began. Graph 3 shows atmospheric carbon dioxide concentrations over the last 420,000 years based on studies of polar ice cores. During ice ages, carbon dioxide levels were around 200 ppm, and rose to about 280 ppm during the warmer periods between the ice ages. Since the Industrial Revolution, atmospheric carbon dioxide concentrations have risen to much higher levels. The evidence contained in these two graphs is why most climate scientists agree that human activities have increased the concentration of carbon dioxide in Earth's atmosphere.

Is the greenhouse effect a bad thing? Definitely not, because life on Earth would not exist without it! But too much greenhouse effect can also cause problems. Venus has a thick atmosphere made of 96% carbon dioxide (compared to Earth's atmosphere that contains less than 0.04% carbon dioxide). The greenhouse effect on Venus is much larger than on Earth, and Venus has a surface temperature of about 450°C! Mars, on the other hand has a very thin atmosphere, only 1/100th as dense as Earth's. Most of Mars' atmosphere is carbon dioxide (95%), but the greenhouse effect is insignificant because the atmosphere is so thin. As a result, the surface temperature of Mars is around -53°C. These facts are summarized by the "Goldilocks Principle": Venus is too hot, Mars is too cold, and Earth is just right.

Want To Do More?

Find out about Charles David Keeling, the science hero behind the atmospheric carbon dioxide measurements at Mauna Loa Observatory: *http://scrippsco2.ucsd.edu/index.php*

Activity 7: Why Should I Care?

What You Will Do: Show how increased carbon dioxide makes the ocean more acidic

Big Idea

Climate change will have consequences for the Earth system and human lives.

(Climate Science Principle 7)

What You Will Need

- Adult partner
- 5 – Clear glass jars or plastic cups, about 250 ml (8 oz) capacity
- 1 – Graduated cylinder or measuring cup, about 250 ml (8 oz) capacity
- 1 – Measuring spoon, about 1 ml (1/4 tsp) capacity
- 1 – Measuring spoon, about 5 ml (1 tsp) capacity
- 1 – Small pot, about 1 liter (1 qt) capacity
- 1 – Funnel, about 7 cm (3 in) diameter
- Safety glasses
- Cheesecloth, about 30 cm (12 in) square
- 500 ml (2 c) finely chopped red cabbage
- Drinking straw
- Boiling water, about 500 ml (2 c)
- Baking soda
- White vinegar

Increased carbon dioxide in the atmosphere is leading to many changes that have serious consequences for Earth's ecosystems, including humans. Climate change is causing ice sheets and glaciers to melt, and sea level rises as the melt water flows into Earth's ocean. Seawater is beginning to contaminate sources of fresh water. Rising sea level is submerging coastal marshes that help protect the shore from severe storms, and bringing structures on land closer to the edge of the ocean. These changes make it more likely that these structures will be damaged by coastal storms, which are expected to increase as additional heat in Earth's atmosphere changes the patterns of winds and precipitation. Heat waves and droughts are also expected to increase, and bring additional threats to human lives.

Limacina helicina, a free-swimming planktonic snail. These snails, known as pteropods, form a calcium carbonate shell and are an important food source in many marine food webs. As levels of dissolved CO_2 in sea water rise, skeletal growth rates of pteropods and other calcium-secreting organisms will be reduced due to the effects of dissolved CO_2 on ocean acidity. Image credit: Russ Hopcroft, UAF/NOAA.

In addition to other impacts of global climate change, ocean acidification poses potentially serious threats to the health of Earth's ocean and its ecosystems. The impact on individual species is expected to vary. A more acidic environment has a dramatic effect on some species that build calcium carbonate (limestone) shells, such as oysters. When shelled organisms are at risk, the entire food web also is at risk. For example, pteropods are an important food source for salmon. According to some research reports, a 10 percent drop in pteropod production could result in a 20 percent drop in the mature body weight of pink salmon (*Oncorhynchus gorbuscha*). These impacts are happening right now, and are affecting marine food webs that provide important sources of food for humans as well as ocean species.

Increased atmospheric carbon dioxide is also causing serious changes in the chemistry of Earth's ocean. The ocean absorbs about a quarter of the carbon dioxide humans release into the atmosphere every year, and this additional carbon dioxide in seawater is causing Earth's ocean to become more acidic. Scientists use a measurement called pH to describe how acidic or basic a solution is. A pH of 7 is considered neutral. Acidic solutions, such as vinegar or lemon juice, have a pH less than 7. The more acidic a solution is, the lower the pH number. Basic solutions, such as milk or baking soda dissolved in water, have a pH greater than 7.

How It Works

Red cabbage contains chemicals that change color depending upon pH. These types of chemicals are called pH indicators. In basic solutions, these chemicals from red cabbage are light blue, but they change to pink-purple in acidic solutions. At the beginning of your demonstration, you will put a very small amount of baking soda into the container of tap water to be sure that it is slightly basic (seawater is normally slightly basic, with a pH of about 8.2). So, when you add the red cabbage indicator solution to the container of tap water, the indicator will have a light blue color.

When you exhale, the air from your lungs contains more carbon dioxide than the air in the atmosphere. Blowing through a straw into the container of tap water bubbles carbon dioxide through the liquid. Some of this carbon dioxide dissolves to form a weak acid (carbonic acid). When this happens, the red cabbage indicator changes to a pink-purple color, showing that the pH has changed and the liquid has become more acidic.

How to Do It

1. Put the chopped red cabbage into a small pot, and pour in about 500 ml (2 c) boiling water to cover the cabbage. Let the mixture rest for about 30 minutes.

2. Fold the cheesecloth so that it is at least four layers thick, but still covers the opening of the funnel. Strain the cabbage mixture through the cheesecloth into one of the glass jars or plastic cups. You will have some liquid left over in the pot. Save this in case you need it later.

3. Pour about 50 ml (1/4 c) of tap water into another glass jar or plastic cup. Add 5 ml (1 tsp) of the red cabbage indicator solution to the jar. The solution should have a pale blue color. The pH of tap water varies from place to place, so if the solution is not pale blue, add a pinch of baking soda, and gently swirl the container so that the baking soda dissolves. Repeat if necessary until the solution has a pale blue color.

4. Pour about 50 ml (1/4 c) of tap water into another glass jar or plastic cup. Add 5 ml (1 tsp) of the red cabbage solution to the jar, then add 5 ml (1 tsp) of white vinegar. The solution should have a pink-purple color.

5. Put about 1 ml (1/4 tsp) of baking soda into another glass jar or plastic cup, fill the container with tap water, and gently swirl the container so that the baking soda dissolves.

