17 unique in-depth investigations to give you an additional lab option for every chapter
All labs tested, safety reviewed, and supported at www.phschool.com
Pre-Lab Discussions and Critical-Thinking Questions to make the most of lab time
Safety Manual and Student Safety Test to make absolutely sure safety comes first
Safety Reviewers

W. H. Breazeale, Ph.D.
Department of Chemistry
College of Charleston
Charleston, South Carolina

Ruth Hathaway, Ph.D.
Hathaway Consulting
Cape Girardeau, Missouri

Field Testers

Tom Barner
F. A. Day Middle School
Newton, Massachusetts

Nikki Bibbo
Russell Street School
Littleton, Massachusetts

Rose-Marie Botting
Broward County School District
Fort Lauderdale, Florida

Tom Messer
Cape Cod Academy
Osterville, Massachusetts

Carol Pirtle
Hale Middle School
Stow, Massachusetts

Pasquale Puleo
F. A. Day Middle School
Newton, Massachusetts

Anne Scammell
Geneva Middle School
Geneva, New York
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Laboratory Investigations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction Lab</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>9</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>11</td>
</tr>
<tr>
<td>12</td>
</tr>
<tr>
<td>13</td>
</tr>
<tr>
<td>14</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>16</td>
</tr>
</tbody>
</table>
## SI Units and Conversion Tables

### Common SI Units

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Unit</th>
<th>Symbol</th>
<th>Equivalents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 millimeter</td>
<td>mm</td>
<td>1,000 micrometers (µm)</td>
</tr>
<tr>
<td>Length</td>
<td>1 centimeter</td>
<td>cm</td>
<td>10 millimeters (mm)</td>
</tr>
<tr>
<td></td>
<td>1 meter</td>
<td>m</td>
<td>100 centimeters (cm)</td>
</tr>
<tr>
<td></td>
<td>1 kilometer</td>
<td>km</td>
<td>1,000 meters (m)</td>
</tr>
<tr>
<td>Area</td>
<td>1 square meter</td>
<td>m²</td>
<td>10,000 square centimeters (cm²)</td>
</tr>
<tr>
<td></td>
<td>1 square kilometer</td>
<td>km²</td>
<td>1,000,000 square meters (m²)</td>
</tr>
<tr>
<td>Volume</td>
<td>1 milliliter</td>
<td>mL</td>
<td>1 cubic centimeter (cm³ or cc)</td>
</tr>
<tr>
<td></td>
<td>1 liter</td>
<td>L</td>
<td>1,000 milliliters (mL)</td>
</tr>
<tr>
<td>Mass</td>
<td>1 gram</td>
<td>g</td>
<td>1,000 milligrams (mg)</td>
</tr>
<tr>
<td></td>
<td>1 kilogram</td>
<td>kg</td>
<td>1,000 grams (g)</td>
</tr>
<tr>
<td></td>
<td>1 ton</td>
<td>t</td>
<td>1,000 kilograms (kg) = 1 metric ton</td>
</tr>
<tr>
<td>Time</td>
<td>1 second</td>
<td>s</td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>1 Kelvin</td>
<td>K</td>
<td>1 degree Celsius (°C)</td>
</tr>
</tbody>
</table>

### Metric Conversion Tables

<table>
<thead>
<tr>
<th>When You Know</th>
<th>Multiply by</th>
<th>To Find</th>
<th>Multiply by</th>
<th>To Find</th>
</tr>
</thead>
<tbody>
<tr>
<td>inches</td>
<td>2.54</td>
<td>centimeters</td>
<td>0.394</td>
<td>inches</td>
</tr>
<tr>
<td>feet</td>
<td>0.3048</td>
<td>meters</td>
<td>3.281</td>
<td>feet</td>
</tr>
<tr>
<td>yards</td>
<td>0.914</td>
<td>meters</td>
<td>1.0936</td>
<td>yards</td>
</tr>
<tr>
<td>miles</td>
<td>1.609</td>
<td>kilometers</td>
<td>0.62</td>
<td>miles</td>
</tr>
<tr>
<td>square inches</td>
<td>6.45</td>
<td>square centimeters</td>
<td>0.155</td>
<td>square inches</td>
</tr>
<tr>
<td>square feet</td>
<td>0.093</td>
<td>square meters</td>
<td>10.76</td>
<td>square feet</td>
</tr>
<tr>
<td>square yards</td>
<td>0.836</td>
<td>square meters</td>
<td>1.196</td>
<td>square yards</td>
</tr>
<tr>
<td>acres</td>
<td>0.405</td>
<td>hectares</td>
<td>2.471</td>
<td>acres</td>
</tr>
<tr>
<td>square miles</td>
<td>2.59</td>
<td>square kilometers</td>
<td>0.386</td>
<td>square miles</td>
</tr>
<tr>
<td>cubic inches</td>
<td>16.387</td>
<td>cubic centimeters</td>
<td>0.061</td>
<td>cubic inches</td>
</tr>
<tr>
<td>cubic feet</td>
<td>0.028</td>
<td>cubic meters</td>
<td>35.315</td>
<td>cubic feet</td>
</tr>
<tr>
<td>cubic yards</td>
<td>0.765</td>
<td>cubic meters</td>
<td>1.31</td>
<td>cubic yards</td>
</tr>
<tr>
<td>fluid ounces</td>
<td>29.57</td>
<td>milliliters</td>
<td>0.0338</td>
<td>fluid ounces</td>
</tr>
<tr>
<td>quarts</td>
<td>0.946</td>
<td>liters</td>
<td>1.057</td>
<td>quarts</td>
</tr>
<tr>
<td>gallons</td>
<td>3.785</td>
<td>liters</td>
<td>0.264</td>
<td>gallons</td>
</tr>
<tr>
<td>ounces</td>
<td>28.35</td>
<td>grams</td>
<td>0.0353</td>
<td>ounces</td>
</tr>
<tr>
<td>pounds</td>
<td>0.4536</td>
<td>kilograms</td>
<td>2.2046</td>
<td>pounds</td>
</tr>
<tr>
<td>tons</td>
<td>0.907</td>
<td>metric tons</td>
<td>1.102</td>
<td>tons</td>
</tr>
</tbody>
</table>

When You Know

- Fahrenheit: subtract 32; then divide by 1.8 to find Celsius
- Celsius: multiply by 1.8; then add 32 to find Fahrenheit
To prepare yourself to work safely in the laboratory, read over the following safety rules. Then read them a second time. Make sure you understand and follow each rule. Ask your teacher to explain any rules you do not understand.

**Dress Code**

1. To protect yourself from injuring your eyes, wear safety goggles whenever you work with chemicals, flames, glassware, or any substance that might get into your eyes. If you wear contact lenses, notify your teacher.
2. Wear an apron or coat whenever you work with corrosive chemicals or substances that can stain.
3. Tie back long hair to keep it away from any chemicals, flames, or equipment.
4. Remove or tie back any article of clothing or jewelry that can hang down and touch chemicals, flames, or equipment. Roll up or secure long sleeves.
5. Never wear open shoes or sandals.

**General Precautions**

6. Read all directions for an experiment several times before beginning the activity. Carefully follow all written and oral instructions. If you are in doubt about any part of the experiment, ask your teacher for assistance.
7. Never perform activities that are not assigned or authorized by your teacher. Obtain permission before “experimenting” on your own. Never handle any equipment unless you have specific permission.
8. Never perform lab activities without direct supervision.
9. Never eat or drink in the laboratory.
10. Keep work areas clean and tidy at all times. Bring only notebooks and lab manuals or written lab procedures to the work area. All other items, such as purses and backpacks, should be left in a designated area.
11. Do not engage in horseplay.

**First Aid**

12. Always report all accidents or injuries to your teacher, no matter how minor. Notify your teacher immediately about any fires.
13. Learn what to do in case of specific accidents, such as getting acid in your eyes or on your skin. (Rinse acids from your body with plenty of water.)
14. Be aware of the location of the first-aid kit, but do not use it unless instructed by your teacher. In case of injury, your teacher should administer first aid. Your teacher may also send you to the school nurse or call a physician.
15. Know the location of the emergency equipment such as fire extinguisher and fire blanket.
16. Know the location of the nearest telephone and whom to contact in an emergency.

**Heating and Fire Safety**

17. Never use a heat source, such as a candle, burner, or hot plate, without wearing safety goggles.
18. Never heat anything unless instructed to do so. A chemical that is harmless when cool may be dangerous when heated.
19. Keep all combustible materials away from flames. Never use a flame or spark near a combustible chemical.
20. Never reach across a flame.
21. Before using a laboratory burner, make sure you know proper procedures for lighting and adjusting the burner, as demonstrated by your teacher. Do not touch the burner. It may be hot. Never leave a lighted burner unattended! Turn off the burner when not in use.
22. Chemicals can splash or boil out of a heated test tube. When heating a substance in a test tube, make sure that the mouth of the tube is not pointed at you or anyone else.
23. Never heat a liquid in a closed container. The expanding gases produced may shatter the container.
24. Before picking up a container that has been heated, first hold the back of your hand near it. If you can feel heat on the back of your hand, the container is too hot to handle. Use an oven mitt to pick up a container that has been heated.

**Using Chemicals Safely**

25. Never mix chemicals “for the fun of it.” You might produce a dangerous, possibly explosive substance.
**SCIENCE SAFETY RULES (continued)**

26. Never put your face near the mouth of a container that holds chemicals. Many chemicals are poisonous. Never touch, taste, or smell a chemical unless you are instructed by your teacher to do so.

27. Use only those chemicals needed in the activity. Read and double-check labels on supply bottles before removing any chemicals. Take only as much as you need. Keep all containers closed when chemicals are not being used.

28. Dispose of all chemicals as instructed by your teacher. To avoid contamination, never return chemicals to their original containers. Never pour untreated chemicals or other substances into the sink or trash containers.

29. Be extra careful when working with acids or bases. Pour all chemicals over the sink or a container, not over your work surface.

30. If you are instructed to test for odors, use a wafting motion to direct the odors to your nose. Do not inhale the fumes directly from the container.

31. When mixing an acid and water, always pour the water into the container first then add the acid to the water. Never pour water into an acid.

32. Take extreme care not to spill any material in the laboratory. Wash chemical spills and splashes immediately with plenty of water. Immediately begin rinsing with water any acids that get on your skin or clothing, and notify your teacher of any acid spill at the same time.

33. Never force glass tubing or a thermometer into a rubber stopper or rubber tubing. Have your teacher insert the glass tubing or thermometer if required for an activity.

34. If you are using a laboratory burner, use a wire screen to protect glassware from any flame. Never heat glassware that is not thoroughly dry on the outside.

35. Keep in mind that hot glassware looks cool. Never pick up glassware without first checking to see if it is hot. Use an oven mitt. See rule 24.

36. Never use broken or chipped glassware. If glassware breaks, notify your teacher and dispose of the glassware in the proper broken-glassware container.

37. Never eat or drink from glassware.

38. Thoroughly clean glassware before putting it away.

**Using Sharp Instruments**

39. Handle scalpels or other sharp instruments with extreme care. Never cut material toward you; cut away from you.

40. Immediately notify your teacher if you cut your skin when working in the laboratory.

**Animal and Plant Safety**

41. Never perform experiments that cause pain, discomfort, or harm animals. This rule applies at home as well as in the classroom.

42. Animals should be handled only if absolutely necessary. Your teacher will instruct you as to how to handle each animal species brought into the classroom.

43. If you know that you are allergic to certain plants, molds, or animals, tell your teacher before doing an activity in which these are used.

44. During field work, protect your skin by wearing long pants, long sleeves, socks, and closed shoes. Know how to recognize the poisonous plants and fungi in your area, as well as plants with thorns, and avoid contact with them. Never eat any part of a plant or fungus.

45. Wash your hands thoroughly after handling animals or a cage containing animals. Wash your hands when you are finished with any activity involving animal parts, plants, or soil.

**End-of-Experiment Rules**

46. After an experiment has been completed, turn off all burners and hot plates. If you used a gas burner, check that the gas-line valve to the burner is off. Unplug hot plates.

47. Turn off and unplug any other electrical equipment that you used.

48. Clean up your work area and return all equipment to its proper place.

49. Dispose of waste materials as instructed by your teacher.

50. Wash your hands after every experiment.
These symbols alert you to possible dangers in the laboratory and remind you to work carefully.

**Safety Goggles** Always wear safety goggles to protect your eyes in any activity involving chemicals, flames or heating, or the possibility of broken glassware.

**Lab Apron** Wear a laboratory apron to protect your skin and clothing from damage.

**Breakage** You are working with materials that may be breakable, such as glass containers, glass tubing, thermometers, or funnels. Handle breakable materials with care. Do not touch broken glassware.

**Heat-Resistant Gloves** Use an oven mitt or other hand protection when handling hot materials. Hot plates, hot glassware, or hot water can cause burns. Do not touch hot objects with your bare hands.

**Heating** Use a clamp or tongs to pick up hot glassware. Do not touch hot objects with your bare hands.

**Sharp Object** Pointed-tip scissors, scalpels, knives, needles, pins, or tacks are sharp. They can cut or puncture your skin. Always direct a sharp edge or point away from yourself and others. Use sharp instruments only as instructed.

**Electric Shock** Avoid the possibility of electric shock. Never use electrical equipment around water, or when the equipment is wet or your hands are wet. Be sure cords are untangled and cannot trip anyone. Disconnect the equipment when it is not in use.

**Corrosive Chemical** You are working with an acid or another corrosive chemical. Avoid getting it on your skin or clothing, or in your eyes. Do not inhale the vapors. Wash your hands when you are finished with the activity.

**Poison** Do not let any poisonous chemical come in contact with your skin, and do not inhale its vapors. Wash your hands when you are finished with the activity.

**Physical Safety** When an experiment involves physical activity, take precautions to avoid injuring yourself or others. Follow instructions from the teacher. Alert the teacher if there is any reason you should not participate in the activity.

**Animal Safety** Treat live animals with care to avoid harming the animals or yourself. Working with animal parts or preserved animals also requires caution. Wash your hands when you are finished with the activity.

**Plant Safety** Handle plants in the laboratory or during field work only as directed by the teacher. If you are allergic to certain plants, tell the teacher before doing an activity in which those plants are used. Avoid touching harmful plants such as poison ivy, poison oak, or poison sumac, or plants with thorns. Wash your hands when you are finished with the activity.

**Fumes** When poisonous or unpleasant vapors may be involved, work in a ventilated area. Avoid inhaling vapors directly. Only test an odor when directed to do so by the teacher, and use a wafting motion to direct the vapor toward your nose.

**Disposal** Chemicals and other laboratory materials used in the activity must be disposed of safely. Follow the instructions from the teacher.

**Hand Washing** Wash your hands thoroughly when finished with the activity. Use antibacterial soap and warm water. Lather both sides of your hands and between your fingers. Rinse well.

**General Safety Awareness** You may see this symbol when none of the symbols described earlier appears. In this case, follow the specific instructions provided. You may also see this symbol when you are asked to develop your own procedure in a lab. Have the teacher approve your plan before you go further.
I, __________________________, have read
the Science Safety Rules and Safety Symbols
sections on pages v–vii of this manual,
understand their contents completely, and agree
to demonstrate compliance with all safety rules
and guidelines that have been established in each
of the following categories:

(please check)

☐ Dress Code
☐ General Precautions
☐ First Aid
☐ Heating and Fire Safety
☐ Using Chemicals Safely
☐ Using Glassware Safely
☐ Using Sharp Instruments
☐ Animal and Plant Safety
☐ End-of-Experiment Rules

__________________________________________
(signature)

Date ________________________________________
Recognizing Laboratory Safety

◆ Pre-Lab Discussion

An important part of your study of science will be working in a laboratory. In the laboratory, you and your classmates will learn about the natural world by conducting experiments. Working directly with household objects, laboratory equipment, and even living things will help you to better understand the concepts you read about in your textbook or in class.

Most of the laboratory work you will do is quite safe. However, some laboratory equipment, chemicals, and specimens can be dangerous if handled improperly. Laboratory accidents do not just happen. They are caused by carelessness, improper handling of equipment, or inappropriate behavior.

In this investigation, you will learn how to prevent accidents and thus work safely in a laboratory. You will review some safety guidelines and become acquainted with the location and proper use of safety equipment in your classroom laboratory.

◆ Problem

What are the proper practices for working safely in a science laboratory?

◆ Materials (per group)

- science textbook
- laboratory safety equipment (for demonstration)

◆ Procedure

Part A. Reviewing Laboratory Safety Rules and Symbols

1. Carefully read the list of laboratory safety rules listed on pages v and vi of this lab manual.

2. Special symbols are used throughout this lab book to call attention to investigations that require extra caution. Use page vii as a reference to describe what each symbol means in numbers 1 through 8 of Observations.

Part B. Location of Safety Equipment in Your Science Laboratory

1. The teacher will point out the location of the safety equipment in your classroom laboratory. Pay special attention to instructions for using such equipment as fire extinguishers, eyewash fountains, fire blankets, safety showers, and items in first-aid kits. Use the space provided in Part B under Observations to list the location of all safety equipment in your laboratory.

Be sure to show the location of all safety equipment in your laboratory. Also give instructions on its proper use. Guidelines pertaining to the use of special equipment, fire-drill procedures, or penalties for misbehavior in the lab might also be discussed at this time.
Name ____________________________ Date __________ Class __________________

RECOGNIZING LABORATORY SAFETY (continued)

Observations

Part A

1. Student is working with materials that can easily be broken, such as glass containers or thermometers. They should be handled carefully, and broken glassware should not be touched.

2. Student is working with a flame and should tie back loose hair and clothing.

3. Student should use oven mitts or other hand protection to avoid burning hands.

4. Student is working with poisonous chemicals and should not let the chemical touch the skin or inhale its vapors. Student should wash hands after the lab.

5. Student is performing an experiment in which the eyes and face should be protected by safety goggles.

6. Student is working with a sharp instrument and should direct the sharp edge or point away from himself or herself and others.

7. Student is using electricity in the laboratory and should avoid the possibility of electric shock. Electrical equipment should not be used around water, cords should not be tangled, and equipment should be disconnected when not in use.

8. Student is working with plants and should handle them according to the teacher’s instructions. Student should tell the teacher if he or she is allergic to certain plants. Students should wash hands after the lab.
RECOGNIZING LABORATORY SAFETY (continued)

Part B

Student responses will depend on the specific safety features of your classroom laboratory. Locations might include such directions as above the sink, to the right of the goggles case, near the door, and so on.

