SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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National Science Education Standard—Earth and Space

Geochemical Cycles

The Earth is a system containing essentially a fixed amount of each stable chemical atom or element. Each element can exist in several different chemical reservoirs. Each element on Earth moves among reservoirs in the solid Earth, oceans, atmosphere, and living things as part of geochemical cycles.

Movement of matter between reservoirs is driven by the Earth's internal and external sources of energy. These movements are often accompanied by a change in the physical and chemical properties of matter. Carbon, for example, occurs in rocks a limestone, in the atmosphere as a gas, in water as dissolved carbon dioxide, and in all living things as complex molecules that control the chemistry of life.

Teacher Materials

Learning Sequence Item:

941

Environmental Cycles

March 1996
Adapted by: Brett Pyle

Movement of elements and Compounds among Earth's Reservoirs. Students should be able to use their knowledge of chemistry and biology to describe various cycles and the energy transformations associated with those cycles. They should understand how weather is affected, and they should understand perspiration cooling of animals, the transpiration effects on plants, and the conditions that drive storms. *(Earth and Space Sciences, A Framework for High School Science Education, p. 145.)*

Contents

This micro-unit was adapted by Brett Pyle (Grady Middle School, Houston, Texas)

941

Learning Sequence

Movement of elements and Compounds among Earth's Reservoirs. Students should be able to use their knowledge of chemistry and biology to describe various cycles and the energy transformations associated with those cycles. They should understand how weather is affected, and they should understand perspiration cooling of animals, the transpiration effects on plants, and the conditions that drive storms. *(Earth and Space Sciences, A Framework for High School Science Education, p. 145.)*

Science as Inquiry	Science and Technology	Science in Personal and Social Perspectives	History and Nature of Science
Perspiring Animals Activity 1	Water Cycles Assessment 2	Stormy Weather Activity 5	
What Has Transpired? Activity 2	Potable Water Assessment 3	Artificial Rain Assessment 1	
Transpiration the Sequel: Leaf in a Cup Activity 3			
Cloud Formation Activity 4			

Suggested Sequence of Events

Event # 1

Lab Activity

1. Perspiring Animals (1 hour)

Event # 2

Lab Activity

2. What Has Transpired? (1.5 hours over 3 days)

Alternative or Additional Activities

3. Transpiration the Sequel: Leaf in a Cup (1 hour)

Event #3

Lab Activity

4. Cloud Formation (1 hour)

Alternative or Additional Activities

5. Stormy Weather (1 hour)

Event #4

Readings from Inquiry, Science and Technology, Science in Personal and Social Perspectives, and History and Nature of Science

Suggested readings:

Halfpenny, James C., “The Cold Facts of Winter.” *Science World,* Decembrr 4, 1992, pp. 9–14.

Plaut, Josh, “A World of Thirst.” *Science World*, December 3, 1993, pp. 10–13.

Freiman, Chana, and Nancy Karkowsky, “Weathering the Summer of 1993.” *Science World,* October 22, 1993, pp. 10–13.

Assessment items can be found at the back of this volume.

Assessment Recommendations

This teacher materials packet contains a few items suggested for classroom assessment. Often, three types of items are included. Some have been tested and reviewed, but not all.

1. Multiple choice questions accompanied by short essays, called justification, that allow teachers to find out if students really understand their selections on the multiple choice.

2. Open-ended questions asking for essay responses.

3. Suggestions for performance tasks, usually including laboratory work, questions to be answered, data to be graphed and processed, and inferences to be made. Some tasks include proposals for student design of such tasks. These may sometimes closely resemble a good laboratory task, since the best types of laboratories are assessing student skills and performance at all times. Special assessment tasks will not be needed if measures such as questions, tabulations, graphs, calculations, etc., are incorporated into regular lab activities.

Teachers are encouraged to make changes in these items to suit their own classroom situations and to develop further items of their own, hopefully finding inspiration in the models we have provided. We hope you may consider adding your best items to our pool. We also will be very pleased to hear of proposed revisions to our items when you think they are needed.

Science as Inquiry

Perspiring Animals

How does perspiration affect body temperature?

