

Global Warming in a Jar

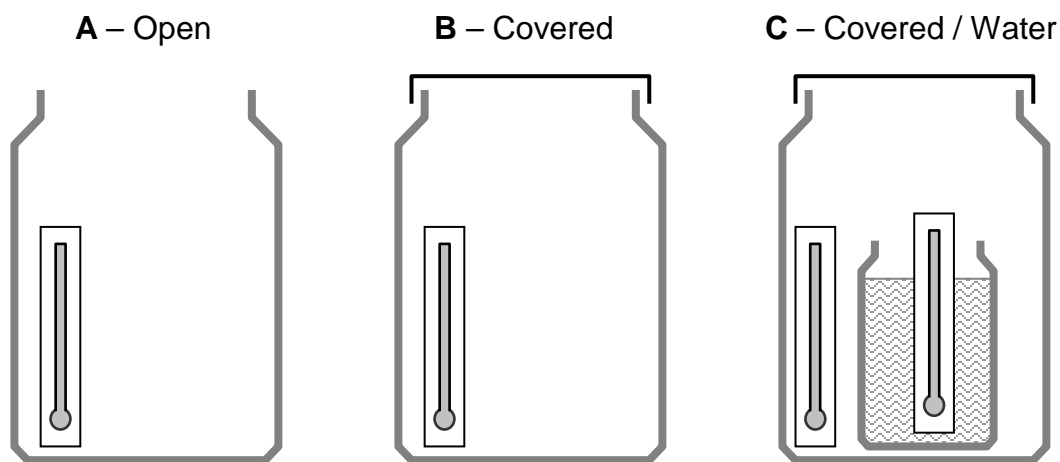
Perhaps you have heard of the *greenhouse effect*. In a greenhouse, short-wave radiation from sunlight passes freely through the glass and is converted to long-wave radiation inside. But the long-wave radiation cannot pass back out through the glass. The result is a build-up of heat inside the greenhouse from the captured solar energy. Certain gases in Earth's atmosphere – especially water vapor and carbon dioxide – act in much the same way as the glass in a greenhouse. We call this situation the greenhouse effect, and we call these gases the *greenhouse gases*, because of their ability to trap energy from sunlight. Most greenhouse gases occur naturally, but some are being added to the atmosphere because of human actions.

Global warming refers to the rise in temperatures at Earth's surface and lower atmosphere over the last century. Most scientists believe that greenhouse gases produced by human activity are contributing to global warming. The danger in this warming is that it could disrupt Earth's climate patterns, cause coastal flooding, and force major adjustments in the way people live. The more we are able to learn about the causes and effects of global warming, the better prepared we may be to deal with the possible consequences of a changing environment.

In this set of experiments you will use models of Earth's atmosphere to see how it is warmed by sunlight. You will also discover how lakes and seas affect this warming by storing and releasing energy from the sun.

Materials: Large pickle jars, smaller jelly jar, laboratory thermometers, white cardboard, sheets of 8½" x 11" white paper, transparent tape, clear plastic wrap, rubber bands, water, anti-fog solution, timer or clock, activity log sheet, graph sheet, question-and-answer sheet.

Preparation: This activity requires a location where there is direct sunlight for a sustained period of time. The experiments use three different models for Earth's atmosphere, as shown below.



Two different experiments are presented, each experiment using a different pair of models:

Experiment 1: Models A and B, where A is the *control*, and the cover (B) is the *variable*.

Experiment 2: Models B and C, where B is the *control*, and water (C) is the *variable*.

Your teacher will tell you which experiments to do and which models to use. Directions for building the models are given on the next page. Note: Prepare each model out of direct sunlight.

Model A: A laboratory thermometer is placed inside a large pickle jar which is left uncovered. Before placing the thermometer, tape it to a strip of cardboard that is a little bit longer and wider than the thermometer. Stand the thermometer on the bottom of the jar and lean it at a slight angle against the wall of the jar.

Model B: Like Model A, except that the jar opening is sealed with clear plastic wrap and a rubber band. Before sealing the jar, spray or wipe a light film of anti-fog solution on the inside of the pickle jar. This coating will make it possible to read the thermometer in the event that water vapor condenses on the inside of the jar during the experiment.