Analyse and Conclude

Look at each of the following drawings and explain why the laboratory activities pictured are unsafe.

1. Safety goggles should always be worn whenever a person is working with chemicals, lab burners, or any substance that might get into the eyes.

2. When diluting an acid, pour the acid into water. Never pour water into the acid. Also, safety goggles and a lab apron should be worn when working with chemicals.

3. Never heat a liquid in a closed container. The expanding gases produced may shatter the container.
Critical Thinking and Applications

In each of the following situations, write *yes* if the proper safety procedures are being followed and *no* if they are not. Then give a reason for your answer.

1. Gina is thirsty. She rinses a beaker with water, refills it with water, and takes a drink.
   
   No; you should never drink from laboratory glassware. The last substance in it may have been poisonous and traces of the poison may remain.

2. Bram notices that the electrical cord on his microscope is frayed near the plug. He takes the microscope to his teacher and asks for permission to use another one.
   
   Yes; electrical appliances with frayed cords or broken insulation may present a hazard and should not be used.

3. The printed directions in the lab book tell a student to pour a small amount of hydrochloric acid into a beaker. Jamal puts on safety goggles before pouring the acid into the beaker.
   
   Yes; safety goggles should always be worn when working with dangerous chemicals.

4. It is rather warm in the laboratory during a late spring day. Anna slips off her shoes and walks barefoot to the sink to clean her glassware.
   
   No; shoes should always be kept on while working in the laboratory in case glassware breaks or chemicals are spilled onto the floor.

5. While washing glassware, Mike splashes some water on Evon. To get even, Evon splashes him back.
   
   No; misbehaving is never acceptable in a laboratory.

6. During an experiment, Lindsey decides to mix two chemicals that the lab procedure does not say to mix, because she is curious about what will happen.
   
   No; never mix chemicals unless directed to do so. The mixing might produce an explosive substance.
Defining Elements of a Scientific Method

Laboratory activities and experiments involve the use of the scientific method. Listed in the left column are the names of parts of this method. The right column contains definitions. Next to each word in the left column, write the letter of the definition that best matches that word.

1. Hypothesis
2. Manipulated Variable
3. Responding Variable
4. Controlling Variables
5. Observation
6. Data
7. Conclusion

A. Prediction about the outcome of an experiment
B. What you measure or observe to obtain your results
C. Measurements and other observations
D. Statement that sums up what you learn from an experiment
E. Factor that is changed in an experiment
F. What the person performing the activity sees, hears, feels, smells, or tastes
G. Keeping all variables the same except the manipulated variable
Analyzing Elements of a Scientific Method

Read the following statements and then answer the questions.

1. You and your friend are walking along a beach in Maine on January 15 at 8:00 AM.
2. You notice a thermometer on a nearby building that reads −1°C.
3. You also notice that there is snow on the roof of the building and icicles hanging from the roof.
4. You further notice a pool of sea water in the sand near the ocean.
5. Your friend looks at the icicles and the pool and says, “How come the water on the roof is frozen and the sea water is not?”
6. You answer, “I think that the salt in the sea water keeps it from freezing at −1°C.”
7. You go on to say, “And I think under the same conditions, the same thing will happen tomorrow.”
8. Your friend asks, “How can you be sure?” You answer, “I’m going to get some fresh water and some salt water and expose them to a temperature of −1°C and see what happens.”

♦ Questions

A. In which statement is a prediction made? 7

B. Which statement states a problem? 5

C. In which statement is an experiment described? 8

D. Which statement contains a hypothesis? 6

E. Which statements contain data? 1, 2, 3, 4

F. Which statements describe observations? 2, 3, 4
Performing an Experiment

Read the following statements and then answer the questions.

1. A scientist wants to find out why sea water freezes at a lower temperature than fresh water.
2. The scientist goes to the library and reads a number of articles about the physical properties of solutions.
3. The scientist also reads about the composition of sea water.
4. The scientist travels to a nearby beach and observes the conditions there. The scientist notes the taste of the sea water and other factors such as waves, wind, air pressure, temperature, and humidity.
5. After considering all this information, the scientist sits at a desk and writes, “If sea water has salt in it, it will freeze at a lower temperature than fresh water.”
6. The scientist goes back to the laboratory and does the following:
   a. Fills each of two beakers with 1 liter of fresh water.
   b. Dissolves 35 grams of table salt in one of the beakers.
   c. Places both beakers in a freezer at a temperature of $-1^\circ C$.
   d. Leaves the beakers in the freezer for 24 hours.
7. After 24 hours, the scientist examines both beakers and finds the fresh water to be frozen. The salt water is still liquid.
8. The scientist writes in a notebook, “It appears that salt water freezes at a lower temperature than fresh water does.”
9. The scientist continues, “I suggest that the reason sea water freezes at a lower temperature is that sea water contains dissolved salts, while fresh water does not.”

Questions

A. Which statements contain conclusions? 8, 9

B. Which statement contains a hypothesis? 5

C. Which statements contain observations? 4, 7

D. Which statements describe an experiment? 6 a–d

E. In which statement is the problem described? 1

F. Which statements contain data? 4, 6 a–d, 7

G. Which is the manipulated variable in the experiment? the amount of salt in water

H. What is the responding variable in the experiment? the temperature at which water freezes
Identifying Errors

Read the following paragraph and then answer the questions.

Andrew arrived at school and went directly to his earth science class. He took off his cap and coat and sat down at his desk. His teacher gave him a large rock and asked him to find its density. Realizing that the rock was too large to work with, Andrew got a hammer from the supply cabinet and hit the rock several times until he broke off a chip small enough to work with. He partly filled a graduated cylinder with water and suspended the rock in the water. The water level rose 2 cm. Andrew committed this measurement to memory. He next weighed the rock on a balance. The rock weighed 4 oz. Andrew then calculated the density of the rock as follows: He divided 2 cm by 4 oz. He then reported to his teacher that the density of the rock was .5 cm/oz.

Questions

1. What safety rule(s) did Andrew break?
   
   He didn’t put on his safety goggles. Also, he didn’t obtain permission from his teacher before obtaining the hammer and breaking the rock.

2. What mistake did Andrew make using measurement units?
   
   He used linear units (centimeters) instead of volumetric units (milliliters).

3. What should Andrew have done with his data rather than commit them to memory?
   
   He should have kept a written record.

4. What is wrong with the statement “He next weighed the rock on a balance”?
   
   A balance is used to determine mass, not weight.

5. Why is “4 oz.” an inappropriate measurement in a science experiment?
   
   Metric units (grams) should be used.

6. What mistake did Andrew make in calculating density?
   
   Density is expressed in mass per unit volume (g/mL), not length per unit weight.
INTRODUCTION

Investigating Seeds

♦ Pre-Lab Discussion

To investigate the natural world, scientists use skills such as making observations, making inferences, and conducting experiments. In an experiment, a scientist changes a specific factor, or variable, and then monitors the effect of the change on another variable. You too can explore the world in this way.

In this lab, you will investigate seeds using the process of scientific inquiry. You will conduct a controlled experiment to observe the sprouting, or germination, of seeds. Each seed contains a young plant in a protective coating. The new plant will emerge under the correct conditions. By carefully controlling the variables, you will learn about the factors that affect germination.

1. What is a manipulated variable?
   A manipulated variable, or independent variable, is the factor that is changed in an experiment.

2. What is a responding variable?
   A responding variable, or dependent variable, is the factor that changes because of the manipulated variable.

3. Why must all other variables be kept constant during an experiment?
   All of the other variables in the experiment are kept constant to be sure that the changes in the responding variable are actually caused by the changes in the manipulated variable.

♦ Problem

What factors affect how quickly seeds germinate?

♦ Materials

- paper cups containing seeds
- tray
- hand lens
- 2 clear plastic cups
- paper towels
- tap water
- metric ruler
- tray
- tap water
- metric ruler
- tray
- tap water
- metric ruler

♦ Safety

Review the safety guidelines in the front of your lab book.

Keep seeds in containers at all times to prevent accidents. Do not eat the seeds.

Teaching Tip: Use this laboratory investigation to focus on the skills of scientific inquiry, which may be new to some of your students.

Advance preparation: Prepare cups of 25–30 of the same type of seed for each group. Use seeds that germinate quickly such as beans, peas, corn, or oat. You may wish to give a different type of seed to each group. To speed germination, soak all of the seeds in water overnight.

Teaching Tip: Encourage students to use the hand lens for closer inspection of the seeds.
INVESTIGATING SEEDS (continued)

♦ Procedure

Part A: Initial Observations of Seeds

1. Obtain a cup of seeds from your teacher. All the seeds should be of the same type. Carefully pour the seeds onto the tray. **CAUTION:** Immediately pick up any seeds that drop onto the floor. Observe the seeds, and use a ruler to determine their size. Make a drawing of one seed under Part A below.

2. Use a hand lens to observe other seed characteristics, such as color and texture. Record your observations below.

Part B: Germinating the Seeds

1. Line two clear plastic cups with a flat section of moist paper towel. Crumple other sections of moist paper towel and place them in the center of the cups.

2. Place about 12–15 seeds in between the paper towel liner and the wall of each cup as shown in Figure 1.

3. Place cup A in a cold place (such as a refrigerator). Place cup B in a warm place. You will need to keep all other variables constant, such as the amount of water and light provided.

4. Each day for about seven days, observe the seeds in both cups. Count the number of seeds that germinated, and record your observations in the data table on the next page.

♦ Observations

   Students must use the same amount of water to keep the paper towels moist and also keep the amount of light constant. To keep both cups in the dark, suggest that students place cup B in a closed box or cabinet.

Part A

<table>
<thead>
<tr>
<th>Diagram of a Seed</th>
<th>Initial Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagram will vary according to the type of seed.</td>
<td>Students need to keep clear records of the characteristics they observe. They should notice color, shape, size, etc.</td>
</tr>
</tbody>
</table>
Part B

<table>
<thead>
<tr>
<th>Day</th>
<th>Cup A</th>
<th>Cup B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Students should record the number of seeds that have germinated and their other observations.</td>
<td>Most seeds will not germinate in the cold.</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

◆ Analyze and Conclude

1. How did the seeds change during your investigation?
   Some seeds most likely will have become swollen, and some of that group will have produced roots and a green shoot.

2. By the end of the investigation, did the seeds in cup A differ from those in cup B? If so, how?
   Yes, the seeds in cup A germinated while those in cup B did not.

3. Based on your results, what conclusion can you draw about the effect of temperature on seed germination?
   Seeds require warm temperatures to germinate. Seeds will not germinate when their environment is too cold.
4. As directed by your teacher, find out what methods and results your classmates obtained. How do those investigations compare with yours?

   Answers may vary depending on the results of the class, but students should report there is no germination of seeds in the cold.

◆ Critical Thinking and Applications

1. Which factor in this investigation was the manipulated variable? Which factor was the responding variable?

   Temperature was the manipulated variable. The number of the seeds that germinated was the responding variable.

2. What variables did you keep constant in this experiment? How could you improve the procedures you used for controlling variables?

   The variables that were controlled include the type of seeds used, the amount of water given, and the amount of light provided. Students will have a variety of improvements to report.

3. How do you know that the differences you observed between the seeds in cup A and those in cup B resulted from differences in temperature?

   Since all other variables except the manipulated variable were kept the same, the differences in the number of seeds that germinated were due to differences in the manipulated variable, the temperature.

◆ More to Explore

How could you adapt this investigation to study another variable involved in seed germination? Write out a plan that identifies the manipulated and responding variables, and the variables you will control. Obtain your teacher’s approval before performing your experiment.

Variables students might wish to investigate would include the amount of water supplied, using different types of soils, or examining germination in a variety of seeds.
Determining the Density of Liquids

Pre-Lab Discussion

If you’ve ever carried bags of groceries, you know that some bags have greater mass than others, even though the volumes of the bags are the same. Mass and volume are general properties of all matter. Density is the ratio of mass to volume. The density of a specific kind of matter helps to identify it and to distinguish it from other kinds of matter. Liquids have density, and you determine their densities in grams per milliliter (g/mL).

In this investigation, you will develop a procedure for finding density and use it to determine the density of several liquids. You will compare the densities of liquids by using a wood float.

1. A rock sinks when placed in water. Which is more dense, the rock or the water?
   - the rock

2. Liquid A has a mass of 32 grams and a volume of 20 milliliters. Liquid B has a density of 1.2 g/mL. Will Liquid B float on Liquid A? Explain your answer.
   - Yes, Liquid B will float on Liquid A because the density of Liquid B (1.2 g/mL) is less than that of Liquid A (32 g/20 mL = 1.6 g/mL).

Problem

How can you determine the density of a liquid?

Possible Materials

(per group)
- 4 graduated cylinders, 100 mL
- balance
- 30 mL ethanol
- salad oil
- salt water
- paper towels
- 4 wooden dowels, about 6 cm long
- glass marker
- salt
- metric ruler

Key Concepts:
Density is the ratio of mass to volume and is a property of all matter. The density of a substance is characteristic and can be used for identification. A less dense material will float on a denser material.

Skills Focus:
Observing, predicting, measuring, calculating, designing experiments

Time Required: 40 minutes

Advance Preparation:
Prepare a salt solution that is notably denser than fresh water by dissolving 100 g of salt in 1 L of water.

Alternative Materials:
If large numbers of graduated cylinders are not available, use a permanent marker and 50 mL of water to calibrate transparent plastic cups. The cups should be as narrow as possible so that the wooden dowels will float without touching the bottom of the cup. Pencils can be used for wooden dowels.

Teaching Tips:
Density will change slightly with a temperature change. Have all solutions at room temperature. If students don’t know which formula to use, refer them to the textbook.

Watch closely for spills. Oil spills can easily cause falls, and ethanol spills can be a fire hazard.

Different dowels should be used for each liquid since the dowel will absorb some liquid, thus changing its density. This also prevents contamination.
DETERMINING THE DENSITY OF LIQUIDS (continued)

◆ Safety  ⚠️ Review the safety guidelines in your lab book.

Wear safety goggles and lab aprons. Never have an open flame in the same room as an open container of ethanol. Report any spills of oil or ethanol to the teacher. Ethanol is poisonous.

After the lab, ethanol can be washed down the drain with running water. Salad oil can be collected in a container, mixed with dish detergent, and washed down the drain.

◆ Procedure

1. Read the entire lab before continuing with the procedure.

2. With your group, design a procedure to find the density of 30 mL of water. Think about what properties of water you need to know to find its density. Your procedure should include keeping the sample of water for Step 6. Write each step of your procedure on a separate sheet of paper.

3. Finish designing the Data Table in Observations to determine the density for water and three other liquids. Add headings and columns to organize the data you will need to find and record. Change the first column if you use other liquids.

4. CAUTION: Wear safety goggles and lab aprons. After the teacher has approved your plan and Data Table, find the density of the sample of water. What mathematical formula will you use to find density? Record all your data and the density of water in your Data Table.

5. CAUTION: There should be no open flames in the room where you're using the ethanol. Ethanol is a poison, so keep it away from your face. Use your procedure to find the density of 30-mL samples of ethanol, salad oil, and salt water or other liquids you are using. Record all your data and the density of these three liquids in your data table. CAUTION: Report any oil or ethanol spills immediately.

6. Set four graduated cylinders side by side, each containing 30 mL of one of the liquids you tested. See Figure 1. Think about their differences in density. Predict how high a wooden dowel will float in each liquid, compared to the other three.

Predictions should indicate that the greater the density of the liquid, the higher the wooden dowel will float.

7. On a separate sheet of paper, write a procedure for testing your prediction. Have the teacher approve your plan, and then carry it out.

Students could use this procedure. Tilt the first cylinder and gently drop the wooden dowel into it, being careful not to spill or splash any liquid. Measure and record the height of the bottom (or top) of the dowel in the cylinder. Remove the dowel, rinse it, dry it, and repeat for the three other liquids.
**Observations**

Data of the liquids listed should show an increasing mass and density from ethanol to oil to water to salt water.

<table>
<thead>
<tr>
<th>Liquid</th>
<th>Mass of Empty Graduated Cylinder (g)</th>
<th>Mass of Graduated Cylinder and Liquid (g)</th>
<th>Mass of Liquid (g)</th>
<th>Volume of Liquid (mL)</th>
<th>Density of Liquid (g/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td></td>
<td>30.0</td>
<td>30</td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>Ethanol</td>
<td></td>
<td>24.0</td>
<td>30</td>
<td></td>
<td>0.8</td>
</tr>
<tr>
<td>Salt water</td>
<td></td>
<td>36.0</td>
<td>30</td>
<td></td>
<td>1.2</td>
</tr>
<tr>
<td>Oil</td>
<td></td>
<td>27.0</td>
<td>30</td>
<td></td>
<td>0.9</td>
</tr>
</tbody>
</table>

**Analyze and Conclude**

1. List the four liquids that you used in this experiment, in order of increasing density.

   Of the liquids listed in the Data Table, the order is ethanol, salad oil, water, salt water.

2. Were your predictions accurate? Make a statement that compares the density of a liquid to how high a wooden dowel will float in it.

   The more dense the liquid, the higher the wooden dowel will float in it.
1. Which has the greater mass, 1 L of water or 1 L of ethanol? Explain your answer in terms of density.

   The water; because the density of water is greater than that of ethanol and the volumes are the same, the mass of the water is greater.

2. Which takes up a greater volume, 1,000 g of water or 1,000 g of ethanol? Explain your answer in terms of density.

   The ethanol; because the density of water is greater than that of ethanol and the masses are the same, the volume of the ethanol is greater.

3. Which is more dense, 1 mL of water or 50 L of water? Give a reason for your answer.

   The densities are the same. As volume changes, mass will change the same amount, so the density of water is always the same.

4. Predict what would happen if you poured all the liquids used in this lab into one beaker.

   The liquids would form layers; from bottom to top they would be salt water, water, salad oil, and ethanol.

**More to Explore**

Does the amount of salt in water affect the liquid’s density? Write a procedure you would follow to answer this question. Have the teacher approve your procedure before you carry out the investigation. Use your results to explain why it is easier for a person to float in the Great Salt Lake than it is to float in a freshwater lake. Wear your safety goggles and apron and wash up afterward.