6. Pour about 50 ml (1/4 c) of tap water into the last glass jar or plastic cup. Add 1 ml (1/4 tsp) of the baking soda solution from Step 5 solution to the jar, then add 5 ml (1 tsp) of the red cabbage solution to the jar. The solution should have a pale blue color.

7. Put on a pair of safety glasses. Blow gently through the straw into the solution prepared in Step 6. Keep blowing for several minutes, until the color of the solution changes from pale blue to pink-purple. You have just shown how dissolved carbon dioxide can make a solution more acidic!

Left: Red cabbage solution;
Right: Blue cabbage solution

This is what is happening to Earth's ocean because of carbon dioxide that has been added to Earth's atmosphere by human activities.

Want To Do More?

This Web page has more information about ocean acidification: **http://www.pmel.noaa.gov/co2/story/What+is+Ocean+Acidification%3F**. Images on this page show what happens to a pteropod (pronounced "TARE-oh-pod") shell when it is exposed to seawater with a pH that is lower than normal. After 45 days, the shell slowly dissolves. Earth's ocean is not this acidic yet, but is predicted become this acidic by the year 2100 if humans continue the present pattern of adding carbon dioxide to the atmosphere.

For more information about ocean acidification, check out these slide shows and videos: *http://coralreef.noaa.gov/education/oa/presentation-videos.html*

Activity 8: Are You Climate Literate?

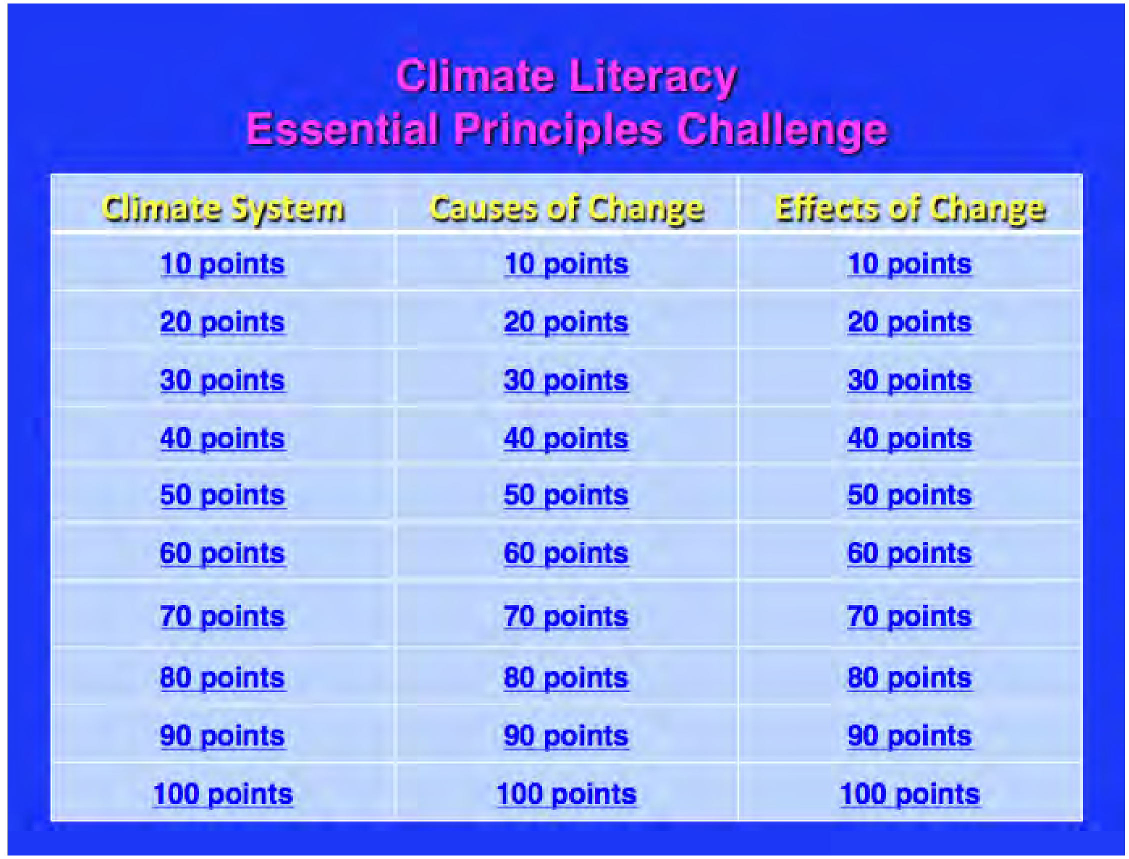
What You Will Do: Play the Essential Principles Challenge

Big Idea
A climate-literate person understands the essential principles of Earth's climate system.

What You Will Need

- Copies of Essential Principles Challenge Cards (pages 33 and 34)
- Glue (spray glue or rubber cement is best)
- Scissors
- (Optional) desk bells or buzzer (see Step 6)
- (Optional) Copy of the Essential Principles Challenge PowerPoint® file (PrinciplesChallenge.ppt) downloaded from [*oceanservice.noaa.gov/education/discoverclimate/areyouclimateliterate.ppt*]
- (Optional) Computer with Microsoft PowerPoint® installed
- (Optional) One or more partners to play the game

Climate Science Literacy means understanding how you affect climate and how climate affects you and the society in which you live.



Home screen from PrinciplesChallenge.pptx file.

Why is Climate Science Literacy important? Because in the last 100 years, Earth's average global temperature increased more rapidly than at any other time in the last 10,000 years. In the 21st century, climate scientists expect temperature will continue to increase, probably even more than it did during the 20th century. Increasing global temperature is causing sea level to rise, and heat waves, droughts, and floods to become more frequent and intense. These changes will affect almost every aspect of human society, including economic prosperity, human and environmental health, and national security.

Scientific evidence indicates that human activities are the primary cause of the ongoing global temperature increase. Climate Science Literacy makes it possible for humans to take actions that can reduce climate change and its impacts.

A climate-literate person:

- Understands the essential principles of Earth's climate system;
- Knows how to assess scientifically credible information about climate;
- Communicates about climate and climate change in a meaningful way; and
- Is able to make informed and responsible decisions with regard to actions that may affect climate.

How It Works

The Essential Principles Challenge is a game based on "Climate Literacy—The Essential Principles of Climate Sciences," which can be downloaded from *http://oceanservice.noaa.gov/education/literacy.html*. The game can be played with the cards included in this activity, or as a PowerPoint®-based game that is somewhat similar to the television game show "Jeopardy." If you are familiar with the PowerPoint® program, you can change the question and answer slides to make your own version of the game.