Overview:

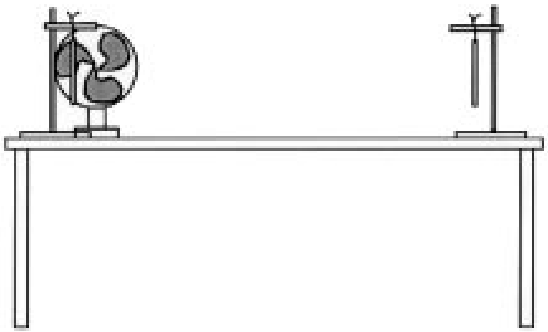
Cooling by animals is primarily done through the perspiration process. This activity attempts to show this process. Some good ways to involve students in this process is to use temperature strips to measure skin temperature. Try measuring skin temperature before and after exercising.

Materials:

Per lab group:
thermometers, 2
ring stands, 2
cotton gauze (or cheese cloth)
spray bottle (fine mist)
fan

Procedure:

The students should hang the one thermometer from each ring stand. The thermometers should come to room temperature and should be at the same temperature. The students should record the starting temperature of each thermometer. They should then place the ring stands at opposite ends of their lab table and position the fan so that it blows on only one thermometer.



Turn on the fan and let it run for five minutes. While the students are waiting they should take turns standing with outstretched arms so that one hand is near each thermometer. The students should record their observations about how each hand feels (which one feels cooler) and then after five minutes record the temperature on each thermometer.

Next have the students wrap a small piece of gauze around the bulb of the thermometer and secure it with a rubber band. Wet both pieces of gauze. Again turn on the fan for five minutes with the same placement as before. As the students are waiting, have each student take turns standing with outstretched arms (one hand near each thermometer) but this time have a lab partner mist the back of each hand with the sprayer. Have the students record their observations and then record the temperature of each thermometer after five minutes.

After the students have completed their observations, discuss their findings and have them come up with explanations for their observations. Some of the questions on the student sheet require the student to synthesize what they observed in the laboratory exercise with the reading material.

Background:

Animals exchange heat with their environment in four ways: conduction, convection, radiation, and evaporation. In still air with a temperature less than your body temperature, the vast majority of the heat loss is from radiation (40%) and convection (50%). Conduction (1%) and evaporation (9%) account for only a small part. Convection and evaporation are quite variable however, and in a breeze of 15 km/hr, heat loss from convection will increase five times. Evaporative cooling is increased by the production of sweat and is also aided by moving air. Evaporative cooling is much more efficient in low humidity, thus the uncomfortable feeling humans get on muggy humid days, even when the temperature is not extreme.

Variations:

You can also have students investigate cooling by increasing conduction. Have the students place their bare arm on a table or countertop (plastic or melamine will work better than wood). Have them note how cool this feels on their arm. The temperature of the table is the same as the temperature of the air so why the difference? The students should review their knowledge of heat conduction to conclude that the plastic is a better conductor of heat than air and thus is “pulling” more heat from their arm, thus making their arm feel cooler.

Adapted from:

Campbell, N. A., Biology, 2nd ed., Redwood City, Calif.: The Benjamin/Cummings Publishing Company, Inc., 1990.

Teacher Sheet

Science as Inquiry

What Has Transpired?

How do we measure transpiration in plant leaves?

Overview:

Plants, like animals, must get rid of excess water. Transpiration uses the stomata and the evaporation process. It can be shown using these simple materials.

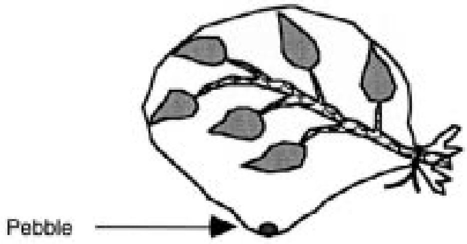
Materials:

Per lab group:

plastic bag, large, clear
string
graduated cylinder
small pebble

Procedure:

Find an area on your school campus with several healthy trees of shrubs. Have each lab group locate an accessible branch with several leaves near the end of the branch. The students should then inflate and place a plastic bag over the end of the branch, covering several leaves. The students should inflate the bag with outside air, not by blowing into it. Once the bag is situated, place a small piece of gravel in the bag and tie the bag securely around the branch to form an airtight seal. The students should make a note of how many leaves were covered by the bag.



The students should leave the bag in place for 24 hours. They then remove the bag and measure the water inside with a graduated cylinder. The students should then determine the amount of water given off by one plant leaf in a 24 hour period.