Students could use this procedure. Put different amounts of salt in the same volume of water (for example, 25 g, 50 g, and 100 g of salt dissolved in 1 L of water), float the wood in the same amount of the solutions, and compare how high it floats. The more salt, the higher the wood floats and the denser the liquid. The water in the Great Salt Lake is denser than fresh water.
Comparing How Liquids Cool

♦ Pre-Lab Discussion

If you have ever heated water or milk to make hot chocolate, you have some experience with heating and cooling liquids. You know that if you stop heating the liquid, it will slowly cool down until its temperature matches that of its surroundings. When you heat a liquid you transfer thermal energy to the particles of the liquid. When the liquid cools, thermal energy flows from the liquid and its container to the cooler surrounding air. In this investigation, you will heat two different liquids and then measure how their temperatures change as they cool down in a given time period.

1. What is temperature?

A measure of the average energy of motion of particles in a substance.

2. What happens to the particles of a liquid when you heat it?

When heat flows in a liquid, its particles gain energy and move faster.

♦ Problem

Do different liquids cool at different rates?

♦ Materials (per group)

- 600-mL beaker
- 2 test tubes
- 10-mL graduated cylinder
- hot plate
- watch or clock with sweep second hand
- 2 thermometers
- 2 test tube clamps
- tap water
- vegetable oil
- ring stand

♦ Safety

Review the safety guidelines in the front of your lab book.

Do not touch the hot plate or beaker with your bare hands. Use an oven mitt to move the test tubes of hot liquid out of the hot water bath. Always wear safety goggles when heating objects.

♦ Procedure

The procedure will take less time and go more smoothly if students work in pairs. Have each student in a pair track the cooling time for one liquid.

1. Read all the steps of the Procedure before you begin work. Based on your everyday past experience, make a prediction about how the cooling of water will compare to the cooling of vegetable oil.
2. Set up the ring stand, hot plate, and beaker as shown in Figure 1. Pour water into the beaker until it is about two thirds full. Turn on the hot plate and begin to heat the water gently. DO NOT boil the water.

3. Meanwhile, put 10 mL of tap water into one test tube. Put an equal amount of vegetable oil into the second test tube. Clamp the test tubes to the ring stand and lower them into the beaker of water as shown in Figure 1. The tubes should not touch the bottom of the beaker. If necessary, add water to the beaker so that the water level is slightly above the liquid level in your test tubes.

4. Carefully place a thermometer in each test tube and continue heating the beaker and tubes of liquid. Occasionally move each thermometer slowly and gently in a small circle to help the liquids heat evenly. **CAUTION:** Take care not to hit the thermometer against the side or bottom of the test tube.

5. Continue heating until the temperature of the liquids in the test tubes rises to about 78–80°C. Turn off the hot plate.

6. Carefully loosen one clamp so that you can raise a test tube out of the beaker. Move it aside to cool in the air away from the beaker. Retighten the clamp. **CAUTION:** The clamps holding the tubes may be warm. Protect your hands from the heat. Move only one tube at a time.

7. When the temperature of this liquid drops to 75°C, begin recording its temperature in your Data Table, every 30 seconds for 5 minutes. Round the temperature values to the nearest 0.5 degree. When you read the temperature, the bulb of the thermometer should be in the middle of the liquid. Gentle moving of the thermometer between readings will help the liquid to cool evenly.

8. Repeat steps 6 and 7 using the second test tube in the water bath. *(Note: If the liquid in this test tube has cooled below 75°C, turn the hot plate on and heat the liquid to 78–80°C again.)*

Students do not have to start tracking each liquid at the same time, but they should start from the same initial temperature. Letting the temperature rise above 75°C gives students time to secure the test tubes away from the heat before they begin their observations.
COMPARING HOW LIQUIDS COOL (continued)

♦ Observations

Data Table

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Temperature (°C)</th>
<th>Time (min)</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>75.0</td>
<td>0.0</td>
<td>75.0</td>
</tr>
<tr>
<td>0.5</td>
<td>73.0</td>
<td>0.5</td>
<td>70.5</td>
</tr>
<tr>
<td>1.0</td>
<td>71.5</td>
<td>1.0</td>
<td>67.5</td>
</tr>
<tr>
<td>1.5</td>
<td>70.0</td>
<td>1.5</td>
<td>65.5</td>
</tr>
<tr>
<td>2.0</td>
<td>68.5</td>
<td>2.0</td>
<td>63.0</td>
</tr>
<tr>
<td>2.5</td>
<td>67.0</td>
<td>2.5</td>
<td>61.0</td>
</tr>
<tr>
<td>3.0</td>
<td>65.5</td>
<td>3.0</td>
<td>59.5</td>
</tr>
<tr>
<td>3.5</td>
<td>64.0</td>
<td>3.5</td>
<td>57.0</td>
</tr>
<tr>
<td>4.0</td>
<td>63.0</td>
<td>4.0</td>
<td>55.0</td>
</tr>
<tr>
<td>4.5</td>
<td>62.0</td>
<td>4.5</td>
<td>53.0</td>
</tr>
<tr>
<td>5.0</td>
<td>61.0</td>
<td>5.0</td>
<td>52.0</td>
</tr>
</tbody>
</table>

Sample Data

You may wish to have students test additional liquids, such as corn syrup, glycerin, or mineral oil. You can split the class into groups and assign liquids to test.

If students obtain data outside the range of temperature values shown here, they can construct graphs using a copy of the blank graph grid at the back of this lab manual.

You may wish to have students draw a best-fit curve through their data rather than graph the data points as shown. Explain to students that some data points will not fall on a best-fit curve.

♦ Analyze and Conclude

1. Use the grid shown to graph your results from the Data Table. Use a different color pencil or different kinds of points for each liquid. (You could use dots for one and triangles for the other.) Make a smooth line through each set of points.

2. Describe the shape and direction of each of your lines on the graph.
   - Both graphs will be curves that drop sharply at first, then begin to level out.
   - The curve for vegetable oil will drop off more sharply than the curve for water.

3. Which of your two liquids loses thermal energy at the faster rate? Explain.
   - Vegetable oil loses thermal energy at a faster rate than water does. The liquid whose curve drops more steeply loses heat more rapidly.
4. How do your results compare with those of your classmates? How might you account for any differences?

Accept all answers that reasonably reflect the class results. Sample explanations for differences in data may include: mistakes in measurement or recording of data; not starting at the same initial temperature; incorrect graphing of data.

◆ Critical Thinking and Applications

1. Look at Exploring Changes of State on page 78 of your textbook. Describe how the graph you made of your data is related to the graph in your textbook.

The graph obtained from the experimental data represents the cooling of a liquid. It is the same section of the graph as shown in part C of the textbook illustration representing the heating of a liquid, but in reverse.

2. How would knowing the rate at which an unknown liquid loses thermal energy be useful?

The rate at which a liquid loses thermal energy (cools) is a distinguishing property of the substance. The data can be compared to known data to help identify the substance.

3. In Step 1 of the procedure, you used an equal volume of liquid in each test tube. Why do you think this is important to do?

Different volumes might affect the rate of cooling. Only one manipulated variable can be tested at a time. In this case we have chosen the identity of the liquid as the manipulated variable.

◆ More to Explore

If two liquids cool at different rates, will they also heat differently? Write out a procedure you would follow to answer this question. Then predict the results. Have your teacher approve your procedure before you carry out the investigation. Was your prediction correct? If not, what happened that was different from your prediction?

Check students’ procedures for safety and completeness. If students start with cool water in the beaker and monitor the temperature as the water and test tubes are heated, they will see similar patterns, but the differences are less pronounced. For this approach to work, they must place room-temperature tubes in already hot (~80°C) water. If the entire system (beaker, bath, test tubes and contents) heat up together, the liquid samples will have virtually identical rates of heating.
Measuring Speed

Pre-Lab Discussion

Perhaps you've heard about the race between the tortoise and the hare. The hare was a fast runner but kept taking breaks because it was so sure of winning. The tortoise could only walk but never took a break. The hare lost the race.

These two racers demonstrate the difference between speed at one particular instant and average speed. To find a person's speed, you need an accurate measurement of the distance he or she travels and how long it takes the person to cover the distance.

In this investigation, you will design and use a plan to find the average speed of a pedestrian.

1. What is the formula used to calculate speed?

   \[
   \text{Speed} = \frac{\text{Distance}}{\text{Time}}
   \]

2. If you calculated the average speed of a runner in a marathon, would the runner be moving at that speed at every point in the race? Give a reason for your answer.

   No, a runner does not maintain a constant speed throughout the race. On hills a runner might slow down, for example.

Problem

How can you find the average speed of a pedestrian?

Possible Materials (per group)

- tape measure or meter stick
- masking tape
- 3 stopwatches

Safety

Review the safety guidelines in the front of your lab book.

Don’t get in the way of the people whose speed you are measuring. Don’t create hazards in the walkway.

Teaching Tips: The best group size for this lab is four students.

If students can’t set up a course outside the classroom, have them set it up in the classroom with students measuring the times of other members of the group walking the course.

Students should agree on when to stop their stopwatches. For example, will they stop when the person’s foot crosses the tape mark, or will they stop when the person’s torso crosses the mark?
MEASURING SPEED (continued)

Procedure

1. Read through the entire lab now.

2. Develop a procedure to find out how fast pedestrians move. Consider the following variables and questions as you develop your procedure.
   - Choose a place that gets a lot of pedestrian traffic. It should have room for you to work without getting in the subjects’ way.
   - How long should the course be?
   - How will you mark the beginning and end of the course?
   - When does a subject officially enter the course and leave it?
   - How will you get accurate beginning and ending times for the course?
   - How many people will you need to do the timing?
   - Include a way to check whether the pedestrian’s rate is variable or constant. For example, you could have timers at the quarter mark, halfway point, and at the three-quarters mark. A fourth person could signal all the timers to begin timing, and each would stop their stopwatch as the pedestrian passed by.

   Write your procedure on a separate sheet of paper.

3. Decide what data you will need to collect. You should gather enough data to be able to show whether the subject speeds up or slows down. Time at least 5 subjects. Adjust the Data Table on the next page so that you can use it with your procedure. You may want to add columns and headings.

4. After the teacher has approved your plan and data table, go ahead with the experiment. Practice your timing technique before trying to record data. You may need to adjust the length of the course.

5. After you collect your data, answer the questions in Observations.

Observations

1. Which pedestrian had the fastest average speed over the entire course? What was it?
   See students’ data tables. For the sample data: Subject E; 2.1 m/s

2. Which pedestrian had the slowest average speed over the entire course? What was it?
   See students’ data tables. For the sample data: Subject D; 1.0 m/s
**MEASURING SPEED (continued)**

**Data Table**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Time (s)</th>
<th>Speed (m/s)</th>
<th>Time (s)</th>
<th>Speed (m/s)</th>
<th>Time (s)</th>
<th>Speed (m/s)</th>
<th>Time (s)</th>
<th>Speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10</td>
<td>1.5</td>
<td>12</td>
<td>1.3</td>
<td>13</td>
<td>1.2</td>
<td>10</td>
<td>1.5</td>
</tr>
<tr>
<td>B</td>
<td>8</td>
<td>1.9</td>
<td>10</td>
<td>1.5</td>
<td>9</td>
<td>1.7</td>
<td>7</td>
<td>2.1</td>
</tr>
<tr>
<td>C</td>
<td>11</td>
<td>1.4</td>
<td>12</td>
<td>1.3</td>
<td>14</td>
<td>1.1</td>
<td>11</td>
<td>1.4</td>
</tr>
<tr>
<td>D</td>
<td>13</td>
<td>1.2</td>
<td>15</td>
<td>1.0</td>
<td>14</td>
<td>1.1</td>
<td>16</td>
<td>0.9</td>
</tr>
<tr>
<td>E</td>
<td>7</td>
<td>2.1</td>
<td>7</td>
<td>2.1</td>
<td>7</td>
<td>2.1</td>
<td>7</td>
<td>2.1</td>
</tr>
</tbody>
</table>

**Course Length:** 60 m

**Sample Data**

Students should record data for 5 or more people. The data table should record times for each pedestrian for parts of the course and for the entire course, speed for parts of the course and average speed for the entire course. Typical walking speeds are between 1 and 2 m/s.

◆ **Analyze and Conclude**

1. Did any of the pedestrians speed up while walking the course? How do you know?
   
   Students can determine if any of the pedestrians were speeding up only if they divided the course and timed travel through each part. If pedestrians speeded up, their average speeds over the segments would increase.

2. Did any of the pedestrians slow down while walking the course? How do you know?
   
   See answer to question 2. If any of the pedestrians were slowing down, their average speeds over the segments of the course would decrease.
Critical Thinking and Applications

1. How accurate do you think the measured times are? Suggest a method that would allow you to get more accurate results in this experiment.

   Answers will vary. One method to improve accuracy would be to have more than one timer at each station and to average their results.

2. Would the results of your investigation have been different if you had timed vehicles on a street rather than people walking? Would it have been easier or more difficult to get accurate results? Give a reason for your answer.

   Students should expect the average speed of vehicles to be faster than that of pedestrians. It would be more difficult to time vehicles because they are moving faster.

3. If you were going to repeat the investigation using vehicles, would you be more likely to get accurate results with a longer course or a shorter course? Give a reason for your answer.

   A longer course would probably give more accurate results because of the faster speed of the cars.

More to Explore

Do you know what your average walking speed is? It probably varies, depending on circumstances, such as whether you’re late or early for school. How could you use your walking speed to measure distance? On another sheet of paper, write a procedure you would follow to answer this question. Include a way to check the accuracy of your measurements. Have the teacher approve your procedure before you carry out the investigation. How could you improve the accuracy of your measurements?

One way to use time to measure distance is to find how long it takes you to walk a measured distance, for example, 10 meters. Then time how long it takes to walk somewhere, divide by the time it takes you to walk 10 meters, and multiply by 10 to get the distance in meters. A way to check accuracy could be to have another person measure the distance by walking it and compare results; if it’s a short distance, measure it with a tape measure. A way to improve accuracy is to walk and time yourself on 10 meters several times and take the average, before measuring an unknown.
How to Use a Microscope

Pre-Lab Discussion

As you explore the natural world in science labs, you will be doing something you do every day—making observations. You use your senses to make observations, but sometimes your senses need help. For several labs in this book, you will be using a microscope to examine organisms and objects that are too small to be seen with the unaided eye. Refer to Figure 1 throughout this lab and other labs that use a microscope.

When you view an object through a microscope, you place the object on a glass slide. The slide may be either a dry-mount or a wet-mount slide. In a dry-mount slide, the object to be examined is placed on the slide and covered with a small square of plastic called a coverslip. In a wet-mount slide, a drop of liquid is placed over the object before being covered with a coverslip. In this investigation, you will learn how to correctly prepare a wet-mount slide and how to observe an object under the microscope.

1. When you carry a microscope, why should you carry it with one hand on the arm of the microscope and the other hand under the base?

   This is a stable way to carry the microscope, so that it doesn’t knock anything and so that sensitive parts of the instrument are not subject to damage.

2. Why should you hold a microscope slide by its edges?

   Holding the slide by its edges prevents fingerprints and smudges from getting onto the slide, thus interfering with the view of the object under the microscope.

Advance Preparation: Have microscopes set up at student stations.
Alternate Materials: A pin or a dissecting probe can be used instead of forceps.
Problem

How do you prepare an object to be viewed under the microscope, and how do you use the microscope to observe the object?

Materials (per group)

- microscope
- microscope slide
- coverslip
- newspaper
- scissors
- plastic dropper
- water
- forceps
- paper towel

Teaching Tips:

For an object to be visible under a light microscope, it must be thin enough for light to pass through it. That is why thin paper, such as newspaper, is required. Any asymmetrical letter may be observed, such as a lowercase “e,” “f,” or “g.”

Never allow the clips to come in contact with the opening in the stage because they will scratch the lens and interfere with viewing objects.

If any of the lenses are dirty, have students carefully clean them with lens paper. Using cloth or other materials instead of lens paper can damage the lenses.

Point out to students that if the letter is in perfect focus as is, they do not need to focus with the fine-adjustment knob.

Safety

Review the safety guidelines in front of your lab book.

Wipe up any spills immediately. Handle slides with care to avoid breakage. Tell the teacher if a slide breaks. If your microscope has a mirror, do not tilt it directly toward the sun. Eye damage can occur if direct sunlight is used as a light source.

Procedure

1. Cut a small letter “d” from the newspaper and place it in the center of a clean microscope slide so that it is in the normal reading position.

2. Using the plastic dropper, carefully place a small drop of water over the letter.

3. Place one side of a clean coverslip at the end of the drop of water at a 45\(^\circ\) angle. See Figure 2. Use forceps to carefully lower the coverslip over the letter “d” and the drop of water. Do not press on the coverslip. It should rest on top of the water. Try not to trap any air bubbles under the coverslip because these will interfere with your view of the specimen. If you have trapped air bubbles, make a new wet-mount slide.

4. Absorb excess water by touching a folded piece of paper towel to the water that comes out around the edges of the coverslip.

Figure 2
5. In Observations, draw a picture of the letter “d” just as you see it on the slide, without the aid of the microscope.

6. Place the slide under the clips on the stage of the microscope. Position the slide so that the letter “d” is directly over the center of the stage opening.

7. Turn the nosepiece so that the low-power objective is facing downward, toward the slide. Use the coarse-adjustment knob to slowly lower the low-power objective until it almost touches the slide. **CAUTION:** To prevent damage to the microscope and the slide, do not let the lens actually touch the slide.

8. Tilt the mirror and adjust the diaphragm until you get the best light for viewing the specimen. **CAUTION:** Do not aim the mirror at direct sunlight.

9. Looking through the eyepiece, use the coarse-adjustment knob to slowly raise the lens until the letter comes into view. **CAUTION:** To prevent damage, do not lower the coarse adjustment while looking through the eyepiece.

10. Use the fine-adjustment knob to focus the letter clearly. You should only need to turn the knob one-quarter of a turn or less.

11. Look at the objectives and the eyepiece of your microscope. Then answer question 1 in Observations.

12. Find the total magnification power of your microscope by multiplying the magnification of the eyepiece lens by the magnification of the objective lens you are using. Then answer questions 2 and 3 in Observations.

13. In Observations, draw a picture of the letter “d” as viewed through the microscope. Record the magnification you are using.

14. While looking through the eyepiece, move the slide to the left. Notice which way the letter seems to move. Now move the slide to the right. Again notice which way the letter seems to move.

15. Switch to the high-power objective lens by revolving the nosepiece so that the high-power lens clicks into place. **CAUTION:** The high-power objective is longer than the low-power objective; it may easily touch and damage the slide. Look at the side of the microscope when switching to the high-power objective to make sure it clears the slide. Using the fine-adjustment knob only, bring the specimen into focus.