Model C: Like Model B, except that a jelly jar filled with water is added to the setup. Start by spraying or wiping the anti-fog solution onto the inside surface of the pickle jar. Fill the jelly jar almost to the top with water and place it inside the larger jar. (*Important: The water should be brought exactly to room temperature before use.*) Add a laboratory thermometer to read air temperature inside the pickle jar. Place a second thermometer inside the water-filled jar. The two thermometers should face the same direction.

Each of the models represents a different set of conditions in Earth's atmosphere:

- * Model A is the *control* for Experiment 1. It represents Earth's atmosphere as it would be without greenhouse gases to trap energy from the sun.
- * Model B has a cover that helps to capture energy from sunlight. The cover acts like greenhouse gases in Earth's atmosphere. What will happen to the air inside this jar? (When performing Experiment 2, this model serves as the *control* instead of Model A.)
- * Model C represents Earth's atmosphere next to an ocean or other large body of water. Will the presence of water produce results that are different from what happens in Model B?

Procedure:

1. Place each model on a sheet of white paper in direct sunlight. Read and record the temperature of each thermometer immediately. Repeat this measurement every 5 minutes for the first 30 minutes. After the first half-hour, readings may be taken and recorded at 15-minute intervals.
2. At the beginning and throughout the experiment, the large jars should be turned so that direct sunlight does not fall on the faces of the air temperature thermometers. The sunlight should fall on the backs of the cardboard strips instead. In this way, accurate readings of air temperature inside the jars will be possible.
3. After completing each round of temperature measurements, observe the jars to see if there are any visible changes taking place inside. Record any changes you see on the log sheet.
4. At some point in the experiment your teacher may draw down the window shades, or the sunlight may turn to shadow. If so, make a note in your activity log as to when this lighting change occurs. Then begin again to read and record temperatures every five minutes for the next 30 minutes, and every 15 minutes thereafter until the experiment is stopped.
5. Make a line graph of the temperature data for each experiment. There will be two or three graphed lines on each sheet, depending on the experiment. Be sure to label each line.
6. Complete the question-and-answer sheet for your experiment(s).

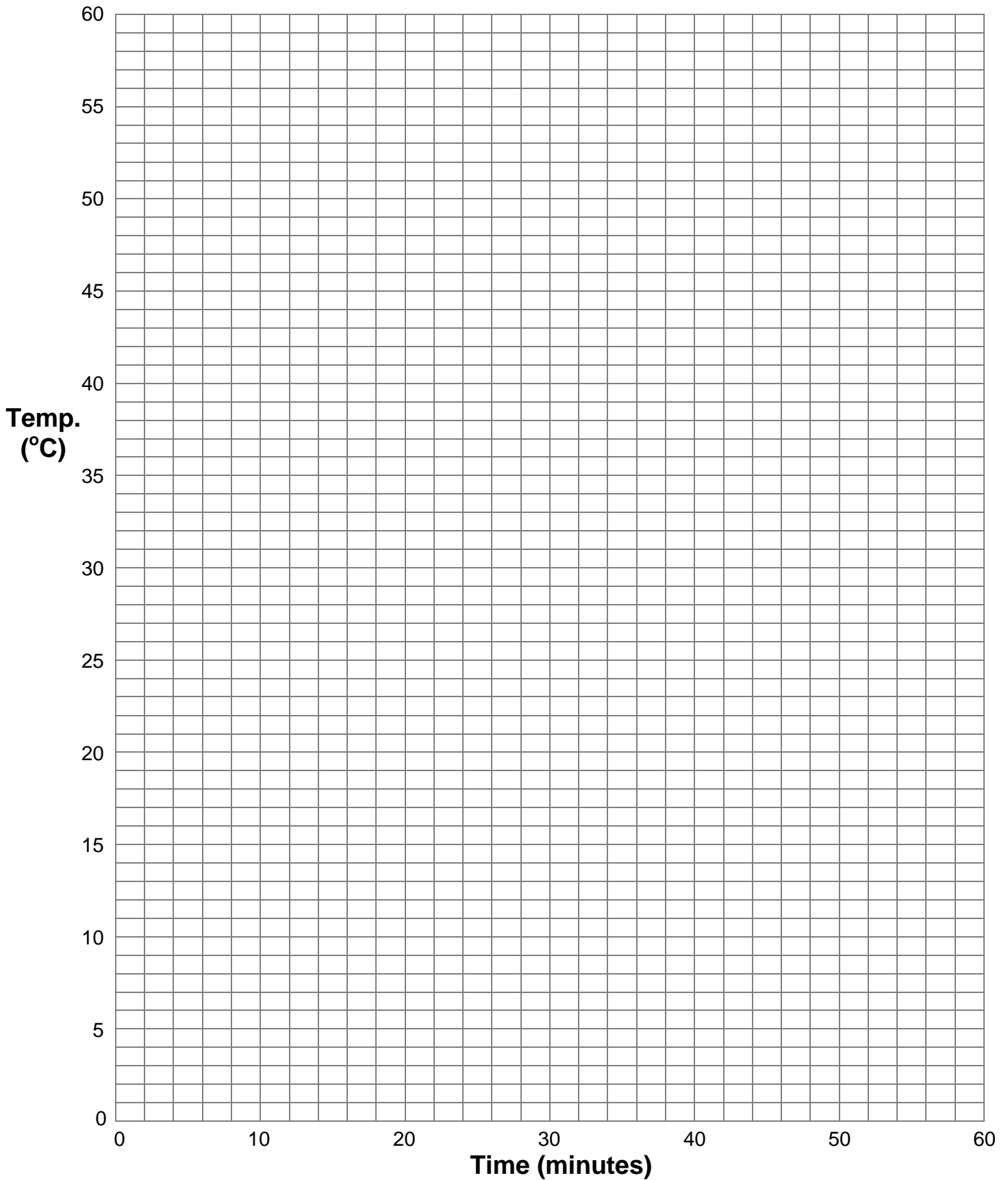
Use this sheet for
experiments of
shorter duration.