When the students have completed this measurement they should measure the same branch only during daylight hours and again during nighttime hours. You can have one (or more) student volunteer from each lab group to come before school to place the bag early in the morning (as close to sunrise as possible). The bag should then be removed after school (as close to sunset as is feasible) and a second bag placed on the same branch. The second bag is removed the following morning. The students can then examine transpiration rates during the daytime and nighttime.

Background:

Plants take in water through their roots. The water then moves through the plant to the leaves where some is used to make food for the plant (photosynthesis). Excess water evaporates through the stomata , or pores, in the leaves. This is the process of transpiration. Changing the water from a liquid to a gas requires heat which must come from the surrounding air. Thus, the process of transpiration acts to cool the air around a plant. This evaporative cooling can reduce the temperature of a leaf 10–15 °C compared to the surrounding air. On a hot sunny day a large tree may lose many liters of water through transpiration. Many desert plants, such as cacti and succulents, have thick waxy coatings on their leaves(or an absence of leaves) to greatly reduce water loss due to transpiration.

The factors that control transpiration are generally the same factors controlling evaporation. Thus a plant will lose the most water on dry, sunny, warm, windy days. Plants reduce water loss due to transpiration in several ways. The stomata are primarily concentrated on the underside of plant leaves which is normally shaded. The waxy cuticle reduces water loss from the remainder of the leaf. The stomata are generally only open during the daylight hours, closing at night when it is too dark for photosynthesis.

Variations:

There are numerous possibilities for variations on this lab. You may want students to test a variety of plants to see if rates of transpiration vary from plant to plant. Students may also test young vs. old leaves on the same plant. Have some students test cacti and compare the results with other plants.

You may also wish to have the students measure the transpiration rates under different weather conditions. This would lengthen the experiment but it could be set up and conducted over a period of days while other experiments were being done. It would be instructive to compare the transpiration rates from a cloudy day and a sunny day. You can also have the students investigate whether temperature affects transpiration rates. All of these extensions will help students determine the controlling factors on this process.

Adapted from:

Bosak, S. V., D. A. Bosak and B. A. Puppa, Science Is . . ., Richmond Hill, Ontario: Scholastic Canada Ltd., 1990.

Campbell, N. A., Biology, 2nd ed., Redwood City, Calif.: The Benjamin/Cummings Publishing Company, Inc., 1990.

an alternative activity for Event 2

Teacher Sheet

Science as Inquiry

Transpiration the Sequel: Leaf in a Cup

How do we measure transpiration in plant leaves?

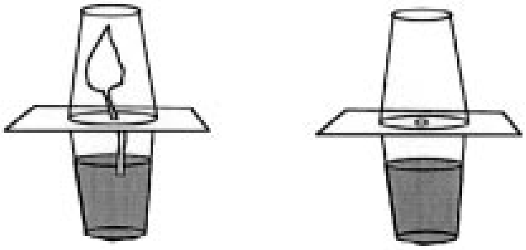
Overview:

Another method to demonstrate transpiration is described. This activity can be conducted completely indoors.

Materials:

Per lab group:
plastic cups, clear, 4
note cards (large enough to cover cup opening), 2
wax paper
graduated cylinder, 10-mL
leaves (live, collected fresh)
tape
hole punch

Procedure:



Cut a piece of wax paper to match the size of each of the note cards. Cover one side of each card and tape the edges. Use a hole punch to place a hole in the center of each card. Have the students fill one cup about halfway and then go outside and collect a fresh tree or shrub leaf and place it in the cup with the stem in the water. The leaf should be as big as possible and still be able to fit in the cup (the second cup will go on top). Back in the classroom the students should place the stem of the leaf through the hole in the note card, place the note card over the cup with water so that the stem is submerged, and place a second cup on top of the leaf. This process should be repeated with the remaining materials to form a second setup with no leaf to be used as a control.

Place the cups in a sunny window and let sit overnight. Have the students make observations the next day and measure the amount of water that has condensed in the top cups. To determine the amount from plant transpiration, subtract the amount from the cup without a leaf (if any).

Students should then compare the amount of water transpired during daylight hours compared to nighttime. You can have one (or more) students volunteer from each lab group to come before school to set up the cups early in the morning (as close to sunrise as possible). The cups should then be emptied, measured, and dried (as close to sunset as is feasible) and the cup replaced over the same leaf. The cup is removed the following morning and measurements made again. The students can then examine transpiration rates during the daytime and nighttime.

