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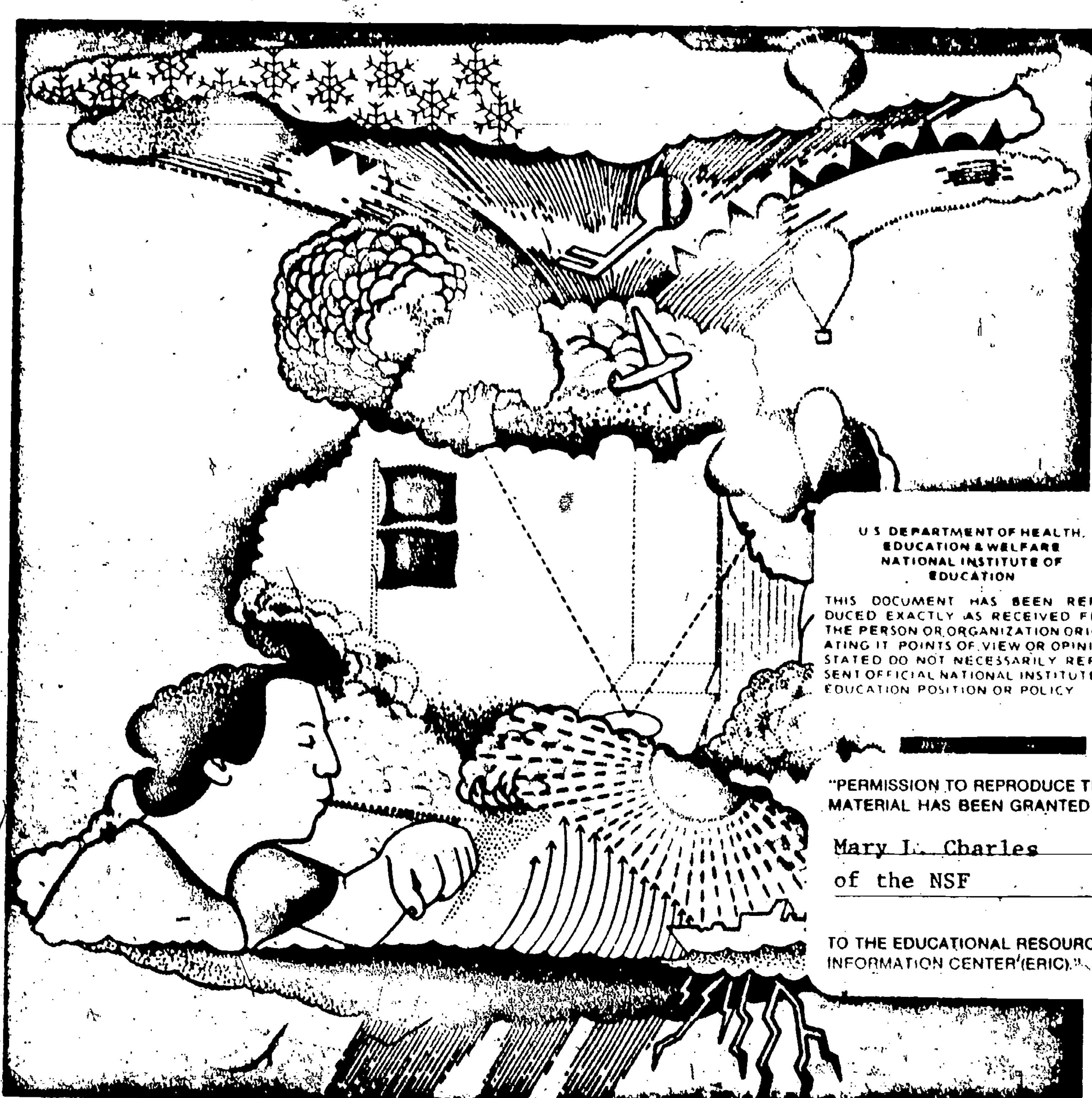
ABSTRACT

This is the student's text of one of the units of the Intermediate Science Curriculum Study (ISCS) for level III students (grade 9). The chapters contain basic information about weather, its measurement and predictions, activities related to the subject, and optional excursions. A section of introductory notes to the student discusses how to use the book and how the class will be organized. Data tables within the workbook format indicate where responses are expected. Illustrations accompany all instructions and the students are expected to select the proper equipment based on the illustrations. (SA)

Winds and Weather



Probing the Natural World/3

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INTERMEDIATE SCIENCE CURRICULUM STUDY

Winds and Weather

Probing the Natural World / Level III

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Foreword

A pupil's experiences between the ages of 11 and 16 probably shape his ultimate view of science and of the natural world. During these years most youngsters become more adept at thinking conceptually. Since concepts are at the heart of science, this is the age at which most students first gain the ability to study science in a really organized way. Here, too, the commitment for or against science as an interest or a vocation is often made.

Paradoxically, the students at this critical age have been the ones least affected by the recent effort to produce new science instructional materials. Despite a number of commendable efforts to improve the situation, the middle years stand today as a comparatively weak link in science education between the rapidly changing elementary curriculum and the recently revitalized high school science courses. This volume and its accompanying materials represent one attempt to provide a sound approach to instruction for this relatively uncharted level.

At the outset the organizers of the ISCS Project decided that it would be shortsighted and unwise to try to fill the gap in middle school science education by simply writing another textbook. We chose instead to challenge some of the most firmly established concepts about how to teach and just what science material can and should be taught to adolescents. The ISCS staff have tended to mistrust what authorities believe about schools, teachers, children, and teaching until we have had the chance to test these assumptions in actual classrooms with real children. As conflicts have arisen, our policy has been to rely more upon what we saw happening in the schools than upon what authorities said could or would happen. It is largely because of this policy that the ISCS materials represent a substantial departure from the norm.

The primary difference between the ISCS program and more conventional approaches is the fact that it allows each student to travel at his own pace, and it permits the scope and sequence of instruction to vary with his interests, abilities, and background. The ISCS writers have systematically tried to give the student more of a role in deciding what he should study next and how soon he should study it. When the materials are used as intended, the ISCS teacher serves more as a "task easer" than a "task master." It is his job to help the student answer the questions that arise from his own study rather than to try to anticipate and package what the student needs to know.

There is nothing radically new in the ISCS approach to instruction. Outstanding teachers from Socrates to Mark Hopkins have stressed the need to personalize education. ISCS has tried to do something more than pay lip service to this goal. ISCS' major contribution has been to design a system whereby an average teacher, operating under normal constraints, in an ordinary classroom with ordinary children, can indeed give maximum attention to each student's progress.

The development of the ISCS material has been a group effort from the outset. It began in 1962, when outstanding educators met to decide what might be done to improve middle-grade science teaching. The recommendations of these conferences were converted into a tentative plan for a set of instructional materials by a small group of Florida State University faculty members. Small-scale writing sessions conducted on the Florida State campus during 1964 and 1965 resulted in pilot curriculum materials that were tested in selected Florida schools during the 1965-66 school year. All this preliminary work was supported by funds generously provided by The Florida State University.

In June of 1966, financial support was provided by the United States Office of Education, and the preliminary effort was formalized into the ISCS Project. Later, the National Science Foundation made several additional grants in support of the ISCS effort.

The first draft of these materials was produced in 1968, during a summer writing conference. The conferees were scientists, science educators, and junior high school teachers drawn from all over the United States. The original materials have been revised three times prior to their publication in this volume. More than 150 writers have contributed to the materials, and more than 180,000 children, in 46 states, have been involved in their field testing.

We sincerely hope that the teachers and students who will use this material will find that the great amount of time, money, and effort that has gone into its development has been worthwhile.

Tallahassee, Florida
February 1972

The Directors
INTERMEDIATE SCIENCE CURRICULUM STUDY

Contents

Notes to the Student

The word *science* means a lot of things. All of the meanings are "right," but none are complete. *Science* is many things and is hard to describe in a few words.

We wrote this book to help you understand what science is and what scientists do. We have chosen to show you these things instead of describing them with words. The book describes a series of things for you to do and think about. We hope that what you do will help you learn a good deal about nature and that you will get a feel for how scientists tackle problems.

How is this book different from other textbooks?

This book is probably not like your other textbooks. To make any sense out of it, you must work with objects and substances. You should do the things described, think about them, and then answer any questions asked. Be sure you answer each question as you come to it.

The questions in the book are very important. They are asked for three reasons:

1. To help you to think through what you see and do.
2. To let you know whether or not you understand what you've done.
3. To give you a record of what you have done so that you can use it for review.

How will your class be organized?

Your science class will probably be quite different from your other classes. This book will let you start work with less help than usual from your teacher. You should begin each day's work where you left off the day before. Any equipment and supplies needed will be waiting for you.

Your teacher will not read to you or tell you the things that you are to learn. Instead, he will help you and your classmates individually. Try to work ahead on your own. If you have trouble, first try to solve the problem for yourself. Don't ask your teacher for help until you really need it. Do not expect him to give you the answers to the questions in the book. Your teacher will try to help you find where and how you went wrong, but he will not do your work for you.

After a few days, some of your classmates will be ahead of you and others will not be as far along. This is the way the course is supposed to work. Remember, though, that there will be no prizes for finishing first. Work at whatever speed is best for you. *But be sure you understand what you have done before moving on.*

Excursions are mentioned at several places. These special activities are found at the back of the book. You may stop and do any excursion that looks interesting or any that you feel will help you. (Some excursions will help you do some of the activities in this book.) Sometimes, your teacher may ask you to do an excursion.

What am I expected to learn?

During the year, you will work very much as a scientist does. You should learn a lot of worthwhile information. More important, we hope that you will learn how to ask and answer questions about nature. *Keep in mind that learning how to find answers to questions is just as valuable as learning the answers themselves.*

Keep the big picture in mind, too. Each chapter builds on ideas already dealt with. These ideas add up to some of the simple but powerful concepts that are so important in science. If you are given a Student Record Book, do all your writing in it. *Do not write in this book.* Use your Record Book for making graphs, tables, and diagrams, too.

From time to time you may notice that your classmates have not always given the same answers that you did. This is no cause for worry. There are many right answers to some of the questions. And in some cases you may not be able to answer the questions. As a matter of fact, no one knows the answers to some of them. This may seem disappointing to you at first, but you will soon realize that there is much that science does not know. In this course, you will learn some of the things we don't know as well as what is known. Good luck!

Air Has Its Ups and Downs

Chapter 1

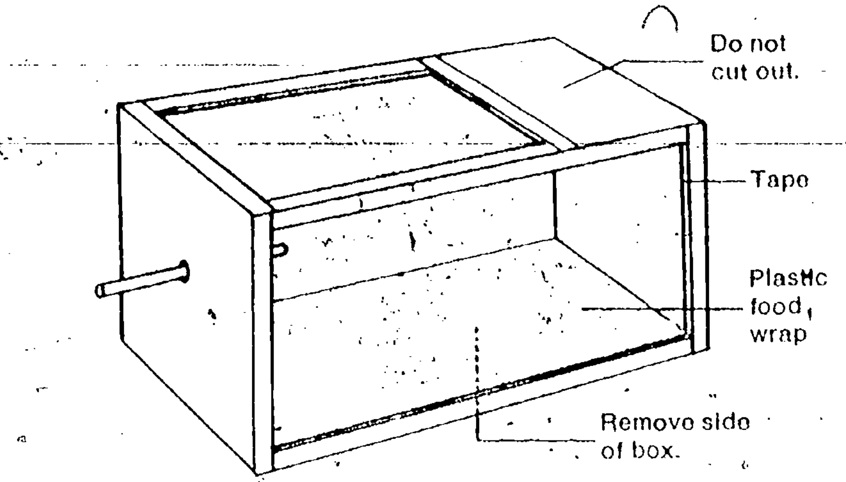
Excursion 1-1 is keyed to this chapter.

How would you like to be able to explain the formation of a giant thundercloud like the one shown on the facing page? "A tough job," you say. Perhaps, but not impossible. To do it, you'll need to find out a few things about air, water, heat, and the earth's surface. You'll need to know how these variables interact to produce changes in the earth's atmosphere. These atmospheric changes are what we call "weather." Of course there is more to weather than a thundercloud. However, old cumulonimbus is an exciting fellow.

Your first task is to find out how warm and cold surfaces affect air. You will need to make an observation box if one isn't already available. To do this, you'll need the following materials:

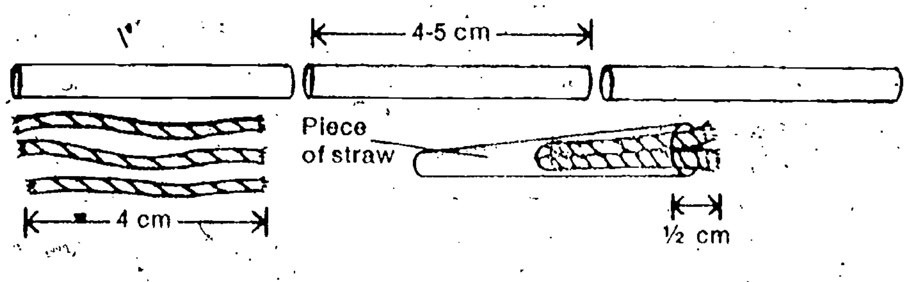
1 cardboard box (about 30 cm x 30 cm x 50 cm)
Clear plastic food wrap
Plastic tape
1 plastic straw

ACTIVITY 1-1. Remove one side of the box; then cut a window in two sides as shown. But leave about $\frac{1}{3}$ of the top intact. Tape plastic food wrap over the windows so that they are airtight. In one end of the box, cut a small hole just large enough to insert a plastic straw.

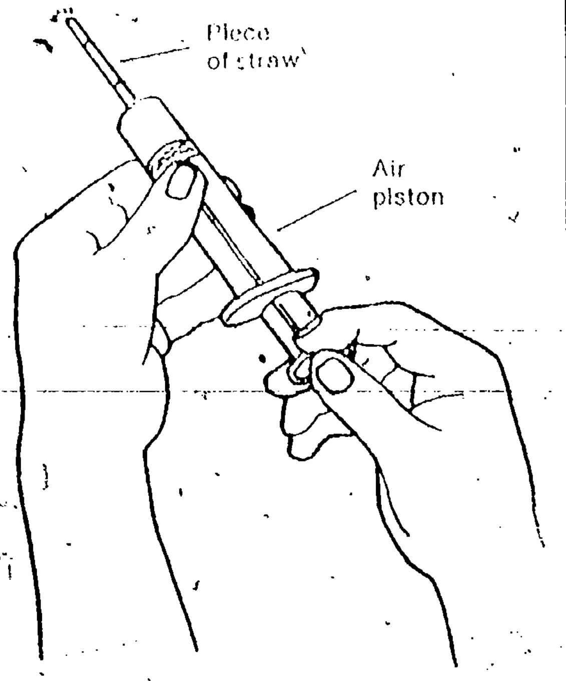


Studying the behavior of air is a bit difficult because air is a mixture of invisible gases. One way to study air is to add smoke particles to it. By watching what happens to the smoke, you can decide what invisible air is doing. The next activities will suggest a simple way to collect some smoke. You will need the following:

- 1 large air piston
- 1 plastic straw
- Heavy cotton string, 12 cm long
- Matches
- Scissors
- Baby-food jar of tap water



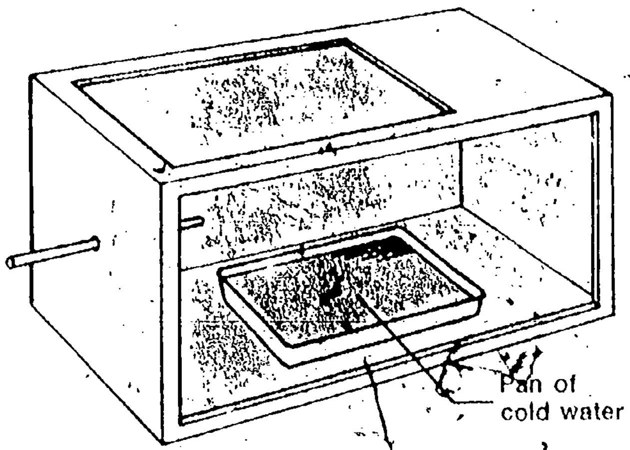
ACTIVITY 1-2. Cut the straw into 4- to 5-cm lengths. Cut the string into lengths of about 4 cm. Double one of the pieces of string twice or more until it will fit snugly in the end of a piece of the plastic straw. Leave about $\frac{1}{2}$ cm of the doubled string sticking out of the straw. Repeat the procedure for the other pieces.



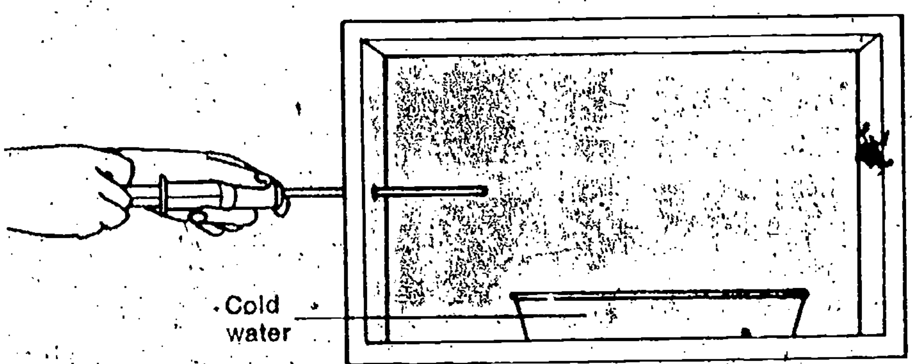
ACTIVITY 1-3. Slip a section of the prepared straw onto the air piston. Light the string, being careful not to melt the straw. Collect smoke in the cylinder by slowly drawing out the plunger. Remove the straw and lay it aside where it won't burn anything. You may need more smoke later.

Now you are ready to see how warm and cold surfaces affect air. You will use your observation box and the smoke you collected in Activity 1-3.

ACTIVITY 1-4. Place a pan of cold water (ice water or even ice cubes if possible) inside the observation box. Be sure the straw is in place through the end of the box. The end of the straw should not be over the pan of water.



ACTIVITY 1-5. Insert a smoke-filled air piston into the straw of the observation box. Gently force smoke through the straw into the box so that it moves very slowly over the cold water. Observe what happens to the smoke.



☐1-1. Describe what happened to the smoke as it moved into the region above the cold surface.

Repeat Activities 1-3, 1-4, and 1-5 using a pan of hot water. But don't throw away the ice. Other students may need it.

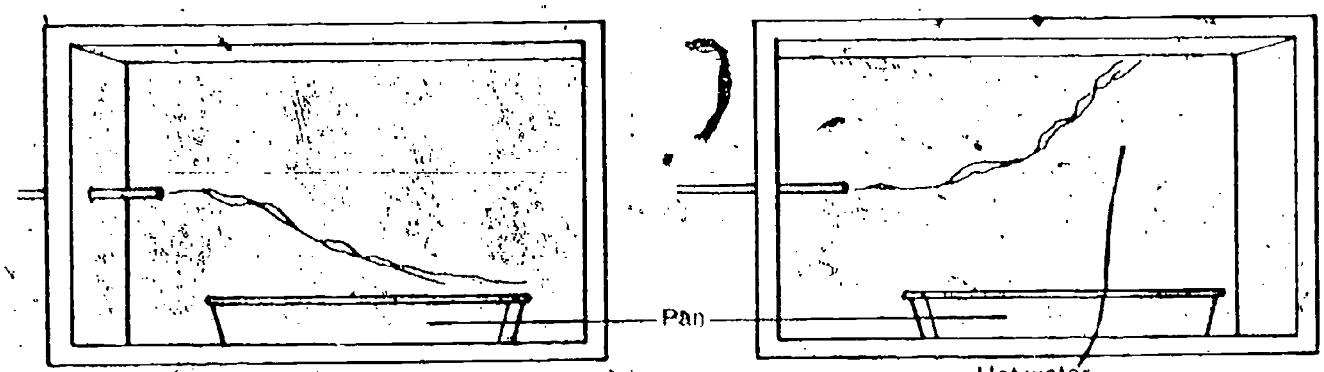
☐1-2. Describe what happened to the smoke as it moved into the region above the warm surface.

If you studied Volume 1 or Volume 2 of the ISCS program, you learned that a change in motion of something occurs only if a force is acting upon it.

☐1-3. How do you know that some force acts on the smoke as it moves into the region above the warm or the cold surface?

Figure 1-1 illustrates the smoke-filled air as it moves above the surface of the cold and the hot water.

Figure 1-1



☐1-4. In Figure 1-1 of your Record Book, draw arrows indicating the direction of the force acting on each of the smoke streams.

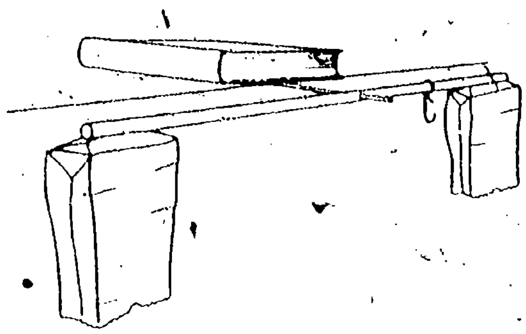
The upward motion of the smoke above the warm surface suggests that the air is rising. This updraft pushes the smoke along with it.

☐1-5. What does the smoke movement tell you about the motion of air over a cold surface?

The vertical (up-and-down) movement of air is very important in producing weather changes. But how can this motion be explained? Putting an activity together with the particle model from ISCS Volume I can help.

Get a partner and the following materials for this activity:

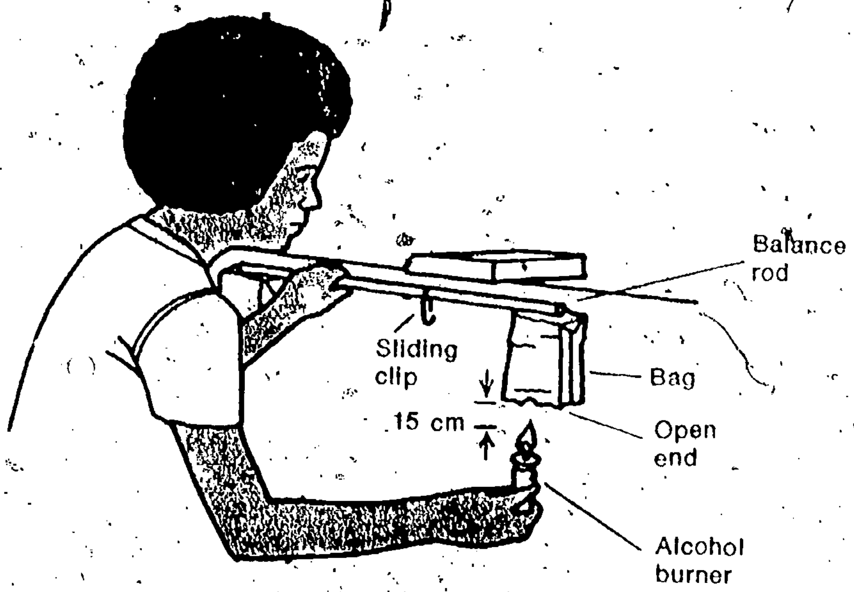
1 pegboard balance rod
1 wire support for rod
2 small paper bags of equal size
2 thumbtacks of equal size
1 alcohol burner
Matches



ACTIVITY 1-6. **Set up the balance rod and wire support as shown. Fasten the two paper bags to the balance rod, using the thumbtacks. Balance the rod by moving the sliding clip. With the rod held stationary as shown, hold a lighted alcohol burner about 15 cm below the open end of the bag on the right.**

Caution *Be careful not to let the bag catch fire! Keep the burner under the bag for 30 seconds.*

ACTIVITY 1-7. **Remove the burner, extinguish it, and gently let go of the bar. Observe the bag for several minutes.**

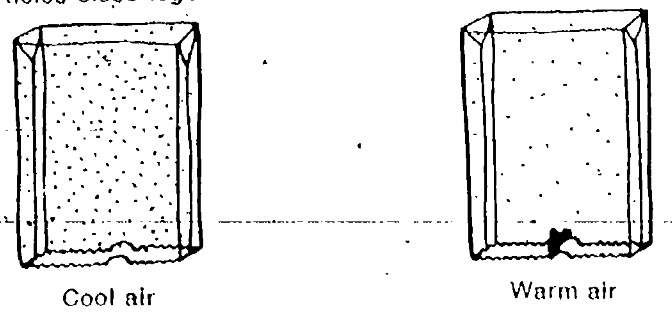


☐**1-6.** Describe your observations from Activity 1-7.

☐**1-7.** According to your observations, which has the greater mass, the bag of warm air or the bag of cool air?

The particle model for matter from Volume I of ISCS suggested that heating a substance causes the particles of the substance to spread farther apart. Thus, the particles in warm air can be thought of as farther apart than the particles in cool air. This idea is illustrated in Figure 1-2.

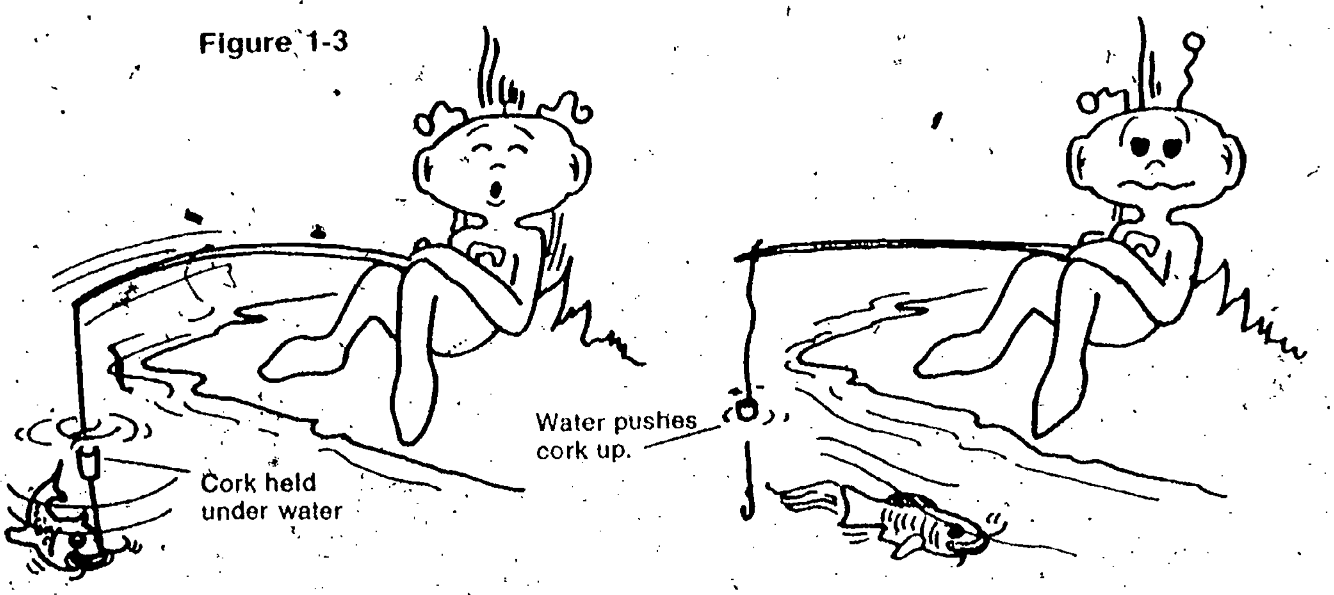
Figure 1-2



☐ **1-8.** The bags shown in Figure 1-2 have the same volume. Which has more gas particles per volume?

It seems reasonable to think that the bag with the greater number of air particles will have more mass and therefore be heavier than the bag with fewer particles. Because the bag of warm air is lighter than the bag of cool air, it is pushed upward by the heavier, cooler air that surrounds it. It behaves somewhat like a cork that is held under the surface of a liquid. Just as the heavier surrounding water pushes the cork up when it is released, so also the surrounding heavier air pushes the lighter, warm air up (Figure 1-3).

Figure 1-3



Balloons of all sizes, some carrying animals and machines, have been propelled upward by the lift of hot gases. Man's first flights into space were aboard such hot-air crafts. Perhaps you'd like to try making your own balloon. If so, get a partner and get going on **Excursion 1-1.**

EXCURSION

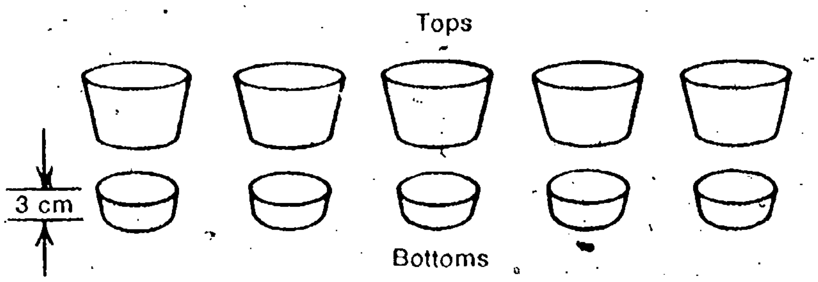
The fact that warm air rises and cool air descends will prove to be very important in helping you explain weather conditions.

But how is the air cooled or warmed? Is it a result of sunlight, or the lack of it? Does the earth's surface have anything to do with this cooling and warming?

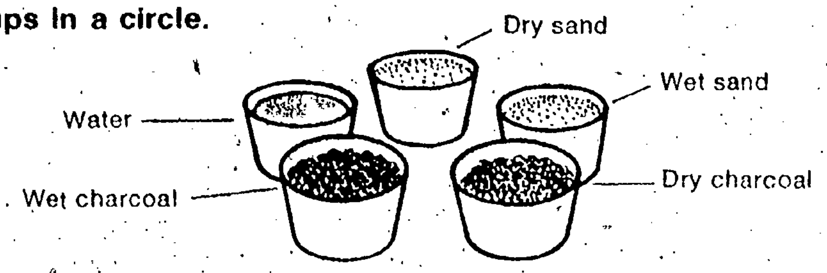
Get a couple of partners to help you find the answers to these questions. Your team will need the following equipment:

5 Styrofoam cups
5 thermometers
Scissors
1 floodlamp (or 150-watt bulb)
Water at room temperature
Dry sand
Finely crushed dry charcoal

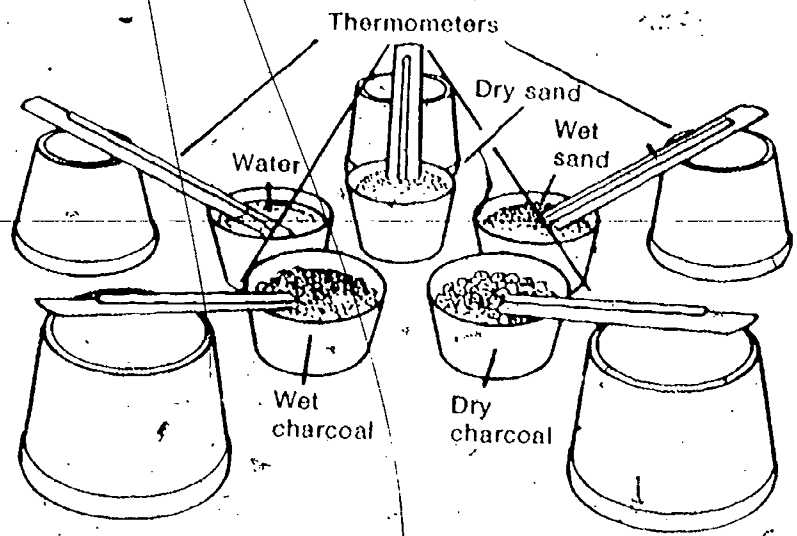
ACTIVITY 1-8. Carefully cut the tops off the five cups about 3 cm from the bottom. Save both tops and bottoms of the cups.



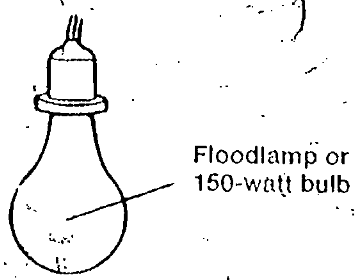
ACTIVITY 1-9. Fill one cup with water at room temperature, one with dry sand, one with wet sand, one with dry crushed charcoal, and one with wet crushed charcoal. Arrange the cups in a circle.

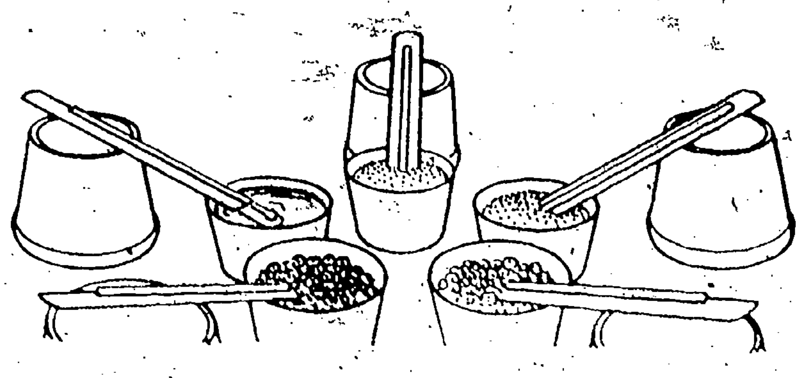


ACTIVITY 1-10. Place a thermometer in each container. Each thermometer bulb should be covered by no more than $\frac{1}{2}$ cm of material.



ACTIVITY 1-11. Hang a 150-watt bulb about 30 cm above the center of the circle of containers. Don't turn the light on until you have recorded the initial temperature for each container. Record your readings in Table 1-1 of your Record Book.





Temperatures should be taken 1, 3, and 5 minutes after the light is turned on. Then again 5 minutes after the light is turned off.