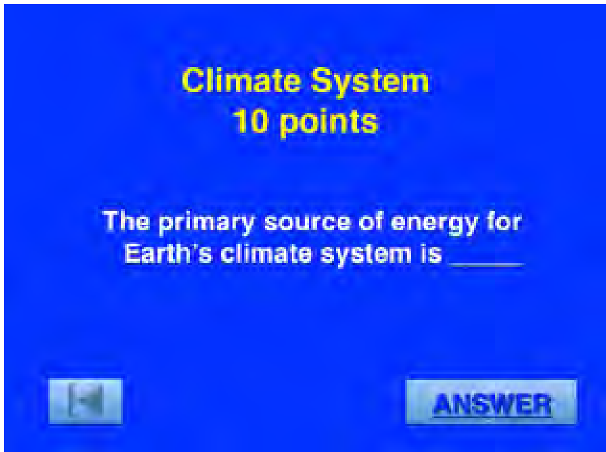
Some of the answers to Challenge questions can be found in this activity book, and all of them can be found in "Climate Literacy – The Essential Principles of Climate Sciences." Each of the answer cards and slides includes Web addresses where additional information can be found.

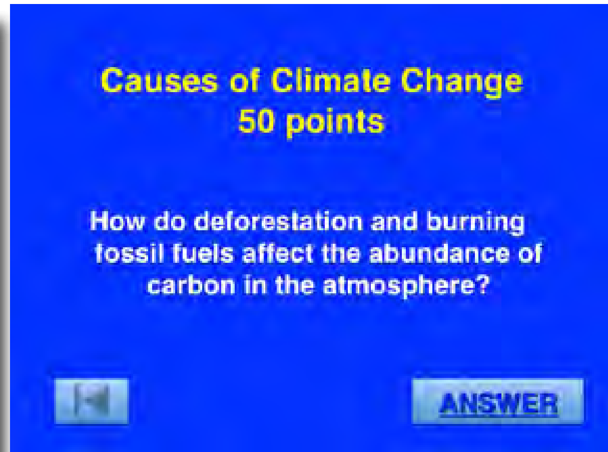
How to Do It

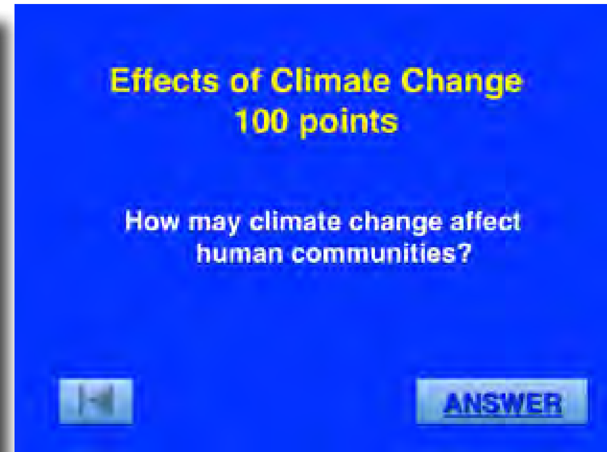
To play the Essential Principles Challenge with the cards included in this activity:

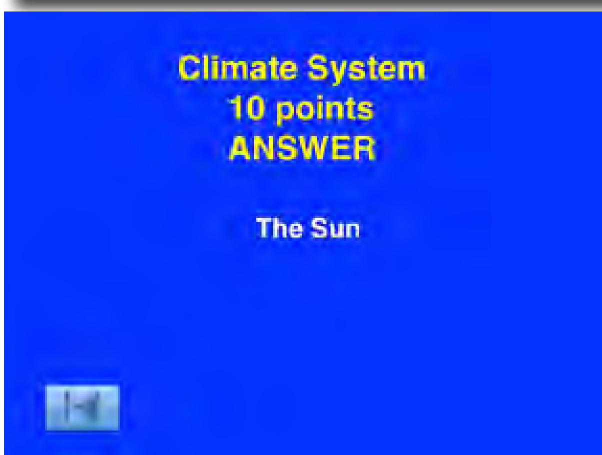
1. Glue the first two pages of the Essential Principles Challenge Cards back-to-back so that the 10 point "Climate System" question card is exactly behind the 10 point "Climate System" Answer card. Cut the cards apart along the dotted lines.

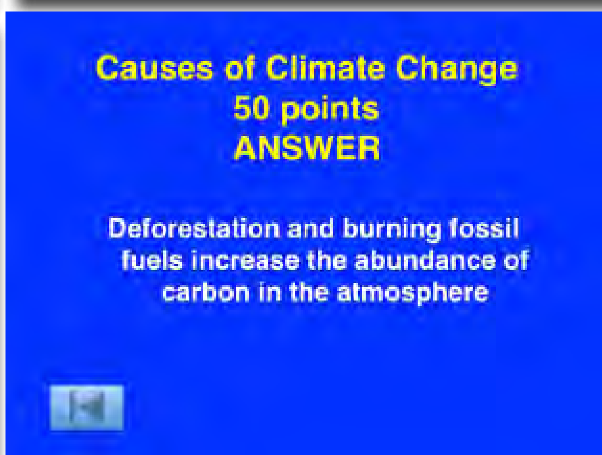
2. Glue the remaining two pages of the Essential Principles Challenge Cards back-to-back so that the 10 point "Effects of Climate Change" question card is exactly behind the 10 point "Effects of