Global Warming in a Jar

Experiment _____

Control Jar: Model _____

Variable Jar: Model _____



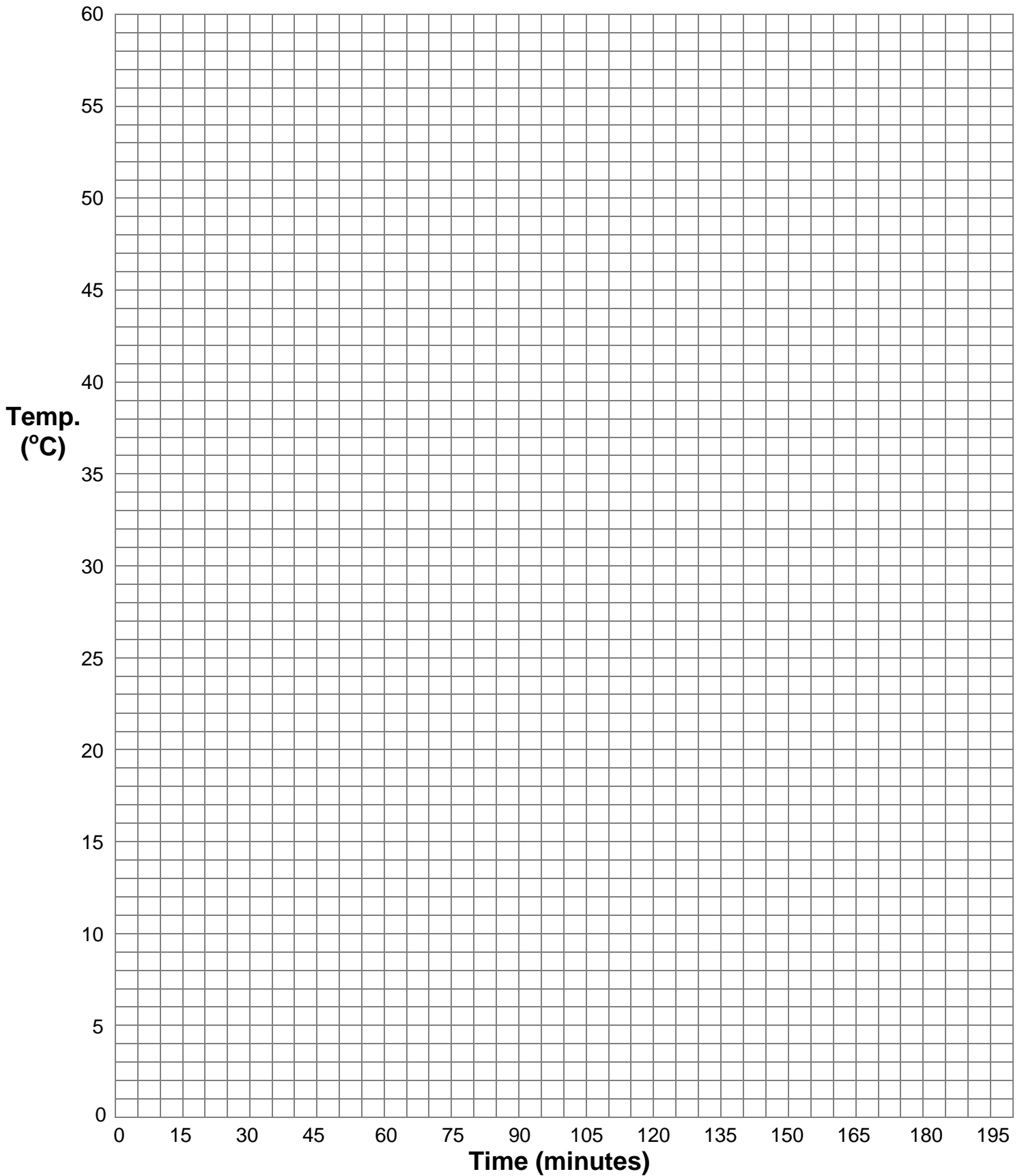
Use this sheet for experiments of longer duration.