Table 1-1

Material	THERMOMETER READING (°C)				
	Light Off at Beginning of Experiment	Light Turned On			Light Off After 5 Minutes Cooling
		After 1 Minute	After 3 Minutes	After 5 Minutes	
Water					
Dry sand					
Wet sand					
Dry charcoal					
Wet charcoal					

Graph the data from Table 1-1 on Figure 1-4 of your Record Book. On the graph, each of the five sets of data should be represented by a different line (see key). Number the temperature lines at left so that the beginning temperatures are near the bottom line and the highest temperature reached in any material is near the top. Remember that the temperature divisions on the lines must represent equal degree intervals.

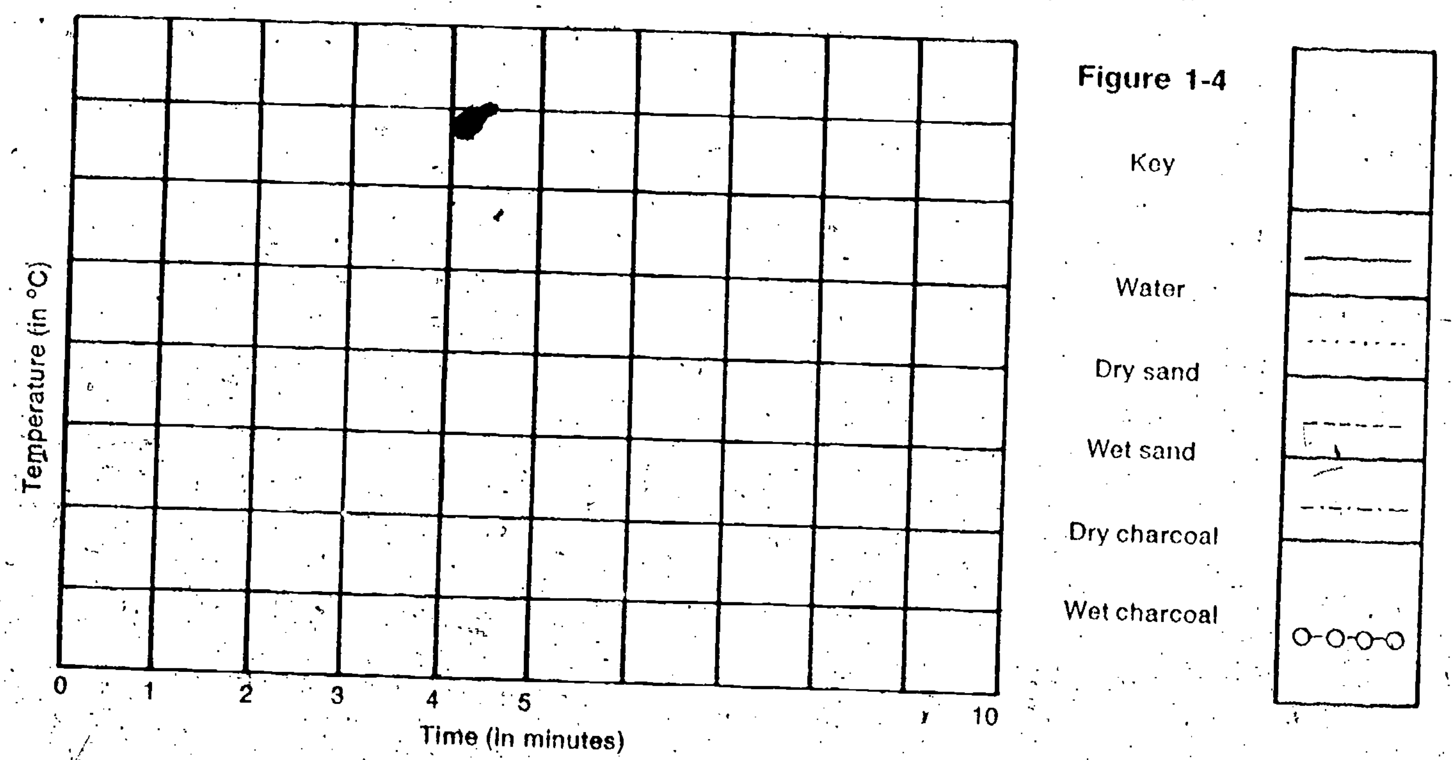


Figure 1-4

The same light shone equally on all the materials for the same period of time. Yet the temperature of some materials increased more than the temperature of others.

☐ **1-9.** Of the dry materials, which showed the greater temperature change, the dark (charcoal) or the light (sand)? Which cooled faster?

☐ **1-10.** Of the wet solids, which showed the greater temperature increase?

☐ **1-11.** Did the dry solid show more temperature increase than the same solid when wet?

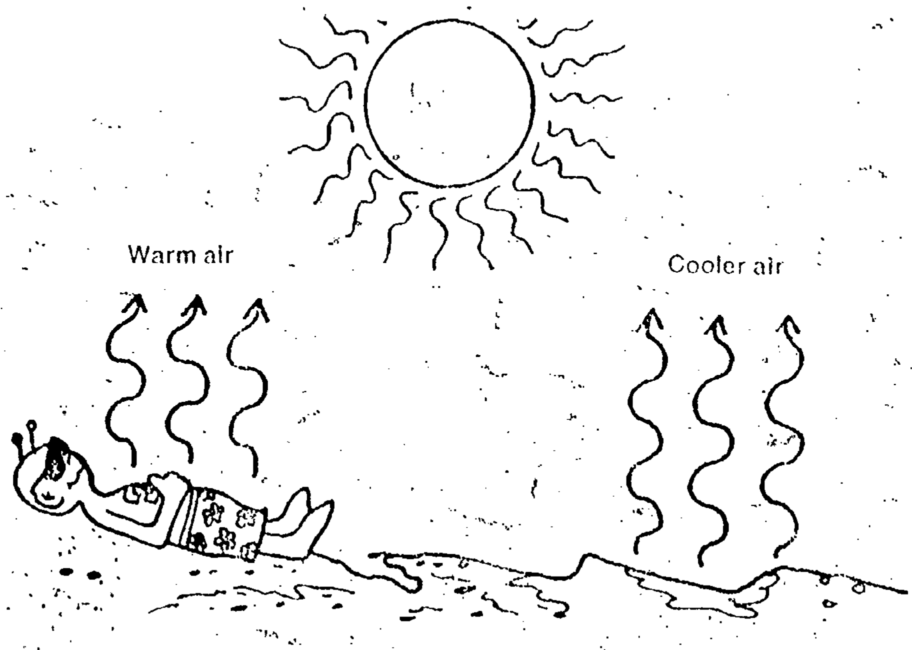
☐ **1-12.** Did the temperature of the water increase as much as the temperature of the solids?

☐ **1-13.** When the light was turned off, which of the substances cooled the most in 5 minutes?

This last investigation you did should have made a couple of things rather obvious:

1. When light reaches a surface, the temperature of that surface will increase.
2. Different kinds of surfaces show different rates of heating and cooling.

It is reasonable to expect that the air above the earth's surface will be warmed or cooled by that surface.

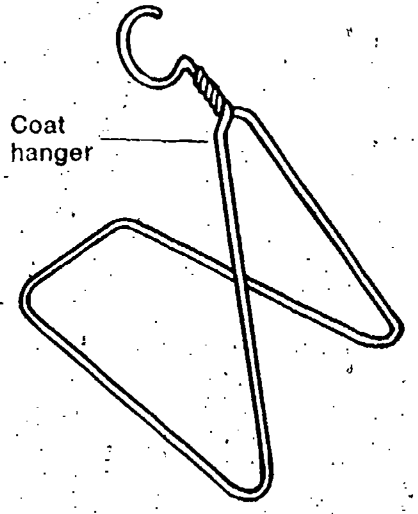


From time to time in this unit, you will be asked to do what are called Problem Breaks. These are problems for you to solve, without much help from your book or from your teacher. The problems will usually help you understand what you are studying in the chapter. But that's not their major purpose. They are designed to give you practice in problem solving and in setting up your own experiments. You should try every problem break—even the tough ones. And in most cases you should have your teacher approve your plan before trying it. The first problem break in this unit is coming up next.

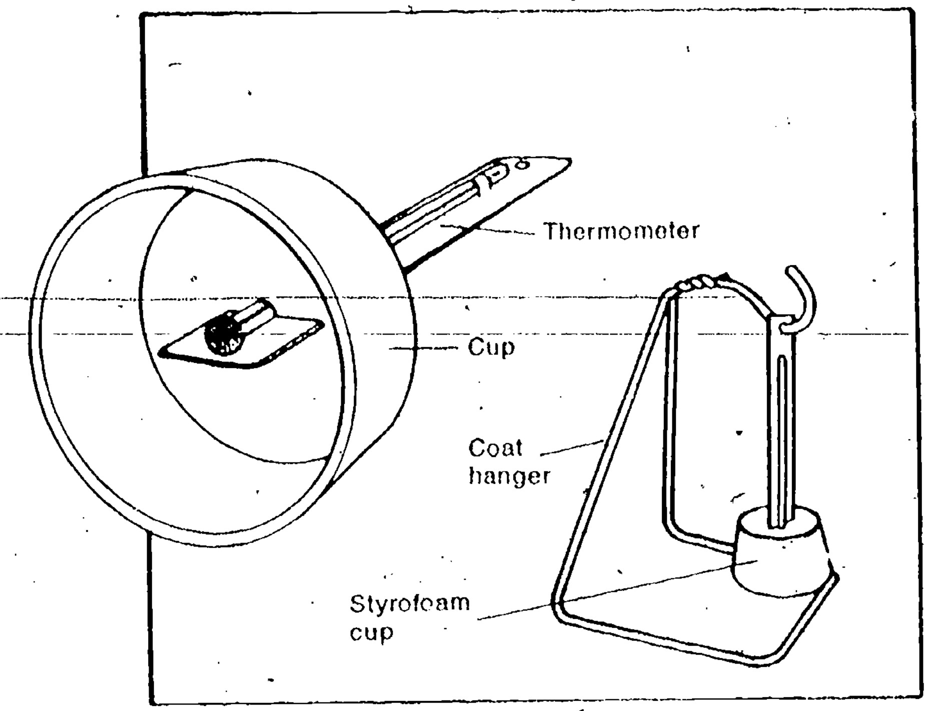
PROBLEM BREAK 1-1

It has been suggested that the air at different points on the earth receives different amounts of heat from the earth. The amount of heat depends on the kind of material that is beneath the air. But is this a reasonable idea? You can find out with a few measurements in the area around your school. Design your own plan for collecting data. A suggestion for preparing your thermometer for outdoor use follows.

ACTIVITY 1-12. Bend a coat hanger as shown. This can be used as a thermometer support.



ACTIVITY 1-13. To insulate the thermometer from winds outdoors, use the bottom of a Styrofoam cup. (You can use one of the cups from Activity 1-9.) Then suspend the thermometer from the coat hanger as shown.



Get permission from your teacher to go outside to locate at least four different kinds of surface as close together as possible. Be sure to get your temperature measurements in the same way at each place.

In the space provided in your Record Book, record your plan, the data you collect, and your conclusions.

☐**1-14.** Did the temperature of the outside air vary, depending upon the surface under it?

The temperature of the earth's surface can be expected to have quite an effect on the up-and-down motion of the air above it. This air movement has a great effect on weather. It is the first step in building the thundercloud mentioned earlier.

You might find it interesting to know that up-and-down air has some real effects on aircraft.

☐**1-15.** Explain the motion of the glider shown in Figure 1-5.

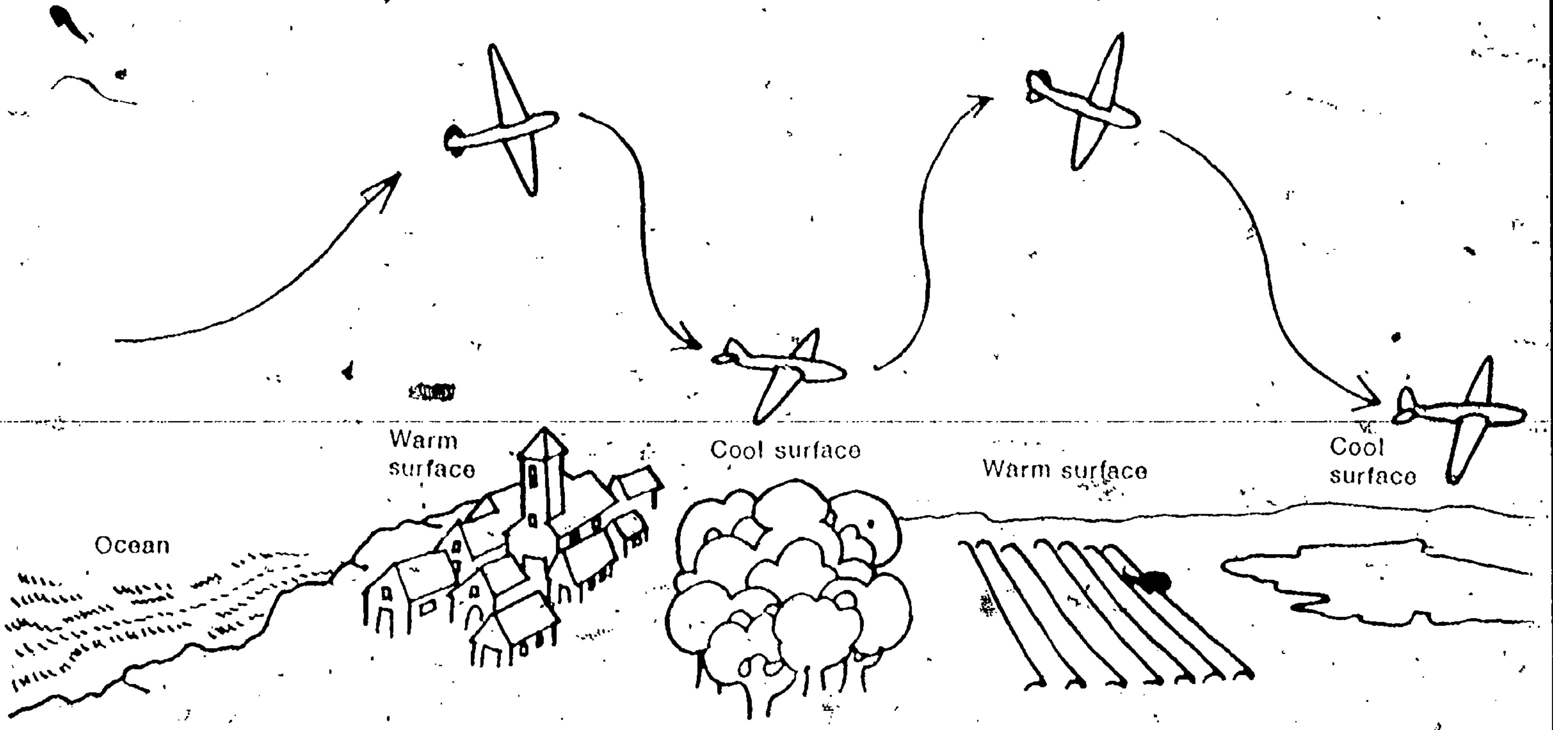
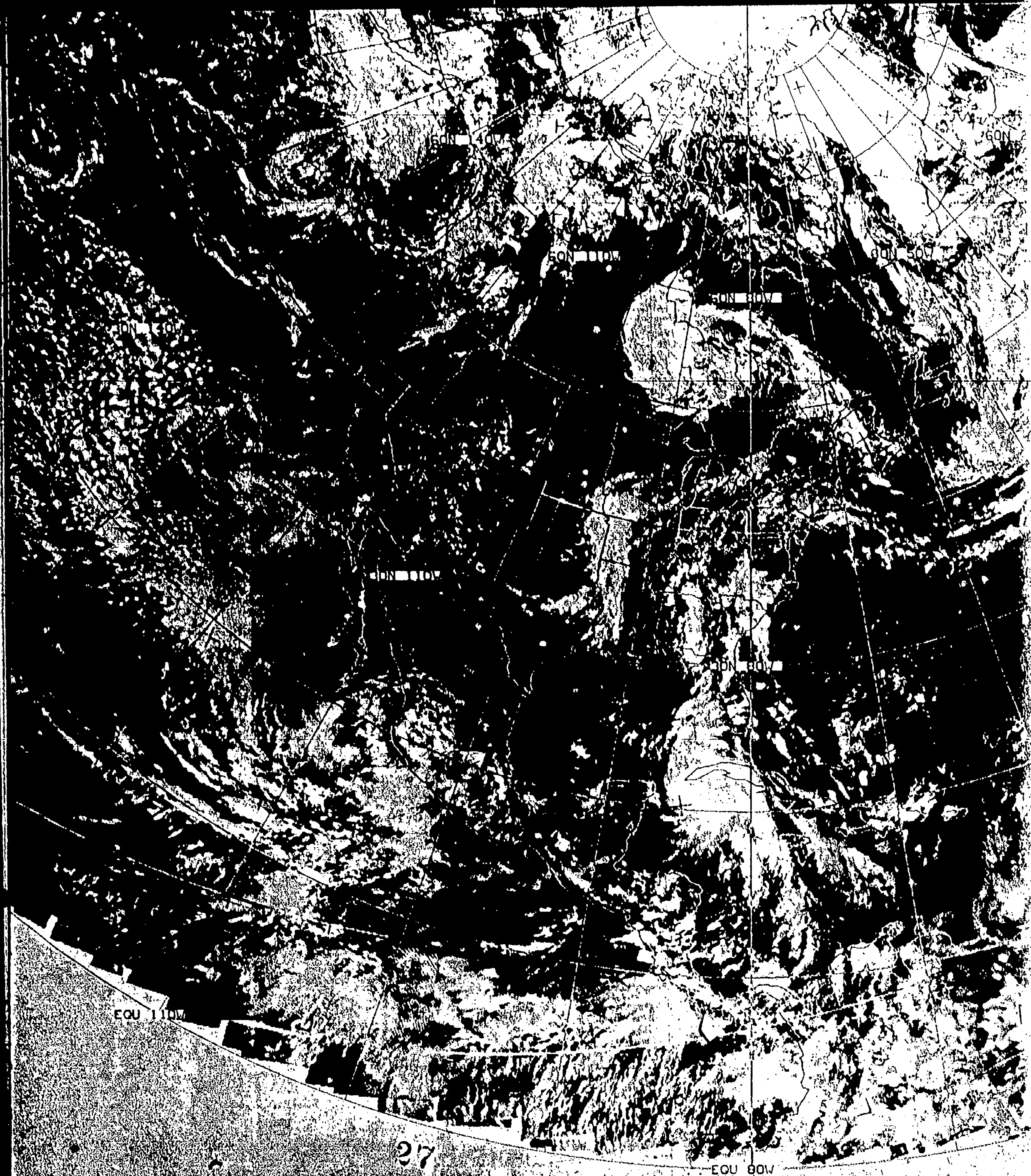


Figure 1-5

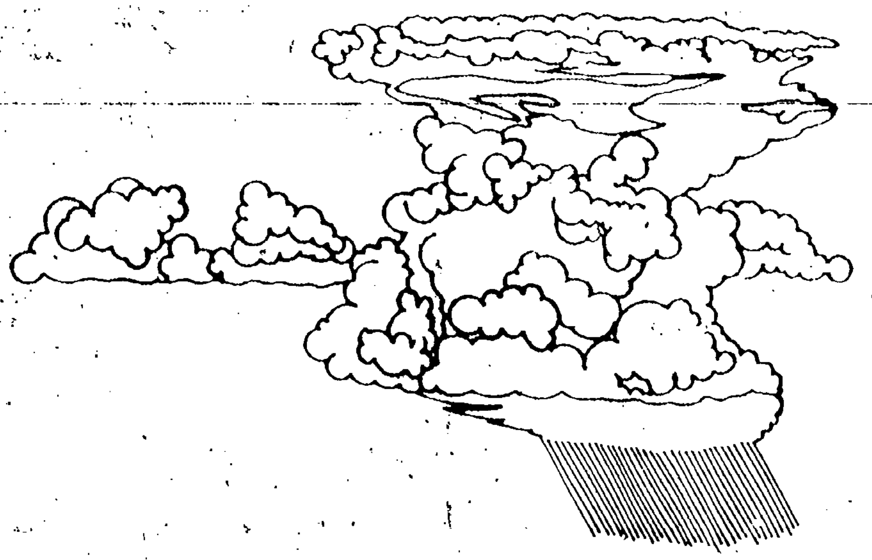
Before going on, do Self-Evaluation 1 in your Record Book.

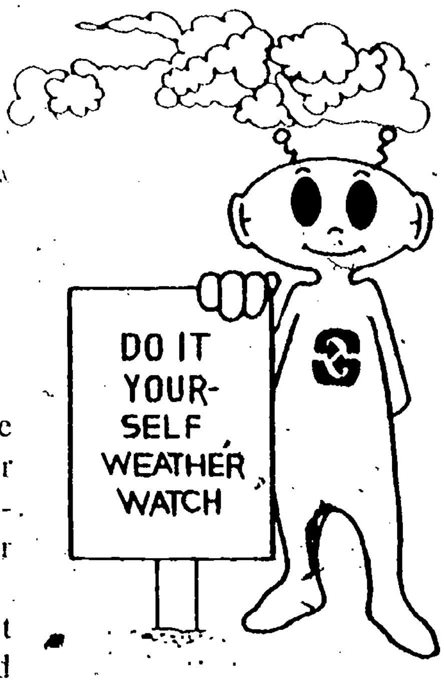


60N 110W
30N 110W
30N 80W
EQU 110W
EQU 80W

Weather Watch

Chapter 2



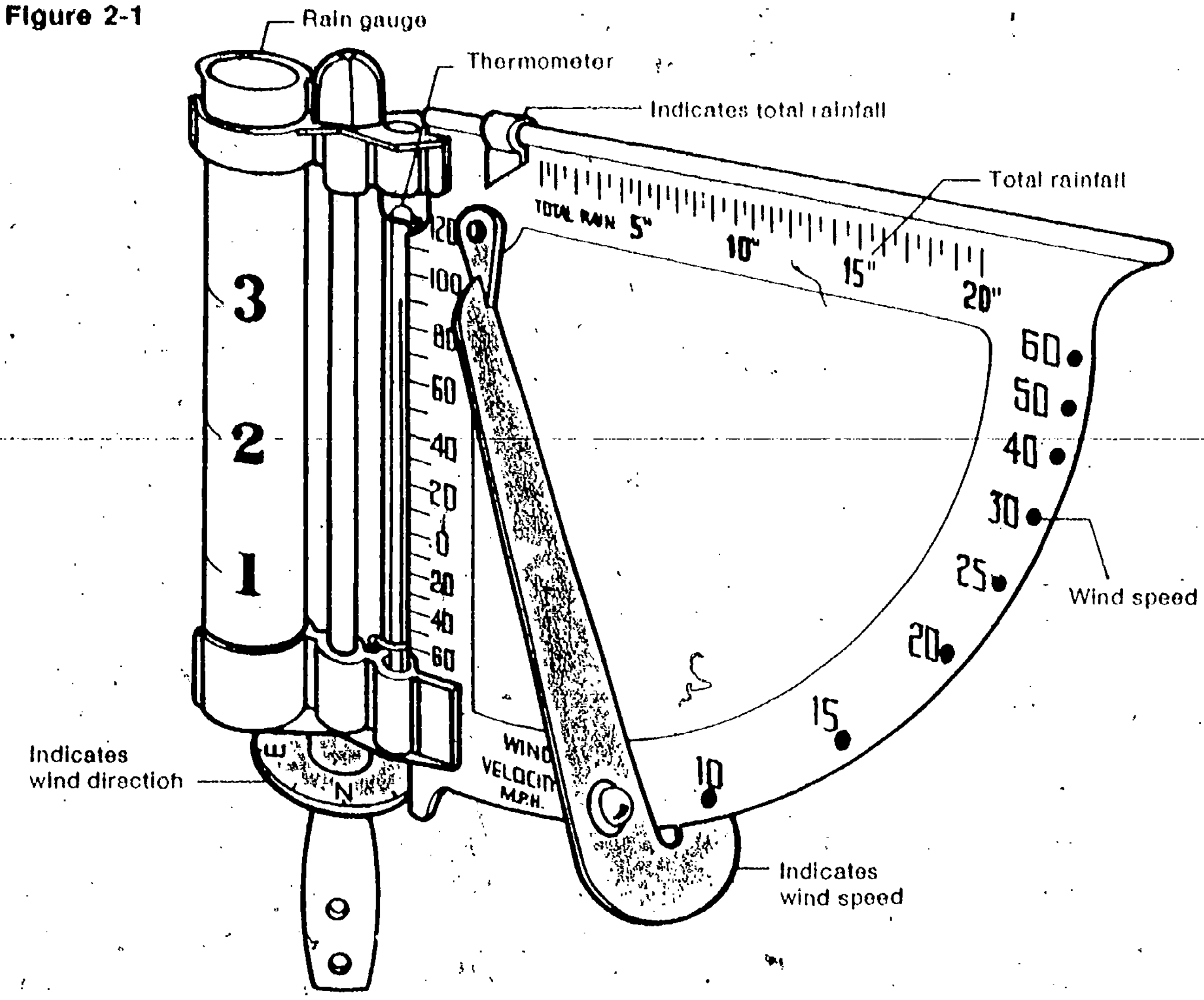


Everyone is interested in the weather, and almost everyone tries to predict what it will be. Some folks spend all their time studying weather patterns. These people are called meteorologists. They want to be able to explain weather changes, and they try to make accurate forecasts.

As you continue your study of this unit, you will do a bit of your own weather forecasting. What you have learned about air will help. But you will also need to collect data on daily weather conditions. To do this, you need to establish a "weather watch."

You will need a record of the daily weather in your city or town during a period of about four weeks. To get this information, you'll need to keep a weather watch—repeated checks of weather instruments. During your weather watch, you will measure certain weather variables every day, including weekends. As far as possible, measurements should be made at the *same time* each day. Most of the measurements will be made using an instrument like the one shown in Figure 2-1. Or, if your school has one, data can be collected from a weather station that has several different instruments.

Figure 2-1



In your Record Book, you will find a weather-watch chart similar to the one shown in Table 2-1. Keep your four-week weather-watch data in this chart.

Here are some suggestions on how to make and record your observations.

1. Date: Record the date you take your reading.
2. Time: Record the time you take your reading.
3. Read the temperature in degrees Fahrenheit to the nearest degree on the weather-station thermometer. Convert to degrees Celsius.
4. Wind direction: Use the wind direction on the weather station. *Remember!* Record the direction *from* which the wind blows.

Table 2-1

Weather-Watch Chart					
1. Date					
2. Time of day					
3. Temperature (°C)					
4. Wind direction					
5. Wind speed (mph)					
6. Cloud type					
7. Cloud cover					
8. Precipitation (in inches)					
9. Barometric pressure (in inches)					
10. Relative humidity					
11. Dew point (°C)					

5. Wind speed: Use the wind speed indicator on the weather station. Record the high and low wind speeds observed over a one-minute period. For example: "From 5 to 8 miles per hour."

Excursion 2-1, "Blowin' in the Wind," will help you use the wind speed and wind direction indicators on the weather-station instrument correctly.

EXCURSION

6. Cloud type: The photographs in Figure 2-2 show the three major types of clouds (cirrus, stratus, cumulus). (**Excursion 2-2,** "Billboards of the Sky," will help you identify additional cloud types.) Use these various pictures to identify clouds as you keep your weather watch. Write down only the symbol for the name of the cloud in Table 2-1. These symbols are given under each picture in Figure 2-2.

EXCURSION

Figure 2-2a Cirrus clouds (Ci)

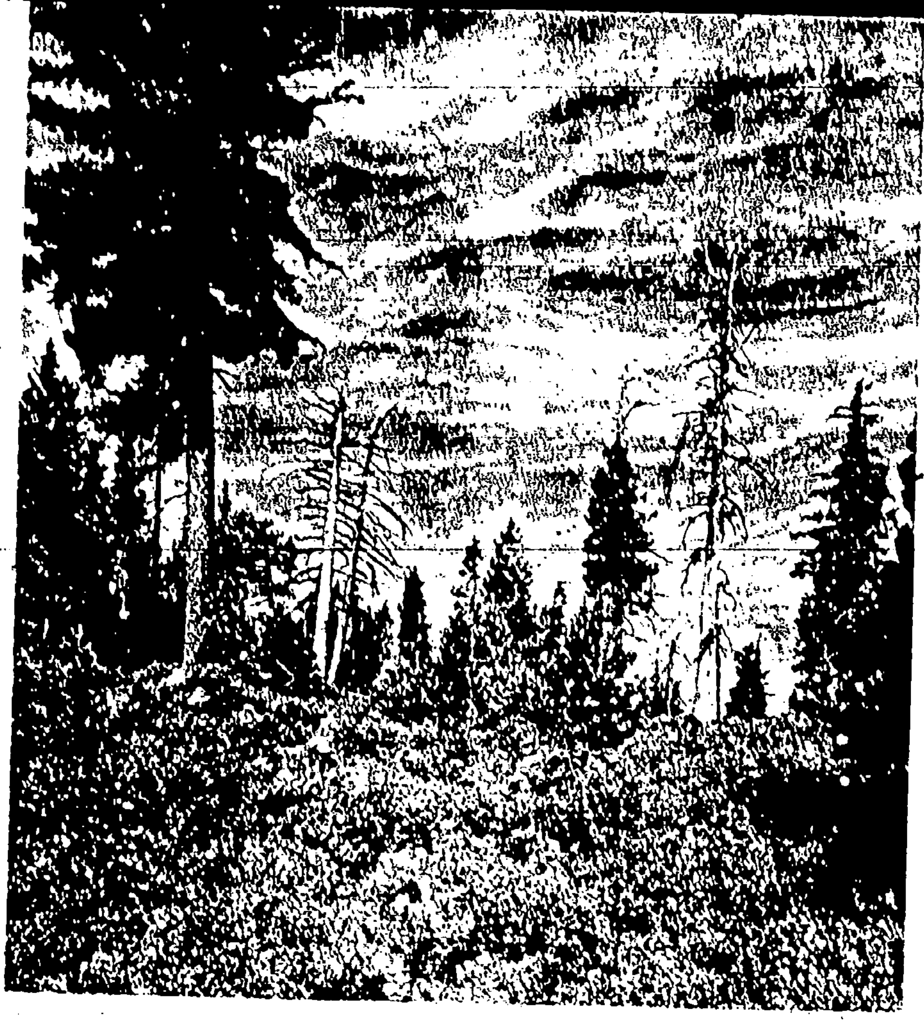
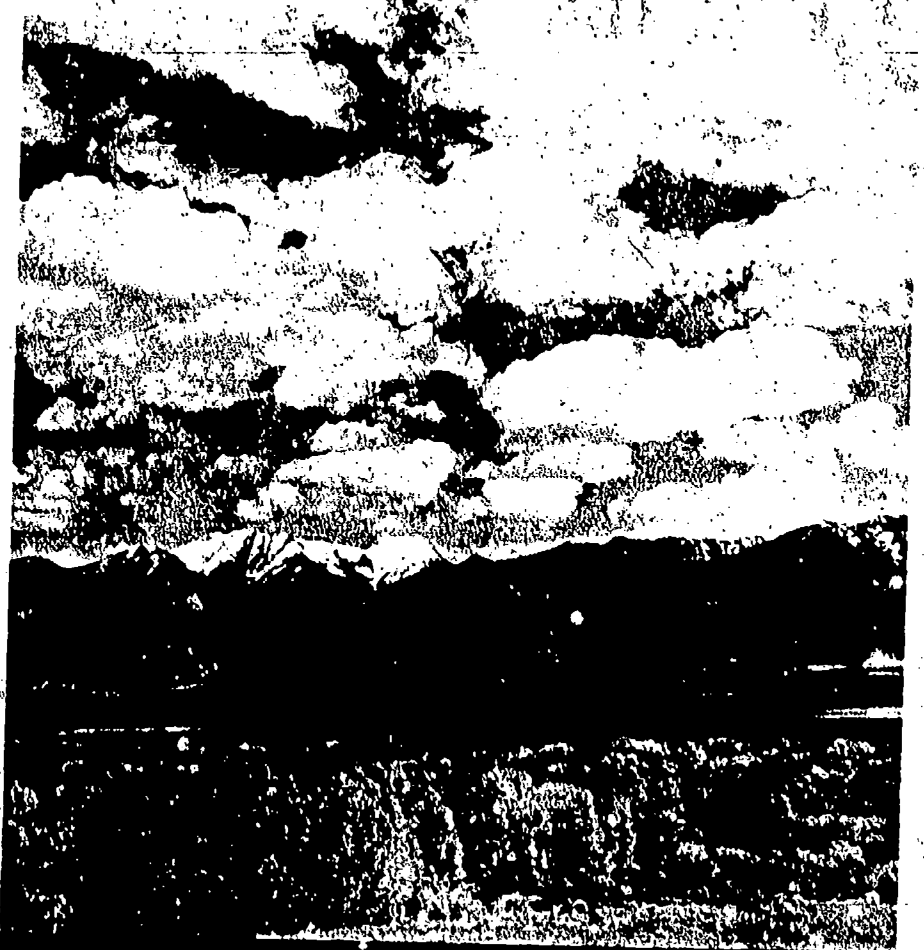


Figure 2-2b Cumulus clouds (Cu)



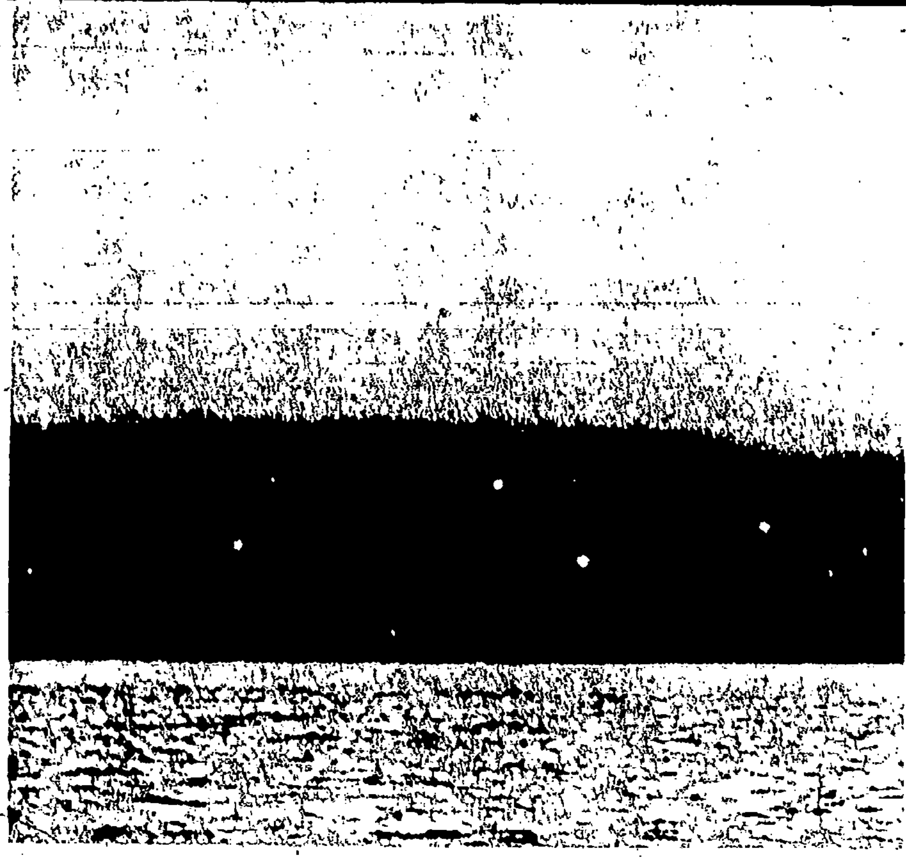


Figure 2-2c Stratus clouds (St)

7. Cloud cover: Estimate how much of the sky is covered by clouds. Use the following symbols to record your data: ○ for clear sky; ◔ for 25% ($\frac{1}{4}$) of the sky covered by clouds; ◑ for 50% ($\frac{1}{2}$) of the sky covered by clouds; ◕ for 75% ($\frac{3}{4}$) cloud cover; ● for complete overcast.
8. Precipitation: The rain gauge on the weather station will keep track of rainfall for you. Rainfall for a given day is the amount of *new* water in the cup since the day before. Snow is also precipitation. Measure the depth of snow at some point where it has not drifted. To determine the rainfall equivalent of snow, divide the number of centimeters of snowfall by 25. (Or, if you measured depth in inches, divide your measurement by 10.)
9. In rows 9, 10, and 11 of the chart, you will add several more items to your data table as you study the remaining chapters.