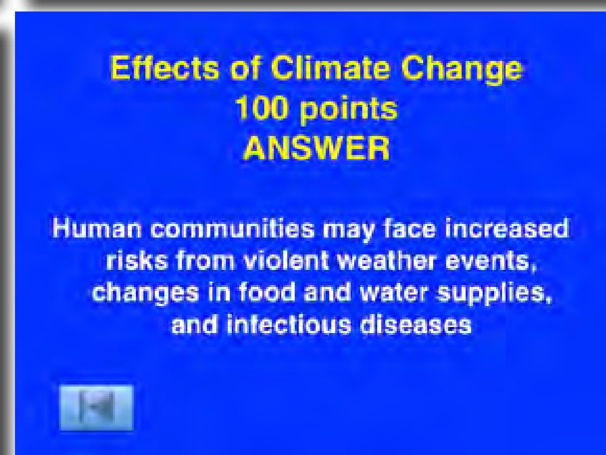












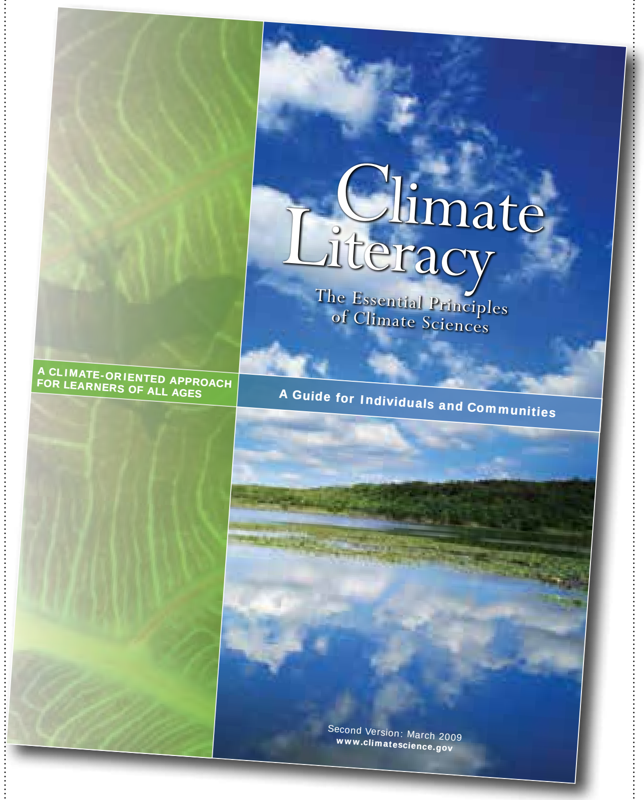
Climate Change" Answer card. Cut the cards apart along the dotted lines.

3. Arrange the cards so that the question sides are all facing up. Shuffle the cards.

4. If you are playing alone, read the question printed on each card, and decide on your answer. Look at the Answer side of the card to find out whether you are correct. Each correct answer is worth the number of points indicated on the card. Write down the number of points you earn for each card, and add these numbers when you have looked at all of the cards. Repeat this step to see if you can improve your score.

5. If you are playing with one or two partners, take turns drawing the top card and stating the answer. Use the Answer side of the card to decide whether a player's statements are correct, and how many points the player receives. When all of the cards have been read, add the points earned by each player to decide a winner.

6. You can also use these cards for a College Bowl type of competition between several players or several teams of players. For this version of the game, one person is the Host, and each player or team has a desk bell or buzzer. To begin the game, the Host reads a Question card and the first player or team to hit their bell or buzzer gets a chance to state the answer. If the answer is correct, the player or teams receives the number of points shown on the card. If the answer is not correct, the team that was second to hit their bell or buzzer gets a chance to answer. If no one provides a



correct answer, no points are awarded and the host moves on to the next card. This process continues until all of the cards have been used. The player or team with the greatest number of points is the winner!

To play the Essential Principles Challenge as a PowerPoint®-based game:

1. Open the PrinciplesChallenge.ppt file in Microsoft PowerPoint®, and select "View Slide Show" from the "Slide Show" drop-down menu.

2. You will see the Home screen, which has three columns labeled "Climate System," "Causes of Change," and "Effects of Change." In each column there are eight boxes labeled with a certain number of points. When you click on one of these labels, a new screen will appear with a question, a box labeled "ANSWER" in the lower right corner, and another box with a rewind icon in the lower left corner. If you click on the 'ANSWER" button a new screen will appear with the answer to the question. Clicking on the rewind icon will return to the Home screen. The ANSWER screens also have a rewind icon.

3. Before beginning a game, players should choose one of the following rules for when the game will end:
   a. When all of the questions have been answered; OR
   b. When each player has answered a certain number of questions from each column: OR
   c. When a certain amount of time has passed since the game started.

4. To play the game, players take turns choosing a question from one of the three columns on the Home screen. One player serves as scorekeeper, and records the number of points each player receives for a correct answer. The object of the game is to accumulate the greatest number of points. When the game ends according to the rule agreed upon in Step 3, the scorekeeper adds up the points earned by each player to decide the winner.

Note: Mention of commercial products or trade names does not imply endorsement by NOAA.

Climate System The primary source of energy for Earth's climate system is _____ **10**	**Climate System** Sunlight that reaches Earth may be reflected by **20**	**Climate System** When Earth emits the same amount of energy as it absorbs, what happens to Earth's average temperature? **30**
Climate System When Earth emits the same amount of energy as it absorbs, Earth's energy budget is ______ **40**	**Climate System** The annual cycle of seasons on Earth is the result of _____ **50**	**Climate System** How much of Earth's surface is covered by its ocean? **60**
Climate System True or False: The greenhouse effect is an abnormal condition caused by human activity. **70**	**Climate System** The minute-by-minute variable condition of the atmosphere on a local scale is called ___ **80**	**Climate System** What results from interactions that involve the Sun and Earth's ocean, atmosphere, clouds, ice, land, and life? **90**
Climate System Earth's systems are connected, and a change in one system can influence the entire system. What do we call interactions that amplify the effects of change? **100**	**Causes of Climate Change** A significant increase or decrease in the Sun's energy output will cause Earth to warm or cool. What do satellite measurements over the past 30 years show about the Sun's energy output? **10**	**Causes of Climate Change** What determines the amount of solar energy absorbed or radiated by Earth? **20**
Causes of Climate Change Which is NOT a greenhouse gas: Water vapor Carbon dioxide Methane, or Oxygen **30**	**Causes of Climate Change** Do small increases in carbon dioxide concentration in Earth's atmosphere make much difference to the climate system? **40**	**Causes of Climate Change** How do deforestation and burning fossil fuels affect the amount of carbon in the atmosphere? **50**

Effects of Climate Change
What happens to organisms that are exposed to climate conditions outside their normal range?

10

Effects of Climate Change
What does evidence from tree rings and scientific observations suggest about Earth's present average temperature?

20

Effects of Climate Change
How is increasing atmospheric carbon dioxide affecting Earth's ocean?

30

Effects of Climate Change
The overwhelming consensus of scientific studies on climate indicates that most of the observed increase in global average temperatures in the last 30 years is due to ___

40

Effects of Climate Change
Widespread burning of fossil fuels has increased the concentration of ______ in the atmosphere.

50

Effects of Climate Change
Do scientists and economists predict that there will be positive changes from global climate change?

60

Effects of Climate Change
How does global climate change affect fresh water resources?

70

Effects of Climate Change
What changes in Earth's ocean may be caused by melting ice sheets and glaciers?

80

Effects of Climate Change
How is weather predicted to change as a result of global climate change?

90

Effects of Climate Change
How may climate change affect human communities?

100

Causes of Climate Change
How do airborne particulates (aerosols) affect Earth's energy balance?

60

Causes of Climate Change
Over the last one million years, what caused the cycles of ice ages and warmer periods between them?

70

Causes of Climate Change
What natural processes reduce the amount of carbon in Earth's atmosphere?

80

Causes of Climate Change
How can life affect Earth's climate?

90

Causes of Climate Change
How long may greenhouse gases remain in Earth's atmosphere?