Background:

This lab is a variation of Activity 2. It is not necessary to do both labs. The first version should yield more water and thus should be easier for the students to measure. This activity can be done almost entirely indoors and if necessary under artificial light if weather is poor. Students should make sure that the leaves themselves are dry before placing them in the cups. They will also need to be very careful to gather all of the water that they can from inside the leaf cup without spilling any. The wax paper will prevent any droplets from soaking into the note card.

Variations:

There are numerous possibilities for variations on this lab. You may want students to test a variety of plants to see if rates of transpiration vary from plant to plant. Students may also test young vs. old leaves on the same plant. Have some students test cacti and compare the results with other plants.

You may also wish to have the students measure the transpiration rates under different weather conditions. They could set some cups in a sunny window while others remain in shade. This would lengthen the experiment but it could be set up and conducted over a period of days while other experiments were being done. You can also have the students investigate whether temperature affects transpiration rates. All of these extensions will help students determine the controlling factors on this process.

Adapted from:
Liem, T. L., Invitations to Science Inquiry, 2nd ed., Chino Hills, Calif.: Science Inquiry Enterprises, 1989.

Science as Inquiry

Cloud Formation

What conditions lead to cloud formation and precipitation?

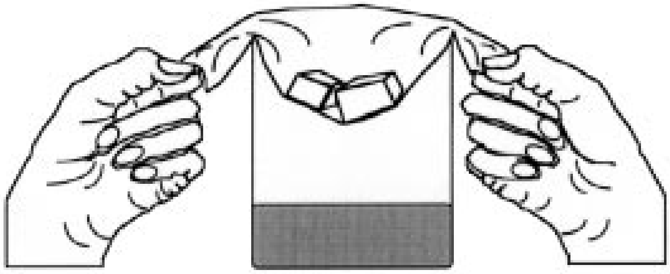
Overview:

This mini-cloud activity is important because students can focus on the variables affecting cloud formation.

Materials:

Per lab group:
beakers, 400-mL, 2
plastic bag, recloseable
ice cubes
matches
hot and cold water

Procedure:



The students place 50 mL of cold water into the first beaker. They place two ice cubes into the plastic bag and then place the bag into the beaker so that the ice cubes are above the water. Have them hold the corners of the bag, pulling down around the edges so that the bag completely covers the opening of the beaker. Do not let them submerge the ice into the water. Students should observe for 2–3 minutes, describe the setup on paper and record observations.

Next the students should repeat the activity using 50 mL of hot water in the second beaker. Repeat process from above. Add ice to bag as it melts. Students should record their observations then remove the ice bag from the second beaker. Light a match and let it burn for 2–3 seconds and then drop it into the hot water. Place the bag of ice back over the beaker and record observations.

Discuss results with the students. Ask what variables seem to affect cloud formation. How do these variables correspond to conditions in the atmosphere? Discussion should include mention of water vapor in the air (humidity), temperature changes and condensation, and particles to “seed” rain droplets.

Background:

Clouds are composed of very small droplets of water or ice (about 10 microns, for comparison a human hair is about 75 microns) called cloud droplets. Because of this small size they fall very slowly. An average droplet would take 48 hours to fall from 1,000 meters. At this rate it would never reach the ground before evaporating even if falling through humid air. Raindrops are formed then from the coalescing of these droplets. An average raindrop would contain about a million times the water of a cloud droplet. In order to coalesce the droplets need some sort of “seed” crystal or particle. That is what is demonstrated in this lab. The process of raindrop formation is in reality somewhat complicated and there are different theories to explain it. For a more complete explanation of these theories (the Bergeron Process and the collision-coalescence process) refer to a meteorology text.

The formation of clouds also requires a lot of water droplets usually provided by water evaporating from lakes or oceans. Warmer temperatures will increase the evaporation rate and lead to more cloud formation, also demonstrated in this activity.

Variations:

Baby food jars could also be used in place of the beakers. In fact any glass container with an opening slightly narrower than the width of the jar will be a little easier for the students to position the bag of ice and form a good seal over the opening.

Adapted from:
Winds and Weather: Probing the Natural World/Level 3, Morristown, NJ: Silver Burdett, 1972.

an alternative activity for Event 3

Teacher Sheet

Science in Personal and Social Perspectives

Stormy Weather

What conditions produce storms?