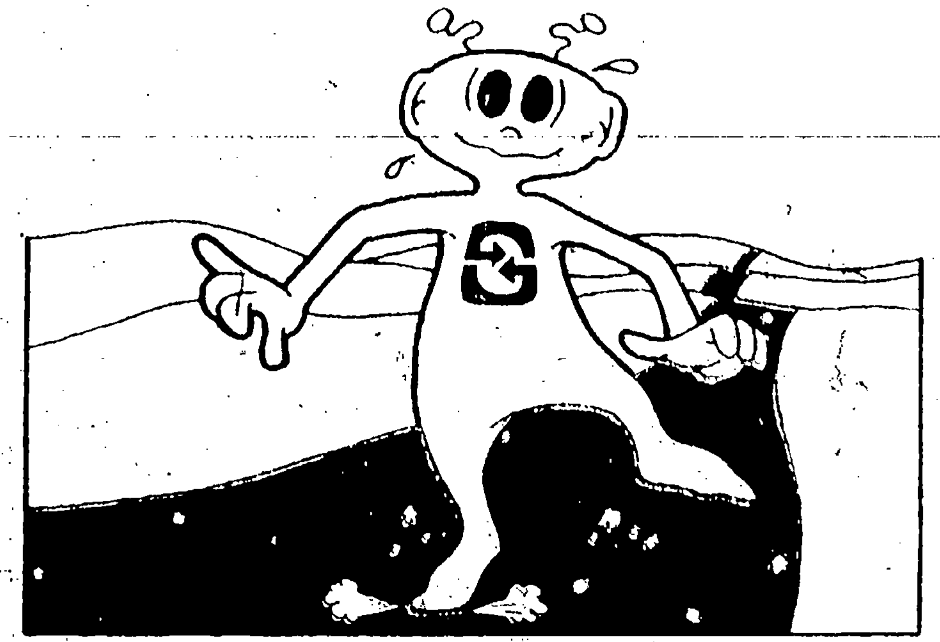
Note *The weather-station instrument is calibrated in the English system. Therefore, you must make frequent conversions (changes) to the metric system.* **Excursion 2-3**, *"The Conversion Excursion," will help you with these changes.*

Remember your weather watch is to continue for four weeks, including weekends if possible.

Before going on, do Self-Evaluation 2 in your Record Book.

Concentrating on Ups

Chapter 3



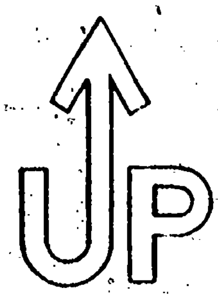
You've learned that different surfaces absorb different amounts of heat from sunlight. All you need do to prove this is to walk around outdoors in the summertime in your bare feet. You'll quickly find that warm and cool spots can exist near each other.

The temperature of the air above the earth's surface is affected by the heat absorbed by the surface. Air above a hot spot is warmed. Air above a cool spot is cooled.

☐**3-1.** What happens to the motion of air as it passes over a hot spot on the earth?

☐**3-2.** What happens to the motion of air as it moves over a cool spot on the earth?

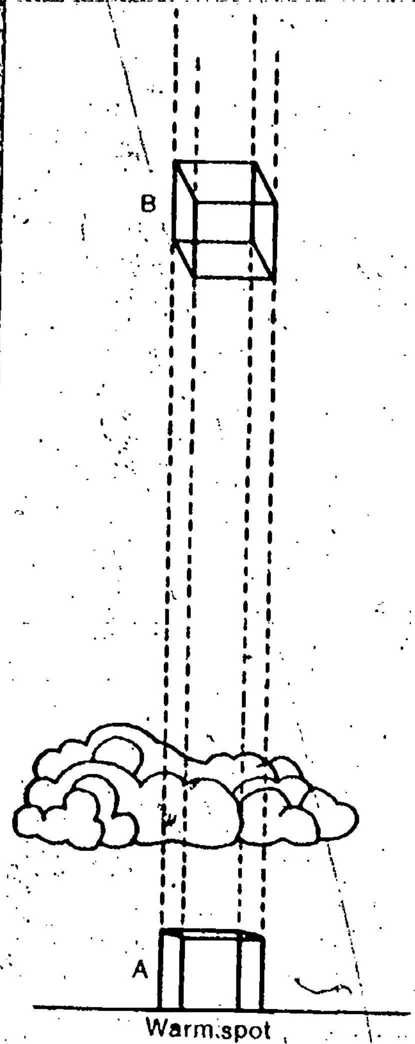
Knowing that air moves up and down over different areas of the earth's surface is a good start in explaining weather changes. However, you need to find out more about how the air is affected by these ups and downs. This is a complicated thing to do. To make your task simpler, concentrate only on the ups for now.



When studying complicated situations, scientists concentrate on only a part of the total situation. This is called using a "systems approach" in investigations.

If you used the ISCS Volume 1 or Volume 2, you've used the systems approach many times before. In using the systems approach, you concentrate only on that part of a complicated situation in which you are interested. That part of the situation is called the system. The rest of the situation can be ignored, except when you want to pay attention to the input to or output from the system. If you wish to examine some ever smaller part of the system, you refer to it as a subsystem.

Figure 3-1 will help you take a systems approach in seeing how air is affected by altitude (height above the earth's surface). The total atmosphere can be thought of as the situation. The vertical column shown represents a column of air extending up from the earth's surface. This column will be the system you will study. Two cubes have been drawn within the column. They represent cubes of air. You can think of them as subsystems of the column of air. Air from outside the column (the system) can flow into the cubes (the subsystems). And air from inside the cubes can flow out of the column.



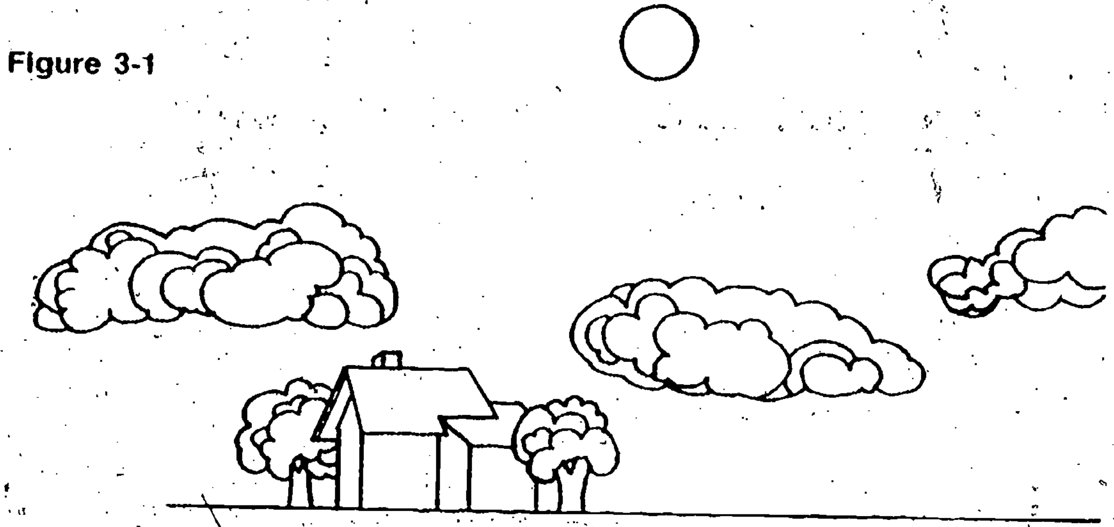


Figure 3-1

Assume that the column of air shown in Figure 3-1 is standing over a warm spot on the earth's surface.

☐ **3-3.** Which cube of air would be warmer?

☐ **3-4.** As air cube A rises, what do you predict will happen to its temperature?

Air is warmed by being near a warm surface. The air closest to the surface is warmed the most. Generally, then, the farther the air is from the earth's surface, the cooler it will be. Thus, cube A in Figure 3-1 should have a higher temperature than cube B.

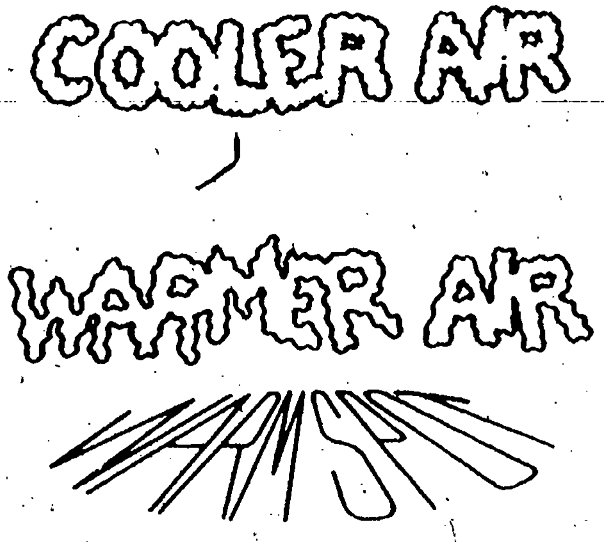


Figure 3-2

PROBLEM BREAK 3-1

Design and conduct an investigation of how air temperature varies with altitude. Record your plan, the data you collect, and the conclusions you reach in your Record Book.

☐**3-5.** According to Figure 3-1, which cube of air has more air above it, A or B?

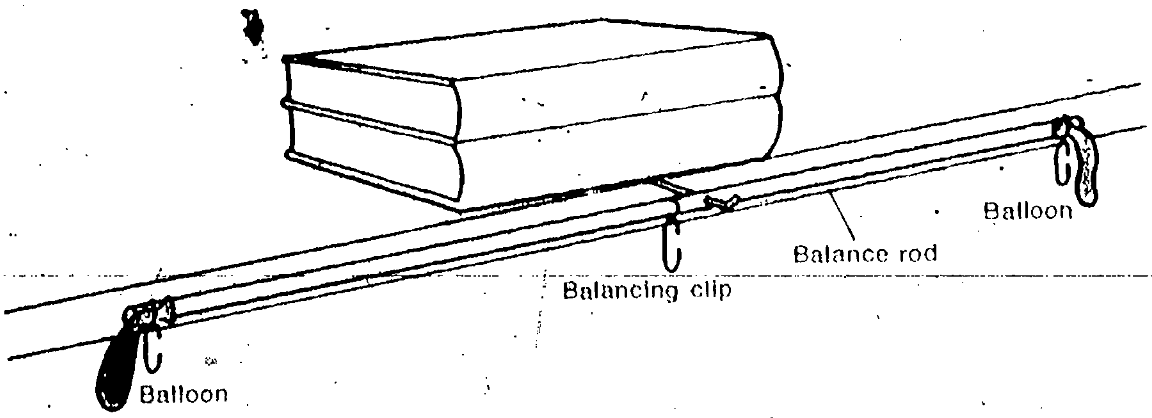
☐**3-6.** Which cube of air would have more weight on it from above?

You may be a bit concerned about question 3-6. In fact you may wonder why such a question was asked. Is it reasonable to think of air as having weight? Try the next activity and find out for yourself.

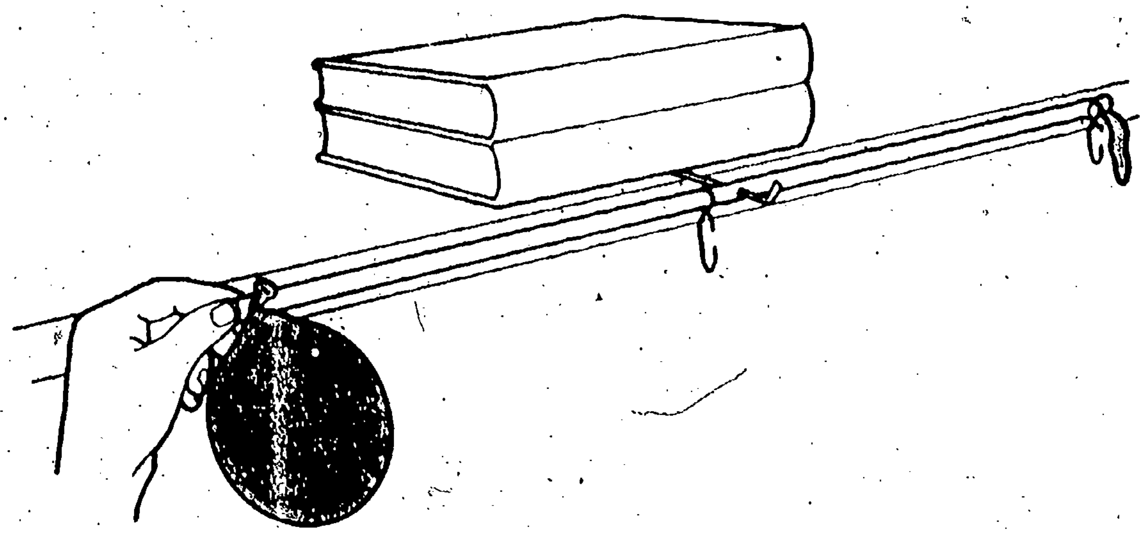
You will need the following materials:

1 balance rod, with 3 balancing clips
1 balance rod wire support
2 balloons of equal size

ACTIVITY 3-1. Fasten the two balloons to the clips as shown. Balance the rod by moving the third clip. (You may have to move it across the wire support.)



ACTIVITY 3-2. Remove one of the balloons, blow it up, and knot the neck. Place the balloon on the table for 5–10 minutes. Then reattach it to the balance arm. Hold the arm level, then gently release it, and observe what happens.



The breath you blew into the balloon is warmer than the room air. That is why you were told to wait a few minutes before comparing its mass. This wait gave it time to cool off a bit.

☐**3-7.** Explain your observation from Activity 3-2.

Now think again about the column of air from Figure 3-1. Every particle of air exerts a downward weight force. All these forces together make the total weight of the column of air.

☐**3-8.** Which cube of air (A or B) has more weight acting on it from above, in Figure 3-1?

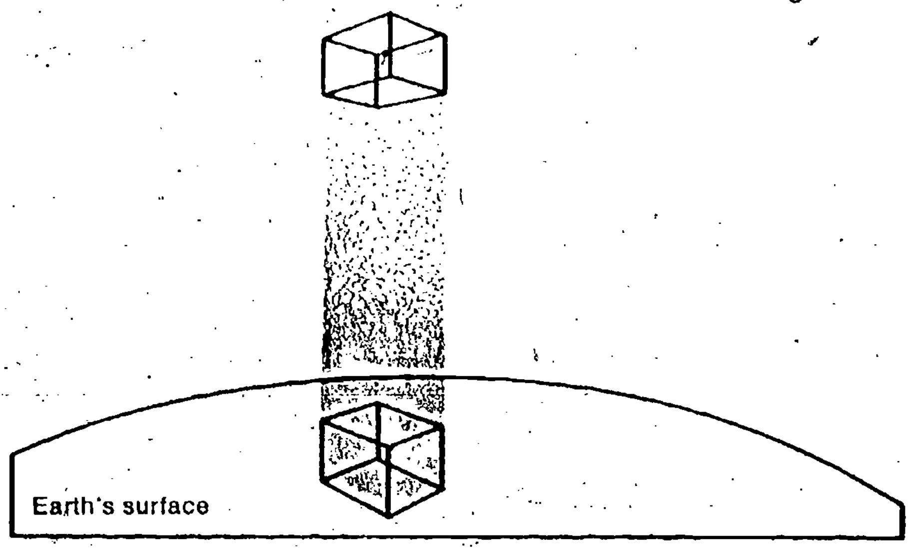
Your answer to question 3-8 should have been "cube A." This is also the answer to the earlier question 3-6.

The total weight of a column of air on imaginary cube A results in the air pressure on that cube.

☐**3-9.** How does the air pressure on cube B compare with the air pressure on cube A?

Figure 3-3 suggests how particles in a column of air might be expected to look.

Figure 3-3



You may want to check your understanding of the term *pressure*. If so, turn to **Excursion 3-1**.

EXCURSION

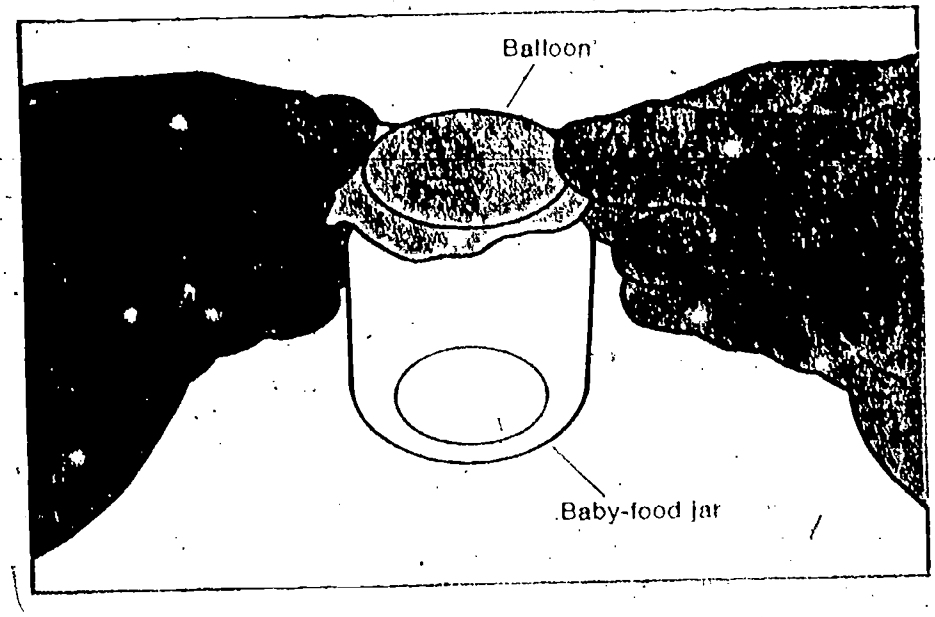
By now you should expect that air pressure will decrease as altitude increases. But you may wonder if air pressure can vary at the same altitude. For example, does atmospheric pressure vary right at the earth's surface?

To answer this question, you need some way of measuring atmospheric pressure. The next activities will show you how to make such a device and how it works.

You need a partner and the following materials:

1 balloon
1 baby-food jar (must be large size)
1 rubber band

ACTIVITY 3-3. **Cut the end off the balloon and stretch it over the mouth of the jar. Be sure the rubber balloon is stretched taut. Then have your partner fasten it in place using the rubber band. The band will have to be doubled once or more to make a tight seal. This seal is very important.**



What you have just made is the basic part of an atmospheric pressure measurer. Before finishing it, however, let's use the particle model, to explain how it should work.

Air is both inside and outside the jar. The particle model (discussed in ISCS Volume I) says that the air particles are in motion (Figure 3-4). They are bouncing against the inside and outside of the rubber cover.

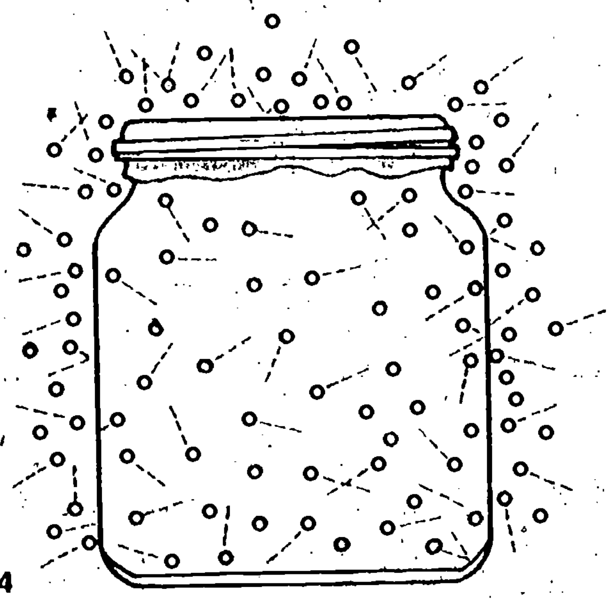
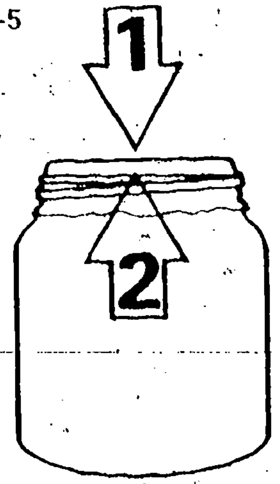


Figure 3-4

If the jar is tightly sealed, no more air particles can enter or leave the jar. The top of the balloon is flat (not bulging in or out.) Therefore, the pressure of the moving air particles against the top of the balloon is balanced by the pressure of the moving air particles inside the jar. This is diagrammed in Figure 3-5, with arrows representing forces. Force 1 is equal to Force 2.

Figure 3-5



If the particles inside the jar exerted more pressure on the rubber covering than the particles outside, the covering would bulge upward (Figure 3-6). In that case, Force 2 would be greater than Force 1.

Figure 3-6

☐**3-10.** What would happen to the rubber covering if the forces (pressure) outside were greater than the pressure inside? (Show your answer by completing the drawing in Figure 3-7 in your Record Book.)

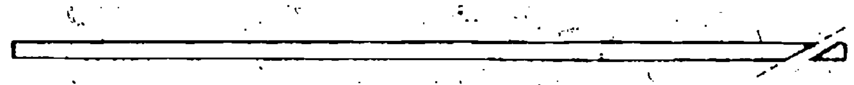
Figure 3-7

The flexible rubber covering allows the volume of the air inside the jar to change. When the air pressure outside the jar increases, the rubber balloon bulges in. When the air pressure outside is lower than it is inside, the rubber bulges out.

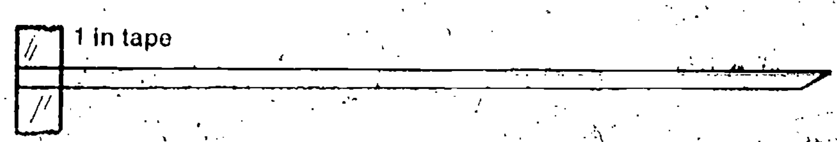
You can add some additional parts to the jar that will make it possible to measure very small changes in the movement of the rubber cover. To do so, you will need the following materials:

1 plastic straw	1 small baby-food jar
1 tongue depressor	Plastic tape
4 rubber bands	Scissors or knife

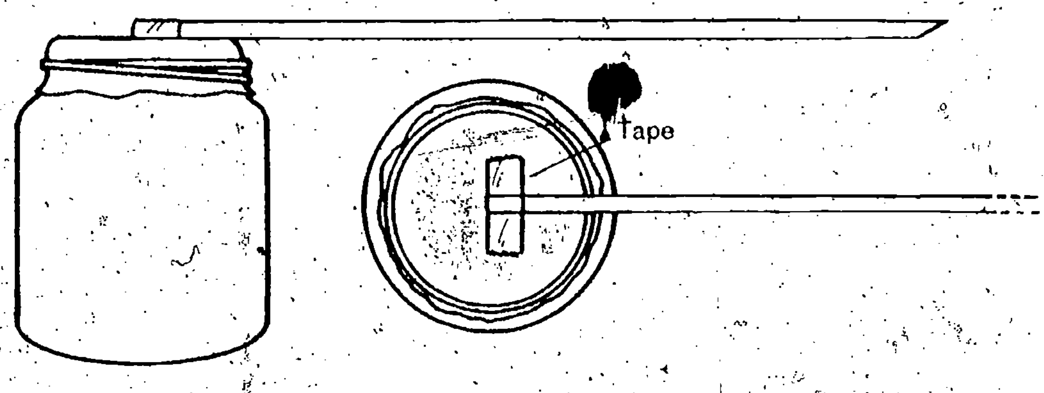
ACTIVITY 3-4. Cut one end of the straw at an angle to make it pointed.



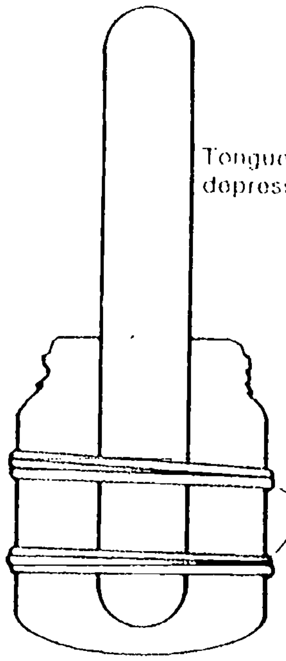
ACTIVITY 3-5. Gently place a one-inch strip of plastic tape on the uncut end of the straw as shown.



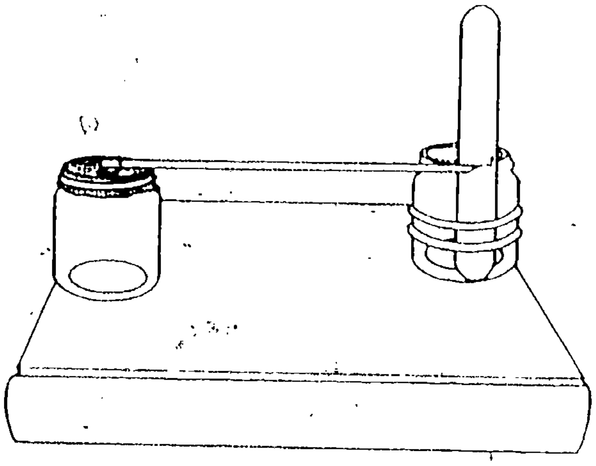
ACTIVITY 3-6. Tape the uncut end of the straw to the center of the balloon as shown. Run your finger nail along the tape on each side of the straw so that it is held tightly to the balloon, both in the center and at the edge of the jar.



ACTIVITY 3-7. Attach a tongue depressor to the second jar as shown.



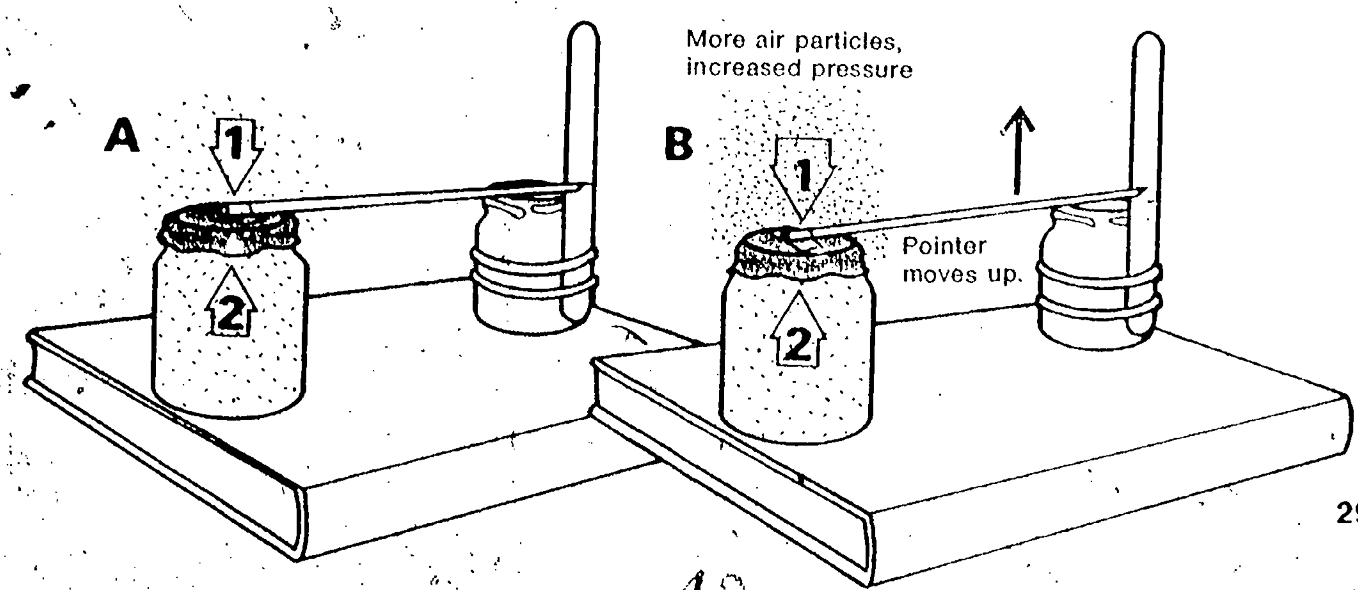
ACTIVITY 3-8. Place the two jars side by side on a level support (such as a large book) so that the pointed straw is in front of the tongue depressor. Mark a short line on the depressor at the point of the straw and label it 0 to show the starting position.



With the tongue depressor's scale in place, your atmospheric pressure measurer is complete. Let's see how it works. Figure 3-8 should help you see this.

When the air pressure is equal inside and outside the jar, the pointer remains at zero (Figure 3-8a). When there is an increase in air pressure outside the jar, the cover is forced down. This moves the pointer up (Figure 3-8b).

Figure 3-8



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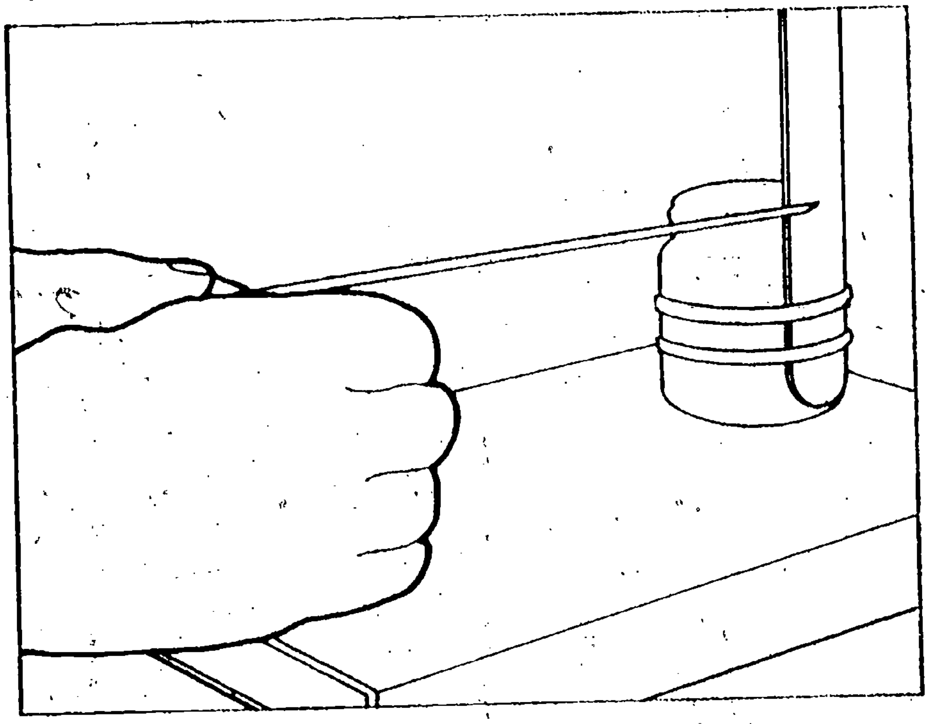
☐3-11. How will the pointer move if the air pressure outside the jar is less than that inside the jar?

☐3-12. Give an operational definition of atmospheric pressure.

If you understand how your instrument works, you should expect the pointer to move down from zero on the scale if the air pressure decreases. The pointer should move up from zero if the air pressure increases.

The measuring device you've made is called a *barometer*. It can be used to measure atmospheric pressure (air pressure.) However, its use is somewhat limited.

ACTIVITY 3-9. Zero the pointer. Then hold your hands on the sides of the jar for several minutes without moving it. Note what happens to the pointer's position.