100

Climate System **The average temperature remains stable (stays the same)** *http://earthguide.ucsd.edu/earthguide/diagrams/energybalance/* **ANSWER - 30**	**Climate System** **Earth's surface, clouds, and ice** *http://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-1-1.html* **ANSWER - 20**	**Climate System** **The Sun** *http://climate.nasa.gov/causes/* **ANSWER - 10**
Climate System **70%** *http://oceanservice.noaa.gov/education/pd/oceans_weather_climate/welcome.html* **ANSWER - 60**	**Climate System** **The tilt of Earth's axis** *http://www.crh.noaa.gov/fsd/?n=season* **ANSWER - 50**	**Climate System** **In balance** *http://earthguide.ucsd.edu/earthguide/diagrams/energybalance/* **ANSWER - 40**
Climate System **Earth's climate** *http://www.epa.gov/climatechange/students/basics/concepts.html* **ANSWER - 90**	**Climate System** **Weather** *http://www.epa.gov/climatechange/students/basics/concepts.html* **ANSWER - 80**	**Climate System** **False** **The greenhouse effect is a natural phenomenon that keeps Earth's surface at a temperature favorable to living organisms.** *http://www.epa.gov/climatechange/students/basics/today/greenhouse-effect.html* **ANSWER - 70**
Causes of Climate Change **The composition of Earth's atmosphere** *http://pa.gov/climatechange/students/basics/today/greenhouse-effect.html* **ANSWER - 20**	**Causes of Climate Change** **Changes in the Sun's energy output are too small to cause recent warming on Earth** *http://www.epa.gov/climatechange/students/scientists/ruled-out.html#one* **ANSWER - 10**	**Climate System** **Positive feedback loops** *http://www.epa.gov/climatechange/students/basics/today/greenhouse-gases.html* **ANSWER - 100**
Causes of Climate Change **Deforestation and burning fossil fuels increase the abundance of carbon in the atmosphere** *http://climate.nasa.gov/causes/* **ANSWER - 50**	**Causes of Climate Change** **Yes; small increases in carbon dioxide concentration have a large effect on the climate system** *education.usgs.gov/lessons/gases.pdf* **ANSWER - 40**	**Causes of Climate Change** **Oxygen** *http://www.epa.gov/climatechange/students/basics/today/greenhouse-gases.html* **ANSWER - 30**

Effects of Climate Change
Increased dissolved carbon dioxide is causing the ocean to become more acidic.
http://www.epa.gov/climatechange/students/impacts/signs/acidity.html
ANSWER - 30

Effects of Climate Change
Earth's average temperature is warmer than it has been for at least the past 1,300 years
http://www.epa.gov/climatechange/students/impacts/signs/temperature.html
ANSWER - 20

Effects of Climate Change
The organisms will adapt, migrate, or die
http://www.epa.gov/climatechange/students/impacts/effects/ecosystems.html
ANSWER - 10

Effects of Climate Change
Both positive and negative changes are predicted, but negative impacts are likely to be greater than positive impacts.
http://www.epa.gov/climatechange/students/impacts/effects/index.html
ANSWER - 60

Effects of Climate Change
Greenhouse gases
http://www.epa.gov/climatechange/students/basics/today/index.html
ANSWER - 50

Effects of Climate Change
Human activities, primarily burning fossil fuels
http://www.epa.gov/climatechange/students/basics/index.html
ANSWER - 40

Effects of Climate Change
Strong storms, heat waves, and changes in precipitation patterns are predicted to increase in many locations
http://www.epa.gov/climatechange/students/impacts/signs/index.html
ANSWER - 90

Effects of Climate Change
Sea level will rise, and changing temperatures may affect large current systems in Earth's ocean
http://www.epa.gov/climatechange/students/impacts/signs/glaciers.html
ANSWER - 80

Effects of Climate Change
Changing precipitation patterns and temperatures will reduce access to fresh water for many people. Winter snow and glaciers that provide water are declining.
http://www.epa.gov/climatechange/students/impacts/effects/water.html
ANSWER - 70

Causes of Climate Change
Ice ages are caused by gradual changes in Earth's rotation and orbit around the Sun
http://oceanservice.noaa.gov/education/pd/climate/factsheets/whatcause.pdf
ANSWER - 70

Causes of Climate Change
Airborne particulates cause cooling by reflecting sunlight, and also cause warming by absorbing and releasing heat energy in the atmosphere
http://epa.gov/climatechange/science/causes.html
ANSWER - 60

Effects of Climate Change
Human communities may face increased risks from violent weather, changes in food & water supplies,and infectious diseases
http://www.epa.gov/climatechange/students/impacts/effects/index.html
ANSWER - 100

Causes of Climate Change
Greenhouse gases may remain in Earth's atmosphere for hundreds of years.
http://epa.gov/climatechange/science/future.html
ANSWER - 100

Causes of Climate Change
By changing the chemical makeup of the atmosphere
www.nsf.gov/news/nsf09202/nsf09202_life.pdf
ANSWER - 90

Causes of Climate Change
Accumulation of marine sediments and accumulation of plant biomass
http://www.epa.gov/climatechange/students/basics/today/carbon-dioxide.html
ANSWER - 80

Activity 9: Communicate!

What You Will Do: Create a unique message about climate change

Big Idea

A climate-literate person communicates about climate and climate change in a meaningful way.

What You Will Need

Depends upon how you decide to communicate your message.

During the last 100 years, Earth's average surface temperature has increased more rapidly than at any other time in the last 10,000 years. Global average temperature is expected to continue to increase over the 21st century, probably more than it did during the 20th century. Human activities are the primary cause of most of the ongoing increase in Earth's average surface temperature. Specifically, human activities that increase greenhouse gases in the atmosphere are causing rapid changes to Earth's climate. Heat waves, droughts, and floods are becoming more intense and happen more often. Global sea level is rising as a result of warmer temperatures. These changes will affect global economies, human and environmental health, and national security.

Humans are at least partially responsible for the global climate change that is happening now (*http://www.ipcc.ch/publications_and_data/ar4/syr/en/spm.html*), but humans also are able to take actions to reduce climate change and its impacts. Reducing greenhouse gas emissions is the key. Burning fossil fuels for energy is a major source of increased greenhouse gases in the atmosphere. Since everyone uses energy, everyone can be part of the solution. Most people use electricity almost constantly (even when they are asleep!) for heating, cooling, transportation, cooking, working, entertainment, and many other activities. Practically everything we touch required energy for manufacturing and distribution. Most of the energy for all these things comes from burning fossil fuels.

Unfortunately, many people are not climate literate, do not understand how human activities have caused climate change, and do not know what they can do to reduce climate change and its impacts. This is why communication is an essential part of climate literacy.

How It Works

At this point, you know a lot about Earth's climate, how it is changing, and how human activities are involved with these changes. In fact, you probably know a lot more about these subjects than many people! A very important part of Climate Literacy is communicating accurate information so more people will understand what is happening and how they can personally respond to Earth's changing climate.