16. In Observations, draw a picture of the letter “d” as seen with the high-power objective lens. Record the magnification you are using.
HOW TO USE A MICROSCOPE (continued)

Observations

1. What is the magnification of each objective of your microscope? What is the magnification of your eyepiece?
   Answers will vary with the type of microscope used. Usually, low power = 10X, high power = 40X, and eyepiece = 10X.

2. What is the total magnification power using the low-power objective?
   Answers will vary with the type of microscope used but should equal eyepiece objective magnification × low-power objective magnification. Usually, 10X × 10X = 100X

3. What is the highest magnification of your microscope?
   Answers will vary with the type of microscope used but should equal eyepiece objective magnification × high-power objective magnification. Usually, 10X × 40X = 400X

Letter “d” Without Microscope

Low-Power Objective

The letter is upside down and backward.

High-Power Objective

Magnification: ________

Magnification: ________

Analyse and Conclude

1. How does the letter “d” as seen through the microscope differ from the way a “d” normally appears?
   The letter “d” is upside down and backward. It is also, of course, larger.

2. When you move the slide to the left, in what direction does the letter “d” appear to move?
   The letter “d” appears to move to the right.
3. When you move the slide to the right, in what direction does the letter “d” appear to move?
   The letter “d” appears to move to the left.

4. How does the ink that was used to print the letter differ in appearance when you see it with the unaided eye compared with the way it appears under the microscope?
   The ink appears solid when you see it with the unaided eye and speckled under the microscope.

5. Briefly explain how to make a wet-mount slide.
   Place the object to be viewed in the center of a clean microscope slide. Using the dropper, place a small drop of water on the object. Hold a coverslip at a 45° angle at the edge of the drop of water and, using forceps, slowly lower the coverslip over the specimen and the drop of water. Soak up any excess water.

◆ Critical Thinking and Applications

1. Why should you always use the low-power objective lens to locate objects mounted on the slide first, even if you want to observe them with the high-power objective lens?
   The lower magnification of the low-power objective lens allows you to see a larger area under the microscope, enabling you to get the object in view under the microscope.

2. Suppose you were observing an organism through the microscope and noticed that it moved toward the top of the slide and then it moved right. In what directions did the organism actually move?
   Specimens viewed through the microscope appear to move in a direction exactly opposite to that of their actual movement on the slide. In this case, the organism actually moved toward the bottom of the slide and then to the left.
More to Explore

New Problem What do other objects look like under a microscope?

Possible Materials Small, common objects or thin pieces of material to observe. Consider which materials you should use from the previous part of this lab.

Safety Follow the safety guidelines in the lab.

Procedure Write your procedure on a separate sheet of paper. Have the teacher approve of your procedure and your list of objects to observe.

Observations Draw what you see when using the microscope. Record the magnifications you used.

Analyze and Conclude Evaluate the objects you observed. What objects worked well? What other kinds of objects would you choose?

Objects that are observed easily using a microscope are thin enough for light to pass through. They are also small enough to manipulate under the lenses.

Help students choose appropriate common objects to observe. Materials must be thin enough to allow light to shine through them. Such objects could include a piece of cotton, a piece of nylon, a human hair, a section of Elodea, or a small piece of a color photograph from a magazine. Remind students to view objects under low-power first before using the high-power objective.
Cell Membranes and Permeability

Pre-Lab Discussion

Can all substances move in both directions through a cell membrane? Why do some substances enter the cell through the cell membrane, while others do not? Sometimes you can use a model to answer questions like these. Part of this investigation models a living cell, so that you can observe changes that the cell membrane controls.

The cell membrane determines what diffuses into a cell. This characteristic of a cell membrane is called permeability. Many cells are semipermeable, which means that not all substances can pass through the cell membrane. Also, the amount of a substance that diffuses through a membrane is influenced by concentration and time.

In this investigation, you will model a cell membrane, determine if the membrane is permeable to certain substances, and find out if the concentration of a substance affects its diffusion.

1. Where is the cell membrane of a cell?

   In cells with cell walls, the cell membrane is just inside the cell wall. In other cells, the cell membrane is the boundary that separates the cell from its environment.

2. What types of materials pass through the cell membrane?

   Materials the cell needs to survive pass through the cell membrane into the cell, including food and oxygen. Waste products pass out through the cell membrane.

Problem

How does a cell membrane work?

Advance Preparation: Make the following starch and iodine solutions (enough for one class).

Starch solution: Mix 20 g starch with 50 mL cold water to form a paste. Add the paste to 1 L boiling water. Stir for 2 minutes. Cool the solution.

Iodine solution for Part A: Use distilled water to make one liter of iodine solution by diluting stock solution from a biological supplier to 1–2% strength, the concentration typically sold over the counter in pharmacies. Alternate Materials: Dissolve 0.75 g potassium iodine in 1 L of distilled water, then add 0.15 g of crushed iodine. Store in a brown bottle.

Iodine solution for Part B: Use the iodine solution from Part A as the 100% solution. Make the 50% solution by combining equal amounts of distilled water and the iodine solution from Part A. Make the 10% solution by adding 9 parts of distilled water to every 1 part of the solution from Part A.

You may prefer to cut the potatoes into cubes before the lab.
**Materials (per group)**
- plastic lunch bag
- twist tie
- 100-mL graduated cylinder
- starch solution
- 200-mL beaker
- glass-marking pencil
- water
- iodine solution, three strengths
- 3 test tubes
- test-tube rack
- 3 plastic cups
- potato cubes
- clock or watch with second hand
- forceps
- metric ruler

**Safety**
Review the safety guidelines in the front of your lab book.

Alternative Materials: Use resealable bags instead of twist ties and regular plastic lunch bags. Dialysis tubing may be used instead of plastic lunch bags, but it is more expensive.

Teaching Tips: Different brands of plastic bags will have different rates of diffusion. Color changes are more obvious after 24 hours.

The starch at the bottom of the “cell” will change color first.

[Part B, Step 3] Using a single-edged razor blade, cut three potato cubes measuring 1 cm on each side for each group of students.

[Part B, Step 4] Dry the razor blade and use it to slice the potato cubes in half. Always dry the razor blade between cuttings.

Iodine is poisonous. Keep it away from your face, and wash your hands thoroughly after using it. Iodine will stain your hands and clothing, so be careful not to spill it. Handle glass objects carefully. If they break, tell the teacher. Do not pick up broken glass.

**Procedure**

Part A: Model of a Cell Membrane

1. Write your name on a beaker with a glass-marking pencil. Then label three test tubes as follows: (1) “Iodine BEFORE,” (2) “Iodine AFTER,” and (3) “Starch.”
2. Fill the beaker with 40 mL of iodine solution. **CAUTION:** Be careful with the iodine solution. If you spill any on yourself, immediately rinse the area with water and tell your teacher. The iodine solution represents the environment outside the model cell.

3. Fill the test tube labeled “Iodine BEFORE” one-fourth full with iodine solution, and then set it aside in a test tube rack.

4. Fill a plastic lunch bag with 40 mL of starch solution, and seal the bag with a twist tie. Be careful not to spill starch onto the outside of the bag. Record the color of the solution in Data Table 1, and then place the bag into the solution in the beaker. The bag represents a cell.

5. Fill the “Starch” test tube about one-half full with starch solution, record the color of the solution, and then place the test tube in the beaker as shown in Figure 1. Let the beaker and its contents stand overnight.

6. The next day, remove the plastic bag and the test tube from the beaker. Record the colors of the solutions in the plastic bag and the test tube the “Color AFTER” column in Data Table 1.

7. Pour iodine solution from the beaker into the test tube labeled “Iodine AFTER” until the test tube has the same amount of solution as the test tube labeled “Iodine BEFORE.”

8. Hold the two test tubes side by side, and look down through their openings. Record the colors of the solutions in the last line of Data Table 1.

**Part B: Effect of Concentration on Diffusion**

1. Label three plastic cups 100%, 50%, and 10%.

2. Obtain about 30 mL of iodine solution at each strength, and pour that amount into the appropriate cup. Record these concentrations in Data Table 2.

3. Put a potato cube in each beaker. If necessary, add additional solution to cover the cube completely. Record the exact time the cubes were added to the solutions in Data Table 2.

4. After 30 minutes, use forceps to remove each potato cube from its solution. Keep track of which sample was in which beaker. The teacher will cut your potato cubes in half.

5. Use a metric ruler to determine the distance that the solution has diffused into each potato cube. See Figure 2. Read each distance to the closest 0.5 mm. In Data Table 2, record the distance that the solution diffused into each cube. **Tell students that the numbers given for the percents in Part B have been simplified.**
CELL MEMBRANES AND PERMEABILITY (continued)

◆ Observations

Data Table 1

<table>
<thead>
<tr>
<th>Solution</th>
<th>Color Before</th>
<th>Color After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starch in model cell</td>
<td>colorless or white</td>
<td>blue</td>
</tr>
<tr>
<td>Starch in test tube</td>
<td>colorless or white</td>
<td>colorless or white</td>
</tr>
<tr>
<td>Iodine in test tubes</td>
<td>dark rusty orange</td>
<td>light orange</td>
</tr>
</tbody>
</table>

Data Table 2

<table>
<thead>
<tr>
<th>Potato Cube</th>
<th>Concentration of Substance</th>
<th>Time Cube Added to Solution</th>
<th>Distance of Diffusion (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100%</td>
<td></td>
<td>2.0 mm</td>
</tr>
<tr>
<td>2</td>
<td>50%</td>
<td></td>
<td>1.0 mm</td>
</tr>
<tr>
<td>3</td>
<td>10%</td>
<td></td>
<td>less than 0.5 mm</td>
</tr>
</tbody>
</table>

◆ Analyze and Conclude

1. What part of the cell does the plastic bag represent?
   The plastic bag represents the cell membrane.

2. What was the purpose of placing a test tube containing starch solution in the beaker of iodine?
   The starch solution in the test tube was used as a control. It showed that starch left standing by itself for 24 hours did not change color.

3. When starch mixes with iodine, the mixture turns blue. What can you infer about the contents of the plastic bag?
   The color change of the starch showed that iodine had mixed with the starch.
4. a. Did starch move out of the bag? Give a reason for your answer.
   No, the starch did not move out of the bag. The liquid outside the bag did not turn blue.

   b. Did iodine move into the bag? Give a reason for your answer.
   Yes, the iodine did move into the bag. When it mixed with the starch, it turned blue. Also, the iodine outside the bag was lighter after the experiment.

5. Based on your results, was the model cell membrane permeable or impermeable to iodine? To starch?
   The model cell membrane is permeable to iodine and impermeable to starch.

6. In Part B, how did the concentration of iodine influence the amount of diffusion that took place?
   Higher concentrations resulted in the iodine diffusing farther into the potato cubes.

**Critical Thinking and Applications**

1. Cell membranes contain small holes, or pores. Pore size may determine why some chemicals can or cannot pass through a cell membrane. In your model, how might the size of the membrane pores compare to the size of the iodine molecules? Explain.
   The membrane pores are larger than the iodine molecules. If they were not, the iodine molecules could not have moved into the model cell.

2. In your model, how might the size of the membrane pores compare to the size of the starch molecules? Explain.
   The membrane pores are smaller than the starch molecules. If they were not, starch molecules would have moved into the iodine solution, and the mixture would have turned blue.

3. Based on what you learned from studying the diffusion of different concentrations, what might be one reason that sick or injured people wear oxygen masks? Explain.
   Oxygen is needed for respiration. The oxygen from an oxygen mask is at a higher concentration than the concentration in air, so that oxygen will diffuse more rapidly into the blood cells that need it.
CELL MEMBRANES AND PERMEABILITY (continued)

More to Explore

New Problem  How does time affect the diffusion of substances across a cell membrane?

Possible Materials  Consider which materials you can use from the previous part of the lab.

Safety  Handle glass objects carefully. Ask your teacher to cut the potato cubes.

Procedure  Develop a procedure to solve the problem. Predict what the results will show. Write your procedure on a separate sheet of paper. Have the teacher approve your procedure before you carry out the investigation.

Observations  On a separate sheet of paper, make a data table like Data Table 2 in which to record your data and observations.

Analyze and Conclude  Did your results support your prediction? Explain your reasoning.

Most students will correctly predict that, the longer the time, the farther the solution will diffuse into the potato cube.

One possible procedure for this investigation would be to cut four 1-cm potato cubes. Keeping one as a control, put the remaining cubes in a beaker half-filled with iodine solution. Using forceps, remove one cube from the solution in the beaker every 10 minutes. Have the teacher slice open each cube. Measure the distance that the solution has diffused into each potato cube.
Comparing Protists

Pre-Lab Discussion

Protists are organisms that have nuclei and live in wet environments, such as ponds, oceans, and the bodies of larger organisms. Other than that, protists don’t have much in common. For example, some live independently as separate cells; others form colonies of many unattached cells. Plantlike protists are autotrophs—organisms that can make their own food. Animal-like protists and fungus-like protists are heterotrophs—organisms that cannot make their own food.

In this investigation, you will observe and compare three common protists: amebas, euglenas, and paramecia.

1. Protists are eukaryotes. What does that mean?
   
   It means that protists all have cells with nuclei.

2. Name three different protist structures that aid in movement.

   The three structures that protists use in moving are pseudopods, cilia, and flagella.

Problem

How are protists similar? How are they different?

Materials (per group)

- 3 plastic droppers
- ameba culture
- microscope slide
- 3 coverslips
- paper towel
- microscope
- piece of cotton
- euglena culture
- paramecium culture

Safety

Review the safety guidelines in the front of your lab book.

Procedure

1. With a plastic dropper, place a drop of the ameba culture on the slide.
2. Make a wet-mount slide by gently laying the coverslip over the drop of ameba culture.
3. Touch a piece of paper towel to the edge of the coverslip to blot up any excess liquid. See Figure 1.

4. Place the slide on the stage of the microscope. Use the low-power objective to bring an ameba into focus. Have the teacher check to see that you have an ameba in focus.

5. Switch to the high-power objective. CAUTION: When turning to the high-power objective, always look at the objective from the side of your microscope. Don’t let the objective hit the slide.

6. Use the fine-adjustment knob to bring the organism into sharper focus. CAUTION: Never focus the high-power objective with the coarse-adjustment knob. The objective could break the slide.

7. Observe an ameba and draw what you see in Plate 1 in Observations. Label the nucleus, cell membrane, cytoplasm, food vacuole, and pseudopods. Record the microscope magnification that you used below your sketch.

8. Carefully clean and dry the slide with a paper towel.

9. Separate a few strands of cotton and place them on the slide. The cotton strands will help slow down the euglena. Using a clean dropper, add a drop of the euglena culture to the strands of cotton.

10. Repeat steps 2–6 with the drop of euglena culture.

11. Observe a euglena and draw what you see in Plate 2 in Observations. Label the nucleus, cell membrane, cytoplasm, eyespot, flagellum, and chloroplasts. Record the microscope magnification you used below your sketch.

12. Carefully clean and dry the slide.

13. Separate a few strands of cotton and place them on the slide. Using a clean dropper, add a drop of the paramecium culture to the strands of cotton.

14. Repeat steps 2–6 with the drop of paramecium culture.

15. Observe a paramecium and draw what you see in Plate 3 in Observations. Label the cytoplasm, cell membrane, cilia, nucleus, contractile vacuole, food vacuoles, oral groove, and gullet. Record the microscope magnification you used below your sketch.

16. Clean and dry the slide once again. Return all the materials to the teacher. Wash your hands when you’re finished with the lab.

◆ Observations

1. Describe the shape of the ameba.
   no definite shape

2. Describe the shape of the euglena.
   oval, with one pointed end and one round end
3. Describe the shape of the paramecium.
   Slipper shape

4. Describe how an ameba moves.
   Streaming of the cytoplasm forms pseudopods.

5. Describe how a euglena moves.
   Whiplike motion of flagellum

6. Describe how a paramecium moves.
   Beating of cilia

7. What structures does the euglena have that the ameba and paramecium do not have?
   Eyespot, flagellum, and chloroplasts

◆ Analyze and Conclude

1. What structures do all protists have?
   Nucleus, cytoplasm, cell membrane, vacuoles

2. Which protist has structures that are characteristic of both autotrophs and heterotrophs?
   Euglena

3. Classify the three protists that you observed as animal-like, fungus-like, or plantlike protists. Give a reason for your answers.
   The ameba and paramecium are animal-like protists. Animal-like protists are heterotrophs and move using pseudopods, cilia, or flagella. The euglena is a plantlike protist. Plantlike protists are autotrophs.
4. Which is the slowest moving of the three protists?

ameba

5. Why are some protists able to move faster than others?

The ameba moves by extending its pseudopods, or parts of its cell. The euglena and paramecium have specialized structures for movement that allow them to move faster.

**Critical Thinking and Applications**

1. Why is the eyespot an important structure in the euglena?

Autotrophs need light to make their own food. The eyespot of the euglena helps it find areas that are light.

2. The paramecium has two types of cilia. One type covers its entire surface. The other is at the entrance to the gullet. How does the paramecium use each type?

The paramecium uses the cilia covering its body to move and sense its environment. It uses the other cilia to sweep food into the gullet.

3. Certain cells in your body, such as white blood cells, move by ameboid motion. What does this mean?

These cells can also move slowly and surround smaller objects as amebas do.

**More to Explore**

A paramecium has thousands of cilia that project through the pellicle—the covering that gives the paramecium its shape. These cilia beat with a wavelike pattern that keeps a paramecium moving smoothly in one direction. Write a hypothesis for how a paramecium will respond when it runs into objects that are in its path. Write a procedure you would follow to test your hypothesis. Have the teacher approve your procedure before you carry out the investigation. Describe how the paramecium responds. Did your results support your hypothesis?

Objects such as cotton strands or toothbrush bristles could be added as obstacles to the paramecia. Alternatively, add boiled, crushed wheat seeds to a culture of paramecia and let the culture sit for several days. The seeds serve as obstacles. Students could then make a wet mount with a drop of the culture. They could search for a paramecium near a seed particle under low power. The paramecium will back up when it encounters an object, and then move forward in a new direction. To do this, the cilia briefly reverse the direction of their beating. The body of the paramecium may turn on its long axis, or it may bend.
Characteristics of Sea Stars

Pre-Lab Discussion

The sea star, or starfish, is a spiny-skinned sea invertebrate in the echinoderm phylum. Echinoderms are animals whose bodies are usually covered with hundreds of small spines. Brittle stars, basket stars, sand dollars, sea cucumbers, and sea urchins are also echinoderms.