Global Warming in a Jar

Experiment _____

Control Jar: Model _____

Variable Jar: Model _____





Global Warming in a Jar

Experiment 1

Before answering these questions about the experiment just completed, check your graphs to be sure they are done correctly. The data points in the graphs should match the data in your table. Look at the graphs and refer to any notes you took during the experiment to help you answer the questions. Write in complete sentences.

1. Although two different models were used – one for the control and one for the experimental variable – most things were kept the same in the experiment. What were they?

2. What is the one thing that was changed (the variable) in this experiment? _____

3. What happened to the temperature of the air in Model A, the control jar? _____

4. What happened to the air temperature in Model B, the covered jar? _____

5. What were the minimum temperature _____, maximum temperature _____, and range (difference) in temperatures _____ in the covered jar?

6. What caused the temperatures in the covered jar to change? _____

7. How was this experiment similar to the warming of Earth? _____

8. If your experiment was put into shadow after being in full sunlight for a period of time, answer this question: What happened to the air temperature in both jars after the jars went into shadow? If this was not done in your experiment, what do you think would have happened?



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Experiment 2

Before answering these questions about the experiment just completed, check your graphs to be sure they are done correctly. The data points in the graphs should match the data in your table. Look at the graphs and refer to any notes you took during the experiment to help you answer the questions. Write in complete sentences.

1. Although two different models were used – one for the control and one for the experimental variable – most things were kept the same in the experiment. What were they?

2. What was changed (the variable) in this experiment? _____

3. What happened to the temperature of the air in Model B, the control jar? _____

4. What happened to the air temperature in Model C, the jar with the water? _____

5. What were the minimum air temperature _____, maximum air temperature _____, and range (difference) in air temperatures _____ in the covered jar?

6. What happened to the water temperature in Model C? _____

7. What were the minimum water temperature _____, maximum water temperature _____, and range (difference) in water temperatures _____ in the covered jar?

8. What caused the air and water temperatures in Model C to change? _____



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Experiment 2 (Continued)

9. How was this experiment similar to the warming of Earth? _____

10. If your experiment was put into shadow after being in full sunlight for a period of time, answer this question: What happened to the air temperature in both jars after the jars went into shadow? If this was not done in your experiment, what do you think would have happened?

11. Comparing the results for Models B and C, how were the changes in air temperature similar?

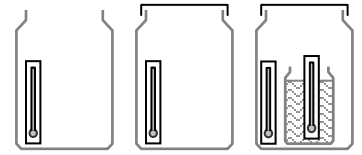
How were they different? _____

Why do you think the changes in air temperature were different? _____

12. If you happened to live near the ocean, what effect do you think the water would have on air temperatures in summer? _____

in winter? _____

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Teachers' Notes

Objectives: Students will simulate the greenhouse effect in a series of simple experiments. They will discover how water bodies may interact with the atmosphere to help regulate air temperatures.