Signs of Climate Change

Source: *http://www.epa.gov/climatechange/kids/impacts/signs/index.html*

Effects of Climate Change

Source: *http://www.epa.gov/climatechange/kids/impacts/effects/index.html*

Believe it or not, students who communicate about serious subjects often receive more attention than adults. One reason for this is that students think of creative ways to communicate. In school, written papers, oral reports, and posters are common methods for communication. All of these communication techniques are also used by professional scientists to share their ideas and information, because communication is an essential part of science. There are many other ways to communicate, and unusual methods can help get people's attention and lead them to think about the information in the message. This Web page describes several different kinds of communication projects: *http://games.noaa.gov/seaturtle/digitalprojects.html*. Table 1 lists some additional ideas.

These ideas are only a starting point; you can probably think of even better ways to communicate information about Climate Literacy to your own audiences!

How to Do It

1. Choose your message. Select one or two ideas about Earth's climate from the other activities in this book. Be sure to include a few things that people can do personally about climate change. For some ideas, check out the Student's Guide to Global Climate Change (*http://www.epa.gov/climatechange/students/solutions/index.html*).

2. Choose your audience. Ask yourself, "Who is supposed to receive this message?" It may seem that the answer should be "Everybody," but the problem with that answer is that different people communicate in different ways. Focusing your message toward a particular audience makes it more likely that your message will be understood.

3. Choose your communication technique. This is where you can be really creative! Think about things that are likely to attract the attention of the audience you identified in Step 2. Then think about unusual ways to present those things, because humans are much more likely to notice unusual events and objects than things that are familiar. Sometimes "unusual" just means that familiar things appear in unusual places. Look over the list of Communication Ideas, think about whether these give you some ideas of your own, then select the technique that you think is most likely to get the attention of your audience. Remember to consider your personal talents and interests as well. Perhaps you can sing, act, dance, play a musical instrument, paint, sculpt, enjoy making things, or have other skills. Think about ways to use these to help deliver your message. Your interest and enthusiasm are powerful tools for communication, because they are likely to attract the attention and interest of your audience.

4. Plan a strategy to deliver your message, including a brief statement of what your message is, who your audience is expected to be, which communication techniques you will use, when you will present your message, and who will be involved with the presentation.

Table 1: Some Communication Ideas

- Banners
- Blogs
- Cartoons
- Cell ringtones
- Computer screen savers
- Dance
- Ebooks
- Electronic newsletter
- Games and Competitions
- Letters
- Musical performances
- Newspapers
- Photography
- Postcards
- Radio (see *http://www.hobbybroadcaster.net/ for more information*)
- Simple robots (see *http://www.instructables.com/id/Robots/ for ideas*)
- Scientific posters (see *http://colinpurrington.com/tips/academic/posterdesign; http://www.ncsu.edu/project/posters/NewSite/*)
- Stories
- Theatre (plays, industrial theatre, ambush theatre, street theatre)
- Videos
- Wall Magazines (periodical publications that appear in public places such as bulletin boards or notice boards)
- Water bottles
- Wearable items (T-shirts, caps, badges, wristbands, pins, jewelry)
- Websites

My Communication Ideas:

Solutions: Alternative Technologies

Source: *http://www.epa.gov/climatechange/kids/solutions/technologies/index.html*

Big Idea

Human activities have changed the way that carbon is distributed in Earth's atmosphere, lithosphere, hydrosphere, and biosphere.

What You Will Need

- A large room or outdoor area where you can play the game
- 1 – Adult Partner
- Several partners to play the game
- Pony beads, regular (8/0) size, in blue, green, clear, and black colors; at least six of each color for each Player in the gam (search the Internet for "pony bead;" also available in some craft stores)
- Signs for four game stations: Lithosphere, Atmosphere, Hydrosphere, and Biosphere
- Four plastic bowls to hold the Pony beads for each station
- White chenille craft sticks (pipe cleaners), about 12 inches long; two for each Player
- Five paper Game Cubes made from patterns at the end of this Activity
- Clear plastic tape
- Scissors
- Copies of "Incredible Carbon Journey Game Record," one for each Player

Activity 10: The Incredible Carbon Journey

What You Will Do: Play the Carbon Journey Game

(adapted from an activity by Roberta M. Burnes, Environmental Education Specialist, Kentucky Division for Air Quality, Frankfort, KY)

The element carbon is one of the most basic building blocks of life on earth. It is found almost everywhere—in plants, animals, pencils, diamonds, soil, and even soda pop. Carbon is able to easily bind with other atoms to form different chemical compounds; this is why carbon exists in so many forms. Carbon can dissolve in water, form chains of atoms to create sugars, and form solid materials like coal and limestone. Carbon in living things can be released through respiration, consumed as food, or transformed into fossil fuels over millions of years. In the atmosphere, carbon exists mainly as carbon dioxide. Carbon dioxide is called a greenhouse gas because it can trap some of the sun's heat in the atmosphere. Without carbon dioxide's natural ability to trap heat in the atmosphere, life as we know it could not exist.

Carbon on Earth is found in the atmosphere, soil and rocks (the lithosphere), water (the hydrosphere), and in living organisms (the biosphere). The activities of living organisms, volcanoes, weather, and many other processes can cause carbon atoms to move from one place to another. This pattern of movement is called the carbon cycle.

Burning fossil fuels breaks the bonds that hold carbon atoms together inside those fuels, and carbon is released into the atmosphere. Scientists have found that the concentration of carbon dioxide in Earth's atmosphere has increased nearly 35% since the beginning of the industrial revolution. Methane, another compound that contains carbon, has increased by 150%. Earth's average global temperature has also increased by more than one degree Fahrenheit over this time period. This sounds like a small increase, but it is enough to cause major changes to earth's climate and ecosystems. Most climate scientists agree that earth's rising temperature is largely due to the increase in carbon dioxide and other greenhouse gases in the atmosphere resulting from burning fossil fuels.

How It Works

This activity is a way to compare the carbon cycle before the industrial revolution with the carbon cycle after humans began burning large quantities of fossil fuels. This is a great way to communicate important ideas about climate science and the carbon cycle.