Overview:

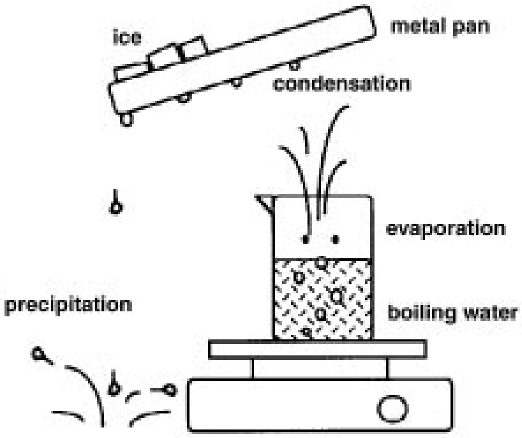
This short activity should lead to a long discussion of weather and weather forecasting.

Materials:

Per lab group:

lab handouts

Procedure:



Review with the students some basic concepts of weather that they are familiar with. These concepts should include a basic understanding of the water cycle. If necessary, demonstrate the experiment shown in Fig. 1 (or have the students do it). There should also be a review of the behavior of warm air and cool air and their buoyancies (this was covered in an earlier activity). Then have the students fill in the diagrams on their sheets. You will need to do this as a class taking input from the students, but much of this information will need to be supplied by the teacher. Diagrams 1 and 2 on the Student Sheet correspond to Fig. 2 that follows; and diagrams 3 and 4 on the Student Sheet correspond to Fig. 3 that follows. The information on cloud types in Fig. 4 can be filled in on the students' Diagrams 1 and 2. Once the students have completed the diagrams they should answer the questions on their handouts.

Background:

After having completed Activity 4, students should have an understanding of the conditions necessary to produce clouds. In this lab the focus is on the natural conditions that must occur to produce rapid cloud formation and ultimately precipitation and storms. This is largely a discussion based activity with students drawing on previous experience to infer outcomes. While it is not possible to create a storm in a lab setting you can show the evaporation-condensation-precipitation cycle with the standard demonstration setup (Fig. 1). Most students will have seen this by 9th grade so it is probably best to not spend a great deal of time with it.

When going through the diagrams with the students they should be able to determine whether an air mass will move over or under the adjacent air mass. The students have addressed the density and buoy-

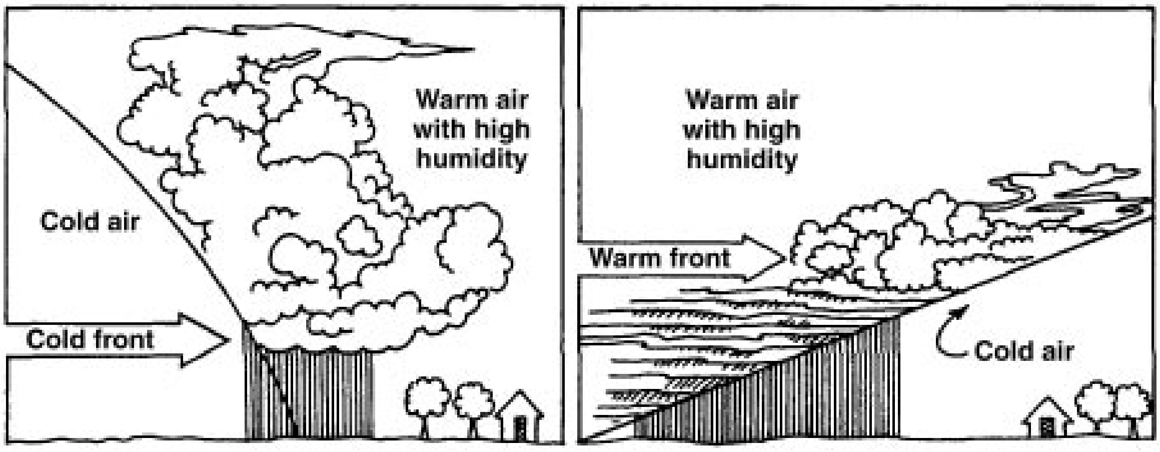


Fig. 2. Resulting storm development when warm air mass is moisture laden (from Winds and Water, 1972).