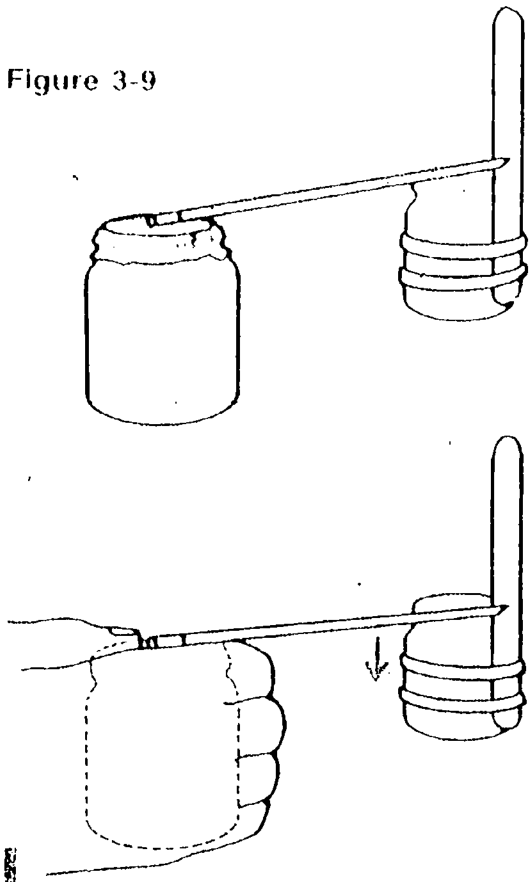
☐3-13. Did the pointer move? If so, in which direction?

☐3-14. Did putting your hands on the jar have the same effect on the pointer as a change in air pressure?

☐3-15. What kind of air pressure change would produce the same result as your hands did? (An increase, or a decrease, in pressure?)

Putting your hands on the balloon jar didn't change the pressure of the atmosphere. But it did change the pressure of the air inside the jar. How can this be? Well, you know that your hands are warm. If they warmed the jar, the air inside would become warmer, too. Then, according to the Volume I particle model, the air particles would move faster. This increased motion would cause the particles to hit the cover and walls harder. The flexible rubber on top of the jar would then bulge out and the pointer would move down (Figure 3-9).

Figure 3-9



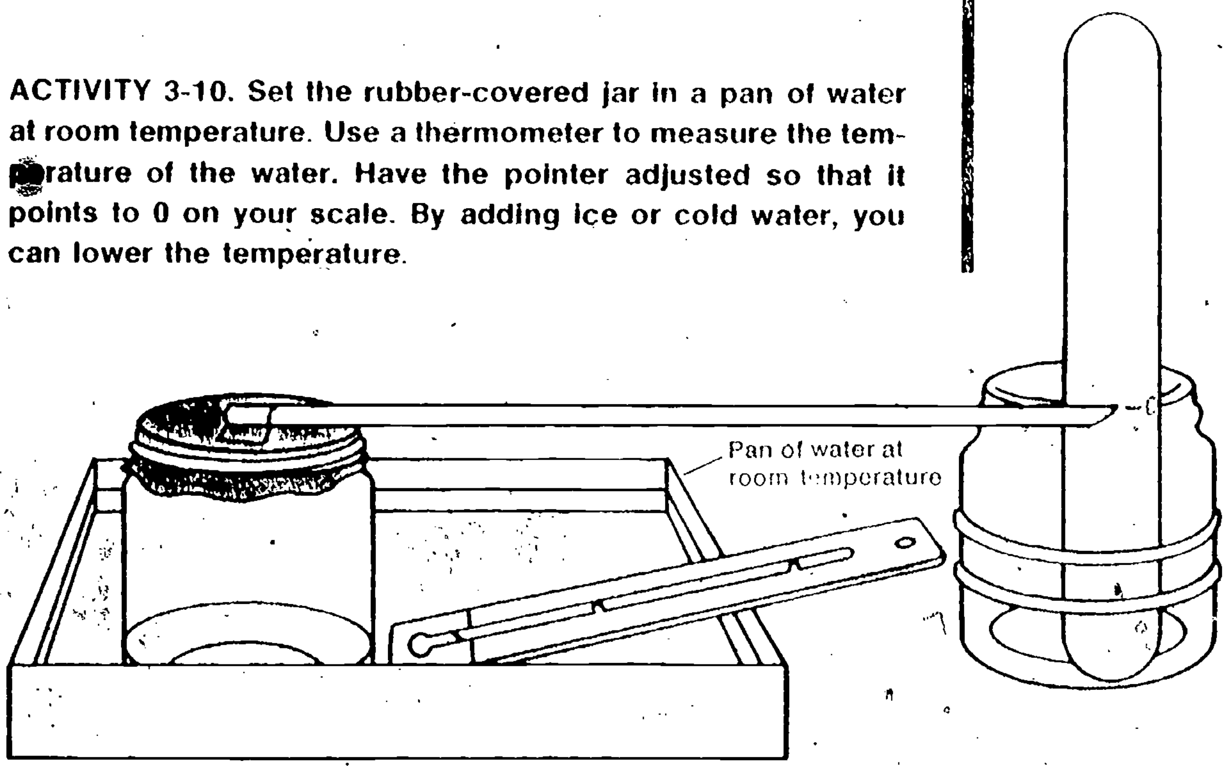
Your barometer reacts to temperature changes as well as to pressure changes.

☐3-16. What effect do you predict decreasing the temperature inside the jar would have on the movement of the pointer from a zeroed position?

PROBLEM BREAK 3-2

Find out how decreasing the temperature of the air in the jar affects the pointer position of the measurer. Activity 3-10 suggests one way to go about this.

ACTIVITY 3-10. Set the rubber-covered jar in a pan of water at room temperature. Use a thermometer to measure the temperature of the water. Have the pointer adjusted so that it points to 0 on your scale. By adding ice or cold water, you can lower the temperature.



14

☐**3-17.** How is the pointer position affected when the temperature of the jar's air is decreased?

The accuracy of your atmospheric pressure measurer depends on the temperature of its surroundings. This of course limits its usefulness. It cannot be used effectively to compare air pressure at places where temperatures are different.

However, it can be used to measure pressure changes if positioned where the air temperature remains about the same. Of course, the measurer must be zeroed while at that location.

You can use your barometer to collect weather-watch data. However, it must first have a calibrated scale. This scale can be made by using a standard barometer. There is one in your classroom. It probably looks like the barometer shown in Figure 3-10.

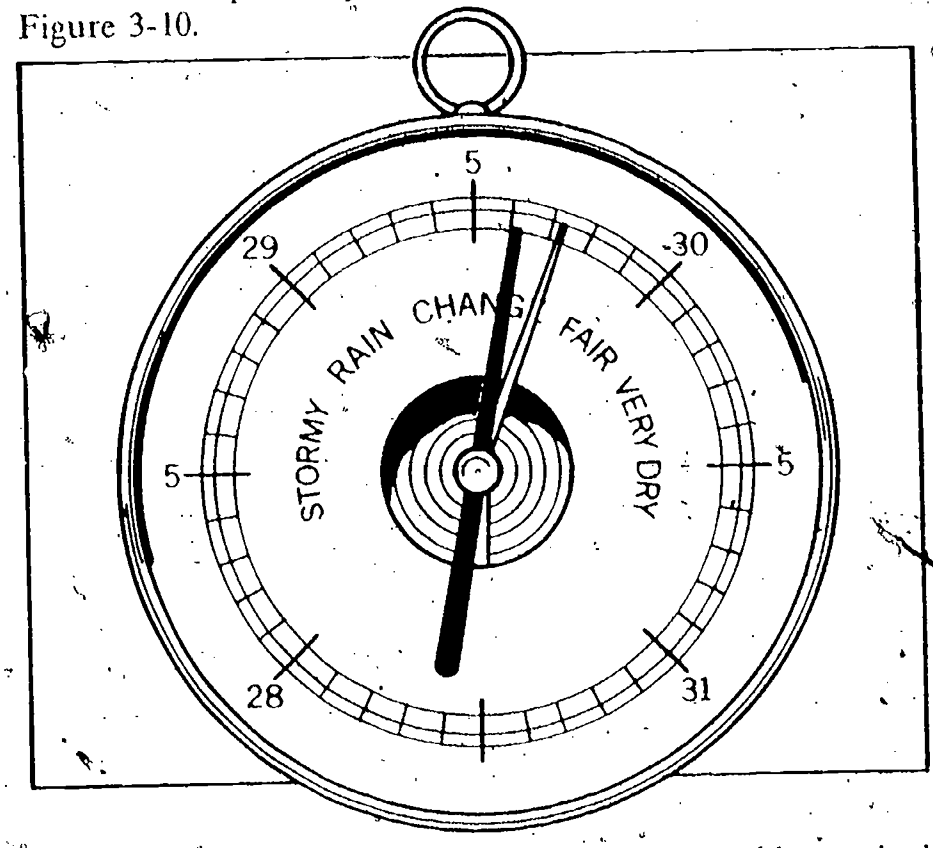


Figure 3-10

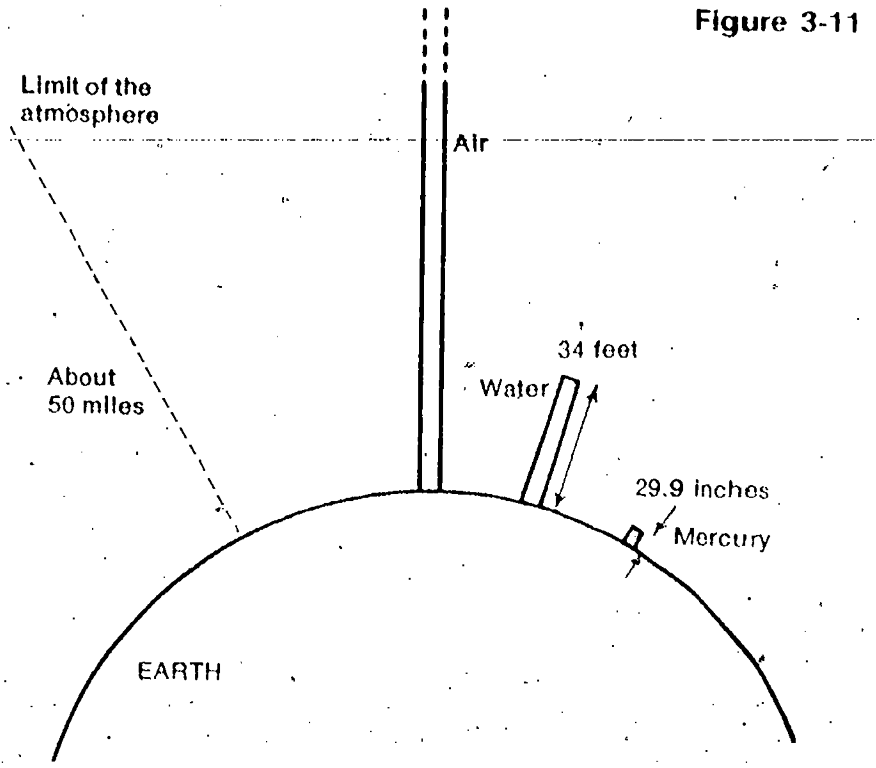
The scale on your room barometer is probably marked in units of length—like inches or millimeters (Figure 3-10). Let us see why pressure is measured in inches, or perhaps millimeters.

Scientists have compared air pressure with the pressure exerted by liquids. They have found the following relationship:

A column of air extending from sea level out to the limit of the earth's atmosphere has the same weight as (a) a 34-foot column of water (with the same diameter as the air column) and as (b) a 29.9-inch column of the liquid mercury (also with the same diameter).

Figure 3-11 illustrates this finding.

Figure 3-11



This relationship means that air pressure can be compared with the pressure exerted by a column of liquid such as mercury or water. Normal air pressure at sea level is equal to the pressure exerted by 29.9 inches of mercury.

☐**3-18.** Use the room barometer to determine the air pressure where you are.

☐**3-19.** Would you expect the barometer reading on a mountain top to be different from that at sea level? Explain your answer.

A bit more information on liquid columns and air pressure can be found in **Excursion 3-2.** Have a look if you're interested. It will help you understand how your classroom barometer works, too.

EXCURSION

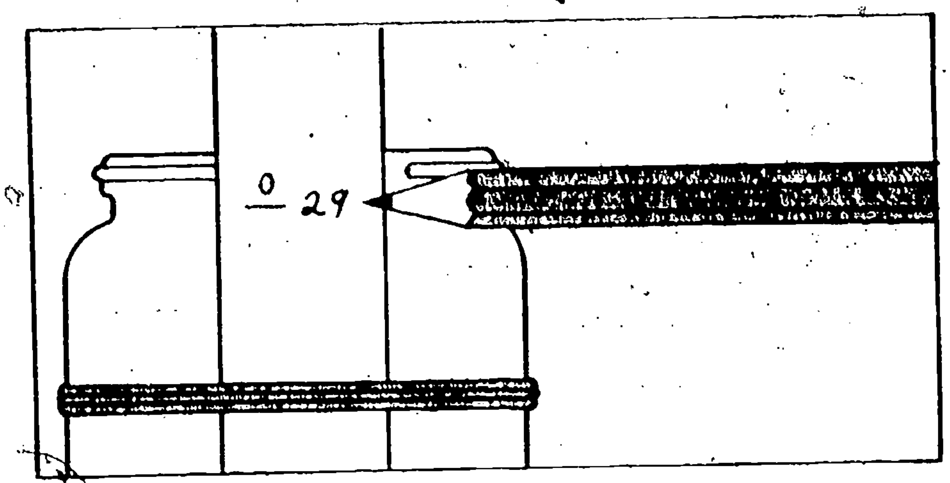
As you continue keeping your weather watch, use the room barometer. To get pressure measures, also do Problem Break 3-3 to get a scale for your own jar barometer.

PROBLEM BREAK 3-3

Ask your teacher where you should set up your jar barometer.

Then zero it in that location. Use the room barometer to get the atmospheric pressure in inches.

ACTIVITY 3-11. Alongside the zero mark, write the pressure you got from the room barometer.



Each day, you can add new marks and numbers to the scale; that is, if the atmospheric pressure really does change in your room!

SUMMING UP

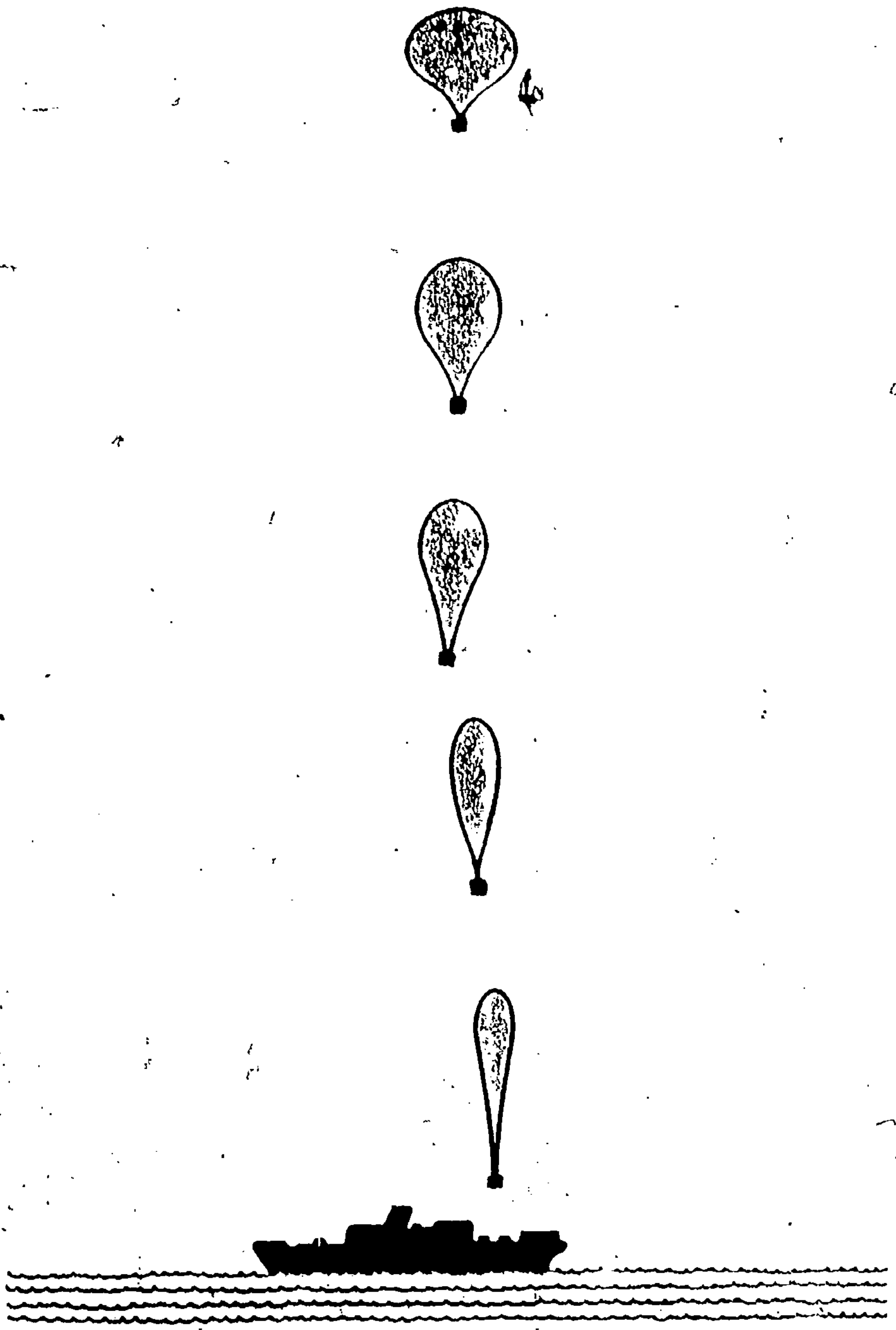
This chapter has taken you beyond the facts that warmer air rises and cooler air falls. You have learned the following:

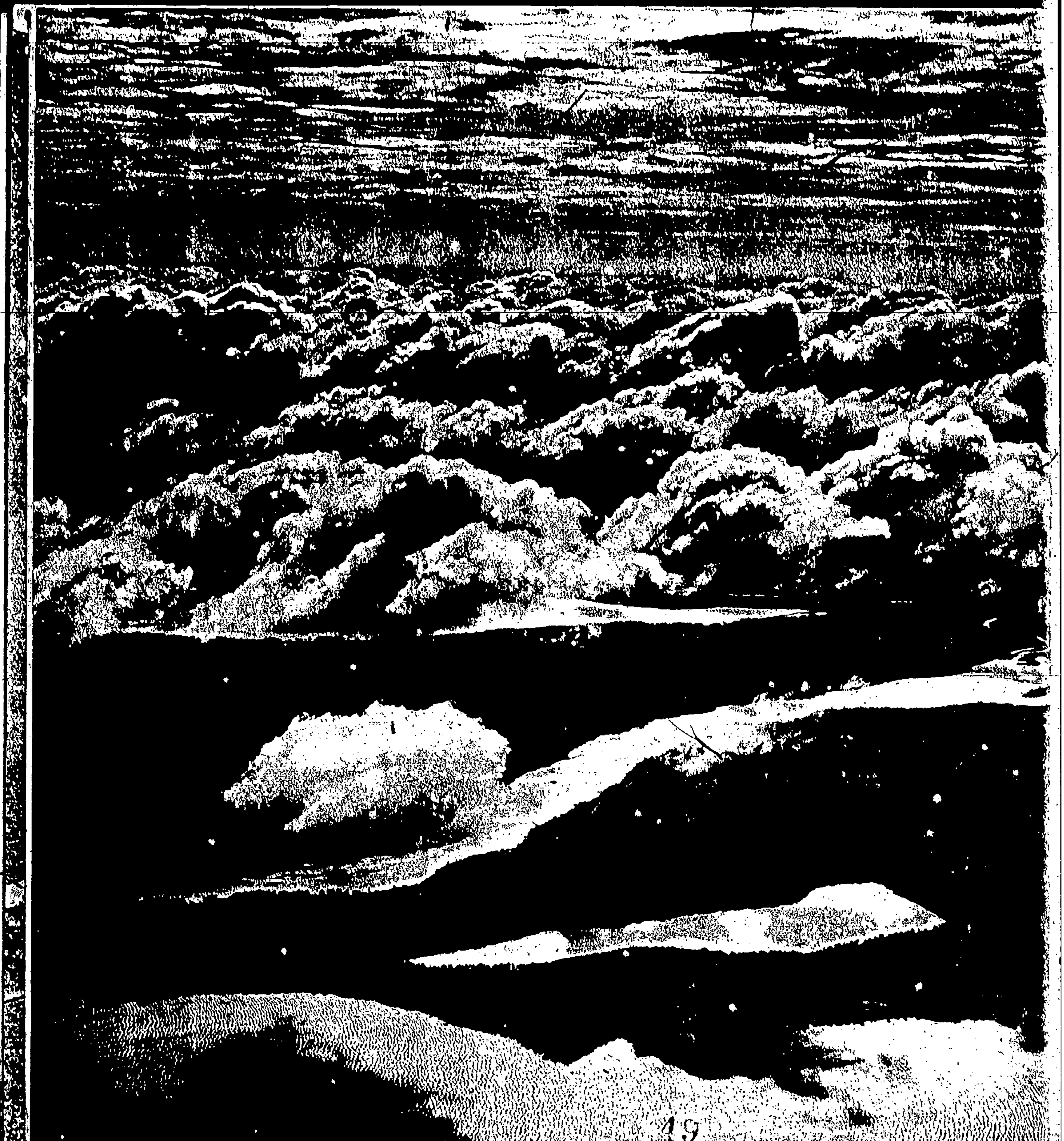
1. As air rises from the earth's surface, the air gets cooler.
2. Air has weight and exerts pressure.
3. The number of air particles decreases with increasing altitude.

4. As air rises, the pressure on it from the air above decreases.
5. Air pressure can and does vary on the earth's surface.

These facts will be very important to your further study of air and weather.

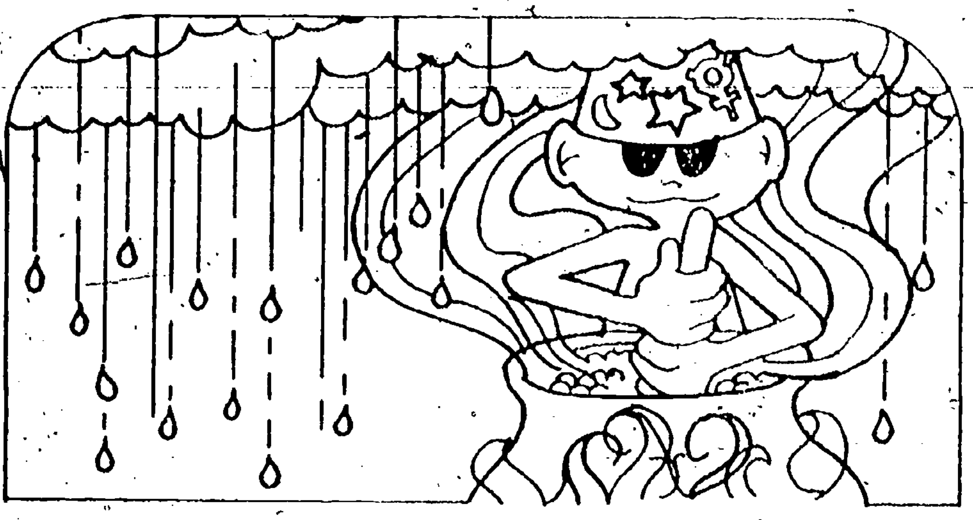
Before going on, do Self-Evaluation 3 in your Record Book.





Making Visible the Invisible

Chapter 4



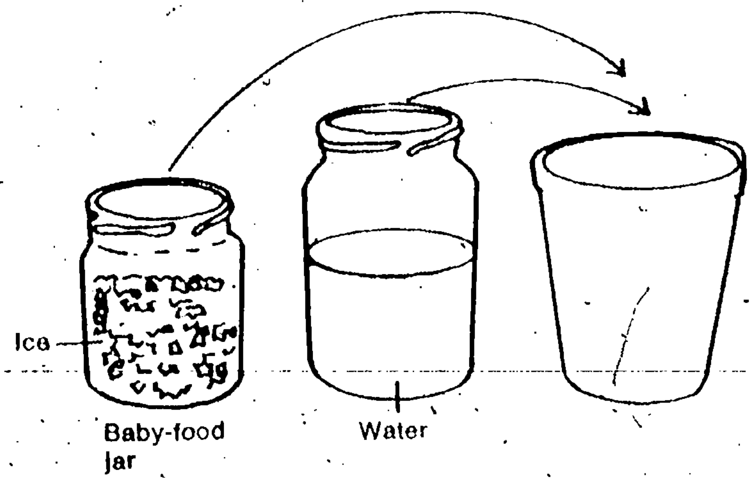
It's no secret to most people that clouds are made of water. We've all seen water falling from the sky. And almost every time this happens, there are clouds up there. Most folks also know that the water in clouds evaporated from the earth's surface. Sunlight on lakes, ponds, rivers, and oceans changes liquid water to water vapor. Trees and other plants release some of the moisture in their leaves to the air, too.

But what most people don't know is why the clouds form, and why they usually form so far above the earth's surface. Perhaps you know the answers, or think you do. Whether you do or not, you should test your ideas with the activities in this chapter and the next.

First, you need to investigate the effect of temperature on the amount of water vapor in air. You and a partner will need the following equipment:

- 1 small baby-food jar of crushed ice
- 1 large baby-food jar half full of water at room temperature
- 1 thermometer
- Aluminum can (or clear plastic cup)

ACTIVITY 4-1. Add ice and water to the can until it is $\frac{2}{3}$ full. Observe what happens on the outside of the container.



☐**4-1.** What did you observe happening on the outside of the container after you added the ice and water?

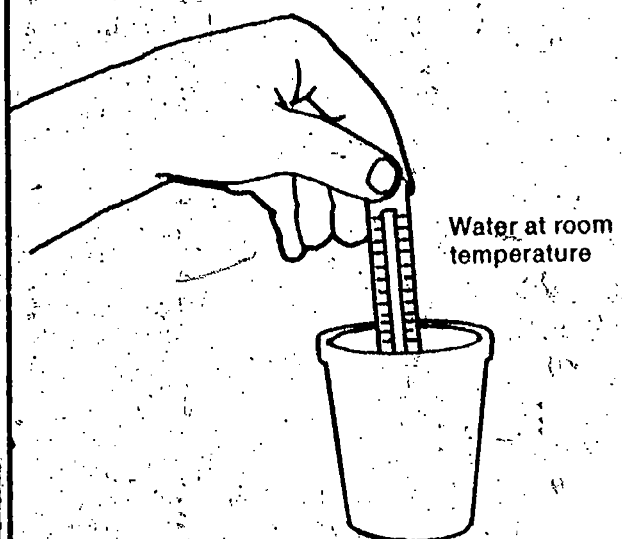
☐**4-2.** Explain your observation in question 4-1.

☐**4-3.** Have you seen this sort of thing happen in other situations? If so, describe them.

You should have found that a film of water formed on the outside of the can.

☐**4-4.** Where did the water droplets that formed on the outside of the container come from?

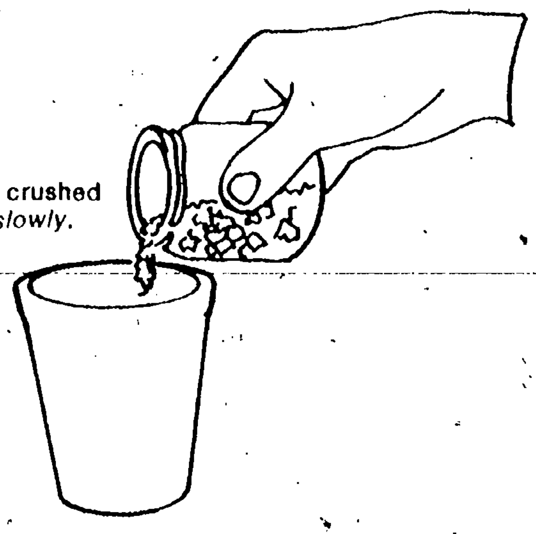
The ice water lowered the temperature of the container. This caused a film of water to form on its outside. But is there a certain temperature at which the moisture first appears? Try to find out by using the equipment you already have. Before you begin, empty the container. Dry it, and allow it to return to room temperature.



ACTIVITY 4-2. When the container has returned to room temperature, fill it $\frac{2}{3}$ full of water at room temperature. Place the thermometer in the water. Record the thermometer reading in Table 4-1 in your Record Book.

☐**4-5.** Does moisture appear on the outside of the container when it is at room temperature?

ACTIVITY 4-3. Add crushed ice to the water in the can, a little at a time. After each addition, stir the water with the thermometer. At the moment the water film first appears on the container, read the temperature.



Note: *Do not breathe on the can while you are observing the thermometer.*

Keep adding small amounts of ice until the moisture forms. Record that temperature in Table 4-1 for Trial 1.

Repeat the activity to get readings for a second and third trial. Record the data. Be sure your water is at room temperature when you begin each trial. If you have ice left over, return it to your teacher, or give it to other students who need it.

Table 4-1

Trial	Room Temp. (°C)	Temperature When Film of Moisture Forms (°C)
1		
2		
3		
Average		

☐ 4-6. What was the average temperature at which the film of water formed?

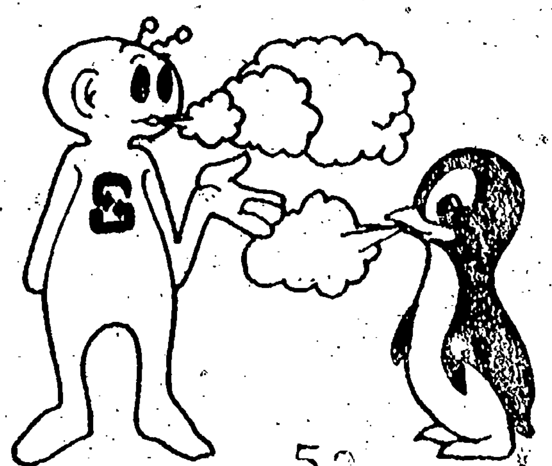
By now perhaps you've figured out that the water which appeared on the can came from the air in your classroom. Water vapor is an invisible gas just like the air. It became visible only when it collected on the surface of the cold container. This changing of the gaseous water to liquid water is called *condensation*. Tiny water droplets form when the air temperature is lowered to some very definite point (called the *dew point*). At that temperature, the air can no longer hold all its moisture. The invisible water vapor from the air then becomes visible as tiny droplets form. The droplets formed on the container because it was much colder than its surroundings. The air near it was colder than the rest of the air in the room.

☐ 4-7. Suppose the temperature of the container had been below freezing. What would you expect to happen to the water in the gaseous form, warm air or cold air?

You can check your answer to this last question by putting a small dry can in the freezing compartment of your home refrigerator.

☐ 4-8. According to your investigation, which will hold more water in the gaseous form, warm air or cold air?

Obviously, clouds aren't invisible. You can see them. This means to make a cloud, you must make invisible water visible. You have just seen one way to make the invisible visible—lower the temperature of the air. You saw water droplets form on the cold surface of the cup.

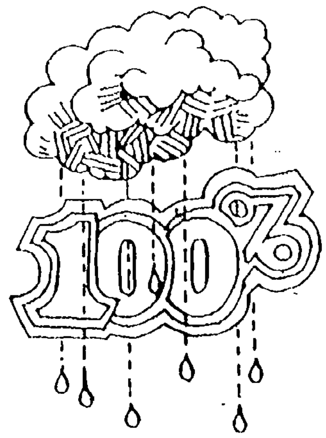


Before you investigate another way to make water vapor visible, you should learn a bit more about water vapor.

You have learned that there is a limit to the amount of water vapor that air can hold. This limit depends upon the temperature of the air. Warm air can hold more water vapor than cold air can hold. You saw what happens when warm moist air is cooled. At a certain temperature (the dew point), the cooling air contains all the moisture it is able to hold at that temperature. If it is cooled below the dew point, some vapor must condense as water droplets.

Meteorologists (weather forecasters) measure the amount of water vapor present in air. They call this measure the *relative humidity*. The measure is actually a comparison. It compares the amount of water vapor in air at some temperature with the greatest amount that could be in the air at that same temperature.

Relative humidity is defined by this formula:



$$\text{Relative humidity} = \frac{\text{Amount of water vapor in air at certain temp.}}{\text{Greatest amount of water vapor possible in air at that temp.}} \times 100\%$$

Suppose the relative humidity of air is 75%. This means that the air contains 75% of the water vapor that it is possible for it to contain at that temperature.

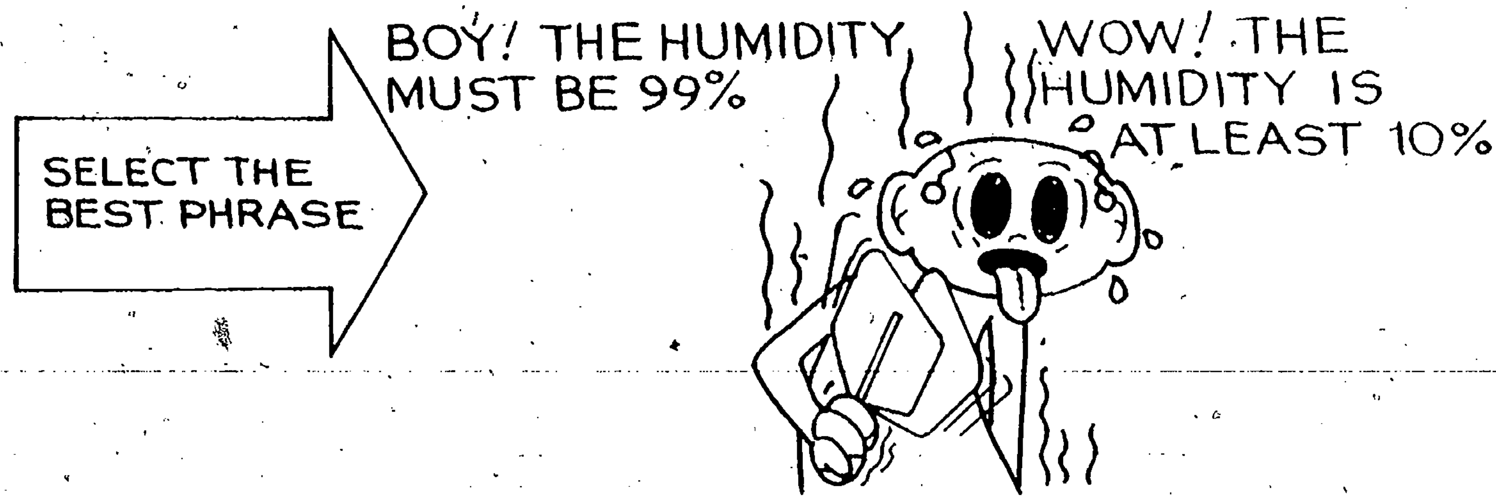
For example, suppose 1,000 milliliters of air at 20° C could contain 20 milligrams of water vapor. The relative humidity is 75% if the air *actually contains* 75% of 20 milligrams (that is, 15 milligrams) of water in each 1,000 milliliters.