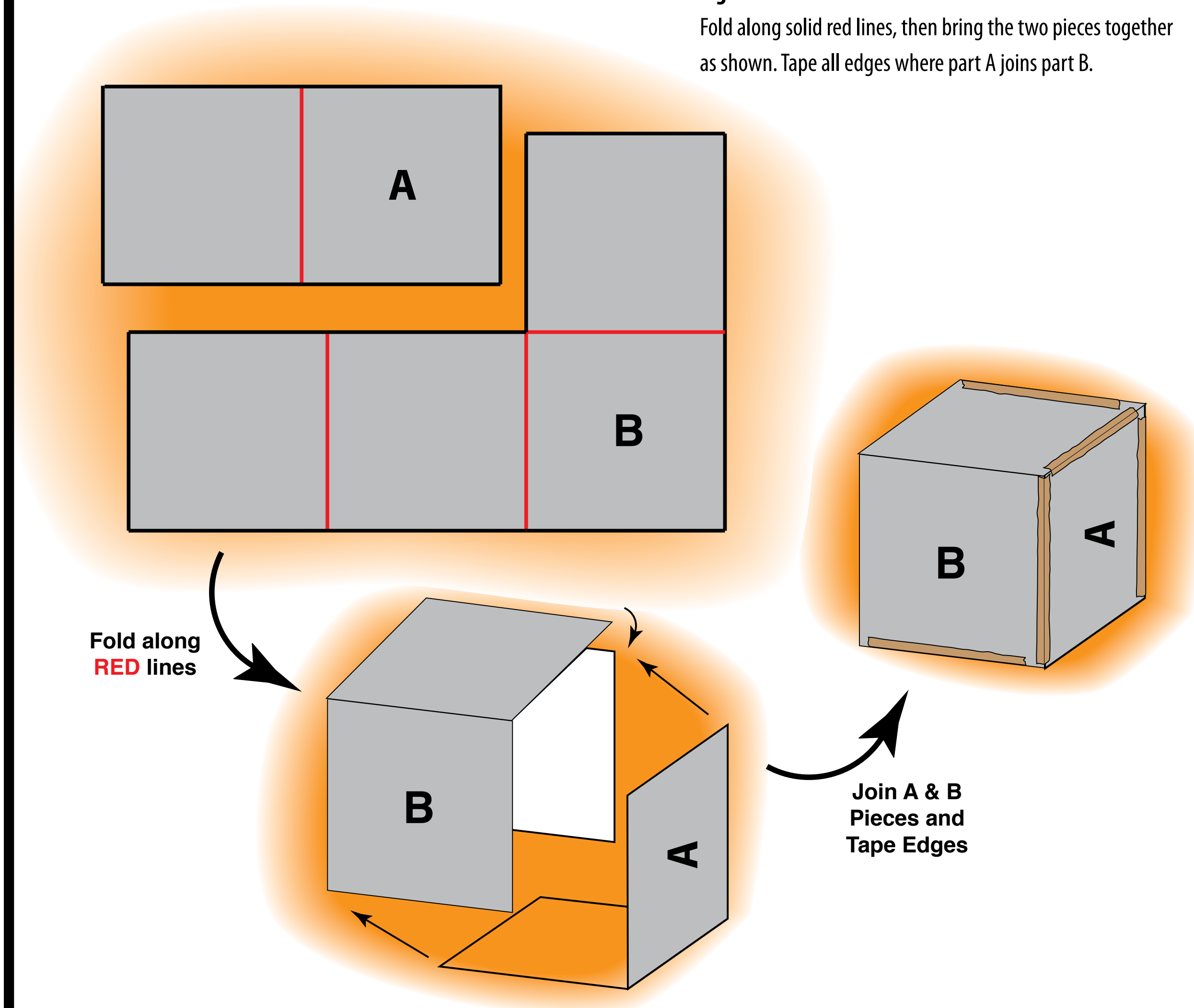
How to Do It

1. Read through all of these steps before you start! Make a copy of the Record on page 48 for each Player. Photocopy pages 43 - 47 onto card stock for the cubes. Make the Game Cubes by cutting two pieces for each Cube from the photocopies of pages 43 – 47. Fold and assemble the pieces to form the Cubes as shown in Figure 1. Tape all of the edges where part A joins part B.

2. Each Player will begin at one station as chosen by the Player or Game Leader. There can be more than one Player at each station. The Game Leader places one of the cubes and one of the plastic containers at each station, then puts the green beads in the container at the Biosphere station, the blue beads in the container at the Hydrosphere station, the clear beads in the container at the Atmosphere station, and the black beads in the container at the Lithosphere station.

Figure 1. Make the Game Cubes

Fold along solid red lines, then bring the two pieces together as shown. Tape all edges where part A joins part B.



3. The Game Leader gives one pipe cleaner and one Game Record to each Player. Have the Player twist a knot or small loop onto one end of the pipe cleaner, and write the name of their starting station on the Game Record.

4. The Game Leader tells the Players they will represent carbon atoms in the carbon cycle. They will travel around the Earth following the journey of a carbon atom in the pre-industrial world – before we began burning lots of fossil fuels.

5. When the Game Leader says, "Go!" each Player places one bead from their station on the pipe cleaner.

6. Each Player rolls the cube at their station to find out where to go next. The Player then moves to the station shown on the cube, and records the name of the new station on the Game Record. If the cube says, "STAY", the Player goes to the back of the line for that station and waits to roll the cube again. While they are waiting to roll the cube, they should take another bead from the station and put it on their pipe cleaner.

7. Each time the Player moves to another station, they do the same thing: Take a bead, roll the cube, and move to the next station (or go to the end of the line and repeat), and record the name of the next station on the Game Record.

8. Players move from station to station for at least 10 minutes or long enough for Players to begin stacking up in the lithosphere line. This may take up to 15 minutes.

9. When most Players have visited the lithosphere several times, the Game Leader says, "Stop." Wherever Players are in line, they should take a bead from that line without rolling the cube and then sit down. This is the end of round one.

10. Ask the Players what color beads they have on their pipe cleaner and what happened to them during their trip. Did they see any patterns? For instance did they stay at any place more than once? Did anyone go back and forth between two stations (for example, biosphere and atmosphere)? What may explain this? Instruct Players to make a bracelet out of their pipe cleaner by twisting the end through the loop on the other end.

Game Leader Tip:
After round one, many Players will have a high portion of black beads on their pipe cleaners. This represents coal, natural gas, oil—all carbon molecules in the lithosphere. Deposits of carbon have accumulated over time from the remains of plants and animals. Over millions of years, these deposits have become transformed into fossil fuels.

11. The Game Leader exchanges the Pre-industrial Lithosphere (L1) cube for the Post-Industrial Lithosphere cube (L2).

12. The Game Leader gives each Player a new pipe cleaner, and says that they are moving into the Industrial Age. This is the beginning of Round 2. Players should twist a loop into the end of the pipe cleaner before proceeding.

13. Have Players pick a station at which to begin their journey.

14. Again, Players pick up a bead from their station and roll the cube. They will move from station to station again for at least 10 minutes or long enough for Players to begin stacking up in the atmosphere line. This may take up to 15 minutes. Each time the Players change stations, they should record the name of the station on the Game Record.