Grade Level: Elementary/Middle

NSES: A1, A2, A3, A4, B1, B3, B6, C3, D1, D3, D4, D6, E1, E2, F4

NHSCF: 1a, 2a, 2b, 4b, 4c, 5b, 5c, 5f, 6a, 6b, 6c, 6d

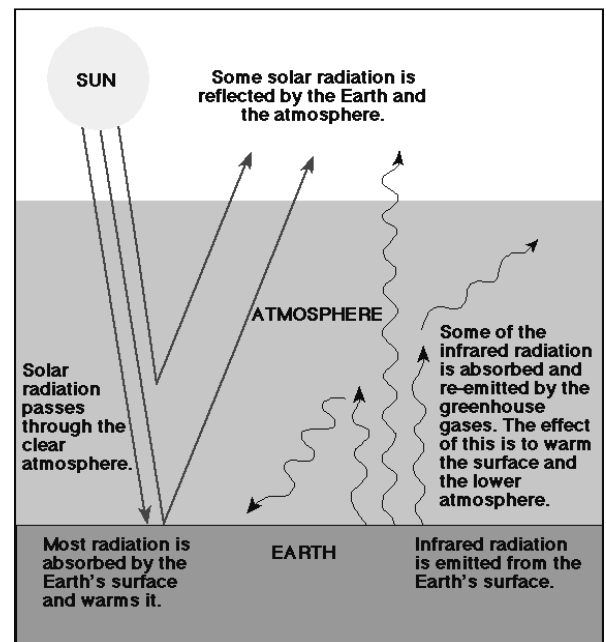
Key Concepts

The so-called greenhouse gases in our atmosphere – especially water vapor (H₂O) and carbon dioxide (CO₂) – have helped to warm Earth and make it hospitable to life as we know it. If not for this warming effect, Earth would be approximately 33°C (59°F) cooler than it is.

About half the solar energy reaching Earth is short-wave radiation, most of which occurs in the form of visible light. Most of the remaining solar energy is infrared, a form of long-wave radiation. A high percentage of the short-wave radiation is absorbed by Earth's surface, where it is converted to infrared radiation. The greenhouse gases warm Earth's surface and lower atmosphere by absorbing and re-emitting infrared radiation, as depicted in the simplified schematic at right.

While almost all of the greenhouse gases present in the atmosphere are the result of natural processes, human activity has produced incremental changes in both the composition of Earth's atmosphere and the concentrations of greenhouse gases. In the last century, the average concentration of carbon dioxide has increased about 25 percent, from 280 parts per million (ppm) to more than 350 ppm, and is still rising. This increase has been attributed to such practices as large-scale deforestation and the burning of fossil fuels.

The cultural ("anthropogenic") enhancement of atmospheric CO₂ is suspected as a major cause of global warming in the last hundred years. Average global temperatures have risen about 0.6°C (1.0°F), over this timeframe.



A Simplified Diagram Illustrating the Greenhouse Effect
Source: NASA Facts, NF-222, April 1998
http://www.gsfc.nasa.gov/gsfcservice/gallery/fact_sheets/earthsci/eos/global_warming.pdf

Other important greenhouse gases are methane, nitrous oxide, and fluorinated organic compounds including chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs). These compounds, although present in small quantities, are up to thousands of times more effective as greenhouse gases than carbon dioxide.

In the student activity “Global Warming in a Jar”, the three models of Earth’s atmosphere are highly simplified representations of very complex systems. They are useful for demonstrating a few of the most basic concepts pertaining to climate mechanics and global warming.

Younger students will benefit immensely from direct instruction in setting up their models, taking measurements, and documenting the results. Experiment 1 is appropriate for the very youngest students. Experiment 2 could be undertaken by this age group with considerable assistance.

Older students should be able to follow the written procedures with limited guidance, monitoring, and intervention from the teacher. It is important that both experiments be conducted at the same time, but not necessarily by every student. Practical limitations of space and materials may necessitate dividing up the experiments among small work groups and sharing the results upon completion. The two experiments can be performed together using three pickle jars, with Model B serving double duty.

The experiments are designed to be conducted in direct sunlight. The substitution of heat lamps is a possibility, provided that careful attention is given to equalizing the radiant energy from the lamps.