Sea stars live in coastal waters and on rocky seashores. They are predators that eat oysters, clams, snails, barnacles, and worms. Sea stars usually have 5 arms branching out from a central disk. Sun stars have 8 to 14 arms, however, and some sea stars have 15 to 24 arms. If an arm breaks off, the sea star can regenerate a new one.

In this investigation, you will examine the external structures of a sea star.

1. What does echinoderm mean, and why is it a good name for this phylum?
   *Echinoderm* means “spiny skinned.” The skin of most of these animals is supported by a spiny endoskeleton.

2. What characteristics are typical of echinoderms?
   *Echinoderms typically have spiny skin, radial symmetry, and a water vascular system.*

Problem

How is the anatomy of a sea star adapted to sea life?

Materials (per group)

- wet paper towels
- preserved sea star
- dissecting tray
- 2 hand lenses

Safety

Review the safety guidelines in the front of your lab book.

To prevent skin irritation, wear aprons and goggles during this investigation.
CHARACTERISTICS OF SEA STARS (continued)

Procedure

1. Put on safety goggles and a lab apron. **CAUTION:** The preservative used on the sea star can irritate your skin. Don't touch your eyes or mouth while working with the preserved sea star. Keep a piece of wet paper towel handy to wipe your fingers after touching the star. Rinse the sea star thoroughly with water to remove any extra preservative. Put the sea star, top surface up, in the dissecting tray. Notice that the sea star’s body has 5 arms radiating from a central disk.

2. Using a hand lens, examine the skin on the top surface. Notice the many coarse spines that cover the entire top surface. The skin is spiny and irregular because parts of the endoskeleton protrude through the skin. Around the base of the spines are jawlike structures. They capture small animals and keep the skin free of foreign objects.

3. Use a hand lens to locate a spine and the jawlike structures around it. See Figure 1. Answer Observations question 1.

4. Study the top surface of the central disk. Answer Observations question 2.

5. Locate a small red or yellow buttonlike structure on the top side of the central disk. This structure contains many tiny pores through which water enters the water vascular system. The water vascular system has water-filled canals that function primarily in movement and feeding.

6. Try to find the anus on the top surface of the central disk. The anus, which opens out from the intestine, lets solid wastes escape from the body.

7. In Observations, label the following structures on the top side of the sea star: central disk, arms, spines, and anus.

8. Turn the sea star over so that its bottom surface is visible. With the hand lens, examine the mouth, an opening in the middle of the central disk. Notice the small spines that surround the mouth. Many types of sea stars feed by pushing part of the stomach through the mouth. The stomach secretes enzymes that digest prey.

9. Find the groove that begins at the mouth and extends down the center of each arm. Find the small tube feet that line the groove. The tube feet are part of the water vascular system. A tube foot is a hollow, thin-walled cylinder with a bulb-like structure at one end and a sucker at the tip. Answer Observations question 3.
10. In Observations, label the following structures on the bottom side of the sea star: groove, mouth, and tube feet.

11. When you have finished examining the specimen, follow the teacher’s instructions for storing the sea star for further use. CAUTION: Wash your hands thoroughly at the end of the lab.

◆ Observations

**Top Side of Sea Star**

**Bottom Side of Sea Star**
1. Describe the appearance of a sea star’s spines.
   The spines are rough, bumpy, and hard.

2. How does the number of spines in the central disk compare to the number of spines in the arm?
   Answers will depend on the specimens used. Many species of sea stars have fewer spines in the central disk than in the rays.

3. How many rows of tube feet does your sea star have?
   Answers will vary. Sea stars generally have 2 or 4 rows per arm.

◆ Analyze and Conclude

1. What do you think the function of a sea star’s spines might be?
   The sea star’s spines support the body and protect it from predators.

2. What kind of symmetry does a sea star have?
   A sea star has five-part radial symmetry.

3. What do you think the tube feet might be used for?
   The tube feet are used as suction cups to grip the surface below the sea star. They are also used for movement and feeding.

4. How do you think a sea star might eat?
   Most of a sea star’s prey have shells. The sea star grasps the prey with all five arms and pulls on the closed shell with its tube feet. When the shell opens, the sea star forces its stomach out through its mouth and into the opening. Digestive chemicals break down the prey’s tissue, and the sea star sucks in the partially digested body.

5. What internal structures enable the sea star to capture food and to move? Explain how the structures do this.
   The water vascular system enables the sea star to capture food and to move. Fluid-filled tubes contract, squeezing fluid into tube feet, which then act like suction cups to grip prey and move the star along surfaces.
Critical Thinking and Applications

1. Sea stars produce large numbers of eggs and sperm. Why is this production an adaptive advantage?
Large numbers of sperm and eggs increase a sea star’s chances of producing young in a marine environment.

2. When a sea star pries open the shell of a clam or an oyster, the mollusk resists. Even if the shell opens only slightly, the sea star will get its meal. How does this happen?
The sea star pushes its thin, membranous stomach out through its mouth and into the slightly opened shell of the mollusk. Digestive enzymes in the sea star’s stomach turn the mollusk into a soupy mixture that the sea star can easily take in.

3. Because sea stars eat many clams and oysters, divers were hired to catch sea stars and chop them into pieces. After this, fishers found even more empty clam and oyster shells than before. Why did their plan backfire?
A sea star can regenerate an entire body from a small part of the central disk and a single arm. Each sea-star piece regenerated a new body, resulting in an increase of the population.

4. Can a sea star move equally well in any direction? Why or why not?
Its five radial arms allow the sea star to move in any direction. The sea star does not have an anterior or a posterior end.

5. Many echinoderms, which are bottom dwellers as adults, have free-swimming larvae. What advantage do free-swimming larvae give to echinoderms?
Free-living larvae allow the new organisms to move away from the parent organisms. They can find new places to live, which provide new sources of food.
CHARACTERISTICS OF SEA STARS (continued)

♦ More to Explore

New Problem Why do sand dollars, sea urchins, sea lilies, sea cucumbers, and brittle stars belong to the same phylum as sea stars?

Possible Materials List and gather the materials you will need. Decide which materials you could use from the previous lab.

Safety Wear aprons and goggles if working with specimens.

Procedure Write a hypothesis that includes those features that you think each of these organisms share. Write a procedure you would follow to test your hypothesis. Have the teacher approve your procedure before you carry out the investigation.

Observations Make drawings and record other observations on a separate sheet of paper.

Analyze and Conclude What characteristics do your observed animals share that place them in the same phylum as sea stars?

Without dissecting the animals, students can observe that all echinoderms share some characteristics: a spiny endoskeleton, radial symmetry, and an internal water-vascular system.

Students could gather specimens of other echinoderms to observe. If live or preserved specimens are not available, make this a research project using printed and electronic information.
Weather and Whooping Cranes

♦ Pre-Lab Discussion

The whooping crane is a tall white bird with red markings on its forehead and face. It is native to certain North American wetlands. In the twentieth century, the population of this magnificent bird has decreased almost to the point of disappearing. In 1941, only 14 cranes were living. Although more than ten times as many cranes are now living, they are still at risk. About half of the cranes live in the wild. They breed in Wood Buffalo National Park in Canada and winter in Aransas National Wildlife Refuge in Texas.

Scientists, working to save the whooping cranes, investigated what abiotic factors affect the birds. In this investigation, you will analyze the data from one such study.

1. What do whooping cranes need to obtain from their habitat?
   The habitat must provide food, water, shelter, and other things the whooping crane needs to live, grow, and reproduce.

2. What abiotic factors might limit the population of whooping cranes?
   Answers may include destruction of habitat, pollution, and bad weather.

♦ Problem

How does precipitation affect the population of whooping cranes?

♦ Materials (per group)
   metric ruler
   calculator
   pencil

♦ Procedure

1. Using Figure 1 and the data in Data Table 1, plot a graph showing how the crane population changed from year 1 to year 16 of the study. The crane population in any given year is the total number of migrating adults and hatched eggs. Answer questions 1–3 in Observations.

2. Study the data in Data Table 1. Answer questions 4–6 in Observations.
WEATHER AND WHOOPING CRANES (continued)

3. Using a calculator, determine the hatching success rate for each year.

\[
\text{Hatching success rate} = \frac{\text{Number of eggs hatched}}{\text{Number of eggs laid}} \times 100\%
\]

Write these values in the corresponding boxes in Data Table 2. Answer Question 7 in Observations.

Data Table 1

<table>
<thead>
<tr>
<th>Year</th>
<th>Migrating Adults</th>
<th>Number of Nests</th>
<th>Eggs Laid</th>
<th>Hatched Eggs</th>
<th>Rainfall (cm)</th>
<th>Snowfall (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>8.9</td>
<td>3.6</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>15.0</td>
<td>0.5</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>11.7</td>
<td>2.0</td>
</tr>
<tr>
<td>4</td>
<td>22</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>6.1</td>
<td>2.8</td>
</tr>
<tr>
<td>5</td>
<td>23</td>
<td>4</td>
<td>6</td>
<td>2</td>
<td>6.4</td>
<td>14.2</td>
</tr>
<tr>
<td>6</td>
<td>23</td>
<td>8</td>
<td>8</td>
<td>4</td>
<td>8.1</td>
<td>4.6</td>
</tr>
<tr>
<td>7</td>
<td>30</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>7.4</td>
<td>0.0</td>
</tr>
<tr>
<td>8</td>
<td>32</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>19.3</td>
<td>7.6</td>
</tr>
<tr>
<td>9</td>
<td>28</td>
<td>4</td>
<td>6</td>
<td>2</td>
<td>15.0</td>
<td>1.3</td>
</tr>
<tr>
<td>10</td>
<td>26</td>
<td>10</td>
<td>10</td>
<td>7</td>
<td>8.1</td>
<td>2.0</td>
</tr>
<tr>
<td>11</td>
<td>32</td>
<td>10</td>
<td>10</td>
<td>6</td>
<td>7.4</td>
<td>2.5</td>
</tr>
<tr>
<td>12</td>
<td>36</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>13.7</td>
<td>7.4</td>
</tr>
<tr>
<td>13</td>
<td>30</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>8.9</td>
<td>1.0</td>
</tr>
<tr>
<td>14</td>
<td>32</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>7.1</td>
<td>1.8</td>
</tr>
<tr>
<td>15</td>
<td>33</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>14.7</td>
<td>6.1</td>
</tr>
<tr>
<td>16</td>
<td>32</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>5.3</td>
<td>1.5</td>
</tr>
</tbody>
</table>
1. When was the crane population at its highest level? When was it at its lowest level?
   year 11; year 2

2. During which year did the population increase the most?
   year 7

3. In which year did the most adult cranes die?
   year 13

4. Which four years were the poorest breeding years for the cranes? In which year were the most eggs laid and hatched successfully?
   years 2, 8, 12, and 15; year 10

5. During which five summers was rainfall greatest?
   years 2, 8, 9, 12, and 15

6. Was snowfall ever high the same year that rainfall was high? If so, in which year or years?
   Answers will vary but should include years 5, 8, 12, and 15.

### Data Table 2

<table>
<thead>
<tr>
<th>Year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>67</td>
<td>0</td>
<td>75</td>
<td>80</td>
<td>33</td>
<td>50</td>
<td>83</td>
<td>0</td>
<td>33</td>
<td>70</td>
<td>60</td>
<td>0</td>
<td>75</td>
<td>75</td>
<td>33</td>
<td>80</td>
</tr>
</tbody>
</table>

Hatching success rate (%)
WEATHER AND WHOOPING CRANES (continued)

7. In which year was total precipitation (rainfall plus snowfall) lowest? What was the hatching success rate that year?
   year 16, with a total of 6.8 cm; 80%

◆ Analyze and Conclude

1. Using data from data tables 1 and 2, plot the points that relate hatching success rate to rainfall on Figure 2 below. What is the relationship between rainfall and hatching success rate? Why do you think this relationship exists?
   In general, increased rainfall results in lower hatching success rate. Explanations may include the flooding of nesting areas.

   ![Figure 2]

2. Suppose you want to find out how rainfall affects the whooping-crane population. Why would you use daily or weekly amounts of rainfall rather than seasonal amounts?
   A few large rains would probably be more devastating to nesting areas than would more frequent lighter rains. Whether or not the rain fell during the nesting season would also be a factor. These specific amounts and times of rainfall would not show up in seasonal data.

3. Suppose that years 10 and 11 had high levels of precipitation. How would this have affected the population? Give a reason for your answer.
   Answers might include that fewer eggs would have hatched and the population might have been greatly altered. Although 13 hatched eggs is a small number, they represent an important increase in a small population.
WEATHER AND WHOOPING CRANES (continued)

Critical Thinking and Applications

1. What other factors besides weather might influence the population growth of whooping cranes? What do you think lowered the whooping crane population to the endangered level?

   Answers will vary but might include the number of predators and the effects of humans on the habitat of the whooping crane. Factors lowering the number of whooping cranes might include destruction and pollution of habitat, killing of the birds by predators and humans, and climate change.

2. Once laws protecting the American alligator went into effect, the alligator population recovered quite rapidly. In contrast, the whooping crane population has remained low in spite of protection. What factors might prevent a rapid increase in the number of cranes?

   Answers might include few young produced per year, small habitat areas, and the fact that the whooping cranes migrate and are thus affected by more environmental factors.

3. Why is international cooperation necessary to protect species that migrate, such as the whooping crane?

   Most migrating species travel across more than one country. Such species need protection in all countries involved.

4. Whooping cranes often lay two eggs. However, a pair can rarely raise two chicks. Therefore, wildlife biologists sometimes “steal” one of the two eggs in the nest and replace it with a fake one of plastic. What do you think the biologists do with the stolen eggs? Why?

   Scientists attempt to increase the hatching success rate by hatching the eggs in captivity. The birds are released when they are old enough, increasing the population.
More to Explore

Find out the difference between an endangered species and a threatened species. Is the whooping crane endangered or threatened? List three species that are endangered and three species that are threatened. What is being done to protect each species?

An endangered species is the most seriously threatened with extinction. The species must be completely protected from human interference or it will die out. A threatened species may be numerous in some areas but its overall numbers are declining and it may become an endangered species.

Encourage students to use a wide variety of resources. The World Almanac provides an up-to-date list of endangered and threatened species. The Internet is another good source. Be sure students understand that they must evaluate information obtained from the Internet. Web sites for the National Wildlife Federation (www.nwf.org), Audubon Society (www.audubon.org), the Sierra Club (www.sierraclub.org), and universities are some reliable sources.
Solar Heating

Pre-Lab Discussion

It has been estimated that 1,000 times more energy reaches Earth's surface from the sun each year than could be produced by burning all the fossil fuels mined and extracted during that year. Imagine if people could use even a small fraction of that solar energy; many of our resource and pollution problems would be solved!

The idea of using the sun's energy is not new. Many ancient peoples used solar energy for heating their homes, including the Egyptians, the Greeks, the Romans, and Native Americans. These peoples built their homes facing the south or southwest, where the sun is located in the sky most often in the Northern Hemisphere. This passive solar-heating system, in which sunlight heats an area, is used today to provide renewable, nonpolluting energy. But the sun is not always shining, so the sun's heat must be collected and stored for later use during the night and on cloudy days. This task is usually part of an active solar-heating system, in which solar energy is collected and distributed throughout a building using fans and pumps.

Solar collectors are used to absorb and collect solar energy. A solar collector is basically a box mounted on a roof. The box is covered with a material that absorbs the sun's energy. This energy transfers to air or water in the box and moves into the building where it can be used. In this investigation, you will discover how the color of an object affects the amount of solar energy it absorbs.

1. What forms of energy are constantly given off from the sun?
   The sun constantly gives off energy in the form of light and heat.

2. What is the difference between a passive solar-heating system and an active solar-heating system?
   A passive solar-heating system converts light from the sun into thermal energy without using mechanical pumps or fans. An active solar-heating system captures the sun's energy, then uses fans and pumps to distribute the heat.

Advance Preparation: Collect metal or plastic containers with fitted plastic lids. The containers should all be about the same size. Tall containers, such as quart-size food containers, will be stable enough to support lab thermometers without tipping over. Each lab group will need two containers that are identical in size and are made of the same materials.

Problem

How does the color of an object affect the amount of solar energy it absorbs?

This lab must be performed on a day when there is adequate sunshine.
SOLAR HEATING (continued)

◆ Materials (per group)
  black and white construction paper
tape
scissors
2 metal or plastic containers with plastic lids
2 thermometers
tongs or gloves
clock or watch
colored pens or pencils

◆ Safety 🕵️‍♂️ ⚠️ Review the safety guidelines in the front of your lab book.

Be careful when using scissors.

◆ Procedure

1. Tape two layers of black paper completely around one container. Also tape two layers of black paper over one of the lids. Keep the edge of the lid paper-free so that it will fit on the can. Tape two layers of white paper completely around the other container. Cover its lid with two layers of white paper.

2. Using scissors, carefully punch a small hole through the center of each lid. Each hole should be just large enough to hold a thermometer.

3. Cover each container with its plastic lid of the same color. Place the containers on a sunny windowsill.

4. Carefully insert a thermometer through the hole in each lid as shown in Figure 1. Make sure the bulb of the thermometer is near but not touching the bottom of the container.

5. Record the temperature of the air in each container every 3 minutes for 30 minutes. Record your data in the Data Table. Then answer the questions in Observations.

6. Use the graph paper on page 47 to make a graph of your data. Plot temperature on the vertical axis and time on the horizontal axis.
## Solar Heating (continued)

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

名叫：__________________________  日期：________  班级：__________________________
**Observations**

**Data Table**

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Temperature in Black Container (°C)</th>
<th>Temperature in White Container (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>19</td>
</tr>
<tr>
<td>6</td>
<td>21</td>
<td>19</td>
</tr>
<tr>
<td>9</td>
<td>22</td>
<td>20</td>
</tr>
<tr>
<td>12</td>
<td>23</td>
<td>20</td>
</tr>
<tr>
<td>15</td>
<td>24</td>
<td>20</td>
</tr>
<tr>
<td>18</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>21</td>
<td>26</td>
<td>20</td>
</tr>
<tr>
<td>24</td>
<td>26</td>
<td>21</td>
</tr>
<tr>
<td>27</td>
<td>26</td>
<td>21</td>
</tr>
<tr>
<td>30</td>
<td>26</td>
<td>21</td>
</tr>
</tbody>
</table>

Temperature in black container will rise faster than that in white container.