15. When most Players have visited the atmosphere several times, stop round 2. Wherever Players are in line, they should take a bead from that line without rolling the cube and then sit down.

Ask the Players what kinds of beads they have on their pipe cleaner and what happened to them in their trip/journey. How did this second round compare with their first journey through the carbon cycle? Did anyone find himself or herself "stuck" in one place? What may explain this?

Game Leader Tip:
Although the amount of carbon in the atmosphere has increased significantly over the last 150 years, it's important to emphasize that the amount of carbon on the earth has not changed. Carbon has simply moved from one place to another.

Although you cannot predict exactly what combinations of beads the Players will put on their pipe cleaners, you can be fairly certain that after the second round, more of the beads will be from the atmosphere. This represents the build-up of carbon dioxide in the atmosphere that is a direct result of the burning of fossil fuels.

If lines at a station get really long, this activity works best if Players take their beads before they arrive at the cube. If you have volunteers, station them along the longest lines of Players and have them distribute the beads while the Players wait their turn to roll the cube. It may also help to have two cubes for each station to minimize the wait time.

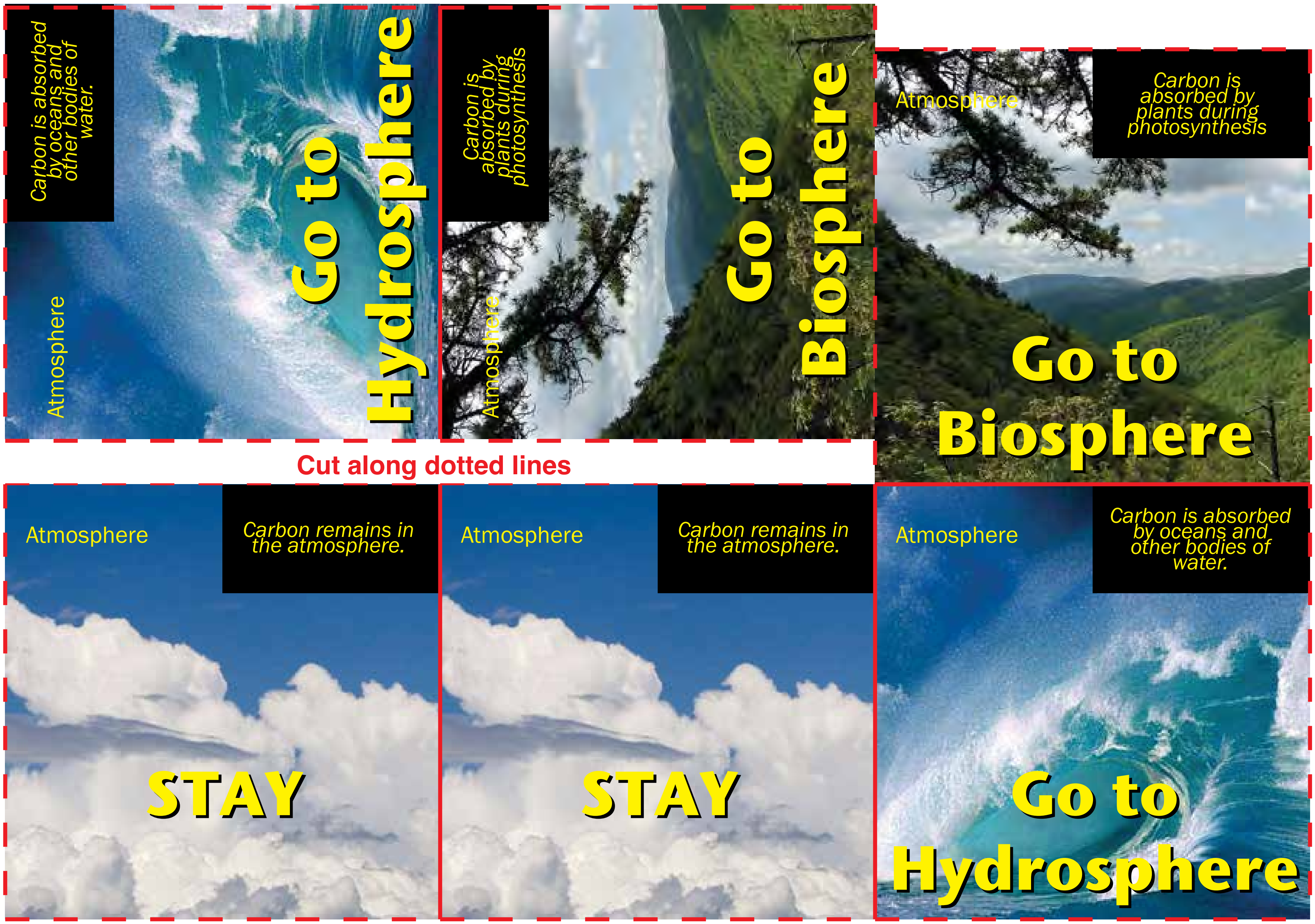
Want To Do More?

Players may create a storyboard, poster, or cartoon about their journeys through the carbon cycle. Players may research and record the processes involved in getting them from one place to the next in the carbon cycle. Did they notice any patterns in the beads on the pipe cleaners? For example, an alternating green-clear bead pattern could represent the cycling of carbon between plants and the atmosphere.

Players may graph the numbers of visits for each of the four spheres in the pre-industrial and post-industrial cycles, and create a master graph that incorporates the data from everyone's journeys in the pre-industrial and postindustrial cycles.

For an animated description of the carbon cycle, go to *http://epa.gov/climatechange/kids/basics/today/carbon-dioxide.html*.

Atmosphere cube



Biosphere cube

Hydrosphere cube

Pre-industrial Lithosphere cube 1

Post-industrial Lithosphere cube 2

Incredible Carbon Journey Game Record

Record your journey through the carbon cycle on this page. Beginning at one end of your pipe cleaner, write the "sphere" you visited for each bead on the pipe cleaner.

Green beads = Biosphere

Blue beads = Hydrosphere

Clear beads = Atmosphere

Black beads = Lithosphere

Round 1	Round 2
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.
6.	6.
7.	7.
8.	8.
9.	9.
10.	10.
11.	11.
12.	12.
13.	13.
14.	14.
15.	15.
16.	16.
17.	17.
18.	18.
19.	19.
20.	20.
21.	21.
22.	22.

Notes

Sketches

"When we try to pick out anything by itself,
we find it hitched to everything else in the universe."

~ John Muir, naturalist, explorer, and writer (1838-1914)

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NOAA's National Ocean Service
Communications and Education Division
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oceanservice.noaa.gov/education/discoverclimate
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