The figures in that example are given below to show how the formula is used:

$$\text{Relative humidity} = \frac{15 \text{ milligrams}}{20 \text{ milligrams}} \times 100\% = .75 \times 100\% = 75\%$$

☐**4-9.** What does it mean to say "the relative humidity is 50%"?

☐**4-10.** Suppose 1,000 ml of air contains 10 mg of water vapor. At this temperature, the same volume of air could contain 50 mg of water. What is the relative humidity of the air?

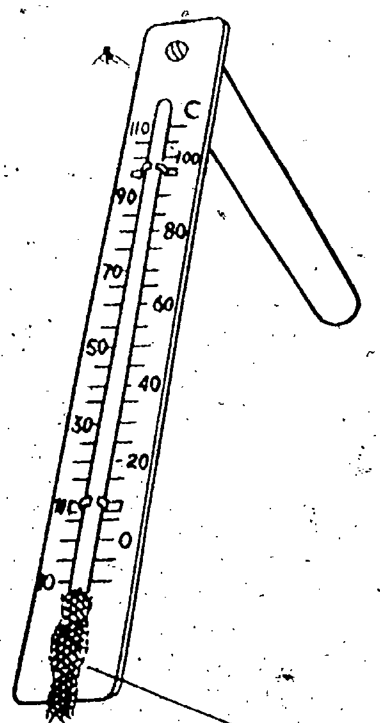


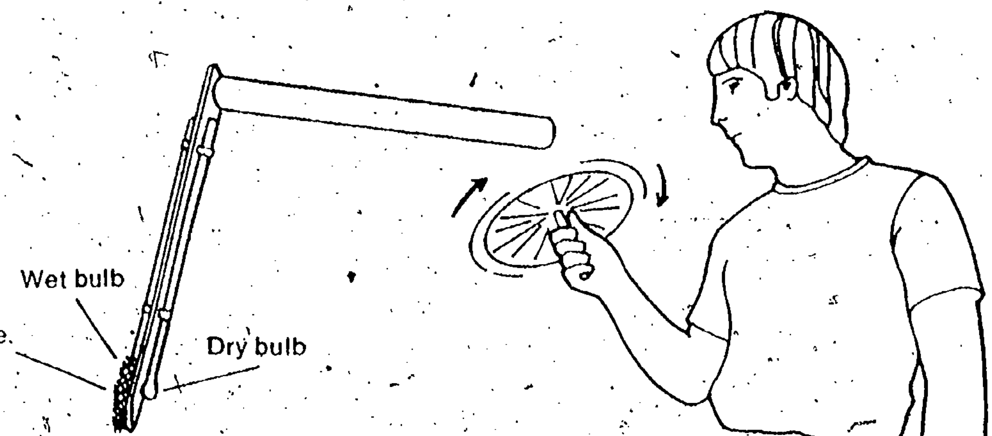
Humidity

In view of the importance of the water vapor content of the air (*humidity*), it would be well to include measurements of this quantity in your weather-watch chart. To do this, you must learn how to get the data you will need.

You will use a sling psychrometer. Activity 4-4 shows what it is and tells you how it is used.

ACTIVITY 4-4. Wet the wick with room-temperature water. Swing the psychrometer around for 15 seconds. *Be careful not to hit anything.* Note the temperatures of the dry bulb and the wet bulb. Whirl it for another 15 seconds. Note the temperatures again. When the wet-bulb temperature reaches its lowest value, record both the wet- and dry-bulb temperatures.





☐**4-11.** Record the two temperatures from Activity 4-4: wet-bulb and dry-bulb.

☐**4-12.** What is the difference in degrees between the wet-bulb and dry-bulb?

To determine the relative humidity, you will need to use Table 4-2. First, find the dry-bulb temperature you measured. (It is in the first column of the table.) That locates the row where you will find the relative humidity.

Move your finger across to the right, until you come to the column that has the value you found (difference between wet- and dry-bulb temperatures). The figure in the box is the relative humidity (expressed in percent). (See Figure 4-1 for a sample of this procedure.)

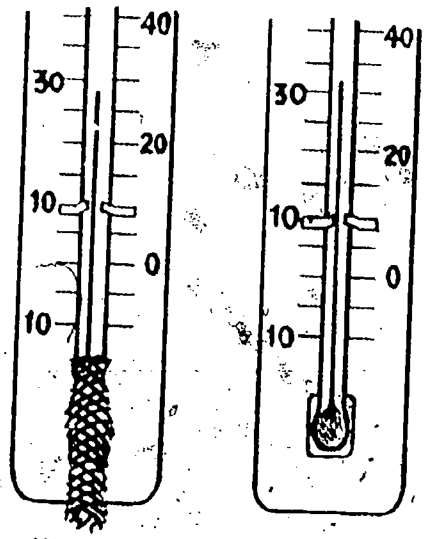


Figure 4-1

Dry-Bulb Temp (°C)	Difference between Wet- and Dry-Bulb Temp. (°C)							
	1°	2°	3°	4°	5°	6°	7°	8°
30	93	86	79	73	67	61	55	50
31	93	86	80	73	67	61	56	51
32	93	86	80	(74)	68	62	57	51
33	93	87	80	74	68	63	57	52
34	93	87	81	75	69	63	58	53

Relative humidity = 74%

Table 4-2

Dry-Bulb Temp. (°C)	Relative Humidity (%)																			
	Difference Between Wet- and Dry-Bulb Temp. (°C)																			
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°
−10	67	35																		
−9	69	39	9																	
−8	71	43	15																	
−7	73	48	20																	
−6	74	49	25																	
−5	76	52	29	7																
−4	77	55	33	12																
−3	78	57	37	17																
−2	79	60	40	22																
−1	81	62	43	26	8															
0	81	64	46	29	13															
1	83	66	49	33	17															
2	84	68	52	37	22	7														
3	84	70	55	40	26	12														
4	85	71	57	43	29	16														
5	86	72	58	45	33	20	7													
6	86	73	60	48	35	24	11													
7	87	74	62	50	38	26	15													
8	87	75	63	51	40	29	19	8												
9	88	76	64	53	42	32	22	12												
10	88	77	66	55	44	34	24	15	6											
11	89	78	67	56	46	36	27	18	9											
12	89	78	68	58	48	39	29	21	12											
13	89	79	69	59	50	41	32	23	15	7										
14	90	79	70	60	51	42	34	26	18	10										
15	90	80	71	61	53	44	36	27	20	13	6									
16	90	81	71	63	54	46	38	30	23	15	8									
17	90	81	72	64	55	47	40	32	25	18	11									
18	91	82	73	65	57	49	41	34	27	20	14	7								
19	91	82	74	65	58	50	43	36	29	22	16	10								
20	91	83	74	66	59	51	44	37	31	24	18	12	6							
21	91	83	75	67	60	53	46	39	32	26	20	14	9							
22	92	83	76	68	61	54	47	40	34	28	22	17	11	6						
23	92	84	76	69	62	55	48	42	36	30	24	19	13	8						
24	92	84	77	69	62	56	49	43	37	31	26	20	15	10	5					
25	92	84	77	70	63	57	50	44	39	33	28	22	17	12	8					
26	92	85	78	71	64	58	51	46	40	34	29	24	19	14	10	5				
27	92	85	78	71	65	58	52	47	41	36	31	26	21	16	12	7				
28	93	85	78	72	65	59	53	48	42	37	32	27	22	18	13	9	5			
29	93	86	79	72	66	60	54	49	43	38	33	28	24	19	15	11	7			
30	93	86	79	73	67	61	55	50	44	39	35	30	25	21	17	13	9	5		
31	93	86	80	73	67	61	56	51	45	40	36	31	27	22	18	14	11	7		
32	93	86	80	74	68	62	57	51	46	41	37	32	28	24	20	16	12	9	5	
33	93	87	80	74	68	63	57	52	47	42	38	33	29	25	21	17	14	10	7	
34	93	87	81	75	69	63	58	53	48	43	39	35	30	28	23	19	15	12	8	5
35	94	87	81	75	69	64	59	54	49	44	40	36	32	28	24	20	17	13	10	7

□4-13. Write an operational definition of relative humidity. (How do you detect and measure it?)

□4-14. What is today's relative humidity?

Back to the dew point

Dew point was defined earlier as the temperature at which air could no longer hold its moisture. At that temperature, water vapor from the air collects on a surface as a liquid (dew) or solid (frost). Remember that warm air can hold more moisture than cold air can. Dew point can be determined from a chart similar to the one you used for relative humidity (see Table 4-3).

Refer to the relative-humidity chart (Table 4-2) and the dew-point chart (Table 4-3) as you answer questions 4-15 and 4-16.

□4-15. What would the relative humidity be when the wet- and dry-bulb temperatures are the same?

□4-16. What would the dew-point temperature be when the wet- and dry-bulb temperatures are the same?

□4-17. Give an operational definition of dew point.

You may wonder why you have to swing the psychrometer to measure humidity and dew point. If so, you should turn to **Excursion 4-1,** "The Shivering Thermometer."

EXCURSION

Up until now, you have not been able to fill in the dew-point or the relative-humidity readings in your weather-watch chart. From now on, record daily readings of the relative humidity and the dew point.

You started this chapter trying to explain why clouds form as they do. You've learned that cooling air can cause the water vapor it contains to condense. However, you haven't really seen any clouds form during your activities. The only condensing you have seen has taken place on a solid surface.

This suggests that water vapor must have some kind of solid surface on which to form liquid droplets. How then can clouds form? Are there such surfaces high in the air?

Table 4-3

Dry-Bulb Temp. (°C)	Dew-Point Temperature (°C)																			
	Difference Between Wet- and Dry-Bulb Temp. (°C)																			
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°
−20	−23	−31																		
−15	−18	−23	−31																	
−10	−12	−14	−17	−23																
−9	−11	−13	−17	−21																
−8	−10	−12	−15	−19																
−7	−9	−11	−13	−17	−20															
−6	−8	−10	−12	−15	−20															
−5	−6	−7	−8	−12	−15	−19	−24	−26												
−4	−5	−7	−8	−11	−14	−17	−22	−25												
−3	−4	−6	−7	−9	−12	−15	−20	−23												
−2	−3	−4	−6	−8	−11	−13	−17	−21												
−1	−2	−4	−5	−7	−9	−12	−16	−18												
0	−1	−3	−4	−6	−7	−10	−13	−17	−20											
1	1	−1	−2	−4	−6	−8	−11	−14	−19	−24										
2	1	−1	−2	−3	−5	−7	−9	−12	−16	−21										
3	2	1	−1	−2	−4	−6	−7	−9	−13	−18										
4	3	2	1	−1	−3	−4	−6	−8	−11	−14	−19	−26								
5	4	3	1	0	−2	−3	−5	−7	−9	−12	−16	−20								
6	5	4	2	1	−1	−2	−3	−6	−8	−9	−12	−16								
7	6	5	3	2	1	−1	−2	−4	−6	−8	−11	−14	−20	−26						
8	7	6	4	3	2	1	−1	−3	−5	−7	−9	−11	−16	−19						
9	8	7	6	4	3	2	0	−2	−3	−5	−7	−9	−13	−16						
10	9	8	7	6	4	3	1	0	−2	−3	−6	−8	−11	−13	−19	−25				
11	10	9	8	7	6	4	3	2	0	−2	−4	−6	−8	−10	−14	−19				
12	12	11	10	9	7	6	4	3	2	1	−1	−3	−5	−7	−10	−13	−19	−24		
13	12	12	11	9	8	7	6	4	3	2	0	−2	−3	−5	−7	−11	−16	−21		
14	13	13	12	11	9	8	7	6	4	3	1	−1	−2	−3	−6	−8	−13	−17		
15	14	14	13	12	11	9	8	7	6	4	3	2	0	−2	−4	−6	−9	−12	−17	−22
16	15	14	13	13	12	11	9	8	7	6	4	3	1	−1	−3	−4	−7	−9	−14	−18
17	16	16	14	14	13	12	11	9	8	7	6	4	2	1	−1	−3	−5	−7	−11	−13
18	17	17	16	15	14	13	12	11	9	8	7	6	4	3	1	−1	−3	−4	−7	−10
19	18	17	16	16	14	14	13	12	11	9	8	7	5	4	2	1	−1	−3	−6	−8
20	19	18	17	17	16	15	14	13	12	11	9	8	7	5	3	2	0	−1	−3	−6
21	21	19	18	18	17	16	15	14	13	12	11	9	8	7	5	4	2	−1	−2	−3
22	21	20	19	18	18	17	16	15	14	13	12	11	9	8	7	6	4	2	0	−2
23	22	21	21	19	19	18	17	16	15	14	13	12	11	10	8	7	5	4	2	0
24	23	22	22	21	20	19	18	17	16	15	14	13	12	11	10	8	6	6	4	2
25	24	23	22	21	21	20	19	18	17	16	15	14	13	13	11	9	8	7	5	3
26	25	24	23	22	22	21	20	19	18	17	16	15	14	13	12	11	9	8	6	4
27	26	25	24	23	23	22	21	20	19	18	17	17	15	14	13	12	11	10	7	5
28	27	26	26	25	24	23	22	22	21	20	19	18	17	16	15	14	13	12	10	8
29	29	28	27	27	26	25	24	23	22	22	21	20	19	18	17	16	15	14	12	11
30	29	28	28	27	26	25	24	24	23	22	22	21	20	19	18	17	16	15	13	12
31	31	29	29	28	27	27	26	25	24	23	22	22	21	20	19	18	17	16	14	13
32	32	31	30	29	28	28	27	26	25	24	23	23	22	21	20	19	18	17	16	15
33	32	32	31	30	29	28	27	27	26	26	24	24	23	22	21	20	19	18	17	16
34	33	33	32	31	30	29	29	28	27	27	26	25	24	23	22	22	20	19	18	17
35	34	34	33	32	31	30	30	29	28	28	27	26	25	24	23	22	21	21	20	19

Almost all air contains some solid particles. Dust, salt crystals, and smoke particles are commonly found in air. These solid particles provide the surfaces needed for droplet formation. Such particles are found at most altitudes, but more of them are found near the earth's surface.

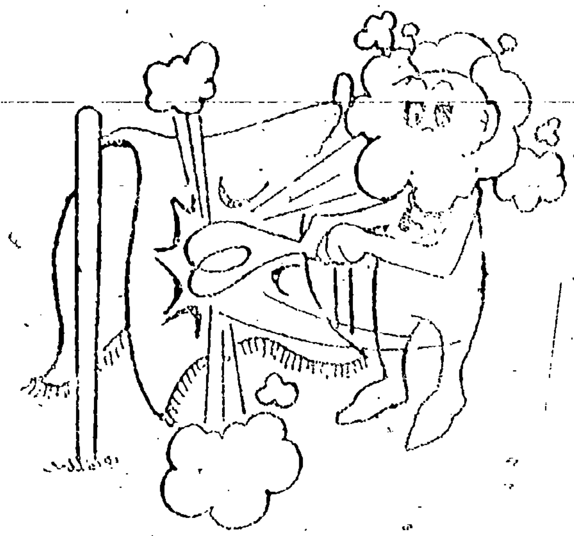
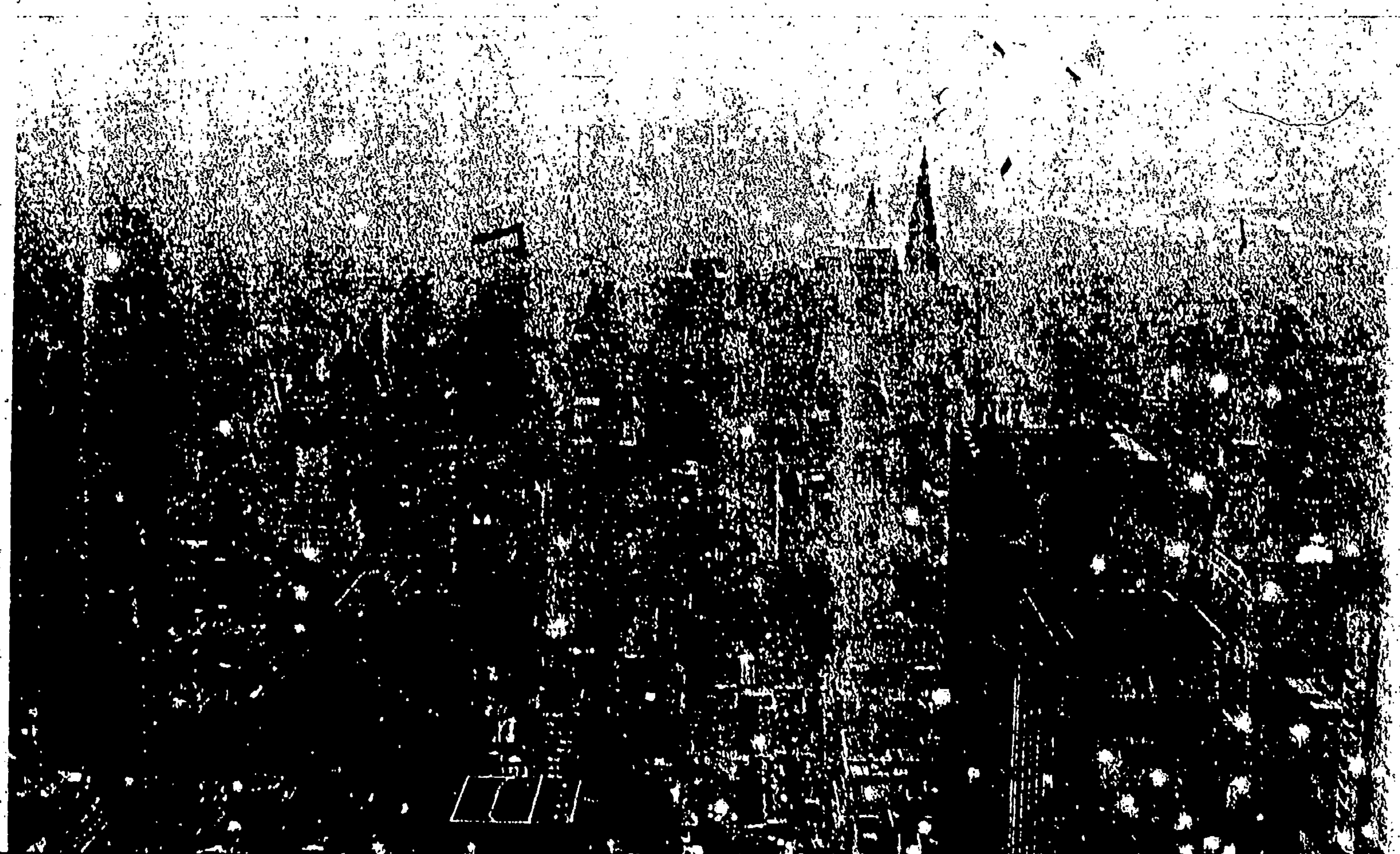


Figure 4-2



☐4-18. If more solid particles are found near the surface of the earth, why do most clouds form at higher altitudes?

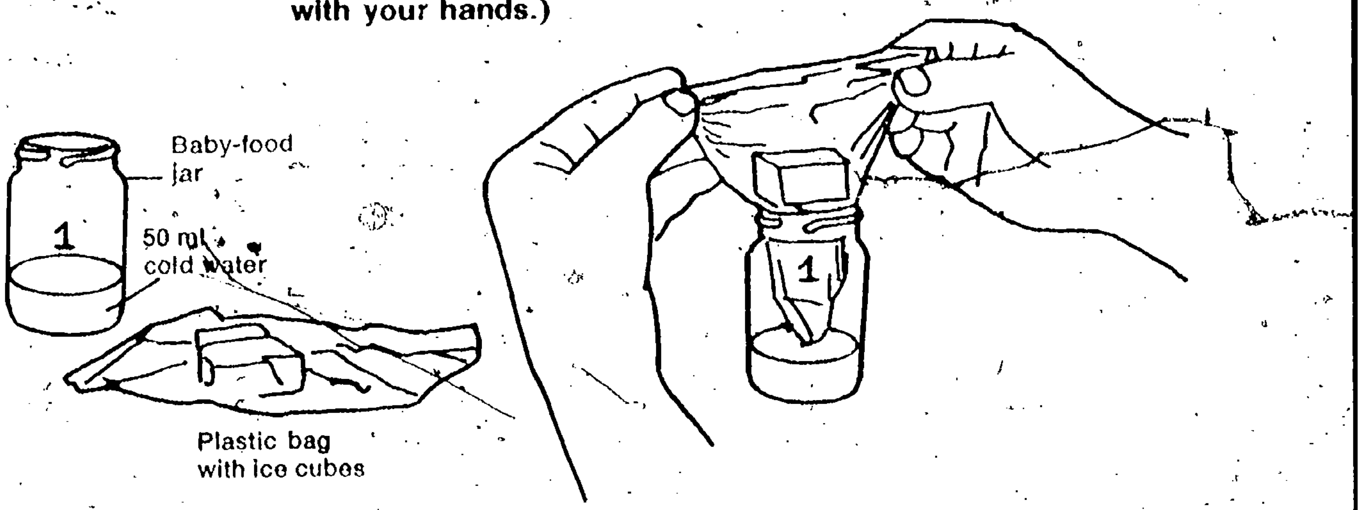
You've seen that decreasing temperature can produce condensation of invisible water vapor.

☐4-19. Suppose the air being cooled also contained fine solid particles such as those in smoke. What do you predict would happen?

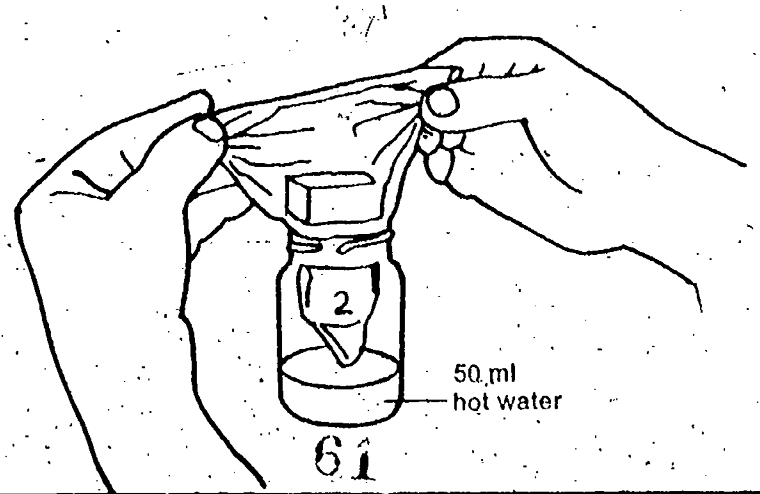
Check your prediction by doing the following experiment. You will need these materials:

- 2 large baby-food jars (labeled "1" and "2")
- 1 plastic sandwich bag
- 2 ice cubes
- Hot and cold water

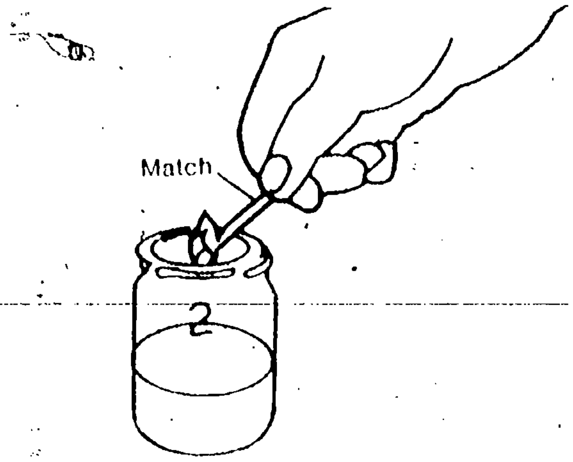
ACTIVITY 4-5. Put about 50 ml of cold water into Jar 1. Then place a plastic bag containing two ice cubes on top of the jar. Observe for about one minute. (Hold the ends of the bag with your hands.)



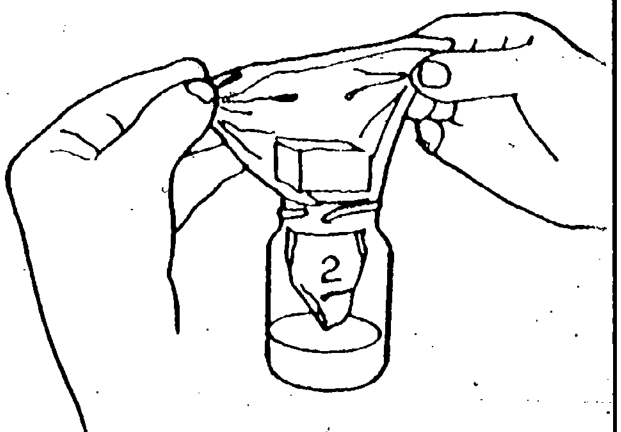
ACTIVITY 4-6. Repeat Activity 4-5, using hot water in Jar 2.



ACTIVITY 4-7. Remove the bag from Jar 2. Light a match. Let it burn for two or three seconds. Drop the match into the jar.



ACTIVITY 4-8. Now place the bag of ice cubes on top of the jar again. Observe for one minute.



Summarize your results in Table 4-4 in your Record Book.

Table 4-4

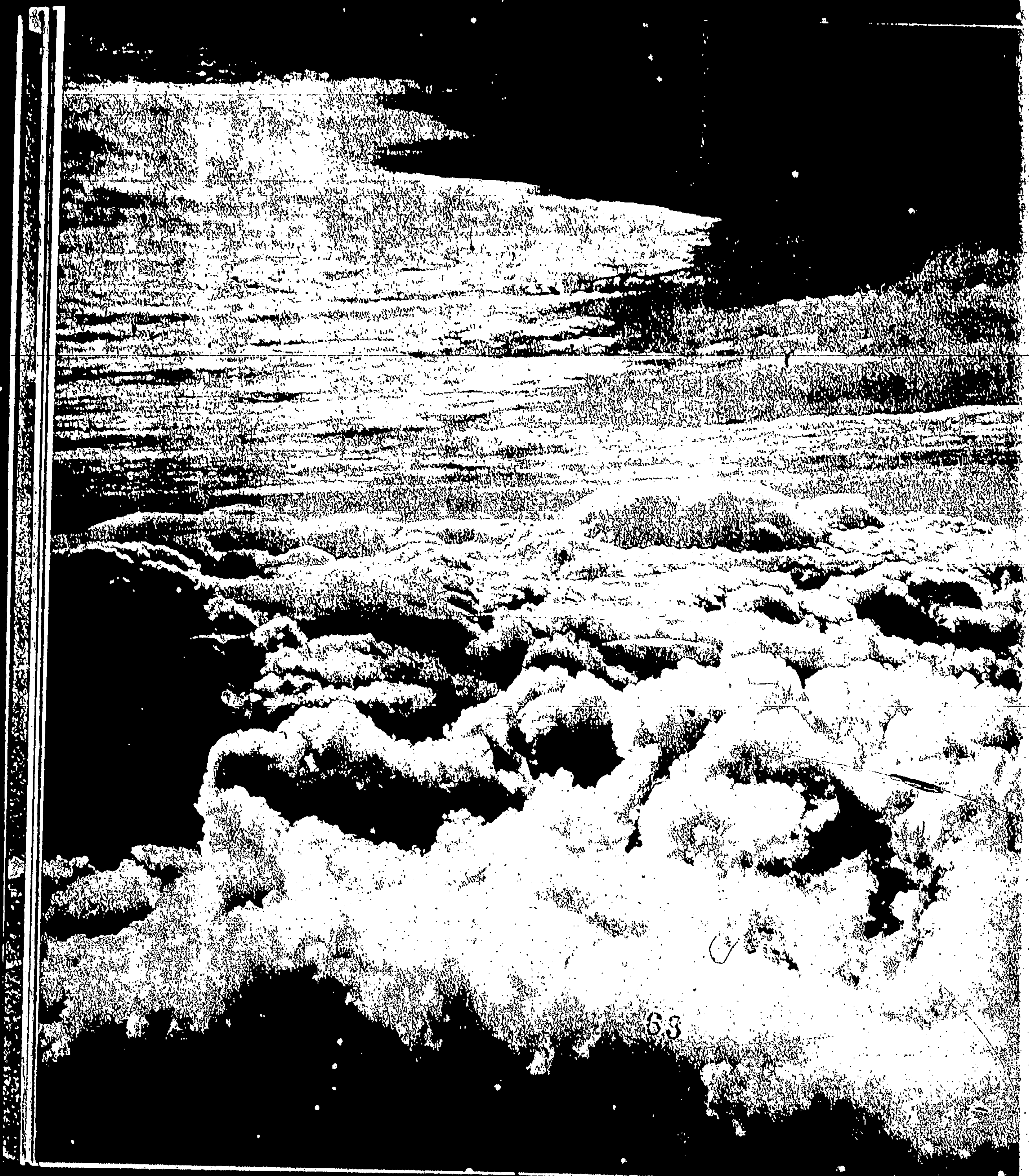
	Observations
1. Jar 1, with cold water	
2. Jar 2, with hot water	
3. Jar 2, with hot water and smoke	

☐**4-20.** Did the presence of smoke particles have an effect on the amount of mist that formed in the jar?

The experiment you did showed you one way to form a cloud. All you have to do is cool wet air that contains solid particles. You know that the atmosphere contains both water vapor and solid particles.

☐**4-21.** What happens to the temperature of air as the air rises to higher altitudes?

Before going on, do Self-Evaluation 4 in your Record Book.



More Reasons for Clouds

Chapter 5

As warm air rises over a warm area, it gradually cools. If this cooling effect continues, the temperature of the air will reach the dew point. Water vapor can then condense to form clouds if enough solid particles are present.

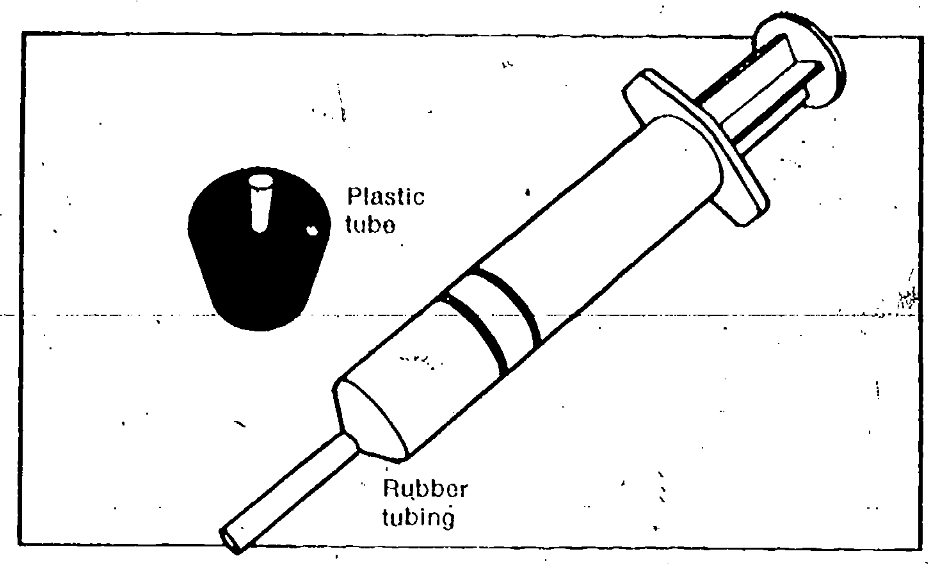
Temperature decrease with increasing altitude is characteristic of air as it rises.

☐**5-1.** What other change occurs in air as it rises?

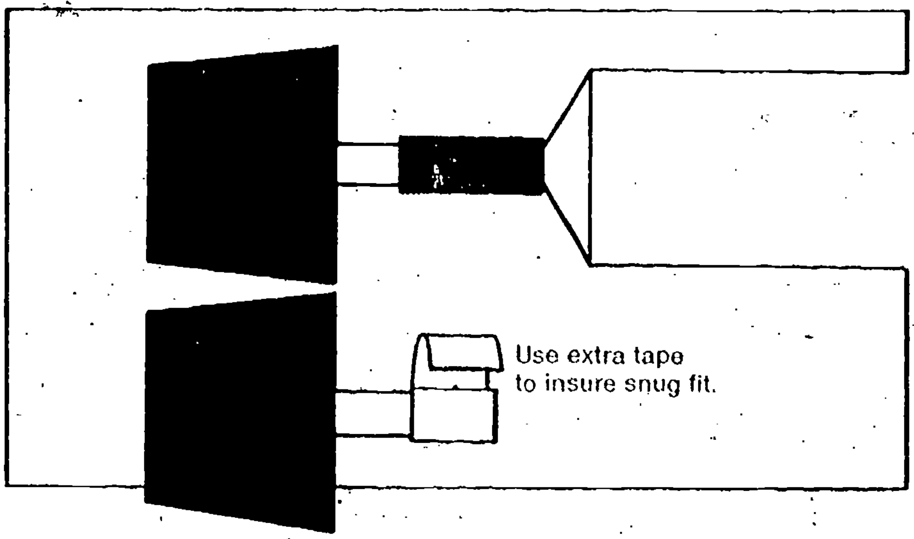
What effects, if any, does the pressure have on cloud formation? To find out, you will need to construct your own pressure chamber. You and a partner will need the following:

- 1 250-ml Erlenmeyer flask
- 1 1-hole #6 rubber stopper
- 1 short piece of rigid plastic tube (5–6 cm)
- 1 short piece of rubber tubing (3–4 cm)
- 1 large air piston
- Water
- Matches

ACTIVITY 5-1. Prepare the rubber stopper and air piston as shown.