1. During which time interval did the temperature in the black container begin to rise? During which time interval did the temperature in the white container begin to rise?

   *Time intervals will vary, depending on the specific conditions of the experiment, but the temperature should begin to rise in the black container first.*

2. What was the final temperature of the air in the black container? In the white container?

   *Final temperatures will vary, depending on the specific conditions of the experiment, but the final temperature should be higher in the black container than in the white container.*

**Analyze and Conclude**

1. Did the color of the containers affect the amount of solar energy they absorbed? Explain your answer.

   *Yes. The container covered with black paper absorbed more energy and heated at a faster rate than did the container covered with white paper.*
2. Did your experiment represent a passive or an active solar-heating system? Explain.

It represented a passive solar-heating system because the container was heated directly by the energy of the sun, and pumps or fans were not used to distribute the heat.

3. What additional variables might have affected your results?

Variables might include the thickness or the composition of the containers, any cold drafts of wind near the windows, shadows cast on either container over the course of the experiment, and proximity to a heat source such as a radiator.

◆ Critical Thinking and Applications

1. Why was it important that both containers be the same size?

If both containers were not the same size, the difference in the amounts of air in each container would be an uncontrolled variable that could affect the results.

2. How would this system need to be modified if it were to be used to heat a home?

Answers will vary, but responses should include some method of transferring the heat to different areas of the home.

3. Based on the results of this experiment, what color clothing would best help you stay warm in the winter? Cool in the summer? Explain.

Wearing dark-colored clothing can help a person absorb more solar energy and so stay warmer in the winter; wearing light-colored clothing can help a person reflect solar energy and so stay cooler in the summer.

4. In what other situations would you be able to apply the knowledge you gained in this investigation? Consider surfaces used both indoors and outdoors, in which heat absorption or reflection is important.

Answers will vary. Some possible situations include choosing a color for an automobile, for the surface of a patio, deck, driveway, or paving stones, for a house or roof, for awnings, shades, or curtains, for a camping tent, or for cooking equipment that makes use of solar energy.

5. What are some advantages of solar energy compared with fossil fuels?

Answers will vary. Most students will conclude that solar energy is a cleaner energy source than fossil fuels are and that its renewability is also a strong advantage.
More to Explore

New Problem  What effect do different colors (other than black and white) have on the absorption of solar energy?

Possible Materials  Consider which materials you can use from the lab. What other materials might you need?

Safety  Be careful when using sharp scissors.

Procedure  Make a hypothesis based on the question you want to investigate. Upon what do you base your hypothesis? Make sure to include a control for analyzing and comparing results. Write your procedure on a separate sheet of paper. Have the teacher approve your procedure before you carry out your investigation.

Observations  Keep records of your observations on a separate sheet of paper.

Analyze and Conclude  How effective are the different colors at absorbing heat from the sun?

In general, the darker the color, the better is the energy-absorbing ability of the material.

Experiments will vary but should be designed to test the energy-absorbing abilities of different colors. Students may use the same setup of the laboratory but tape a different color of construction paper around each of the containers.
Making Models of Sedimentary Rocks

Pre-Lab Discussion

Layers of rock that formed at the bottom of ancient seas in some cases now lie exposed, thousands of meters above sea level. The processes that formed this rock lasted millions of years. So did the Earth movements that exposed the rock, pushing and tilting it into high mountains. To study such slow natural processes, scientists and engineers use models in their laboratories to imitate, or simulate, the real thing. They try to give their models the look and feel of actual rock.

The three types of rocks—igneous, metamorphic, and sedimentary—are all formed in different ways. In this investigation, you will create models of sedimentary rocks and explore their properties.

1. How do sedimentary rocks differ from other rocks?

   Sedimentary rocks are formed from particles deposited by wind or water.

2. What four steps occur during the formation of a clastic sedimentary rock?

   Erosion, deposition, compaction, and cementation

Problem

How is sedimentary rock formed, and what are its properties?

Possible Materials (per group)

- sand
- soil
- gravel
- fossils
- plaster of Paris
- powdered chalk
- salt
- pans
- spoons
- water
- paper towels
- streak plate
- materials of known hardness
- newspapers

Teaching Tips:

To speed drying, have students use paper towels to blot excess water out of newly made rocks. Review physical weathering and how it differs from chemical weathering. Students can explore chemical weathering in More to Explore.
MAKING MODELS OF SEDIMENTARY ROCKS (continued)

◆ Safety 🧿 🧼 🧴 Review the safety guidelines in the front of your lab book.
Wear safety goggles and lab aprons. Wash hands frequently during this activity.

◆ Procedure

1. Starting with the list of materials, brainstorm with other students how to create models of sedimentary rocks. You may also be able to collect natural materials outside of your school or near your home. You do not have to use all of the listed materials. You may want to use other materials as well.

2. CAUTION: Put on your safety goggles and lab apron. Start to experiment with materials to create your model rocks. How will you form layers? How could your model imitate the pressures that cement particles and fragments into rock? Will the rock layers have fossils?

3. Start to record your rock-making procedures on a separate sheet of paper. Your plans should include all classes of sedimentary rock: clastic, organic, and chemical. What materials can you use to model clastic rock? How will you model layered formations? How can you simulate different-size particles for a conglomerate? How might you model an organic rock? A chemical rock?

4. After the teacher approves your procedure, create your rock models. If your models are not coming out the way you want, modify your procedures. Sketch your rock models in Observations. Set the models aside to dry. Wash your hands when you’re finished.

5. When your model rocks are completely dry, explore their properties. Observe and record in the Data Table color, texture, overall hardness, pattern, and resistance to weathering. Resistance to weathering is determined by whether the rock remains intact or crumbles when tested. What type of test could show whether your rock is weak or strong? What other properties should you evaluate? Have the teacher approve any test before you conduct it.

6. Compare models with several classmates. For each model rock, state what type of sedimentary rock it represents, how it was made, and its properties.

◆ Observations

<table>
<thead>
<tr>
<th>Sketches of Sedimentary Rock Models</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clastic</strong></td>
</tr>
<tr>
<td>Sketches of clastic rocks should show the individual ingredients, such as gravel and sand.</td>
</tr>
</tbody>
</table>
**Analyze and Conclude**

1. What determines the properties of your model rocks?
   
   The properties are determined by the composition of the rocks.
   
2. Why might you choose to have fossils in your rock models?
   
   Organic rocks are made from previously living organisms. Fossils could be found in this type of rock.
   
3. How does compaction during the model-making process change the strength of the model rock?
   
   Compaction increases strength.
1. Compare and contrast the different types of sedimentary rocks.

All types are formed from particles by erosion, deposition, compaction, and cementation. They differ in composition. Clastic rocks are made of broken pieces of other rocks. Organic rocks are formed from previously living materials. Chemical rocks are formed from mineral solutions.

2. Would the actual rocks that your models represent be a good material to use to build bridges or buildings? Why or why not?

Many sedimentary rocks are useful building materials. They are soft enough to be easily cut and hard enough to be relatively weather resistant as building materials.

3. What properties of your rocks make them useful or limit their usefulness?

Answers may include that soft rocks have limited uses because they weather easily.

More to Explore

You have seen how sedimentary rocks differ in their resistance to physical weathering. How resistant are they to chemical weathering? Write a procedure you would follow to answer this question. Use actual sedimentary rocks and vinegar. Have the teacher approve your procedure before you carry out the investigation. Wear safety goggles and laboratory aprons while carrying out your procedure.

Most clastic or organic sedimentary rocks will react with the vinegar, indicating that they would be attacked by chemical weathering. Many chemical sedimentary rocks, such as rock salt, will not react with the acid. Encourage students to notice local buildings, tombstones, or statues that are made of sedimentary rock and have been affected by chemical weathering.
**Predicting Lava Flows**

**Pre-Lab Discussion**

You know that a liquid becomes a solid if its temperature is lowered enough that the substance freezes. If you freeze a mixture of cream, eggs, and flavoring in an ice-cream maker, the result is ice cream. When the molten wax on a candle cools, it turns into a solid. The type of material that results depends on the liquid you started out with.

Volcanic rocks form on Earth’s surface when lava cools and hardens. But are all rocks formed from lava the same?

Because different types of lava are made from different materials, they also behave differently when they flow on Earth’s surface and harden into rock. Two main types of lava differ in how easily they flow because of their silica content. In this investigation, you will relate the ease of flow of different types of lava to the shapes of the volcanoes they form.

1. In addition to silica content, what are two other differences between different types of lava?
   - temperature and gas content

2. If you are comparing how easily different types of lava flow, why do you have to make sure that the temperature of each is the same?
   - Ease of flow also depends on temperature. Cooler lava is thicker than hotter lava. To make an appropriate comparison, only one factor can be varied at a time.

**Problem**

How do the temperature and composition of lava affect the way it flows?

**Possible Materials (per group)**

- molasses, about 20 mL
- cornstarch, about 25 mL
- spoon
- watch or clock with second hand
- cookie sheet or food tray
- graduated cylinder, 100 mL
- water
- paper towels
- newspaper
- 3 paper cups or beakers, at least 100 mL each
Sustainability
Review the safety guidelines in the front of your lab book.
Wear a lab apron and safety goggles while doing this activity.

Procedure
Part A: Modeling Types of Lava

1. Add about 25 g of cornstarch to a cup or beaker. Add about 25 mL of water, a small amount at a time, to the cornstarch while mixing. A runny mixture, about the thickness of milk, should result. This mixture is a model of low-silica lava.

2. To model high-silica lava, use a spoon to place about 5 mL of molasses into a different cup or beaker.

3. Compare and contrast the thickness of the two types of “lava.” Predict which type will move faster down a slope. Explain your reasoning.
   
   Students may predict that the “low-silica lava” will flow faster because it is thinner.

4. Decide what types of data you will need to collect. Add columns, rows, and headings to the Data Table in Observations as appropriate.

5. After the teacher has approved your procedure and Data Table, conduct your investigation.

Part B: Modeling Lava at Different Temperatures

1. Use molasses to investigate the effect of temperature on lava flow.

2. Predict whether a hot sample or a room-temperature sample of molasses will move faster down a slope. Explain your reasoning.

   Answers may vary. Sample: The hot molasses will flow faster because it will be thinner than the cool molasses.

3. Design an experiment to test your prediction. Write down your procedure on a separate sheet of paper. Repeat Steps 4 and 5 from Part A. Obtain a hot sample of molasses from your teacher.

4. Follow any special instructions the teacher gives you about cleaning up your work area. Throw any “lava” materials, paper towels, and newspaper in the trash can. Do not wash any materials down the drain. Wash your hands after everything else is cleaned up.

   The materials used are not caustic but might plug a drain.
**PREDICTING LAVA FLOWS (continued)**

**Observations**

<table>
<thead>
<tr>
<th>Data Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students should observe that “low-silica lava” is thinner and flows faster than does “high-silica lava.” They should also observe that hotter “lava” flows faster than does cooler “lava.”</td>
</tr>
</tbody>
</table>

**Analyze and Conclude**

1. In Part A, which type of “lava” flowed slower, high-silica or low-silica “lava”? In Part B, which type of “lava” flowed slower, hot “lava” or room-temperature “lava”?

   high-silica lava, room-temperature lava

2. Compare two types of lava: pahoehoe and aa. How are they similar? How are they different? How were these two types of lava represented in this experiment?

   They are similar in that they are both low-silica lava. They differ in temperature; pahoehoe is hotter than aa and flows more easily. The hot molasses represented pahoehoe; the room-temperature molasses represented aa.

3. In the space below, sketch and name the type of volcano that would be formed from low-silica lava. Sketch and name the type of volcano that would be formed from high-silica lava next to the other volcano below. Students’ sketches should show a volcano with gentle slopes—a shield volcano—on the left and a volcano with steep slopes—a cinder cone volcano—on the right.

4. Describe the kind of eruptions you would expect as a volcano forms from low-silica lava.

   The eruptions would be relatively quiet, with spurting and flowing lava but no explosions.
5. Describe the kind of eruptions you would expect as a volcano forms from high-silica lava.

The eruptions would be more explosive than with low-silica lava.

◆ Critical Thinking and Applications

1. How does the shape of a volcano help you draw conclusions about the type of magma near the surface beneath the volcano?

The shape of the volcano indicates the amount of silica in the magma that erupted to the surface.

2. What type of magma occurs near the surface beneath a composite volcano? Give a reason for your answer.

Because the magma beneath composite volcanoes is high in silica, these volcanoes alternate between explosive eruptions and eruptions of thick lava.

◆ More to Explore

New Problem  How does the gas content in magma affect the shape of a volcano?

Possible Materials  modeling clay
                          vinegar
                          baking soda
                          paper towels

Procedures may include forming a cone from the modeling clay. Students may place varying amounts of baking soda in the cone and then add a consistent amount of vinegar each time.

Safety  Wear safety goggles and laboratory aprons.

Procedure  Develop a plan to determine how volcano shape depends on the gas content of the magma. Write the steps of your plan on another sheet of paper. Have the teacher approve your plan before you carry out your investigation. (Hint: Vinegar and baking soda will react to form a gas.)

Observations  Record your observations in a data table on a separate sheet of paper.

Analyze and Conclude  Based on your observations, write a statement of how the gas content of magma is related to the shape of the volcano.

Observations should show that the more baking soda used, the more gas formed, and the more explosive the eruption. Observations should indicate that the more explosive the eruption, the steeper the slope that formed.
Field Testing a Body of Fresh Water

Pre-Lab Discussion

Fresh water in streams, ponds, rivers, and lakes is far from pure. Fresh water usually contains dissolved substances and a range of sediments suspended in the water. Some suspended substances can make fresh water look dirty and murky. The amount of acid in a substance is measured by pH values. Dissolved substances can sometimes change the pH of water.

Oxygen dissolved in water is necessary for fish to live. Around 4 to 5 mg/L of dissolved oxygen is the lowest amount that will support fish. The presence of nitrogen in the form of nitrate indicates pollution. Nitrates cause the growth of plankton and water weeds that provide food for fish. However, if algae grow too much, oxygen levels will be reduced and fish will die. Nitrate levels below 90 mg/L have little effect on warm-water fish, but cold-water fish are more sensitive to nitrate levels.

Phosphorus can come from phosphate-containing rocks or from fertilizers, detergents, and pesticides. Too much phosphorus causes overgrowth of algae and reduces dissolved oxygen. The recommended maximum for phosphorus is 0.1 mg/L. Most freshwater organisms can live only in water between 0°C and 35°C.

When determining water quality in a body of fresh water, the factors described above are only some of those that must be considered. In this investigation, you will examine a body of fresh water near your school.

1. How do sediments get into fresh water?

   Moving water causes erosion, so fresh water picks up sediments. Some of these sediments are suspended in fresh water, while others dissolve in the water.

2. How is the amount of oxygen in a body of water affected by a large amount of algae in the water? Explain how this might occur.

   When the algae layer becomes so thick that it begins to block out the sunlight, some plants in the water cannot carry out photosynthesis. They stop producing food and oxygen and die. The amount of oxygen in the water decreases.

Problem

What is the quality of a nearby body of fresh water?
FIELD TESTING A BODY OF FRESH WATER (continued)

◆ Possible Materials

(\textit{per group})

- water samples of a stream, pond, river, or lake
- thermometer
- pH paper
- 100-\text{mL} graduated cylinder
- large test tubes with stoppers
- 250-\text{mL} beaker
- large jars
- hand lens
- petri dishes with agar
- plankton net
- water quality test kits
- waterproof boots

Advance Preparation: Be sure you have signed permission slips from parents or guardians for this field trip. Use a buddy system near the water.

You may want to examine a topographical map of the region that includes the body of water to be studied. Determine the source or sources of the water and discuss how the body of water’s location might affect the water quality.

Alternate Materials: If you do not wish to do this investigation as a field study, you can collect and label water samples from different sources, such as streams, ponds, rivers, and lakes, and have students test the samples in class.

In addition to the materials listed in the student lab, the following materials should be made available: droppers, spoons, funnels, filter paper, balances, microscopes, slides and cover-slips, field guides to plants and animals, heavy twine, hydrometer, tweezers, and sorting trays. Small baby food jars with lids can be substituted for test tubes.

◆ Safety \(\text{Safety}\) Review the safety guidelines in the front of your lab book.

Use caution when near a body of water. Wear waterproof boots. Wash all equipment thoroughly before taking water samples and doing tests. Wash your hands thoroughly after completing this investigation.

◆ Procedure

1. As a class, discuss the bodies of fresh water in your community. Determine which body of water you will examine. The type of water body chosen may influence some of the tests you want to do. For example, if you are investigating a stream or river, you may want to measure water velocity.

2. Some of the tests you may want to perform include the following: temperature, pH, dissolved oxygen, nitrate, phosphorus, suspended solids, dissolved solids, bacteria content, salinity, and types of microorganisms present in the water.

3. With your group, decide what tests you will perform. List the different tests you plan to do in the Planning Table on the next page. Research the methods of doing these tests and read the instructions in the water-testing kits to determine how much water you need to test and what materials you will need.

4. Decide how you are going to gather your water samples. What observations can you make at the water site? You may also want to examine the soil at the water’s edge and complete a plant and animal survey in the immediate area around the water.

You may want each group to do 2 or 3 tests and share results so that a variety of tests can be done more manageably.

Teaching Tips:

You may want to have several parents or other adults accompany the class on the field trip.

Student groups may share water sites and share the test-taking procedures.
5. Predict whether the water site is polluted. What were the reasons behind your prediction?

Students might base their predictions on the clarity of the water, odors from the water, presence or absence of wildlife, or presence of nearby sources of pollution such as factories or farms.

6. On a separate sheet of paper, write a procedure to follow to complete your water quality investigation. After the teacher approves your investigation plan, gather your material for the field study. Be sure all of your water-sampling equipment is clean before you use it. You do not want to contaminate your samples.

7. Complete the tests you have decided to do. Use the Data Table provided on the next page to record your observations and the data you gather. If you are doing a plant and animal survey, record your results on a separate sheet. Compare your data with that of other groups in your class.

---

### Planning Table

<table>
<thead>
<tr>
<th>Water Test</th>
<th>Amount of Water Needed</th>
<th>Materials Needed to Complete Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Data will vary depending on the body of water tested and the tests students choose to perform. Most tests done with test kits, such as pH and nitrates, require 5–10 mL of water sample. Tests for dissolved oxygen require about 60 mL.</td>
</tr>
</tbody>
</table>
Observations

1. What observations can you make at the water site? Is the water clean or dirty? What plants and animals are in the immediate area around the water?