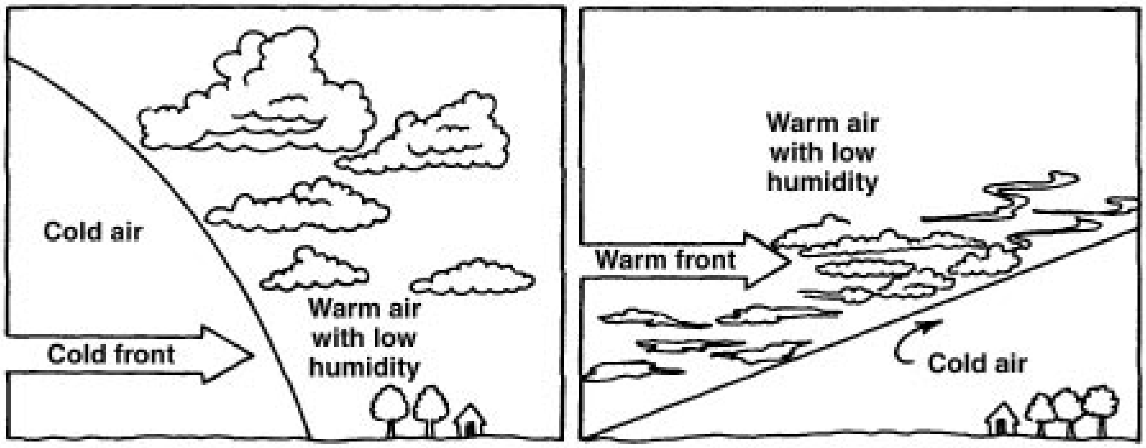


Fig. 3. Cloud development when warm air mass is not moisture laden (from Winds and Water, 1972).

ancy of air masses in a previous activity and should recognize that cold air masses will be denser than warm air masses. The sudden bringing together of a cold air mass with a warm, humid air mass forces the warm air mass upward as it is less dense. As the warm humid air rises it cools producing rapid cloud formation and subsequent storms. The type of clouds formed depends on the interaction and that is the focus of this lab.

In Figure 2 we see the result of a very humid warm air mass as it encounters a cold air mass. Note that the steepness of the fronts is different. The slope of the cold front is steeper because the leading edge of the front is slowed by surface friction. In the case of a warm front, the cold air mass is actually moving and retreating in front of the warm air mass, keeping the slope lower as the warm air rises and overrides the cold air.

The cold front in Fig. 2 will produce extremely tall cumulonimbus clouds and generally a more violent storm. The warm front can be distinguished by the appearance of very high cirrus clouds which pre-

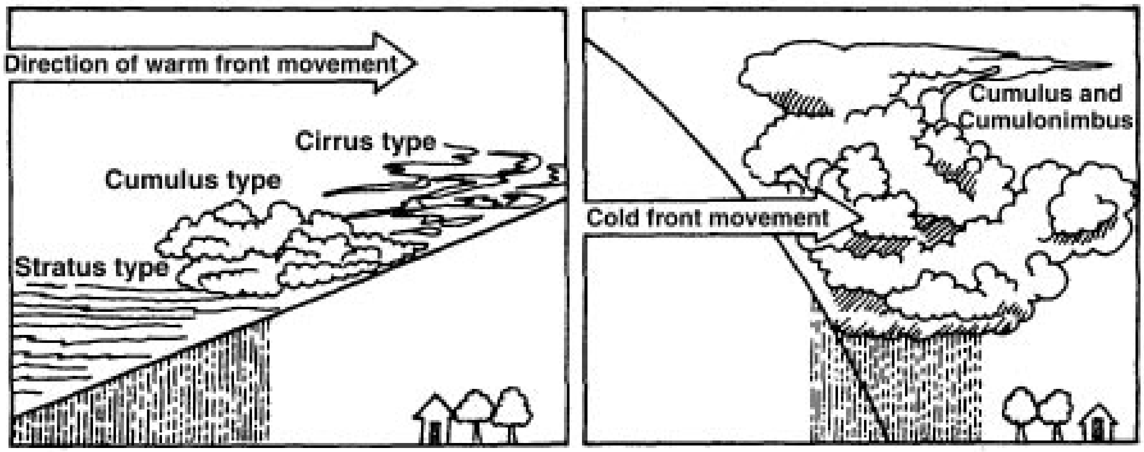


Fig. 3. Cloud development when warm air mass is not moisture laden (from Winds and Water, 1972).

cede the storm. These are followed by cumulus clouds and eventually stratus clouds which produce the rainfall. In some cases when the warm air is very unstable, large cumulonimbus towers can be produced as the warm front overrides cooler air. This may be difficult to distinguish on the ground from the similar cloud formation of an oncoming cold front.