ACTIVITY 5-2. Complete the assembly as shown. The plastic tube must fit snugly into the rubber tubing. If necessary, add a few wraps of tape to increase the diameter of the plastic tube.

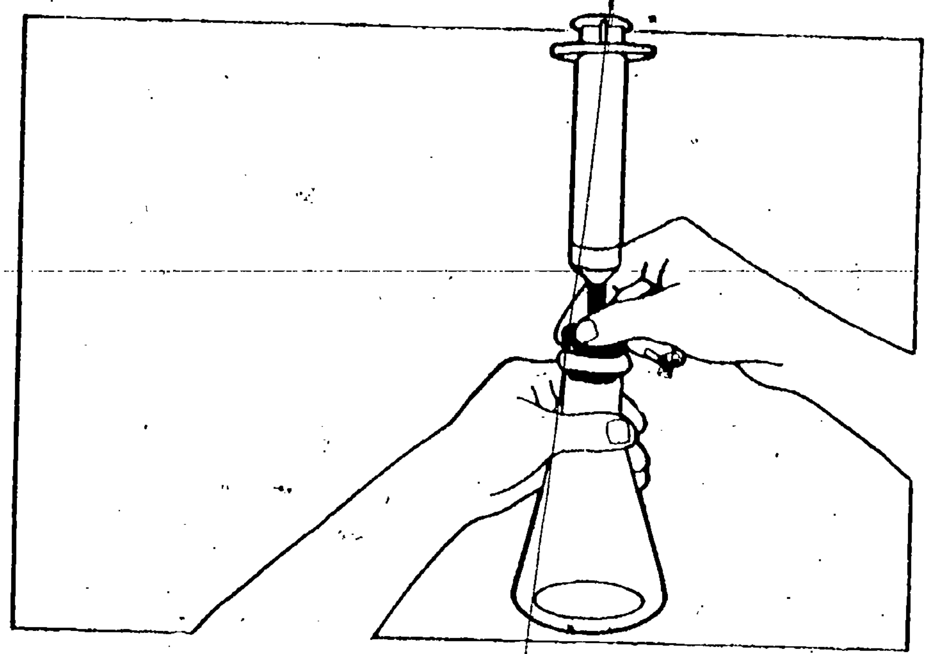


☐ **5-2.** Does the air in the flask contain water vapor?

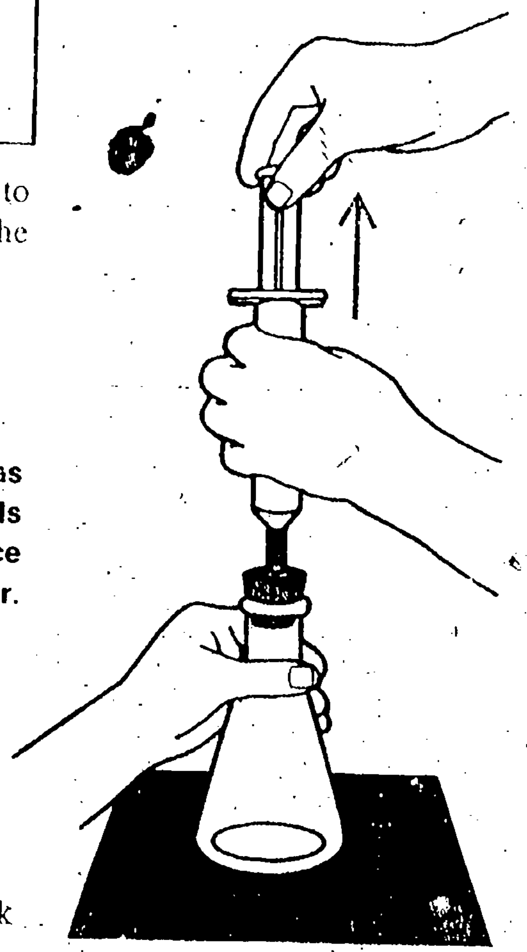
☐ **5-3.** What is today's humidity?

Think of your flask of air as the rising cube discussed in Chapter 3. As it ascends, the pressure on the air decreases. To see what effect this has, you can use the air piston and stopper.

ACTIVITY 5-3. Push the plunger of the air piston all the way in. Then insert the stopper tightly into the flask. Support the flask so that it doesn't tip over.



To reduce the pressure within the flask, you need only to remove some of the air. You can do this by pulling out the air piston plunger.

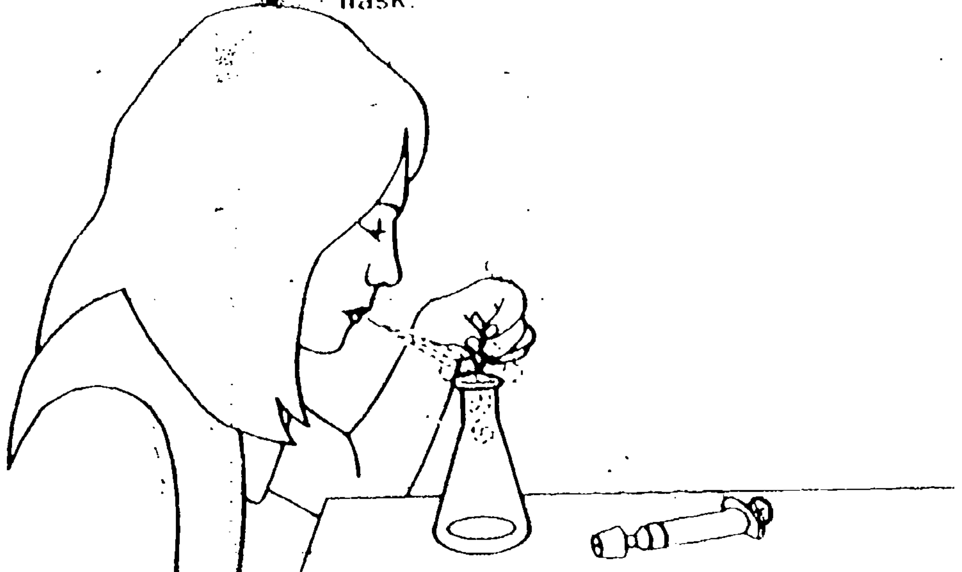


ACTIVITY 5-4. Place the flask on a dark background such as a sheet of black construction paper. While your partner holds the flask securely on the table, *quickly* lift the plunger to reduce the pressure. Try not to pull it all the way out of the cylinder. Observe the flask carefully as you decrease the pressure.

☐**5-4.** Describe any changes you observed within the flask as the pressure was reduced.

You may want to repeat Activity 5-4 a few times to check your observations.

ACTIVITY 5-5. Add a very small amount of smoke to the air in the flask. You can do this by just blowing some of the smoke into the flask. The smoke should not be visible in the flask.



Repeat Activity 5-4 with the contaminated air.

☐**5-5.** Describe any changes within the flask as the pressure is reduced.

☐**5-6.** What happens when you increase the pressure again by pushing the plunger back in?

☐**5-7.** What effect would decreasing air pressure be likely to have on cloud formation above the earth's surface?

Figure 5-1

The clouds you observed in the baby-food jar and in the flask probably were very faint. They may have looked only like a mist or fog. But then that is exactly what a cloud is. If you've ever been in one, you know it to be a misty experience.

PROBLEM BREAK 5-1

You've seen faint mists form both when temperature is changed and when pressure is changed. How would cloud formation be affected if both these factors were changed together? Would the cloud mist be thicker? Join forces with another team and design a plan to answer these questions. Then get your teacher's approval. There is a space for your work in your Record Book.

Let's pause for a moment and review what you have been doing in this unit up to this point. You have been putting together many observations of how air behaves.

So far you've learned these things:

1. The atmosphere is heated differently depending on the nature of the surface of the earth. Generally, dry landmasses produce more heating of the air than do surface waters (Figure 5-2).

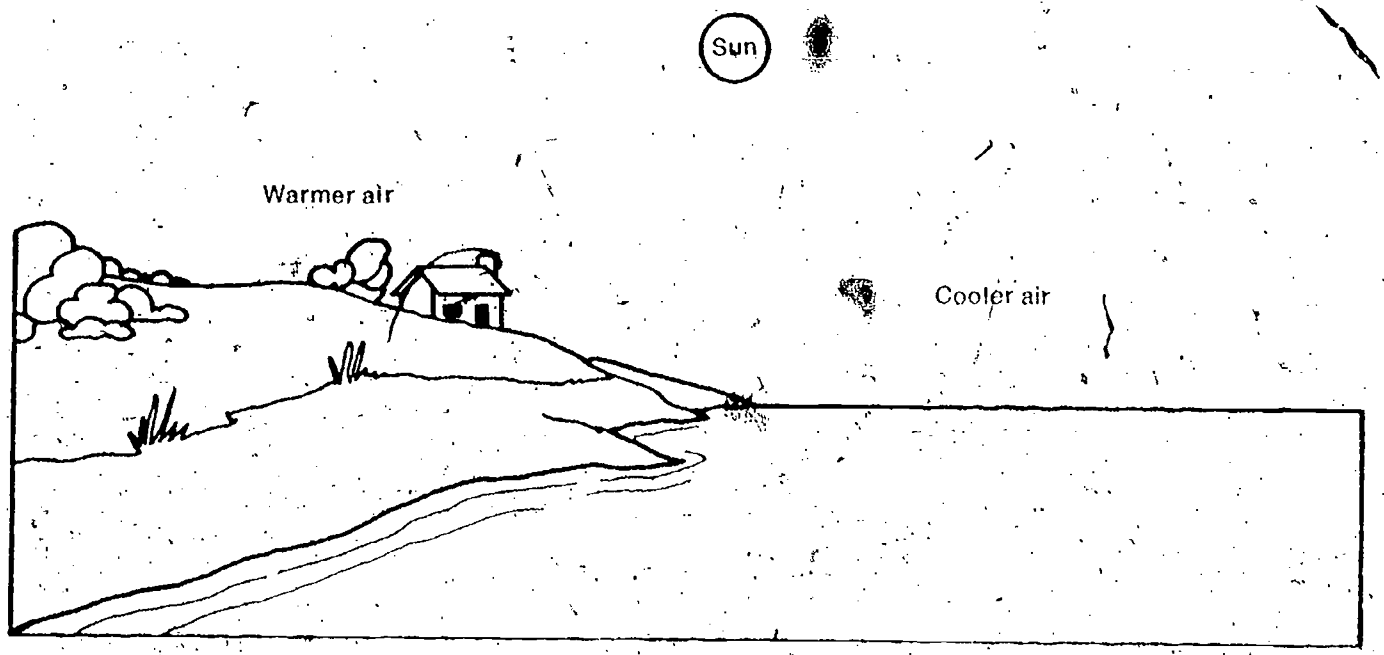


Figure 5-2

2. Warm air rises, or to say it another way, cold air settles toward the earth's surface.
3. As air rises from the earth's surface, the air's temperature decreases and so does the pressure on it.

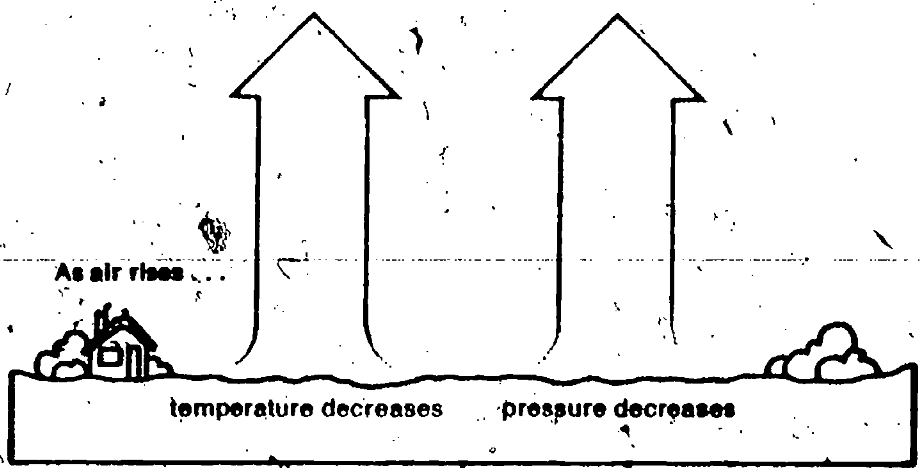


Figure 5-3

4. Decreasing either pressure or temperature, or both, causes invisible water vapor to condense into liquid droplets around tiny solid particles of dust, smoke, and salt. These water droplets accumulate and become visible as mists and clouds.

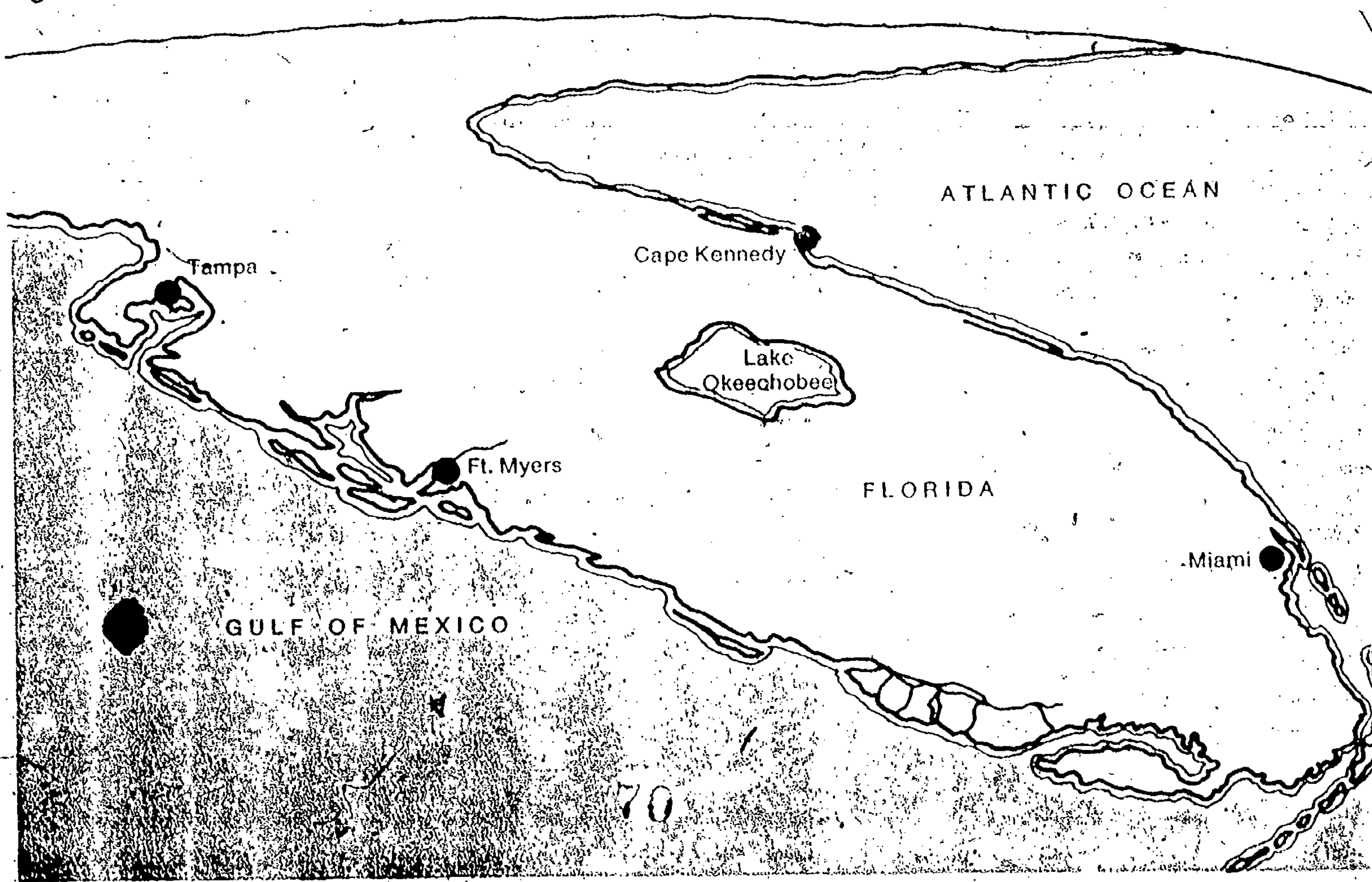
How high in the atmosphere does all this happen? If you are interested in finding out, see **Excursion 5-1,** "How High Are the Clouds?"

As you know, scientists aren't satisfied with observations alone. They want to explain their observations and how they relate to each other. Thus, they invent ideas to account for what they see. These invented ideas are called *mental models.* You have been using a common mental model to explain some of your observations of the behavior of air. The model you've used is the particle model for matter.

The particle model assumes that air and water and all matter are composed of tiny invisible particles. This model can be used to explain why warm air rises. And, it can explain why air pressure decreases with increasing altitude. But can you use what you know to explain one day's weather in Florida? See if you can.

Examine carefully the cloud patterns in each of the satellite photographs of the state of Florida (Figures 5-4 and 5-5). Compare the cloud patterns you see with the map of Florida that is provided with each figure.

Figure 5-4


ATLANTIC OCEAN
Cape Kennedy
Tampa
Lake Okeechobee
Ft. Myers
FLORIDA
Miami
GULF OF MEXICO

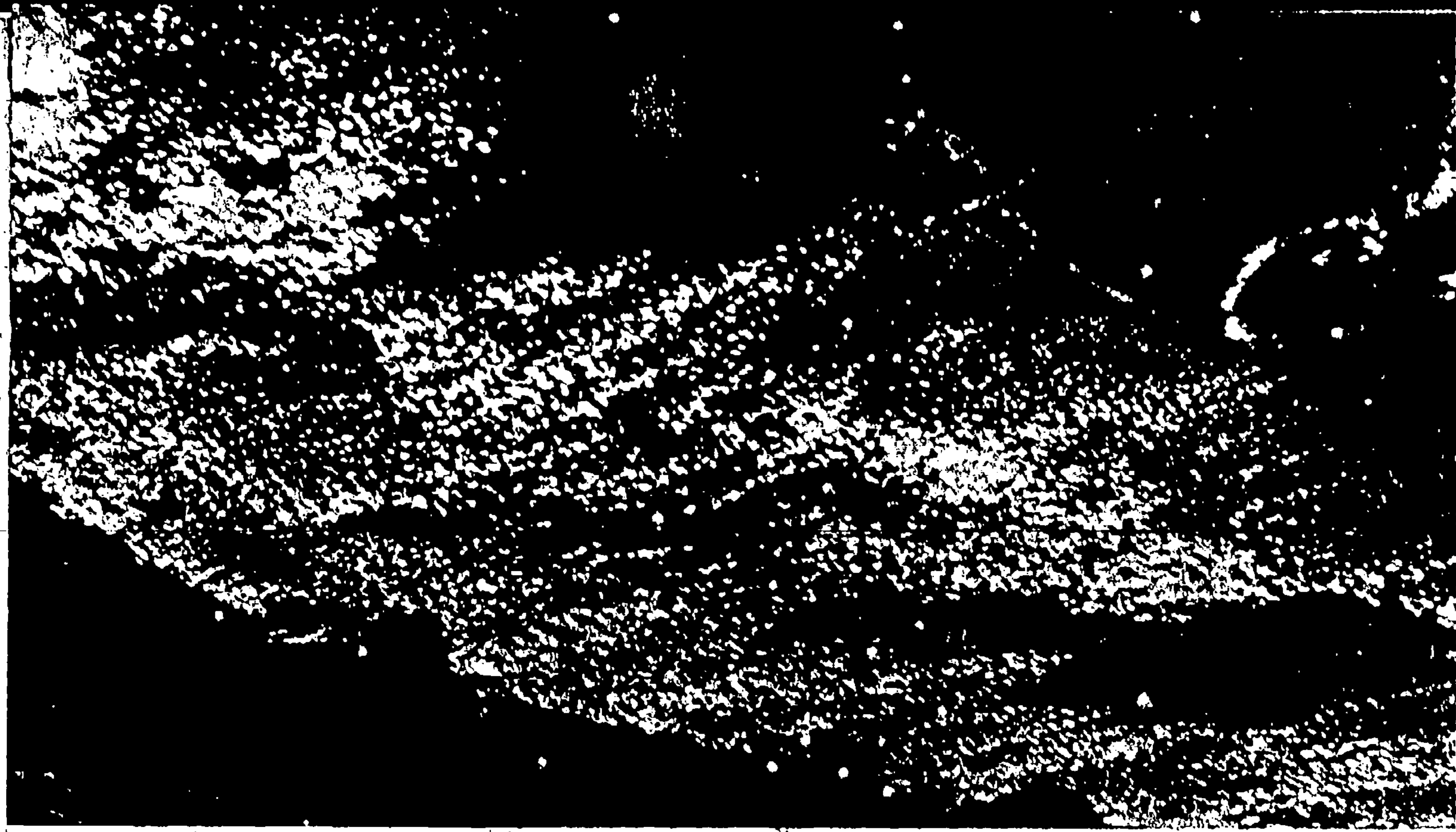
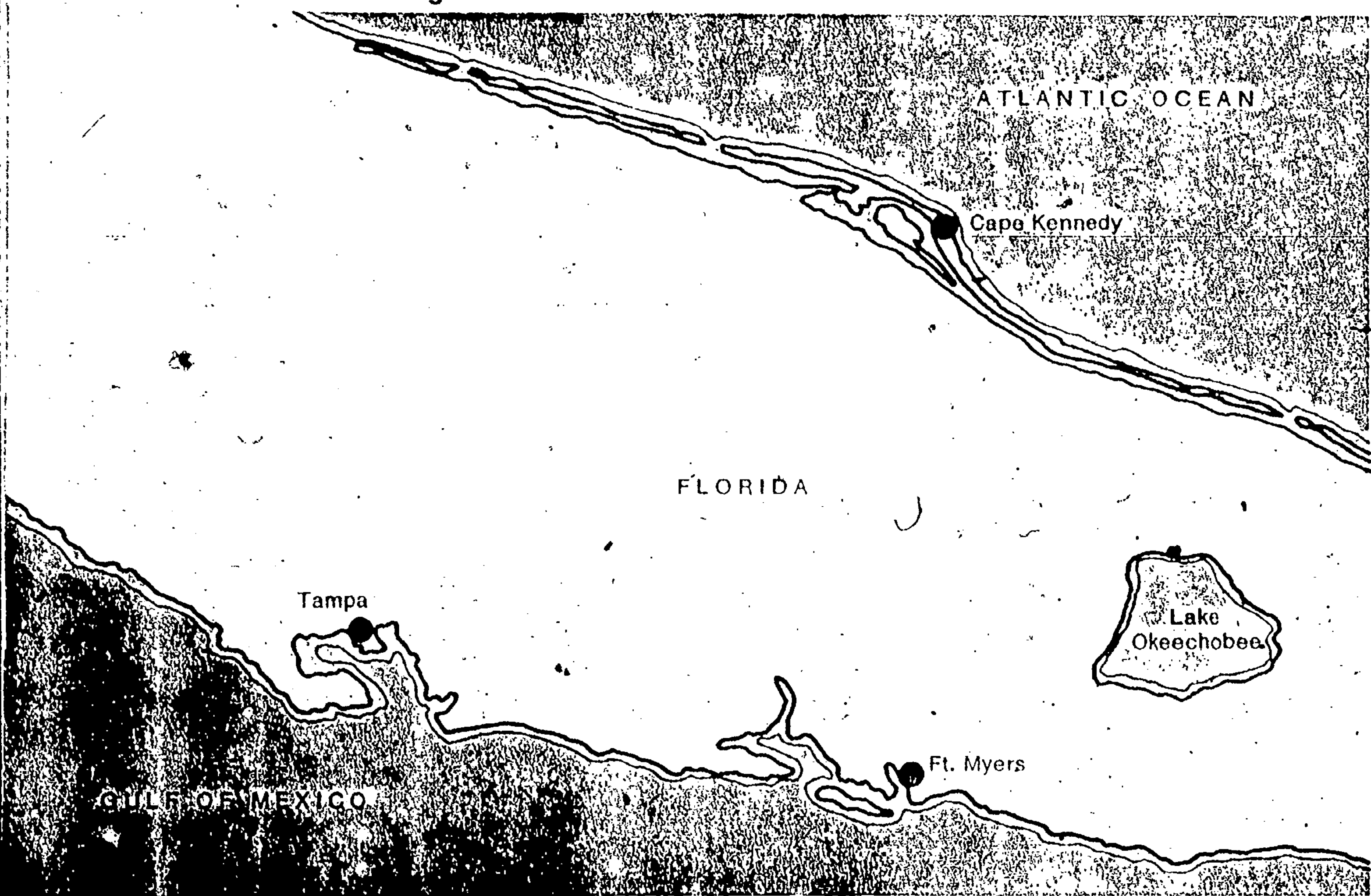


Figure 5-5


ATLANTIC OCEAN
Cape Kennedy
FLORIDA
Tampa
Lake Okeechobee
Ft. Myers
GULF OF MEXICO

☐ **5-8.** Would you have predicted that most of the clouds shown in Figures 5-4 and 5-5 would be over the land instead of the water? Why?

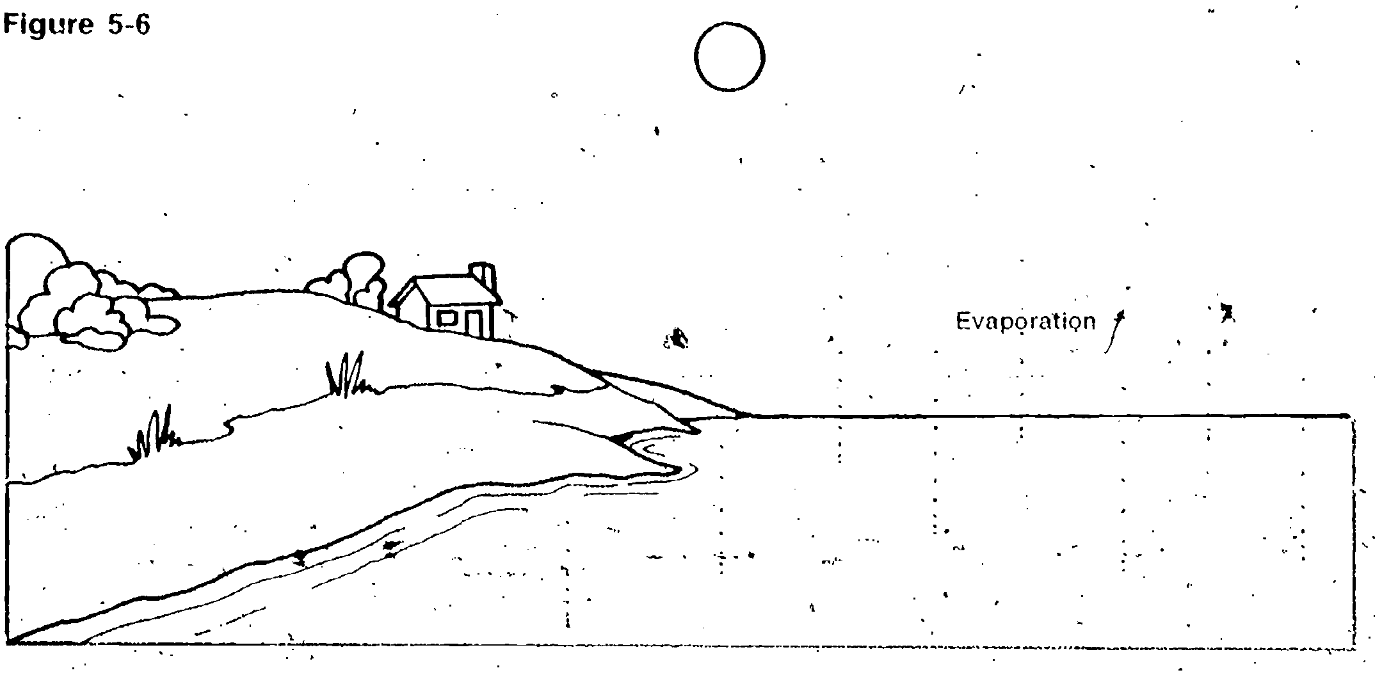
Question 5-8 isn't easy. But perhaps you are closer to a reasonable answer than you think. Try the next two questions.

☐ **5-9.** Where would you expect air to be warmer in the daytime, over land or over water? (Hint: Recall your investigation in Chapter 1, beginning with Activity 1-8.)

☐ **5-10.** Where would you expect the greater uplift of air to occur in the daytime, over land or over water?

For clouds to form, air containing water vapor must be uplifted. It is reasonable to assume that the air over water contains more water vapor than the air over dry land contains (Figure 5-6).

Figure 5-6

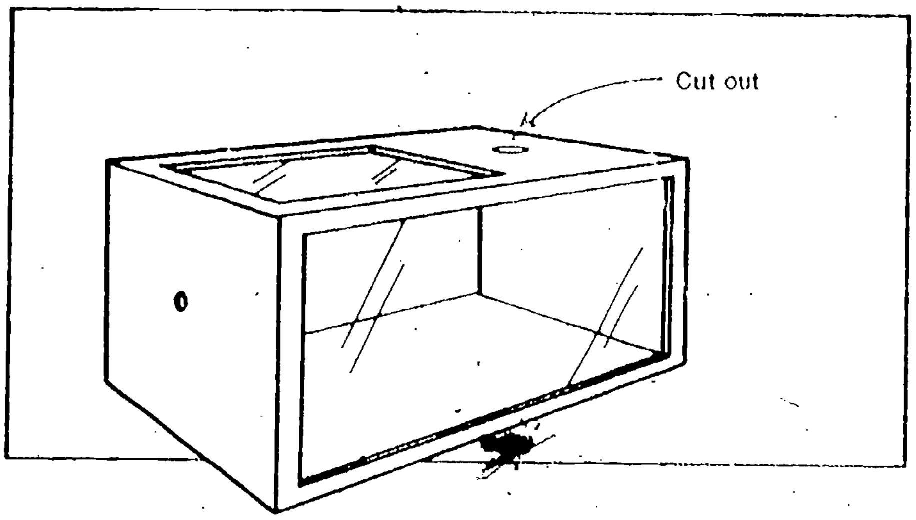


But the air over dry land is being warmed faster and therefore rises. According to what you have learned about air, you should expect clouds to form over land if the land air contains enough water vapor. And according to Figures 5-4 and 5-5, it does contain enough water vapor. Almost all the clouds are over land. Another investigation may help you explain how the land air gets some of its moisture.

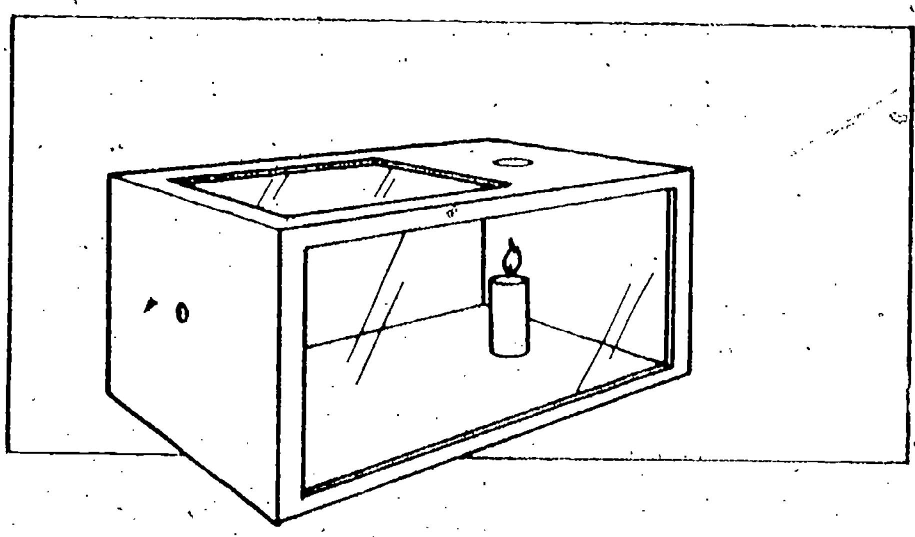
You will need the following:

1 observation box (from Chapter 1)
1 short candle (4-5 cm)
Heavy cotton string, 12-cm length
1 plastic straw
Sharp knife or scissors

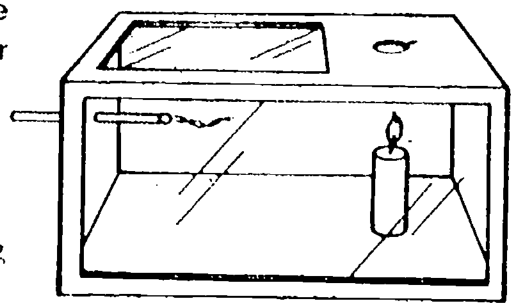
ACTIVITY 5-6. Cut a small hole (about 4 cm in diameter) in the top of the observation box as shown.



ACTIVITY 5-7. Light the candle and place it directly under the hole in the box. The tip of the flame should be at least 10 cm below the hole.



ACTIVITY 5-8. **Double the string and insert it in the plastic straw as shown. Light the string. It should glow but not be flaming. Insert the straw into the box. Observe the behavior of the smoke in the box.**



☐**5-11.** Describe what happens to the smoke from the string as the hot air above the candle rises.

Think of the candle as representing the hot land in the daytime. The land (candle) is heating the air above it. Let the smoke from the string represent the invisible moist air over a cooler area nearby. (This might be a body of water, such as a large lake or an ocean.)

☐**5-12.** Describe how you think cool moist air will behave as it comes in contact with an area where warm air is rising.

Up until this last activity, you have concentrated only on air moving up and down. In this activity, you saw that horizontal (sideways) movement also occurs. This horizontal movement is called *wind.* It is a very important feature in all weather.