Students should make qualitative observations of the water, including comments about the color and whether the water is clean. Diagrams and notes on the plants and animals in the immediate area can be taken and later classified, using a field guide.

Data Table

<table>
<thead>
<tr>
<th>Water Test</th>
<th>Observations</th>
<th>Test Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissolved oxygen</td>
<td>Numerous fish observed in pond. Therefore, expect D.O. is at least 4 mg/L.</td>
<td>8 mg/L</td>
</tr>
<tr>
<td>pH</td>
<td>Extensive variety and number of plants at water's edge. Numerous fish. Expect pH within range of 6.0 to 8.0.</td>
<td>7.2</td>
</tr>
</tbody>
</table>
FIELD TESTING A BODY OF FRESH WATER (continued)

♦ Analyze and Conclude

1. The pH of most rivers, lakes, and streams in the United States falls within the range of 6.0 to 8.0. Many species of fish can live in water with this pH range. Would the water in your sample support fish life? Explain.

   Answers will vary. If the pH of the water is below 6.0 or above 8.0, the water sample would most likely not support fish life.

2. Which of your tests indicates a problem with the body of water you tested? Which did not?

   Answers will vary. Dissolved oxygen levels below 4 mg/L, nitrate levels above 90 mg/L, and phosphate levels above 0.1 mg/L indicate water problems. Students should determine which tests indicated water pollution and which values fell within normal levels.

3. How did the plants and animals found in and around the body of water give an indication of water quality?

   Answers will vary. The presence of a variety of plants and animals in and around the body of water would indicate that the water pollution level may not be extremely high.

♦ Critical Thinking and Applications

1. How might the amount of suspended solids in a stream or pond differ if you measured them right after a heavy rainstorm?

   After a heavy rainstorm, the water is likely to contain more suspended and dissolved solids because of runoff.
2. Different fish have different temperature requirements. The following list contains the maximum water temperature in which each species of fish can survive.

- brook trout: 25.5°C
- carp: 41.0°C
- bluegill sunfish: 34.3°C
- yellow perch: 30.8°C
- fathead minnow: 33.7°C
- brown bullhead: 34.8°C

Would any of these fish be able to survive in the water you tested? If so, which ones?

Answers will vary. Students should report the water temperature of the body of water they tested. Any species of fish with a maximum water temperature tolerance above the stated water temperature would be able to survive in the water tested assuming that all of its other needs were met.

3. Water in a swampy or boggy area is usually very acidic, or has a low pH. Imagine that water from a swamp flows into a stream at point A. How do you think the pH of water samples taken upstream and downstream from point A would compare?

The pH of the water sample taken downstream from point A would be lower than the pH of the water sample taken upstream.

◆ More to Explore

If the conditions you found in the fresh water you investigated need improvement, write a plan for steps that should be followed to improve the water quality. Share your plan with the class and mail it along with a cover letter to an appropriate local official or environmental agency.

Student plans will vary depending on what problems students found with the body of water tested. Plans should indicate specific directions for raising or lowering unacceptable levels of acidity, minerals, or sediments present. If unacceptable levels are found, students should investigate the source or sources of the pollutants.
Moisture in the air dissolves many pollutants. When the moisture falls as rain or snow, it removes the pollutants from the air. In many cases, this process is beneficial because it cleans the air. When the pollutants in the moisture are nitrogen oxides and sulfur oxides, however, the result is acid rain.

How can you tell whether rain is acidic? The process is simple. You dip specially treated paper in rainwater and compare the color of the paper to a pH color scale. The pH scale ranges from 0 to 14 and is a measure of how acidic or basic a substance is. Pure water is neutral and has a pH of 7. Solutions with a pH greater than 7 are basic, and those with a pH less than 7 are acidic. The lower the number, the more acidic the solution is. Grapefruits, lemons, vinegar, and other sour foods are acidic.

In this investigation, you will use pH indicator paper to determine the pH of some common substances. You will examine how acids affect materials used for buildings, statues, and other structures.

1. What acids are likely to be in acid rain?
   nitric acid and sulfuric acid

2. What is the main source of the pollutants that cause acid rain?
   The main source of nitrogen oxides is the burning of fossil fuels at high temperatures. The main source of sulfur oxides is the burning of high-sulfur coal.

**Problem**

How can acid rain affect building materials?

**Possible Materials (per group)**
- distilled water
- lemon juice
- white vinegar
- carbonated water
- pH color scale
- pH indicator paper
- 8 beakers, 100 mL
- glass marker
- 2 small samples each of limestone, sandstone, marble, and granite

**Safety**

To prevent slips or falls, immediately wipe up any water spilled on the floor. Notify the teacher immediately if any glass breaks.

**Equipment-supply houses or garden centers sell rocks that you can use for samples. You can also have students help you gather rocks from the environment.**

**Alternative Materials:** Substitute large plastic cups for the beakers. You could add other building materials to the samples: concrete chunks, roof tiles, stucco samples, steel, and so on.

**Teaching Tips:** Demonstrate how to test using indicator paper and comparing the color to a scale, usually found on the paper container.
**Procedure**

**Part A: Modeling Acid Rain**

1. Read the entire lab before continuing your investigation.

2. You will design an experiment to test the effects of acid rain on building materials. First, you need to decide what you will use for acid rain. Experiment with different solutions. Use the indicator paper to determine the pH of each solution to find out if it is a good model of acid rain. Record your data in Data Table 1.

3. Decide what you will use as a control. Your control should be a solution that has a pH of typical rainwater (5–5.6). Add this information to Data Table 1.

4. Get the teacher’s approval of your models before going on to Part B.

**Part B: Testing Acid Rain on Materials**

1. Brainstorm some materials that buildings, monuments, and other structures are made of. Then decide what building materials you will test and how you will test them. Write your procedure on a separate sheet of paper.

2. Use Data Table 2 to record your observations and other data. Add headings to the data table. Plan to make observations today and tomorrow. You may need to make another data table on a separate sheet of paper for tomorrow’s observations.

3. Have the teacher approve your procedure before carrying out your experiment.

4. Predict which building material will be the most affected by acid rain. Which material will be least affected? Give reasons for your predictions.

   Students may base their predictions on how strong they think the material is. They may think that a heavyweight material with a smooth texture is stronger than a lightweight material with a grainy texture. The masses of the samples before and after they sit in acid will vary, but all rock samples will be affected. Of the materials listed, limestone will be the most affected, and granite the least.

**Observations**

**Data Table 1**

<table>
<thead>
<tr>
<th>Acid Rain Model (description)</th>
<th>Acid Rain Model (pH)</th>
<th>Control (description)</th>
<th>Control (pH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>lemon juice: 2.0</td>
<td>white vinegar: 2.5</td>
<td>carbonated water: 3.0</td>
<td></td>
</tr>
</tbody>
</table>
Data Table 2

<table>
<thead>
<tr>
<th>Building Material</th>
<th>Limestone</th>
<th>Sandstone</th>
<th>Marble</th>
<th>Granite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day: 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid Rain Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Limestone will immediately effervesce in acid. Limestone and marble will likely lose the most mass. Besides changes in mass, students may observe visible changes in the size and shape of some materials over the two days.

◆ Analyze and Conclude

1. Did any building material have an immediate reaction that you could see? If so, which one(s), and what was the reaction?
   If students test limestone, it will immediately start fizzing.

2. Which building material changed the most in a day? How did you measure the change?
   Limestone in acid will change the most. Students should be able to measure a change in the sample's mass. They should also recognize the change visually.

3. Which building material changed the least? How did you measure the change?
   Granite will change the least. It isn't likely to lose much mass in a day.

4. How can acid rain affect buildings, statues, and other structures made of the materials you tested?
   Answers will vary. Students should recognize that, among the listed materials, limestone will be most affected by acid rain, so buildings made from limestone are most likely to suffer deterioration from acid rain.

◆ Critical Thinking and Applications

1. How would your results have been affected if your acid rain had been more acidic? Less acidic?
   The more acidic the rain, the faster the material would have deteriorated. Rain that was less acidic would not change the material as much in the same amount of time.
2. Cleopatra’s Needles are large obelisks, each weighing about 200 tons. They are made of red granite and carved with hieroglyphics. Figure 1 shows an obelisk. One of the Needles was shipped from Egypt to New York City in 1880. The New York monument’s hieroglyphics have almost disappeared, while a similar monument in the Egyptian desert has changed little over the past 3,000 years. Explain one of the probable reasons this difference exists.

The obelisk in New York City is probably being destroyed, at least in part, by acid rain. Acid rain would affect it more than the Egyptian obelisk, since New York City has more rain and probably more pollutants than the Egyptian desert.

**More to Explore**

**New Problem** How is *Elodea*, a freshwater plant, affected by acid rain falling into a pond where it grows?

**Possible Materials** Consider which materials you can use from this lab. What other materials will you need?

**Safety** To prevent slips or falls, immediately wipe up any liquid spilled on the floor. Handle glass objects carefully. If they break, tell the teacher. Do not pick up broken glass. Be sure to wear safety goggles and an apron and wash up after you’re done.

**Procedure** Write a hypothesis about the effects that acid rain has upon *Elodea* plants. Then write a procedure you could follow to test your hypothesis. Have the teacher approve your procedure before you carry out the investigation.

**Observations** Keep careful records of your observations on a separate sheet of paper.

**Analyze and Conclude**

1. Does acid rain affect *Elodea*? Support your conclusions with data collected during the investigation.

   *Elodea* plants will show signs of distress and may die while growing in acidic conditions. *Elodea* in distilled water should not show any appreciable changes.

2. How might acid rain affect other plants and animals that live in fresh water?

   Other living things in water bodies that collect acid rain may show signs of distress.

*Elodea* plants and aquarium gravel are available in pet stores that sell fish. If *Elodea* is not available, provide *Cabomba* or *Sagittaria* (grassleaf).
Using a Psychrometer to Determine Relative Humidity

Pre-Lab Discussion

Even without rain, the air can be very wet because it contains invisible water vapor. The amount of water vapor in the air is known as humidity. As air gets warmer, it can hold more moisture. Meteorologists usually speak of relative humidity—the amount of water vapor in the air compared to the maximum amount that air can hold at a particular temperature.

You can measure relative humidity with a psychrometer, which consists of two thermometers. One thermometer has a dry bulb, and one has a wet bulb. A piece of wet cloth surrounds the bulb of the wet-bulb thermometer. When the wet bulb is exposed to air, water in the cloth evaporates, just as it does from wet clothing. Water evaporation requires heat energy, so it cools the wet bulb.

In this investigation, you will construct a sling psychrometer and use it to measure the relative humidity of the classroom.

1. What is the difference between humidity and relative humidity?

   Humidity is the amount of water vapor in the air at a given time. Relative humidity is the amount of moisture in the air compared to the maximum possible air moisture at that temperature.

2. Would you expect the temperature of the wet-bulb thermometer to be higher on a humid day or on a dry day? Give a reason for your answer.

   The temperature of the wet-bulb thermometer would be higher on a humid day because not much evaporation will cool the wet-bulb thermometer.

Problem

How can you use a psychrometer to find the relative humidity of the classroom?
Using a Psychrometer to Determine Relative Humidity (continued)

**Materials (per group)**
- 2 identical thermometers
- strip of gauze, 10 cm
- piece of thread, 20 cm
- piece of cardboard, approximately 20 cm \times 30 cm
- water at room temperature
- transparent tape
- bucket
- small plastic cup
- plastic dropper
- large index card

Advance Preparation: Cut a gauze strip and a piece of thread for each group. Collect shirt cardboard or the cardboard backing from notepads, one for each group. Let water sit in a bucket for a few hours prior to the lab so that it is at room temperature.

Alternative Materials: Use cotton cloth instead of gauze.

Teaching Tips: Use only alcohol thermometers if at all possible.

Remind students to tape the thermometers securely to the cardboard before picking it up.

The gauze surrounding the wet-bulb thermometer must be saturated with water before fanning begins.

Use the provided sample data to show students how to use the relative humidity table prior to starting the lab.

**Safety**

Review the safety guidelines in the front of your lab book.

Handle the thermometer carefully. If it breaks, tell your teacher. Do not pick up broken glass.

**Procedure**

1. **CAUTION:** Handle the thermometer carefully; it’s breakable. Wrap the gauze around the bulb of one thermometer and tie it in place with the thread.

2. Tape the thermometers side by side with the two bulbs extending over the edge of the cardboard. See Figure 1.

3. Scoop some water from the bucket into a small plastic cup. Use this water and the plastic dropper to thoroughly wet the gauze.
4. Hold the cardboard up in the air. Carefully fan the thermometer bulbs with the index card until the temperature of the wet-bulb thermometer stops dropping. Predict the difference in temperatures between the two thermometers. Explain your reasoning.

If the relative humidity feels low, students may predict a difference of at least 5 degrees, reflecting the ability of the water on the wet bulb to evaporate quickly.

Read the temperatures on both thermometers. Record these numbers in the data table next to the sample data. Calculate the difference between the two readings.

5. Find the relative humidity in Data Table 1 below, using the temperature difference between the dry bulb and the wet bulb. Express relative humidity as a percentage. For example, suppose the dry-bulb reading is 21°C and the wet-bulb reading is 15°C. The difference is 6°C. The number on the table where the row of the dry-bulb reading (21) and the column of the difference (6) intersect shows the relative humidity (53%). These numbers are included in Data Table 2 as sample data. Record your own data next to them.

<table>
<thead>
<tr>
<th>Dry-Bulb Reading (°C)</th>
<th>Difference Between Dry-Bulb and Wet-Bulb Readings (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td>10</td>
<td>88 76 65 54 43 34 24 15 10</td>
</tr>
<tr>
<td>11</td>
<td>89 78 67 56 46 36 27 18 9</td>
</tr>
<tr>
<td>12</td>
<td>88 78 67 57 48 39 29 21 12</td>
</tr>
<tr>
<td>13</td>
<td>89 79 69 59 50 41 32 23 15 7</td>
</tr>
<tr>
<td>14</td>
<td>89 79 69 60 50 42 34 26 18 10</td>
</tr>
<tr>
<td>15</td>
<td>90 80 71 61 53 44 36 27 20 13</td>
</tr>
<tr>
<td>16</td>
<td>90 80 71 62 54 46 38 30 23 15</td>
</tr>
<tr>
<td>17</td>
<td>90 81 72 64 55 47 40 32 25 18</td>
</tr>
<tr>
<td>18</td>
<td>91 81 72 64 56 49 41 34 27 20</td>
</tr>
<tr>
<td>19</td>
<td>91 82 74 65 58 50 43 36 29 22</td>
</tr>
<tr>
<td>20</td>
<td>91 82 74 66 58 53 46 39 32 26</td>
</tr>
<tr>
<td>21</td>
<td>91 83 75 67 60 53 46 39 32 26</td>
</tr>
<tr>
<td>22</td>
<td>92 83 75 68 60 54 47 40 34 28</td>
</tr>
<tr>
<td>23</td>
<td>92 84 76 69 62 55 48 42 36 30</td>
</tr>
<tr>
<td>24</td>
<td>92 84 76 69 62 56 49 43 37 31</td>
</tr>
<tr>
<td>25</td>
<td>92 84 77 70 63 57 50 44 39 33</td>
</tr>
<tr>
<td>26</td>
<td>92 85 77 70 64</td>
</tr>
</tbody>
</table>
USING A PSYCHROMETER TO DETERMINE RELATIVE HUMIDITY (continued)

**Observations**

Data Table 2

<table>
<thead>
<tr>
<th></th>
<th>Sample Data</th>
<th>Your Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry-bulb reading</td>
<td>21°C</td>
<td></td>
</tr>
<tr>
<td>Wet-bulb reading</td>
<td>15°C</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>6°C</td>
<td></td>
</tr>
<tr>
<td>Relative humidity</td>
<td>53%</td>
<td></td>
</tr>
</tbody>
</table>

1. Which of the two thermometers measures the air temperature?
   - The dry-bulb thermometer measures the air temperature.

2. What is the relative humidity in your classroom?
   - 53% for the sample data; Students’ data will likely be close to the outside relative humidity if the classroom is not air-conditioned. The relative humidity in an air-conditioned room will likely be lower than that outside.

**Analyze and Conclude**

1. What is the relationship between evaporation and the wet-bulb temperature?
   - Evaporation is a cooling process. As water evaporates from the gauze around the thermometer bulb, the temperature drops.

2. Explain your answer to question 1 in terms of energy.
   - Evaporation requires energy. As water evaporates from the gauze, energy is taken from the air surrounding the gauze and then moves away from the thermometer.

3. What is the relationship between evaporation and relative humidity?
   - The relationship is inverse. The lower the relative humidity of the air, the faster evaporation will be.

4. Predict the difference between the dry-bulb and wet-bulb readings when the relative humidity is 100%. Give a reason for your answer.
   - If the relative humidity is 100%, the surrounding air could not hold any more moisture, so evaporation isn’t possible. Therefore, both thermometers would read the same.
5. Predict how the relative humidity inside your classroom compares with the relative humidity outdoors. How could you test your prediction?

Predictions will vary. You could use the same equipment and take outdoor readings. Then use the chart to determine the outdoor relative humidity.

◆ Critical Thinking and Applications

1. Does the air in your classroom tend to be moist, dry, or somewhere in between? Give a reason for your answer.

Answers will vary. Many indoor environments tend to be dry in winter and moist in summer.

2. Would you feel more comfortable in a desert where the temperature is 35°C or in a rain forest where the temperature is 35°C? Give a reason for your answer.

You would likely feel more comfortable in a desert because the air would have a lower relative humidity and would allow sweat to evaporate more quickly. The evaporation would cool your body.

3. How can you tell, without using a psychrometer, whether the air is moist or dry?

Possible answers include dry skin or nose and throat irritations if the air is very dry; “sticky” or damp feeling if the air is very moist.

4. Why does running a dehumidifier in your home during the summer help make you feel more comfortable?

A dehumidifier removes moisture from the air. Less humidity allows faster evaporation of sweat and makes you feel cooler.
5. Antarctica is the coldest place on Earth. Explain why the parts of Antarctica not covered by glaciers are a frigid desert.