Figure 3 shows the results of warm air masses with low humidity when they encounter a cold air mass. In this case the clod development is more sparse and rainfall, if any, will be very light. A warm front can still be distinguished from a cold front by the same sequence of cloud types. In this case, however, the cold front will produce only cumulus clouds and a warm front will not develop stratus clouds.

Figure 4 shows the cloud types that develop from the different fronts. These are the typical systems that develop when the warm air mass is humid. This is the primary distinction that the students can use to identify what type of system is moving into their area and be able to make predictions about future weather conditions.

Variations:

After completing this lab have the students keep a log of cloud observations and correlate them to weather patterns. They can use weather maps from the newspaper to note when cold fronts or warm fronts are moving through their area and correlate that information with their cloud data. The students could also make predictions based on their cloud observations without looking at the newspaper or evening news. At the end of a week or two, the teacher could provide copies of each days weather map for the previous two weeks and the students could check their predictions.

Adapted from:

Chelius, C. R., and H. J. Frentz, A Basic Meteorology Exercise Manual, 3rd ed., Dubuque, Iowa: Kendall/Hunt, 1992.
Lutgens, F. K., and E. J. Tarbuck, The Atmosphere, 2nd ed., Englewood Cliffs, NJ: Prentice-Hall, 1982.
Winds and Weather: Probing the Natural World / Level 3, Morristown, NJ: Silver Burdett, 1972.

Science in Personal and Social Perspectives

Artificial Rain

Item:

Scientists have developed a technique of using certain chemical compounds to produce “artificial” rain. Airplanes are used to apply the chemicals to clouds. Do you think this practice is beneficial or harmful in the long run? Explain your position.

Answer:

Science as Inquiry/Science and Technology

Water Cycles

Item:

Visualize how the water cycle works.

Materials. A water cycle model, bag of ice cubes, lamp, water.

Set up the water cycle model. Put appropriate amount of water in the model. Put ice cubes in a container on top of the model, cover with the cover. Place a lamp about 4–cm above the water (steaming or boiling water may be used to fill the model). Observe as the hydrologic process takes place.

What actually powers the water cycle? Where does most of the water cycle start? What process takes place to form clouds?

Answer:

Science and Technology

Potable Water

Item:

Given 200 mL of non-potable water, design a plan to purify the water using only natural products to produce potable water (no less than 25 mL in volume).

Answer:

The response should include a sketch of the apparatus, list of materials and method of conducting the purification. Commercially available filters are not acceptable.

Consumables

Item	**Quantity (per lab group)**	**Activity**
cotton gauze (or cheese cloth)	—	1
ice cubes	—	4
lab handouts	—	5*
leaves, live, collected fresh	—	3*
matches	—	4
note cards (large enough to cover cup opening)	2	3*
pebble, small	1	2
plastic bag, large, clear	1	2
plastic bag, recloseable	1	4
plastic cups, clear	4	3*
string	—	2
tape	—	3*
water, hot and cold	—	4
wax paper	—	3*

Non-Consumables

Item	**Quantity (per lab group)**	**Activity**
beaker, 400-mL	2	4
fan	1	1
hole punch	1	3*
graduated cylinder	1	2
ring stand	2	1
spray bottle (fine mist)	1	1
thermometer	2	1

*indicates alternative or additional activity

Key:
1. Perspiring Animals
2. What Has Transpired?
3. Transpiration the Sequel: Leaf in a Cup
4. Cloud Formation
5. Stormy Weather

Activities

Bosak, S. V., D. A. Bosak and B. A. Puppa, *Science Is . . .*, Richmond Hill, Ontario: Scholastic Canada Ltd., 1990.

Campbell, N. A., *Biology*, 2nd ed., Redwood City, Calif.: The Benjamin/Cummings Publishing Company, Inc., 1990.

Chelius, C. R., and H. J. Frentz, *A Basic Meteorology Exercise Manual,* 3rd ed., Dubuque, Iowa: Kendall/Hunt, 1992.

(continued)

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Lutgens, F. K., and E. J. Tarbuck, The Atmosphere, 2nd ed., Englewood Cliffs, NJ: Prentice-Hall, 1982.
Winds and Weather: Probing the Natural World/Level 3, Morristown, NJ: Silver Burdett, 1972.