The particle model for matter can be used to explain the sideways movement of air that you observed. Recall two things this model says:

1. When air is heated, its particles spread out.
2. A volume of warm air has less mass than the same volume of cool air.

These two ideas explain why the air moved as it did in the observation box. As the temperature of the air above the candle increased, its particles spread out. Thus, it became lighter, so to speak, than the cool air in the box. The cool air, now the heavier air, pushed the lighter air up and took its place.

☐**5-13.** What would happen to the cool air after it replaced the warm air?

Figure 5-7 illustrates the air-flow patterns you should expect when warm and cool areas are side by side.

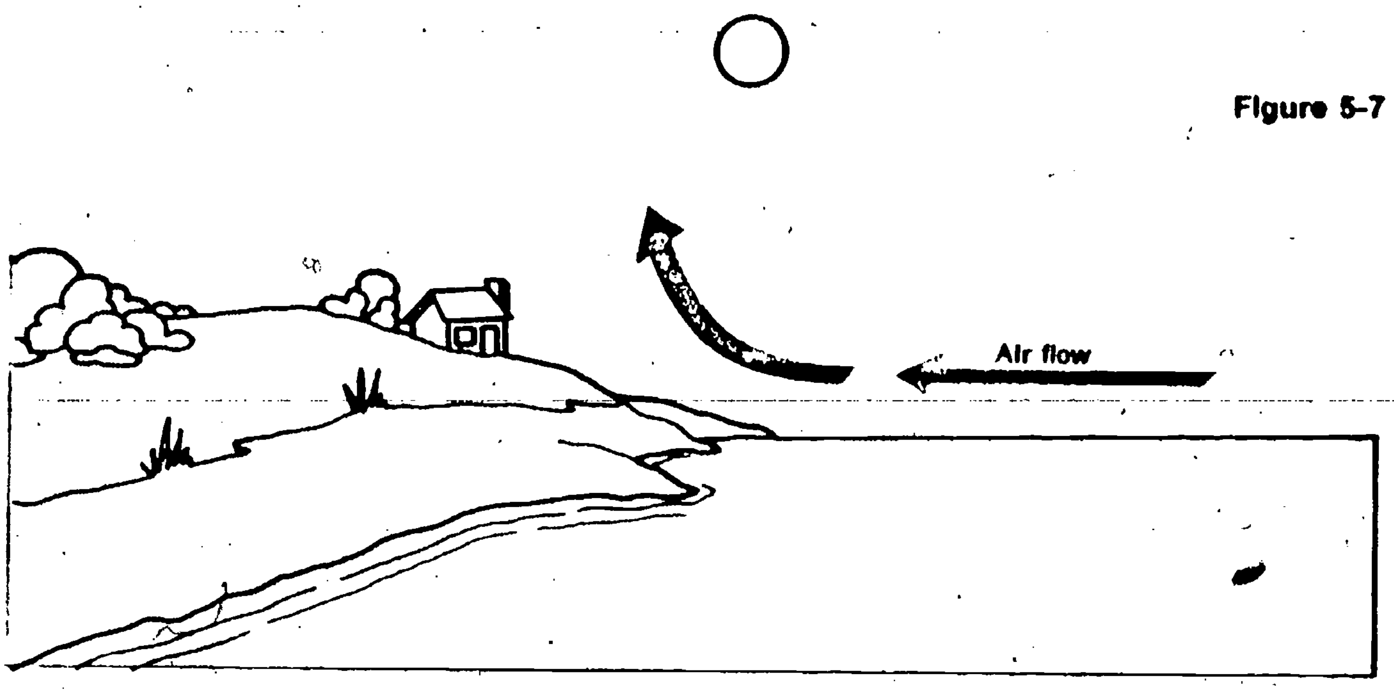


Figure 5-7

Suppose the cool area is adding moisture to the air, as in Figure 5-7. If so, the moisture will be lifted as the air moves over the land.

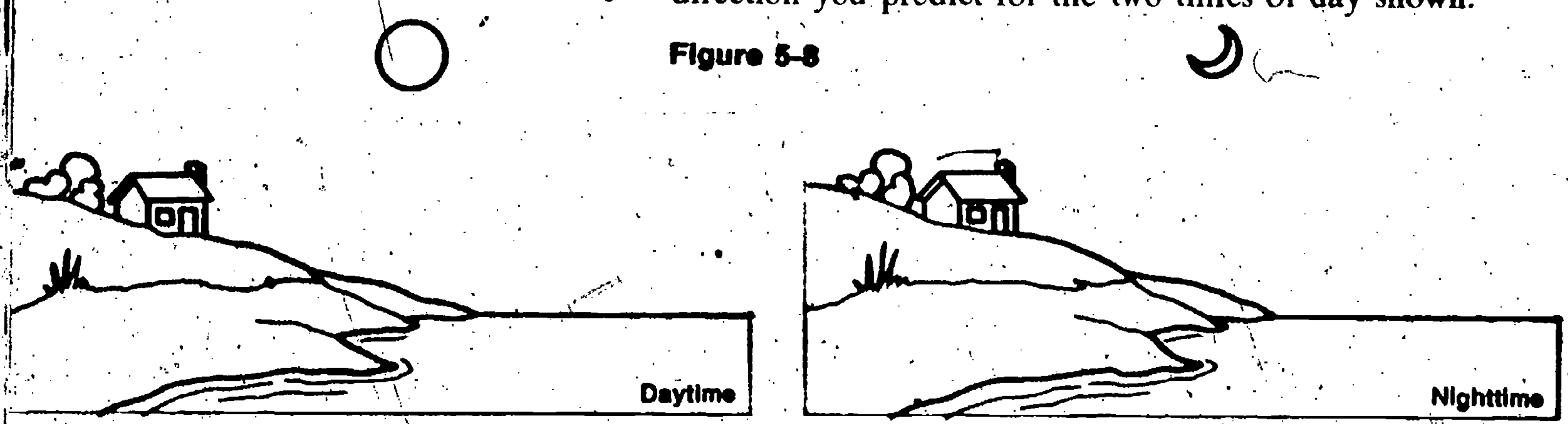
☐ **5-14.** Will the increased moisture content improve chances for cloud formation?

PROBLEM BREAK 5-2

If you live near the ocean or a very large lake, you may have noticed some peculiar things about wind. Wind direction often seems to be related to the time of day. During warm, daylight hours, the wind blows from one direction. Then, during cool, night hours, it blows from the opposite direction.

In Figure 5-8 of your Record Book, indicate the wind direction you predict for the two times of day shown.

Figure 5-8



☐**5-15.** Use what you know about air to explain your decision about wind direction.

The fact that air moves horizontally is no surprise to you. You feel that motion frequently. You also see it in the motion of other objects. Even those things you've been trying to account for—the clouds—are affected by wind. Moving air carries them across the sky.

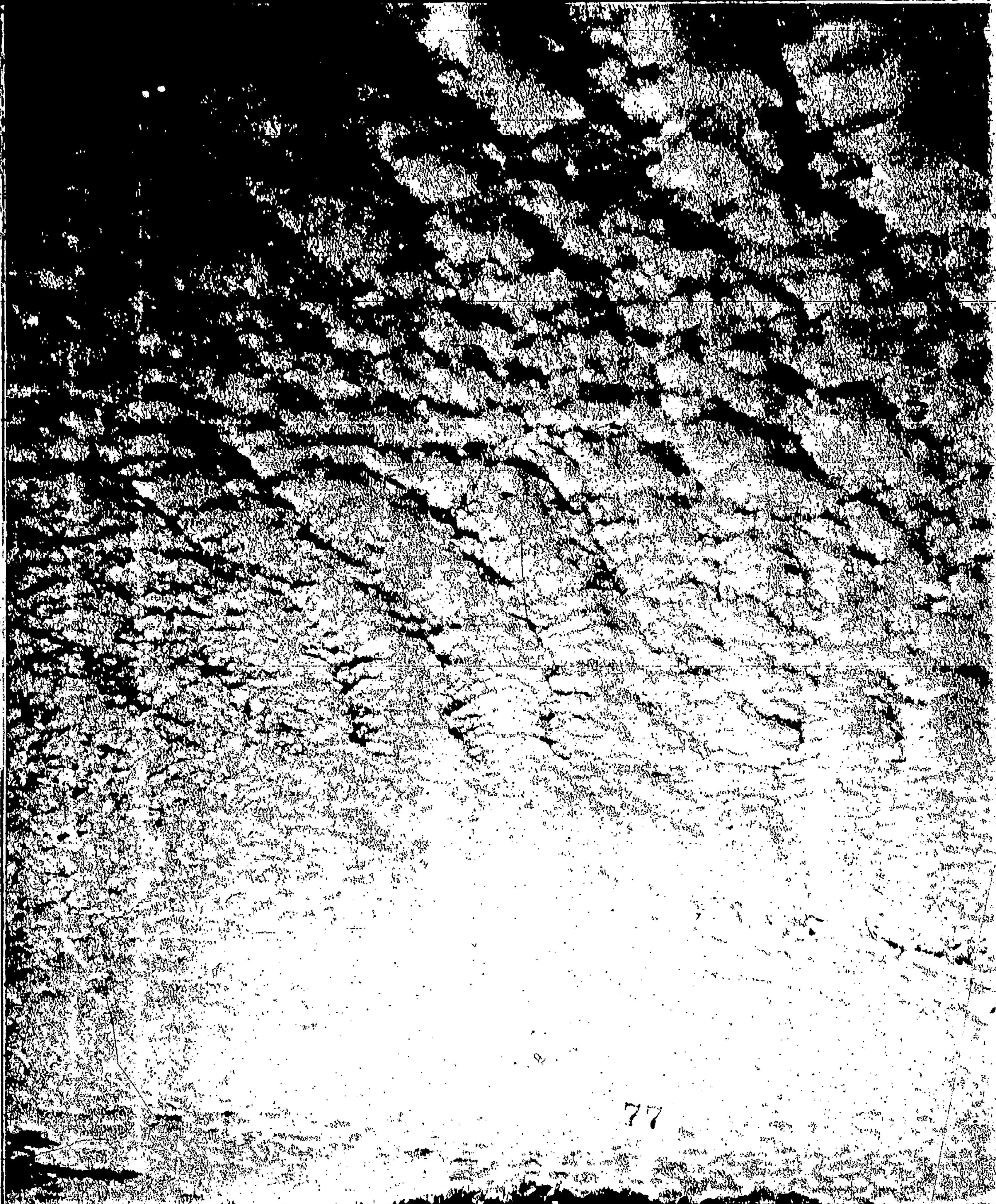
If you are interested in *how fast* clouds move, see **Excursion 5-2,** "Building a Nephoscope."

EXCURSION

Light and heat are the energy sources for all weather on the earth. You've seen how they drive air up, down, and sideways. You know that without heat little water vapor could be added to air, and without moisture there would be no clouds.

In the next chapters you will investigate other effects of air movement. And, as a result, you'll learn more about predicting and explaining weather changes. You may even find an explanation for rain.

Before going on, do Self-Evaluation 5 in your Record Book.



Other Cloud Formers

Chapter 6

An unmanned weather satellite orbiting far above the earth took the photograph shown in Figure 6-1. The picture shows the pattern of clouds over about half the earth's surface. It was taken on May 8, 1967.

Figure 6-1

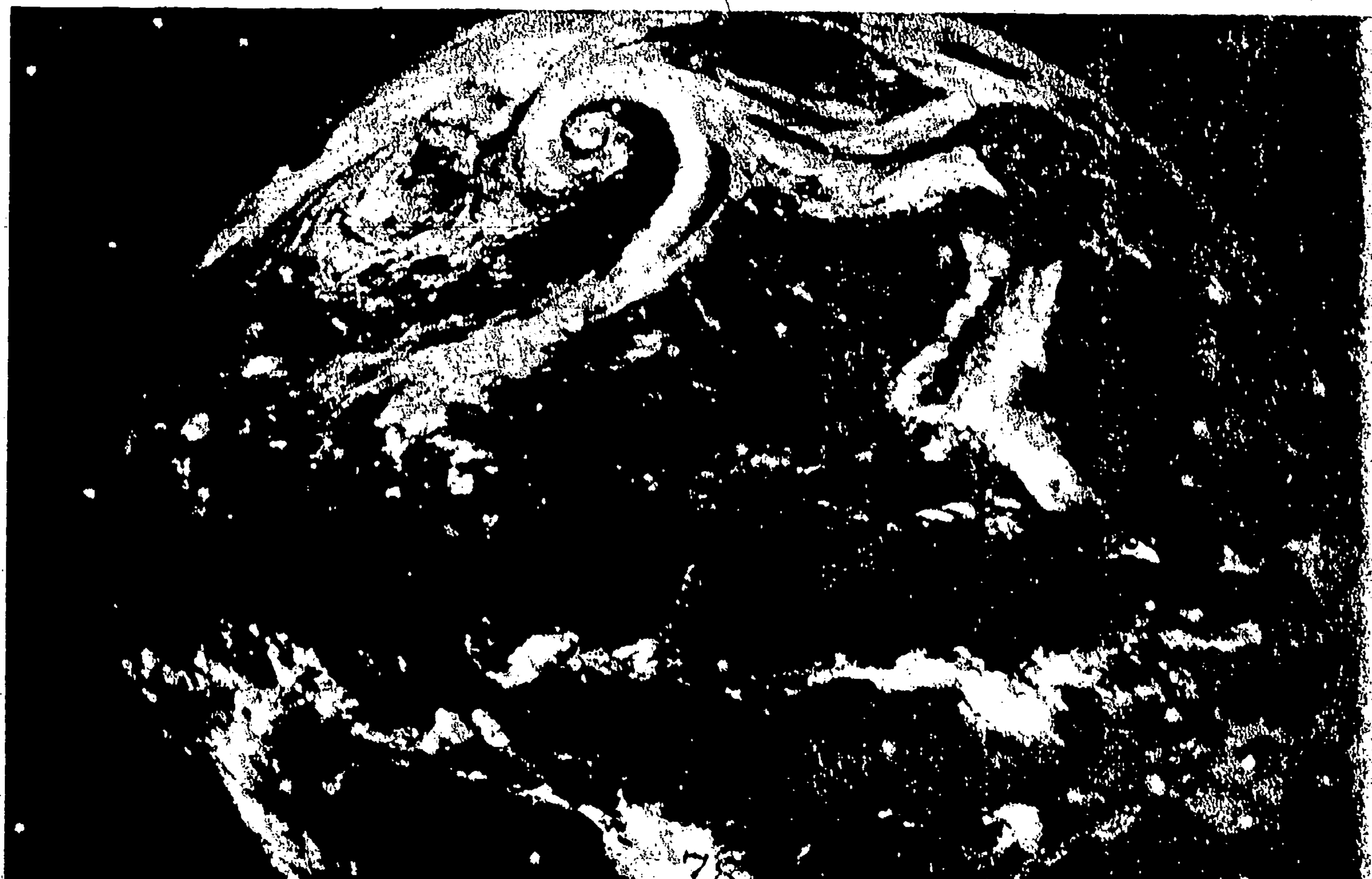
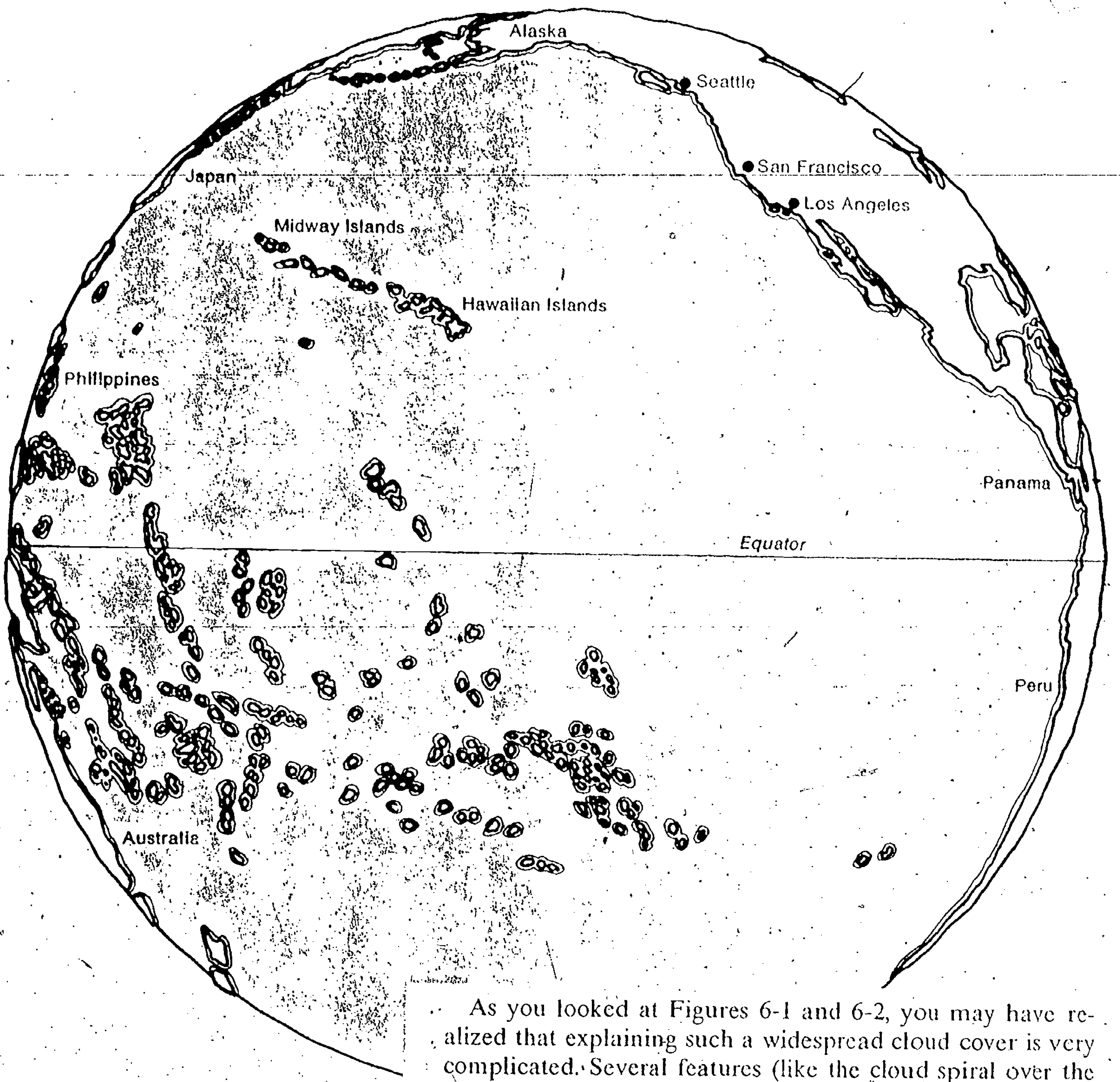


Figure 6-2 will help you identify where the clouds in Figure 6-1 are located.



As you looked at Figures 6-1 and 6-2, you may have realized that explaining such a widespread cloud cover is very complicated. Several features (like the cloud spiral over the northern Pacific Ocean) can't be explained with the simple heated-air model you've been thinking about. Obviously, clouds don't just form over land areas either. You can see that much of the Pacific Ocean is shown covered by clouds.

Factors other than air-temperature differences above different earth surfaces must be involved in forming clouds. Something else must be pushing the air upward at those places where heavy clouds are forming over water. What is this force?

Take a closer look at the spiral area of cloud formation in the upper left-hand part of Figure 6-1. Figure 6-3 shows an enlarged drawing of this feature. Examine the general shape of the cloud pattern. Notice particularly the two "legs" that project from the central core of the pattern.

Figure 6-3

In Figure 6-4, symbols and numbers have been added to the diagram of the cloud spiral. Each symbol cluster contains values for temperature, barometric pressure, wind speed, and wind direction.

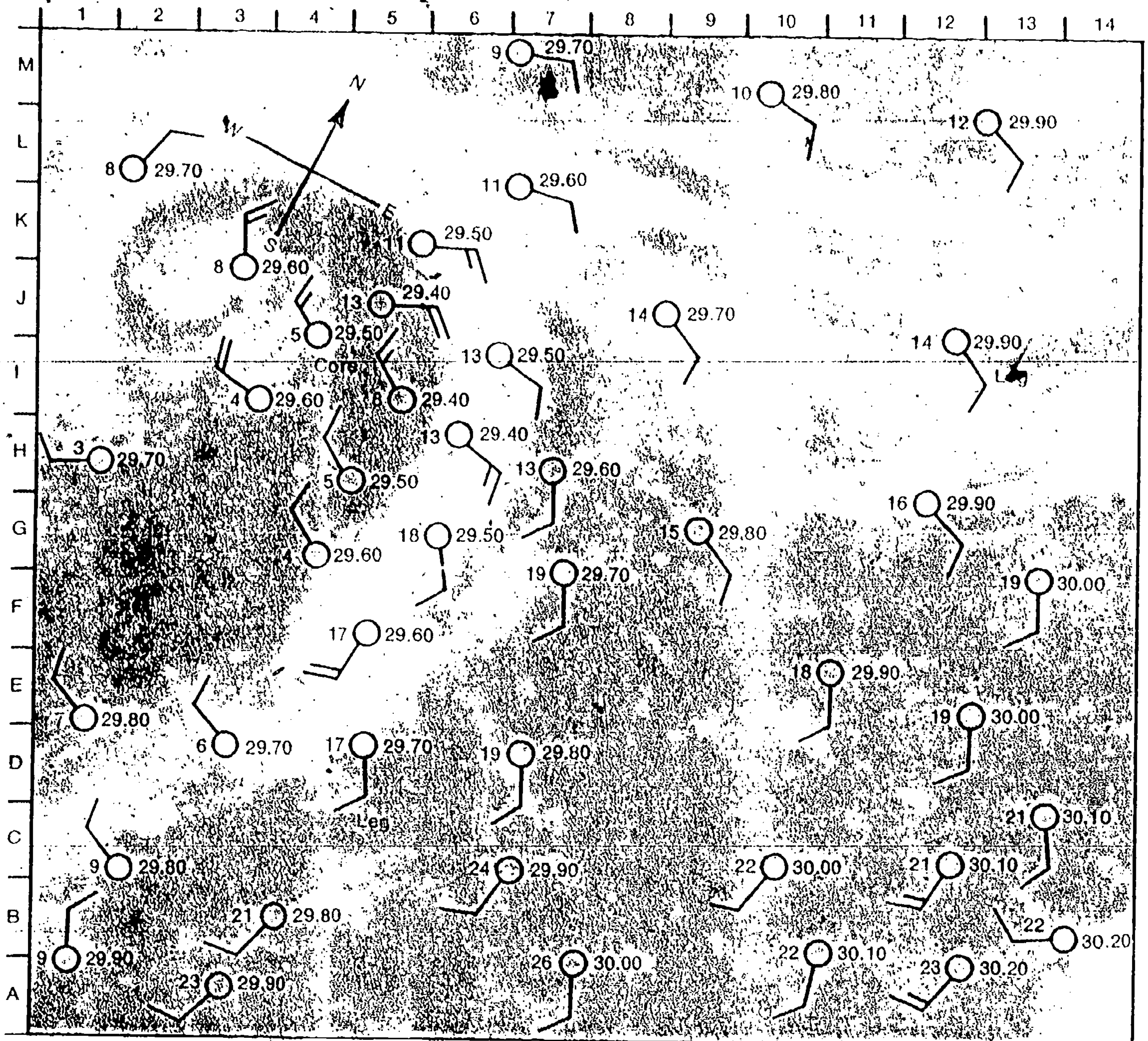


Figure 6-4

The code symbols in Figure 6-4 are used to squeeze the maximum amount of information into the minimum amount of space.

Figure 6-5 shows the meaning of these symbols.

Wind speed	
mph	Symbol
Less than 1	
1 to 3	
4 to 7	
8 to 12	
13 to 18	
19 to 24	
25 to 31	

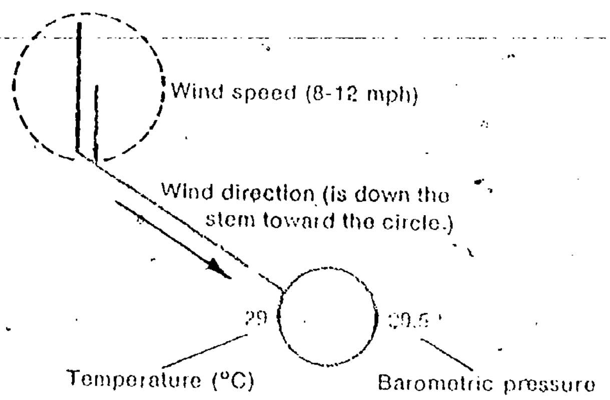
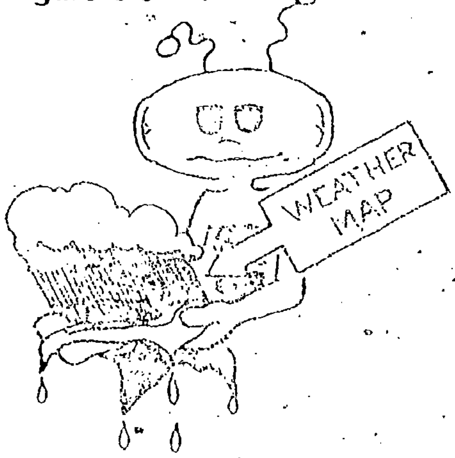


Figure 6-5



Notice that the border of Figure 6-4 is labeled like the border of a city map. This makes it possible to locate areas on the drawing easily. For example, the location of the symbol at the very top of the figure might be described as M7.

☐6-1. Using the border symbols and a straightedge, describe the following locations by letter and number.

Highest barometric pressure
Highest wind velocity
Lowest barometric pressure
Highest temperature
Lowest temperature

Examine the clusters of measurements in Figure 6-4 carefully. Try to find a relationship between the numbers in these and the pattern of cloud formation. Look particularly for large differences in temperature and pressure within a small area and the effect of these differences in terms of cloud formation.

□ 6-2. Describe any relationships you think you find between the pattern of cloud formation shown in Figure 6-4 and the measurements of temperature, pressure, wind speed, and wind direction.

Now let's find out if you've discovered any important relationships between the cloud patterns and the symbols. Run your finger along the "leg" of clouds extending down from the central core of the spiral. Notice the temperature readings on the two sides of the leg.

□ 6-3. On which side of the leg (east or west) are the temperatures lower? Compare any differences in temperature along the lower leg with those in other parts of the drawing.

Examine the temperature differences on the two sides of the other leg—the one extending toward the east (right) from the central core of the spiral.

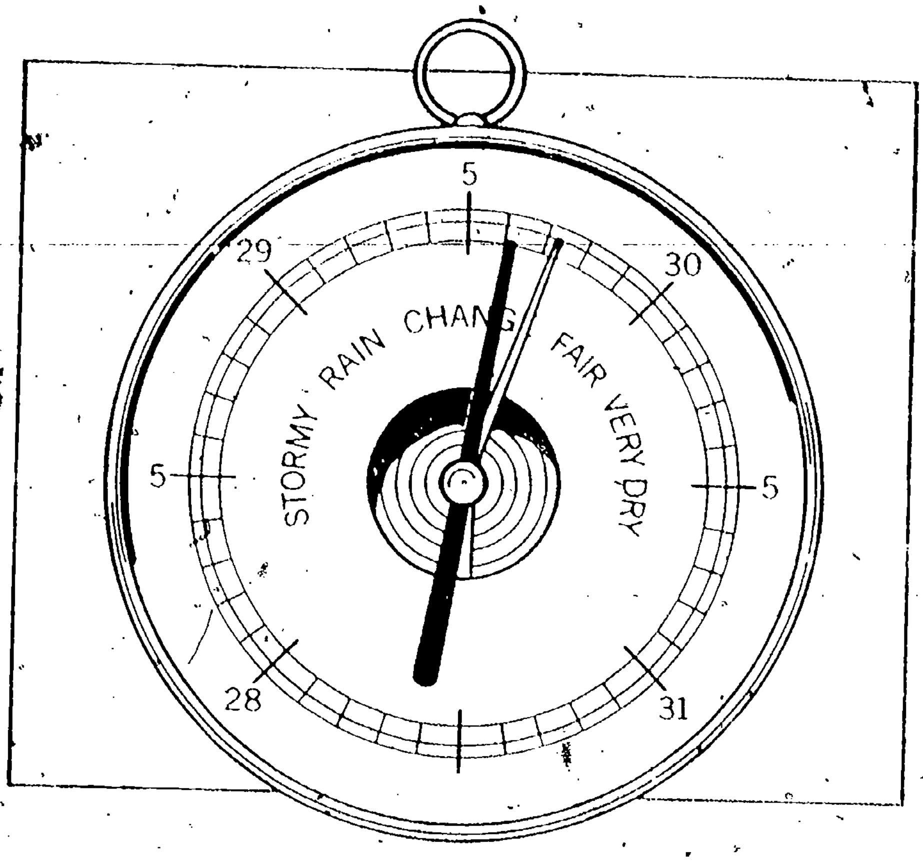
□ 6-4. On which side (north or south) of this leg are the temperatures lower?

□ 6-5. How do the temperature differences on the two sides of the legs compare with temperature differences found elsewhere in the figure?

The two legs of the cloud spiral lie in areas in which cold air is in contact with warmer air. In one case, the warm air lies to the east of the cold air; in the other, it lies to the south. These temperature differences are important. Moist air is apparently lifted in some way to form clouds along these two lines of rather sharp temperature difference.

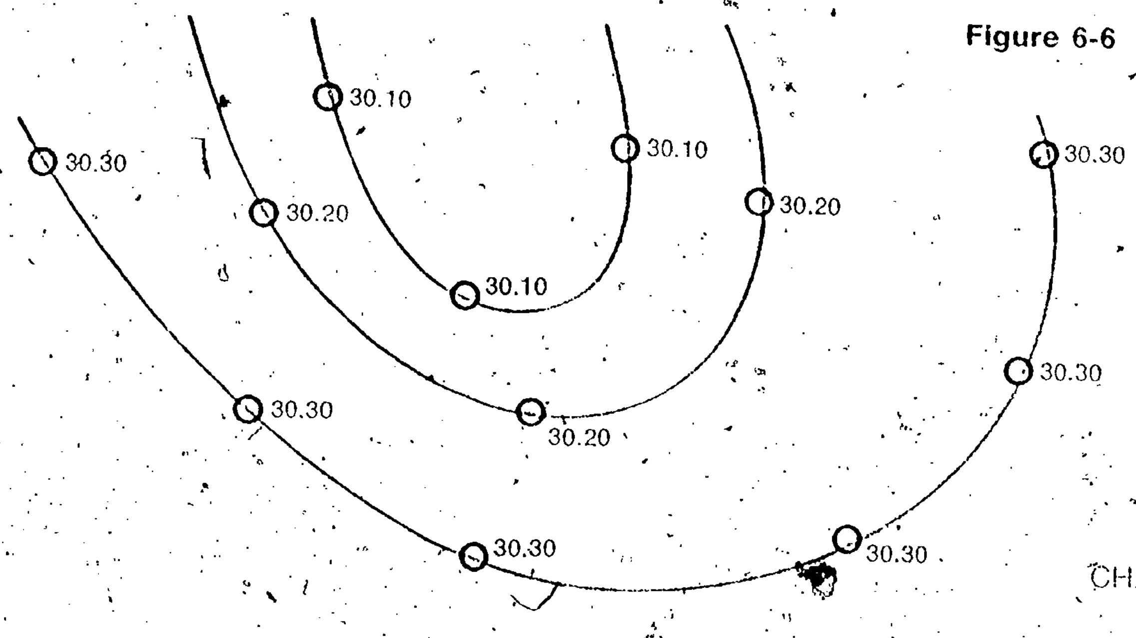
Now examine the central core of the cloud spiral for a moment. The presence of heavy clouds suggests that air is being lifted in this area, too. But the temperature differences at this point are not so sharp as those along the legs of the spiral. Some other cloud-forming factor must be at work in the core.

□ 6-6. Besides temperature differences, what other factor produces cloud formation?

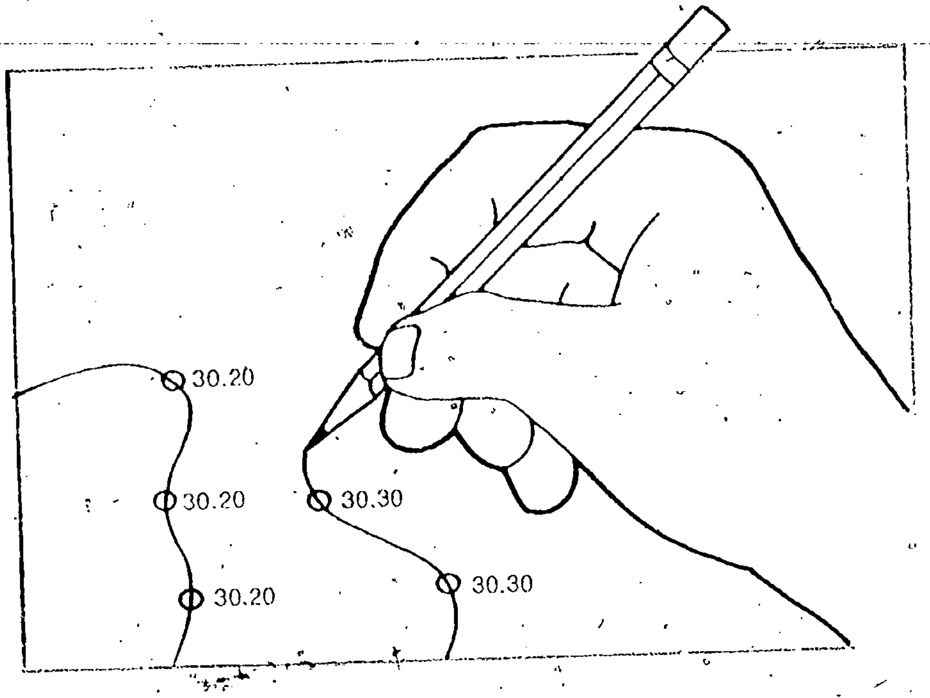


If you have been keeping your daily weather watch, you've learned by now that air pressure varies. It is slightly different from day to day even at the same spot on the earth. In keeping track of pressure changes, weather scientists (meteorologists) often plot their pressure measurements on special maps. Then they draw lines through all equal barometer readings plotted on the map (Figure 6-6).