The experimental apparatus includes both large (preferably gallon-size or larger) pickle jars as well as smaller jelly jars (12- to 16-ounce size works well). If the larger jars are not available, the setup may be modified to use 2-liter soda bottles and 8-ounce jars. Remove the labels and bottoms of the soda bottles and cut off their tops before use.

Even the youngest students will be able to understand the concepts of *control* and *variable*. The control represents the baseline condition, which is replicated exactly in each setup of the experiment. The experimental variable is the one thing that is changed, for the purpose of measuring its effect on the baseline condition. By limiting each experiment to one variable, there is less likelihood of confusing the cause of an observed effect. Thus, Model A is paired with Model B in the first experiment; while Model B is paired with Model C in the second experiment.

In Experiment 1, the sealing of the jar is the variable. The anticipated effect of this action is that the air in the jar will be warmed by sunlight, and this thermal energy will be contained by the cover. If the sunlight is suddenly eliminated, the air temperature in the sealed jar will gradually return to that of the control.

In Experiment 2, both jars are sealed, and the addition of a water reservoir is the variable. The anticipated effect of this change is that both air and water will heat up. However, the water is a heat sink that will moderate the heating of the air. Here’s how: Short-wave radiation from the sun passes through the clear air but is absorbed by the water, where the energy is converted into long-wave radiation. The water also absorbs long-wave radiation from the heated air if the air is warmer than the water. When the

sunlight is cut off, the air temperature in the jar slowly falls to below that of the water, and the warmer water heats the surrounding air by emitting long-wave radiation. The back-and-forth exchange of energy between air and water moderates air temperatures in the pickle jar and continues to do so as long as there is any temperature differential between the two media.

Since air has a lower heat capacity (ability to store energy) than water, the air temperature responds more quickly to sunlight and rises faster than that of the water. Similarly, the air in the jar cools more quickly than the water when the experimental model is placed into shadow. A comparison of the air and water temperature curves will show the water temperature lagging the air temperature.

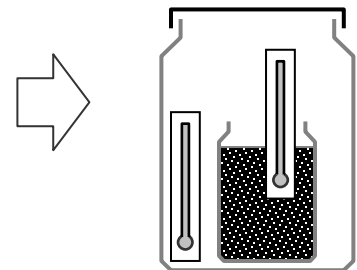
Because the thermal storage capacity of water allows Model C to retain more energy over a longer time frame, the pickle jar stays warmer and returns to ambient temperature more slowly after the loss of direct sunlight. A similar phenomenon is repeated on a much larger scale on Earth when air masses are warmed or cooled by adjacent water bodies. One prominent result is that seaside locations tend to have more temperate climates than inland locations, a fact that students may already be familiar with. This analogy is not exact, since the air in the pickle jar is contained for the duration of the experiment whereas air over the ocean is constantly being replaced.

In Model C, the rising temperature will cause some of the water to evaporate. As the experiment progresses, the air within the jar may become saturated with water vapor so that condensation begins to appear on the glass. The condensation forms because the wall of the jar is at or below the dew point and slightly below the air temperature inside the jar.

Using an anti-fog solution may help to overcome any condensation that would make reading the thermometers difficult. Anti-fog solutions are available commercially or as homemade concoctions. As a preview activity, students might enjoy doing Internet research and performing a few simple experiments to find an effective homemade anti-fog solution. Possible agents include vinegar, liquid soap, and furniture spray polish.

Experiment 1 is of shorter duration and can be performed in a single class session. Experiment 2 requires a longer period to demonstrate fully the influence of the water as a heat sink. For middle school students, it may be possible to schedule the experiments across several consecutive class periods with students in each class continuing the work of the preceding class.

Extension: Repeat Experiment 2 using damp, moderately compacted potting soil in place of water as the variable. The soil simulates a dark landmass in contact with the atmosphere. Compare results with water.



For additional information on global warming and the greenhouse effect, visit these websites:

<http://earthobservatory.nasa.gov/Library/GlobalWarming/>
<http://www.dnr.state.wi.us/org/caer/ce/eek/earth/air/global.htm>
<http://www.ipcc.ch/pub/spm22-01.pdf>
<http://unfccc.int/resource/iuckit/index.html>