_Very cold air can hold very little water vapor, therefore the air is very dry and little precipitation falls._

◆ More to Explore

In Analyze and Conclude question 5, you predicted how the relative humidity in the classroom compares with the relative humidity outdoors. Now test your prediction. Write a procedure you can follow. You may wish to include other areas in your school in your investigation, for example, the cafeteria or gym. Be sure to make predictions for these places before testing them. Have the teacher approve your procedure before you carry out the investigation. Be sure to wear your safety goggles.

_If the classroom is air-conditioned, chances are good that the relative humidity outdoors will be greater than that in the classroom. Students could make their predictions based on how high the humidity feels to them in various places. Suggest students compare their calculated relative humidity with the actual value given in a weather report._
Investigating Weather Maps

◆ Pre-Lab Discussion

Accurate weather forecasting requires analysis of detailed information about atmospheric conditions in many locations. In the United States, weather data from more than 300 local weather stations are used to prepare daily maps of the weather throughout the country. A detailed map may contain more than 10,000 data points. Such detailed maps are useful for making weather predictions.

Every minute of the day, weather stations, weather ships, satellites, balloons, and radar are recording temperature, pressure, wind direction, and other data and feeding them into the Global Telecommunications System (GTS). From this information, powerful supercomputers develop an image of conditions in the entire atmosphere and make forecasts for up to one week.

In this investigation, you will study how weather is presented, then prepare a simplified weather map and analyze it to discover relationships between weather and certain variables such as temperature and pressure.

1. What are three kinds of information that you could get from a newspaper weather map?
   Answers might include the areas getting precipitation, the type of precipitation, temperatures in different cities, the locations of different fronts, and areas of high and low pressure.

2. What kind of weather is associated with a low?
   Clouds and precipitation

3. What kind of weather is associated with a high?
   Dry, clear weather

◆ Problem

How can you make a weather map and use it to understand relationships between weather and certain atmospheric variables?

◆ Materials (per group)

- pencil
- colored pencil

Alternative Materials: A crayon can be substituted for a colored pencil.

Teaching Tips: Review the concepts of high- and low-pressure areas before the lab.

Go over one or two example stations with students before they begin Part B.

Have an overhead of the map on hand in case students have questions.

Remind students to use a light color for the shading in Part B, Step 4.
INVESTIGATING WEATHER MAPS (continued)

♦ Procedure

Part A
Read the following steps and study the diagrams to learn how weather data are presented on station circles.

1. Figure 1 shows the correct notation of some weather data recorded at an observation station. The circle represents the observation station. The data have specific positions inside and outside the station circle.

2. Isobars are lines on a weather map that connect stations that report the same atmospheric pressure. These pressures are measured in millibars (mb), so isobars are labeled in millibars. To record the pressure on the station circle, use only the last three digits of the pressure and omit the decimal point. Look at the atmospheric pressure shown on the station circle in Figure 1. The atmospheric pressure is 1019.6 mb, which is recorded on the station circle as 196.

3. Think of the station circle as the point of an arrow. Attached to the station circle is a line, which is the arrow’s shaft. The wind direction is represented as moving along the arrow’s shaft toward the center of the station circle. Wind directions are given in degrees and represent the direction from which the wind is blowing. Figure 2 will help you determine wind direction. In Figure 1, the wind is blowing from the southwest toward the northeast.

4. Look at Figure 19 on page 523 of your textbook. It shows the data from station circles placed on a map. Compare the symbols discussed above with the symbols in Figure 19. Notice that the temperature is in degrees Fahrenheit.

Part B
1. The Data Table on the next page lists data collected at various weather stations on a particular day. Starting with Seattle, transfer all the data provided on the table to the appropriate observation stations on the map. Use the station circles and weather symbols discussed above. The station circle for San Francisco is done for you.
### Investigating Weather Maps (continued)

#### Data Table: Observation Stations

<table>
<thead>
<tr>
<th>Weather Station</th>
<th>Wind Speed (mph)</th>
<th>Wind Direction</th>
<th>Atmospheric Pressure (mb)</th>
<th>Temperature (°F)</th>
<th>Type of Precipitation</th>
<th>Cloud Cover (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seattle</td>
<td>7</td>
<td>260°</td>
<td>1020.8</td>
<td>42</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Bend</td>
<td>10</td>
<td>200°</td>
<td>1023.5</td>
<td>40</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>San Francisco</td>
<td>8</td>
<td>135°</td>
<td>1020.0</td>
<td>48</td>
<td>fog</td>
<td>25</td>
</tr>
<tr>
<td>Los Angeles</td>
<td>12</td>
<td>150°</td>
<td>1021.0</td>
<td>41</td>
<td>fog</td>
<td>25</td>
</tr>
<tr>
<td>Phoenix</td>
<td>11</td>
<td>50°</td>
<td>1021.1</td>
<td>45</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ely</td>
<td>2</td>
<td>15°</td>
<td>1025.1</td>
<td>37</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dubois</td>
<td>18</td>
<td>225°</td>
<td>1024.0</td>
<td>38</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Helena</td>
<td>15</td>
<td>315°</td>
<td>1020.0</td>
<td>41</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Medicine Hat</td>
<td>20</td>
<td>345°</td>
<td>1020.1</td>
<td>40</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Bismarck</td>
<td>18</td>
<td>0°</td>
<td>1014.3</td>
<td>48</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Casper</td>
<td>12</td>
<td>350°</td>
<td>1016.0</td>
<td>50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pueblo</td>
<td>8</td>
<td>315°</td>
<td>1015.3</td>
<td>50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Roswell</td>
<td>22</td>
<td>350°</td>
<td>1016.0</td>
<td>48</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Del Rio</td>
<td>38</td>
<td>315°</td>
<td>1012.0</td>
<td>50</td>
<td>thunderstorms</td>
<td>100</td>
</tr>
<tr>
<td>Galveston</td>
<td>5</td>
<td>225°</td>
<td>1016.0</td>
<td>72</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>Dallas</td>
<td>29</td>
<td>315°</td>
<td>1007.9</td>
<td>60</td>
<td>hail</td>
<td>100</td>
</tr>
<tr>
<td>Oklahoma City</td>
<td>45</td>
<td>315°</td>
<td>1007.7</td>
<td>57</td>
<td>thunderstorms</td>
<td>100</td>
</tr>
<tr>
<td>Kansas City</td>
<td>2</td>
<td>215°</td>
<td>1002.3</td>
<td>58</td>
<td>rain</td>
<td>100</td>
</tr>
<tr>
<td>Burwell</td>
<td>22</td>
<td>325°</td>
<td>1009.3</td>
<td>52</td>
<td>rain</td>
<td>100</td>
</tr>
<tr>
<td>Minneapolis</td>
<td>15</td>
<td>45°</td>
<td>1008.2</td>
<td>51</td>
<td>drizzle</td>
<td>100</td>
</tr>
<tr>
<td>Sioux Lookout</td>
<td>20</td>
<td>50°</td>
<td>1016.8</td>
<td>46</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>Chicago</td>
<td>10</td>
<td>45°</td>
<td>1005.2</td>
<td>58</td>
<td>drizzle</td>
<td>100</td>
</tr>
<tr>
<td>Little Rock</td>
<td>8</td>
<td>225°</td>
<td>1009.3</td>
<td>67</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>New Orleans</td>
<td>5</td>
<td>225°</td>
<td>1017.9</td>
<td>73</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nashville</td>
<td>5</td>
<td>220°</td>
<td>1011.1</td>
<td>68</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>Cincinnati</td>
<td>7</td>
<td>90°</td>
<td>1009.8</td>
<td>57</td>
<td>rain</td>
<td>100</td>
</tr>
<tr>
<td>Detroit</td>
<td>10</td>
<td>75°</td>
<td>1011.9</td>
<td>54</td>
<td>drizzle</td>
<td>100</td>
</tr>
<tr>
<td>Sault Ste. Marie</td>
<td>15</td>
<td>45°</td>
<td>1013.1</td>
<td>50</td>
<td>drizzle</td>
<td>100</td>
</tr>
<tr>
<td>Quebec</td>
<td>8</td>
<td>100°</td>
<td>1017.0</td>
<td>50</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>Boston</td>
<td>12</td>
<td>100°</td>
<td>1018.1</td>
<td>52</td>
<td>fog</td>
<td>25</td>
</tr>
<tr>
<td>Buffalo</td>
<td>7</td>
<td>75°</td>
<td>1016.0</td>
<td>52</td>
<td>drizzle</td>
<td>100</td>
</tr>
<tr>
<td>New York</td>
<td>10</td>
<td>80°</td>
<td>1017.6</td>
<td>56</td>
<td>fog</td>
<td>50</td>
</tr>
<tr>
<td>Hatteras</td>
<td>14</td>
<td>90°</td>
<td>1019.1</td>
<td>60</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Charleston</td>
<td>15</td>
<td>225°</td>
<td>1017.8</td>
<td>70</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>Atlanta</td>
<td>3</td>
<td>225°</td>
<td>1014.6</td>
<td>70</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Jacksonville</td>
<td>2</td>
<td>200°</td>
<td>1018.1</td>
<td>73</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tampa</td>
<td>2</td>
<td>230°</td>
<td>1018.0</td>
<td>74</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>Miami</td>
<td>8</td>
<td>180°</td>
<td>1019.8</td>
<td>78</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
INVESTIGATING WEATHER MAPS (continued)

2. On your map, find the observation station with the highest atmospheric pressure. Just above it, write H (for high). Find the observation station with the lowest atmospheric pressure. Just above it, write L (for low). Starting at this point, which is the center of a low-pressure area, sketch a cold front and a warm front. Refer to page 103 in your textbook for the way fronts should look. The cold front will be between stations where winds change from southwest to northwest and temperatures decrease suddenly. The warm front will be between stations where winds change from east to southwest and temperatures rise suddenly.

3. Draw the following isobars on your map: 1008 mb, 1012 mb, 1016 mb, 1020 mb, and 1024 mb. Label each isobar.

4. Draw a line around all the locations where precipitation has fallen. Shade the precipitation area with a colored pencil.

**Observations**

1. Which observation station reported the highest atmospheric pressure? The lowest atmospheric pressure?
   
   Ely reported the highest atmospheric pressure, and Kansas City reported the lowest atmospheric pressure.
INVESTIGATING WEATHER MAPS (continued)

♦ Analyze and Conclude

1. According to your map, is precipitation usually associated with an area of low pressure or an area of high pressure?
   
   Precipitation is usually associated with low pressure.

2. Compare wind direction around the low-pressure center with wind direction around the high-pressure center. Use clock directions in your answer.
   
   Winds blow counterclockwise around the low-pressure center and clockwise around the high-pressure center.

3. Compare the type and location of precipitation associated with the cold front to those associated with the warm front.
   
   Thunderstorms and hail are associated with the cold front, while drizzle and rain are associated with the warm front.

4. Describe changes in temperature and wind direction associated with the passage of the warm front.
   
   When the warm front passes, temperatures rise and the wind direction shifts from east to southwest.

5. Describe changes in temperature, wind direction, and atmospheric pressure associated with the passage of the cold front.
   
   When the cold front passes, temperatures fall, wind direction shifts from southwest to northwest, and the barometer rises.

♦ Critical Thinking and Applications

1. Look at your weather map. Assume that the storm center is moving in a north-easterly direction. Describe at least three changes in the weather in Cincinnati, Ohio, if the low-pressure center moves to Sault Ste. Marie.
   
   Answers might include winds shifting to the southwest, temperature increasing, clouds decreasing, and rain ending.

2. Can yesterday’s weather map help you predict tomorrow’s weather? Give a reason for your answer.
   
   Students will probably answer yes because you can tell the direction the highs, lows, and fronts are moving.
INVESTIGATING WEATHER MAPS (continued)

3. Before weather satellites existed, weather forecasts for cities on the West Coast were not as reliable as those for cities in the Midwest. Explain this difference.

In the United States, weather generally moves from west to east. Weather data could be gathered from land stations to the west of cities in the Midwest, but there were no land stations to the west of cities on the West Coast.

◆ More to Explore

Refer to the two maps below to answer the questions.

1. If the low-pressure area in the middle of the country on March 27 continues at its present speed and direction, where will it be centered on March 29?

The low would likely be centered over Ohio, Pennsylvania, or West Virginia.

2. Predict the weather conditions in Mississippi as the cold front moves through on March 29.

Temperatures will drop, and winds will probably become gusty out of the northwest.

Thunderstorms might occur, followed by clearing skies and higher pressure.

3. Draw a weather map that predicts the locations of the fronts, highs, and lows for March 29.

Maps will vary somewhat but should indicate a general west-to-east movement of all the weather features on the map.
Measuring the Diameter of the Sun

Pre-Lab Discussion

If you look at the full moon in the sky and a golf ball in your hand, they seem to be about the same size. However, you know that they are much different in size. They look about the same to you because they are at much different distances from you. For example, from Earth, the sun and moon appear to be about the same size because the moon is much closer to Earth than the sun is.

How can you measure the size of something as far away from you as the sun is? Although Earth is about 150,000,000 km from the sun, you can still make accurate measurements of the sun’s size. In this investigation, you will construct a simple device and use it to collect data that will allow you to calculate the diameter of the sun.

1. What part of the sun do you see when you look at its image?
   the photosphere

2. Why must you look at the sun indirectly instead of directly?
   Eyes might be damaged by the intensity of the sun’s rays.

Problem

What is the diameter of the sun?

Materials (per group)
- meter stick
- card, 20 cm × 25 cm
- card, 10 cm × 15 cm
- scissors
- tape
- square of aluminum foil, 15 cm × 15 cm
- drawing compass or pin

Advance Preparation: Precut the slits. You may want to precut the square hole as well.

Teaching Tips: As a safety measure, cut the slits for students with a razor blade. To ensure that the slits are straight and parallel to the sides of the cards, first mark where to cut. Carefully cut each slit in the shape of an I so that the meter stick will go through the cards without tearing them.

The foil must be tight over the hole in the cardboard so that the pinhole directs the image onto the other card.

Have one student hold the meter stick steady and another student move the card.

Have an alternative activity available in case the sun is not shining all day.

Before students do the calculations, review how to use cross products to solve a proportion.

Safety Review the safety guidelines in the front of your lab book.

Use caution in handling sharp objects such as the compass, pin, and scissors.
Never look directly at the sun; direct sunlight can damage your eyes.
MEASURING THE DIAMETER OF THE SUN (continued)

◆ Procedure

1. Have your teacher cut a slit in each card in the positions shown in Figure 1 so that the meter stick can fit snugly in them.

![Figure 1]

2. Draw two parallel lines exactly 8 mm apart near the center of the small card, as shown in Figure 1.

3. Cut a square hole, about 3 cm × 3 cm, in the larger card and cover it with aluminum foil. Use tape to hold the foil securely in place. Punch a very small hole near the center of the foil with a compass point or a pin.

4. Slide the large card near one end of the meter stick. Set the card perpendicular to the meter stick and tape it in place. Slide the small card on the other end, perpendicular to the meter stick.

5. **CAUTION:** Never look directly at the sun. Direct sunlight can damage your eyes. Aim the end of the meter stick with the foil-covered card toward the sun. Move the meter stick until the shadow of the large card covers the smaller card. A bright image of the sun will fall on the smaller card. Move the smaller card along the meter stick until the image exactly fills the space between the two parallel lines.

6. Make sure both cards are still perpendicular to the meter stick. Measure the distance between the two cards to the nearest millimeter. Record the distance and the diameter of the image in the Data Table below.

◆ Observations

Data Table

<table>
<thead>
<tr>
<th>Distance Between Two Cards</th>
<th>Diameter of Sun's Image</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Distance between cards will vary. The sun’s image is 8 mm in diameter.
MEASURING THE DIAMETER OF THE SUN (continued)

◆ Analyze and Conclude

1. The diameter of the sun’s image equals the distance between the parallel lines on the small card. The average distance between Earth and the sun is approximately 150,000,000 km. Using the formula below, calculate the diameter of the sun.

\[
\frac{\text{diameter of the sun (km)}}{\text{distance to the sun (km)}} = \frac{\text{diameter of the sun’s image (mm)}}{\text{distance between two cards (mm)}}
\]

Answers will vary but should be approximately 1,391,000 km.

2. The actual diameter of the sun is 1,391,000 km. Using the formula below, determine the percentage of error in your calculated value for the sun’s diameter.

\[
\text{percentage of error} = \left( \frac{\text{difference between your value and the correct value}}{\text{correct value}} \right) \times 100\%
\]

If students are careful with their observations and calculations, their calculated value should be within 10 percent of the sun’s actual diameter.

3. What could account for an error in your calculated value for the sun’s diameter?

Answers may vary. An average value for the distance between the sun and Earth was used, and measurements on the small card and on the meter stick are not exact.

◆ Critical Thinking and Applications

1. How could you use the technique in this investigation to make other astronomical measurements?

Sample answer: When the moon is full, its diameter could be measured. With a light-gathering instrument such as a telescope, the diameters of some planets could be measured.
MEASURING THE DIAMETER OF THE SUN (continued)

2. A camera operates in a way similar to the setup for your experiment. Light through a small hole projects an image onto the film. A common film size is 35 mm. Some film is 110 mm. If the image projected is the size of the film, which size of film must be closer to the hole that projects the image?

The 110-mm film must be closer. The greater the distance, the larger the image.

3. How might clouds affect the accuracy of your measurement in this investigation?

If a cloud partly covers the sun, the image might appear smaller than it normally would. Total cloud cover would probably make the image too faint to be seen and measured properly.

More to Explore

New Problem  What is the diameter of the moon?

Possible Materials  Students can use the hole punch to make a hole in the card. They should move the card on the meter stick until the moon fills the hole as viewed through the card. The student’s eye should be at the end of the meter stick. Data collected should consist of the distance from the eye to the card and the diameter of the hole.

Procedure  Remind students to do this nighttime activity with adult supervision.

1. Develop a plan similar to the one you used in the investigation to determine the diameter of the moon. (Hint: Because you can observe the moon directly, you can look through a small hole directly at the moon.) Write the steps to your procedure on another sheet of paper. What data will you need to collect? What mathematical formula will you use to calculate the diameter?

2. After your teacher has approved your plan, use your setup and formula to find the diameter of the moon. (The average distance from the moon to Earth is 368,500 km.)

Observations  On another sheet of paper, make a data table similar to the one in the investigation in which to record your data.

Analyze and Conclude

1. What is your calculated diameter of the moon?

2. If you were given the diameter of the moon instead of its distance from Earth, how could you find the distance?

To find the moon’s distance from Earth, the same formula would be used. Students would find a cross product and divide both sides of the equation by the diameter of the hole to find the moon’s distance.