Figure 6-6



ACTIVITY 6-1. On Figure 6-4 in your Record Book, connect all equal barometric readings with *lightly penciled* lines. The lines should pass directly through the station circles that have the same barometric readings. These lines should be smoothly curved, and no line should cross another.



Lines connecting areas of equal barometric pressure are known as *isobars*. (*Iso-* is a common prefix meaning "equal.")

☐**6-7.** Describe the pattern of barometric pressure revealed by the isobars you drew on Figure 6-4.

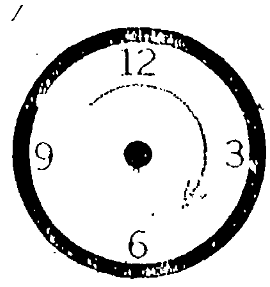
☐**6-8.** Is the barometric pressure fairly high, or fairly low, where the core of the cloud spiral has formed? (Label this center on your Figure 6-4 as "High" or "Low.")

Well, you probably agree now that the areas of greatest cloud formation in Figure 6-4 lie along a line of sharp temperature differences or over an area of low barometric pressure. This suggests that sharp differences in temperature and pressure are acting as cloud-forming agents. Therefore, these variables have an important influence upon the weather.

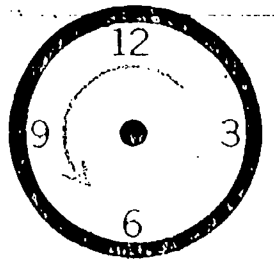
Clouds aren't the only thing of interest in Figure 6-4. Take a look at the wind directions indicated there. Notice particularly the relationship between wind direction and the isobars you drew on the figure.

[ ]6-9. Describe the pattern of wind direction in the area of low pressure on Figure 6-4 (clockwise or counterclockwise?).

[ ]6-10. What relationship, if any, do you notice between the pattern of wind direction and the spiral shape of the cloud mass?



Clockwise



Counterclockwise

Earlier, you used a model for the cause of wind that depended upon unequal heating of the earth's surface. (If you need to review this idea, see the last part of Chapter 5.) According to that model, wind is simply cooler air moving into an area of greater heating.

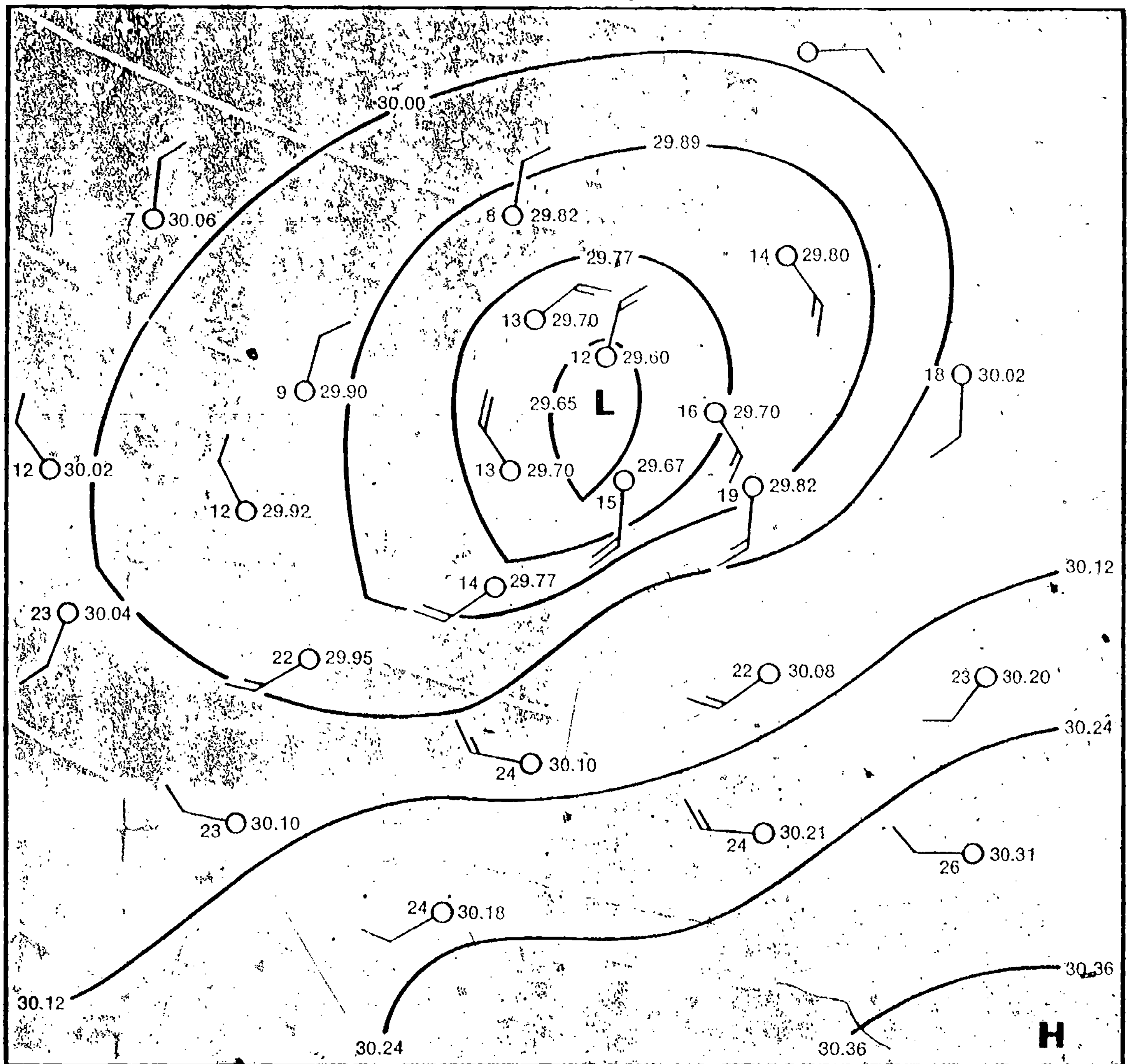
The situation in Figure 6-4 is more complicated than that. The low-pressure area obviously has a great effect on the movement of air. The air seems to move around the area in a counterclockwise direction. This will become more important in the next chapter.

You can see that many problems complicate the task of making predictions about weather. Sometimes more than one weather-influencing agent is operating at the same time. Then it is hard to decide which of the assembled data is most important.

At this point, you may be ready to consider what you've inferred about the effects of low-pressure areas and lines of temperature differences as part of your weather model. Before you do, however, you should find out whether the example in Figure 6-4 was an isolated situation. Do the relationships you observed hold true in other situations, too?

Figures 6-7 and 6-8 each contain a satellite photo and a set of weather data collected at the time the photo was taken. Examine each figure carefully. Try to find out whether the relationships you found in Figure 6-4 hold for these areas as well.

Figure 6-7

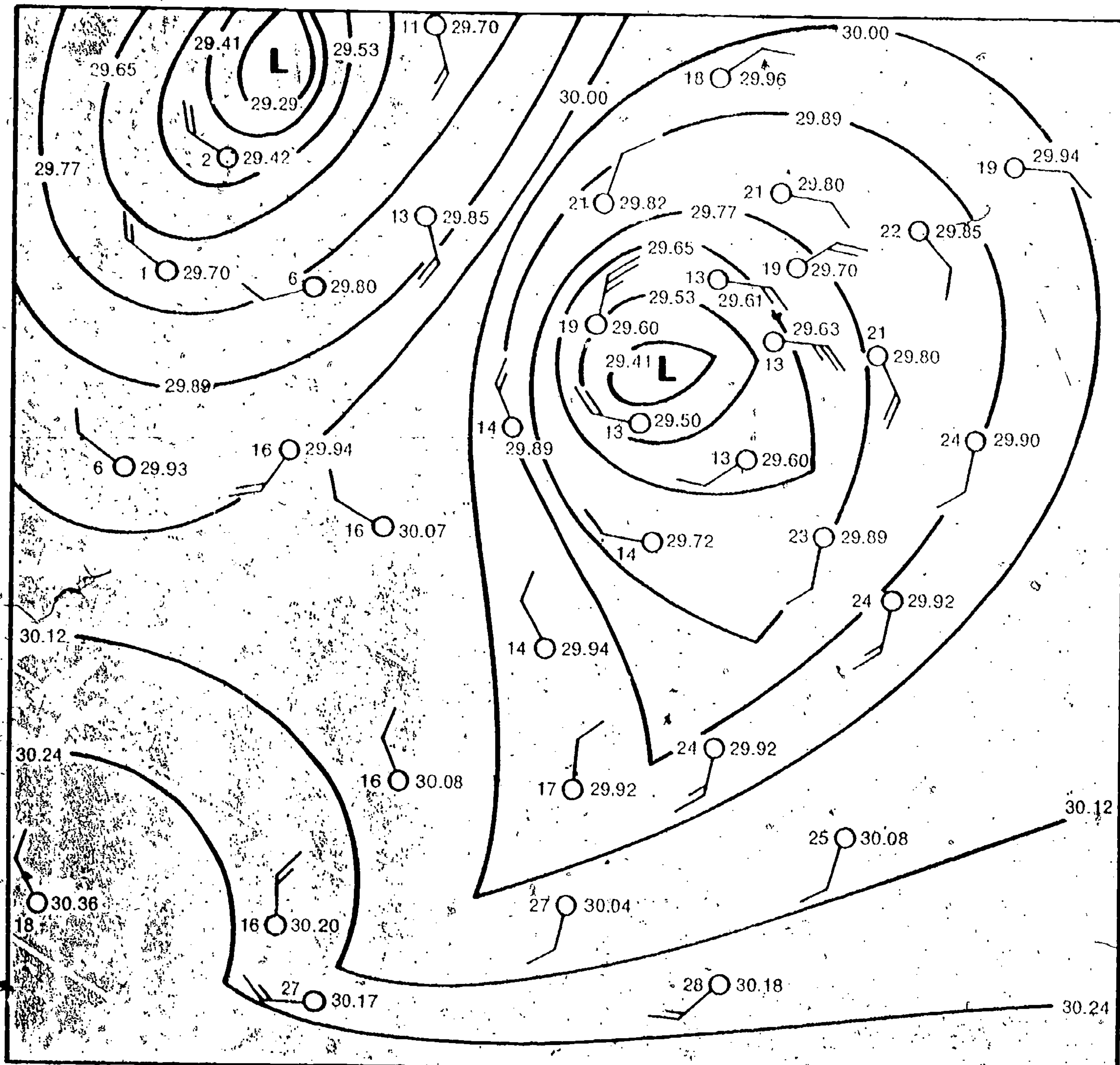


☐6-11. Describe the flow of air near the low-pressure areas in Figures 6-7 and 6-8 (clockwise or counterclockwise?).

☐6-12. Describe how the distribution of clouds in the two figures relates to the pressure and temperature data given.

☐6-13. Are your answers to questions 6-11 and 6-12 what you expected?

Figure 6-8

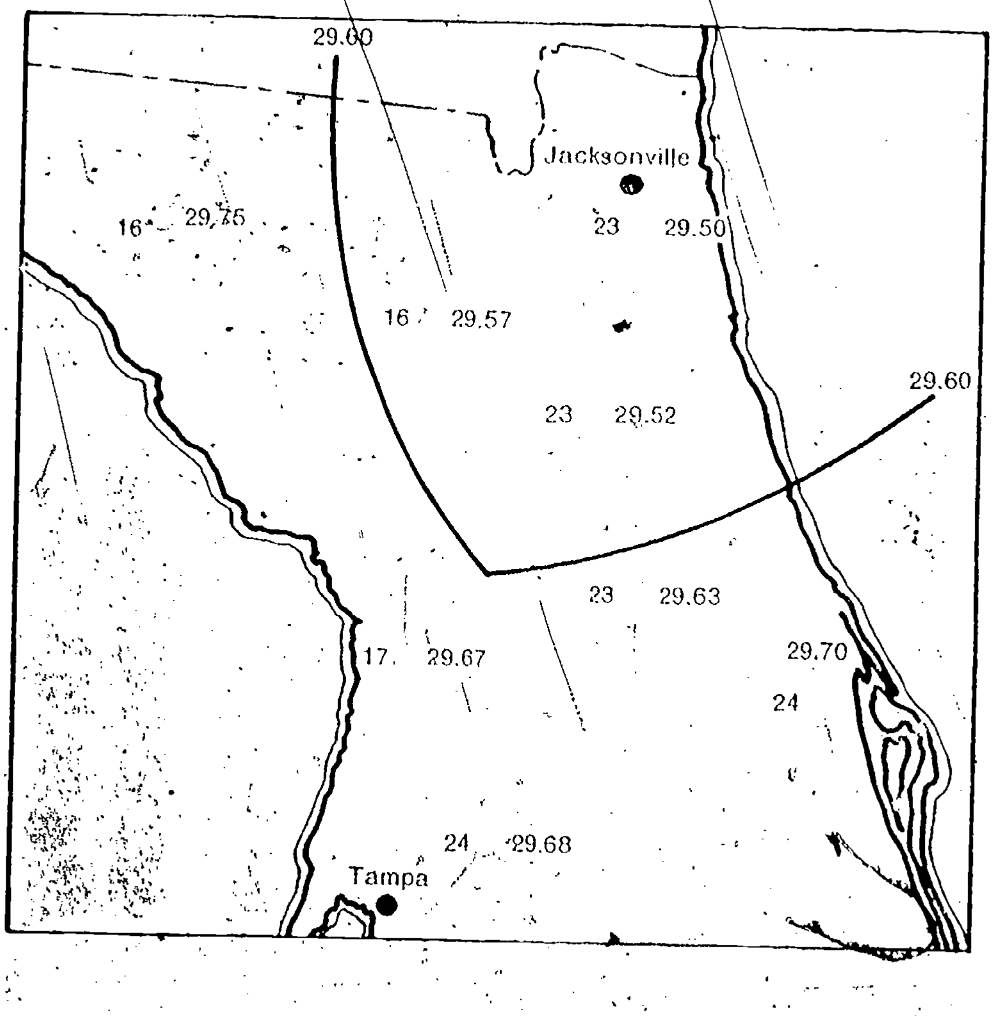


PROBLEM BREAK 6-1

Figure 6-9 shows the Florida peninsula once more. Weather data have been included on the map. Your problem is to sketch on the map the pattern of clouds you would predict on the basis of the data shown. In making your prediction, you may assume that lines of temperature difference and low-pressure areas *are* cloud-forming agents. This time, however, you may neglect the fact that the difference in temperature over land and water can cause cloud formation, too. (It is still part of our weather model, but we'll put it aside for the moment.)

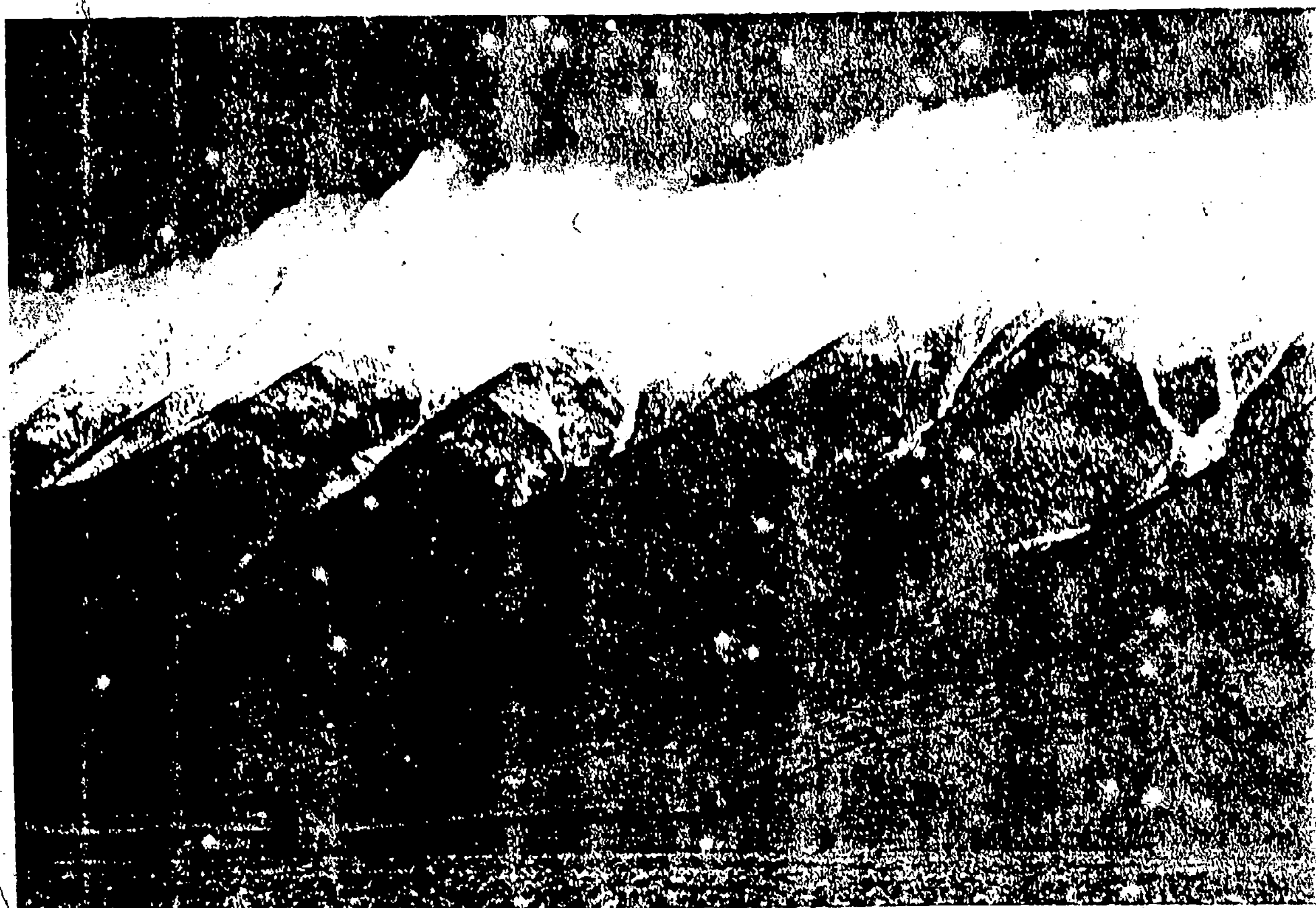
Complete your sketch now. Start by drawing in isobars of 29.50 and 29.70. The 29.60 isobar has already been drawn in. Note that there is only one reading of both 29.50 and 29.70. Therefore, you will have to use your judgment and experience in drawing the isobars. You should also draw a dotted line where you think there is a sharp difference in temperature. Shade in the clouds as your last step.

Figure 6-9



Then see how your conclusions compare with those of other students. Your teacher can offer you some advice if you are having difficulty with this activity.

In the next chapter, you will make the final test of your model for weather. You can judge your model by seeing if it helps you make predictions about weather. First, though, you need to look at one other air-lifting (cloud-forming) factor.



Because the earth's surface is very irregular, air must often flow up over mountains and down into valleys. As air is pushed up the side of a mountain, it is cooled, and there is less pressure from the atmosphere above.

Figure 6-10

□ **6-14.** What result would you expect as moist air moves up and over a mountain?

The upward flow of moist air has great significance in mountainous regions. There may be abundant precipitation on one side of a mountain but little on the other side. For example, notice in Figure 6-11 that the vegetation is not the same on the two sides of the mountain.

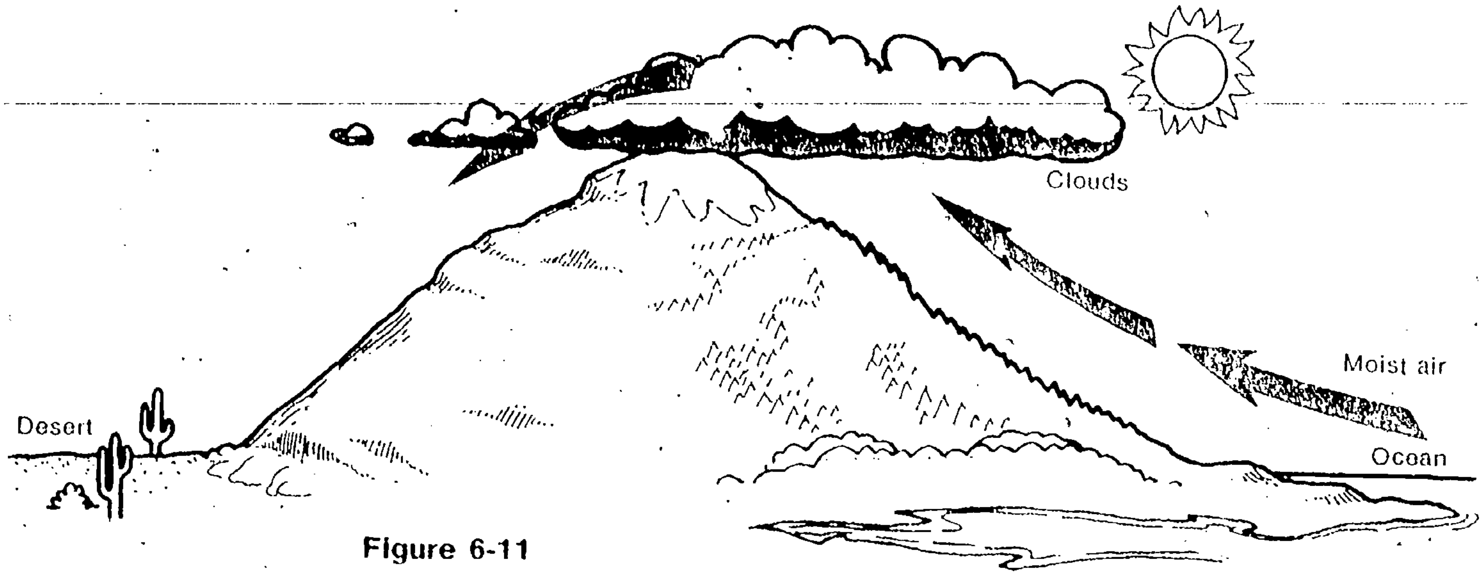


Figure 6-11

☐**6-15.** Explain why there is more vegetation on one side of the mountain than on the other in Figure 6-11.

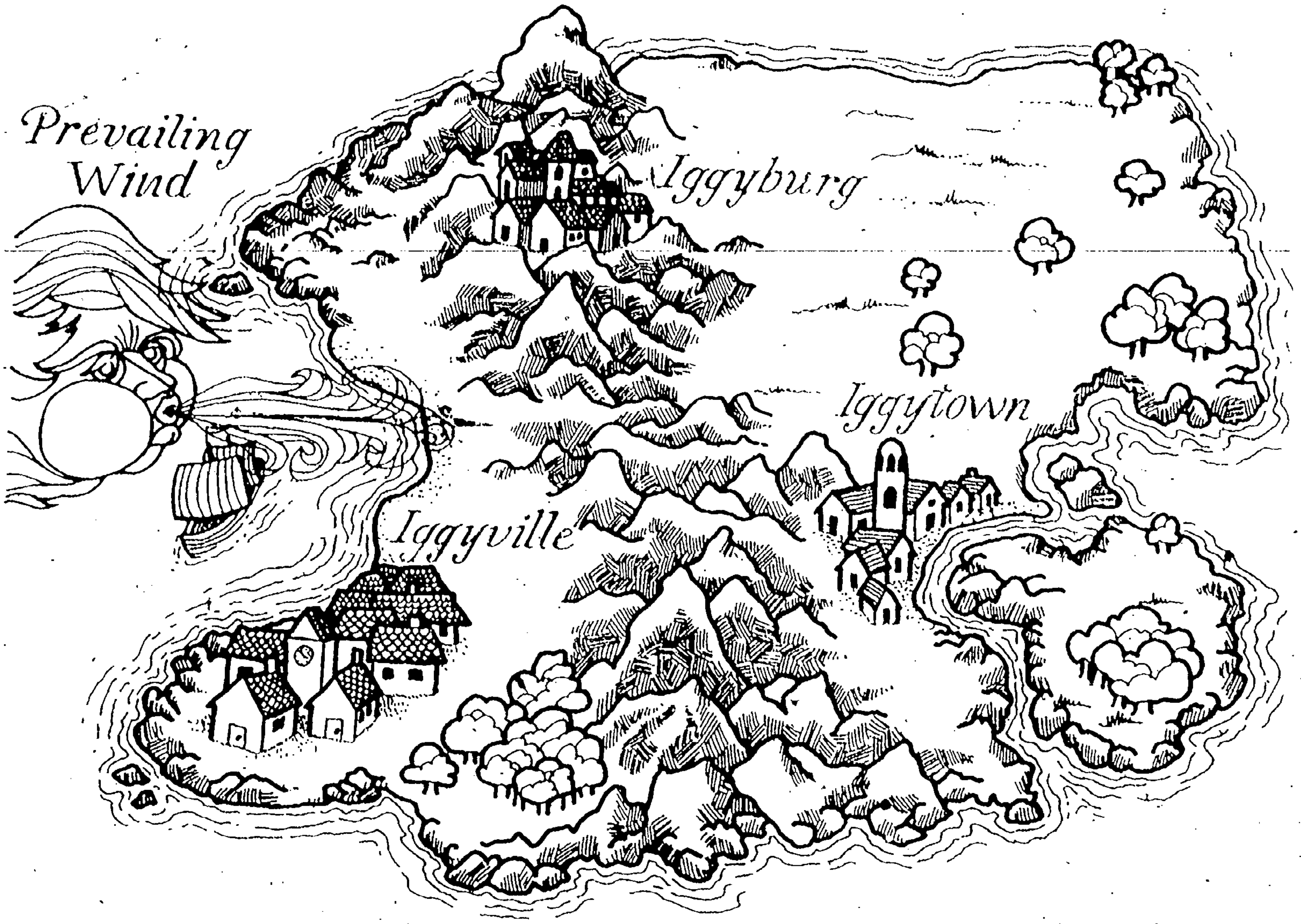
You have been introduced to several factors that can produce cloud formations. Landforms may produce air lifting. Sharp changes in barometric pressure and abrupt temperature changes can produce clouds. And, as you saw earlier, surface heating of land areas can produce cloud formations, especially along coastal regions.

PROBLEM BREAK 6-2

Here's your chance to use some of your experience to make predictions. In solving this problem, consider two ways that air is forced upward:

(a) by the differential heating of the earth's surface and
(b) by mountains.

An aerial view of Iggy's Island is shown below. There are three communities on the island. The direction of the prevailing (usual) wind is shown by the arrow.

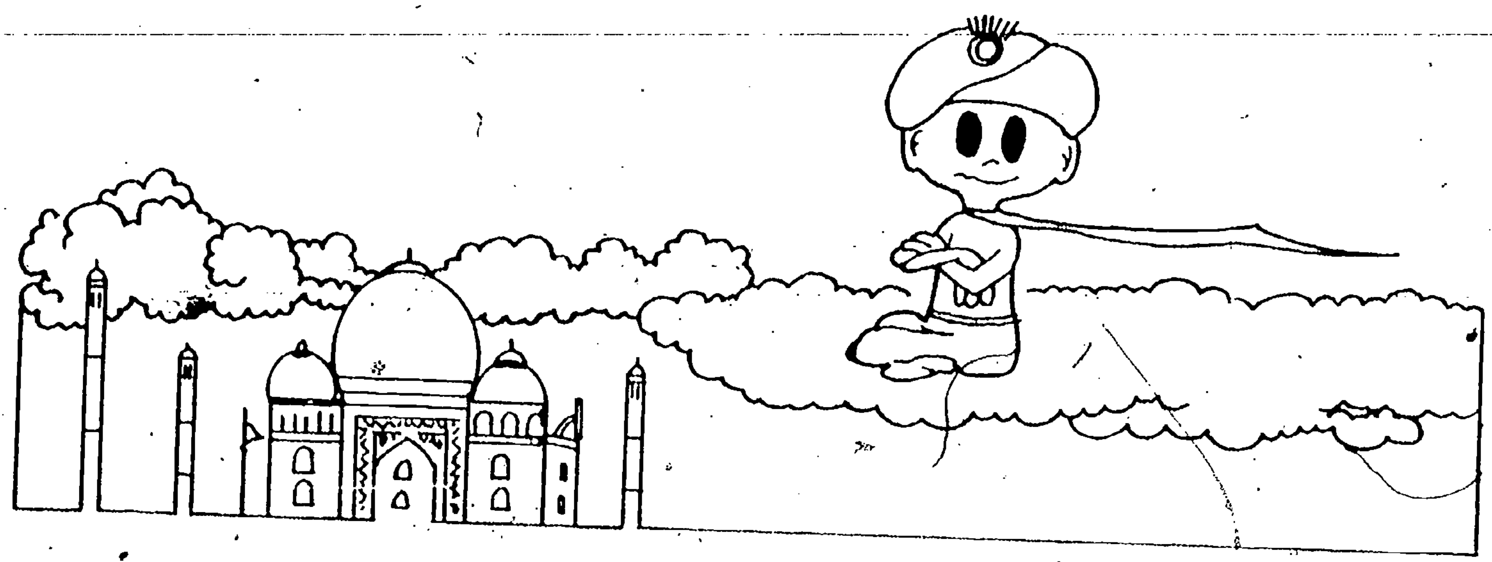


In the space provided in your Record Book, discuss the weather you predict for each of the three communities. Answer such questions as the following: Which community has the cloudiest, and which has the clearest, weather? Which community gets the most, and which gets the least, rainfall?

Before going on, do Self-Evaluation 6 in your Record Book.

Moving Weather

Chapter 7



According to the model you've developed, the uplifting of air has important effects upon the weather. This process appears to be linked to cloud formation. Thus, it is responsible for all kinds of precipitation (rain, snow, sleet, and hail). This lifting process also seems linked to wind characteristics.

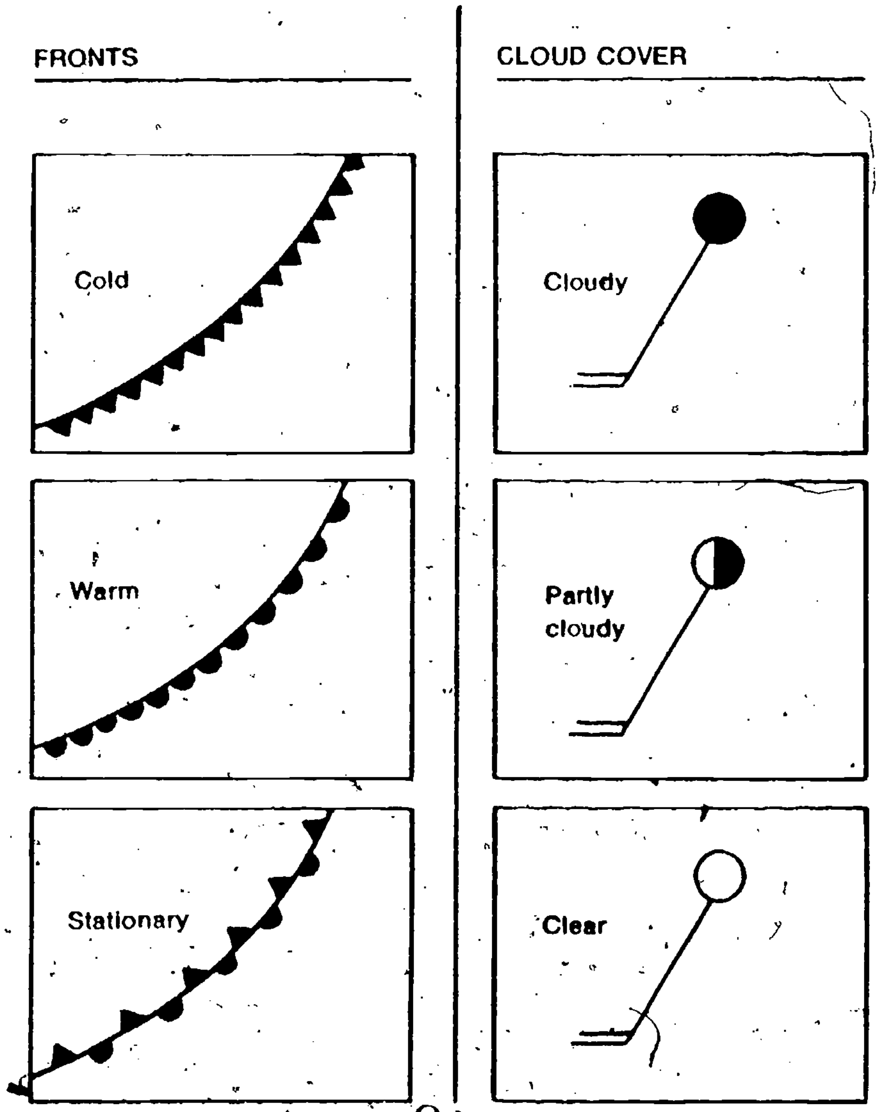
When you began this unit, your objective was to learn to predict the weather. The air-uplift model suggests some ways to do this. Suppose you could somehow know in advance when uplifting air would occur in your area. This would let you make some good guesses as to what to expect in terms of cloudiness and wind. But how can you predict when air is going to be uplifted?

According to your model, air is uplifted in at least four major areas.

1. Over a surface where air is heated.
2. Along lines where there is sharp difference in air temperature.
3. In areas of relatively low barometric pressure.
4. Where there are geographic features such as mountains.

Predicting when air will be lifted really boils down to knowing when one or more of these agents exist in an area. Since mountains and seacoasts don't move, it is fairly easy to predict their effects. But what about lines of temperature difference and low-pressure areas? Do these things move about? If so, is there enough order to their moving to allow predictions to be made? Figures 7-1 through 7-4 will help you find out.

Figures 7-1 through 7-4 show temperature and pressure data for most of the United States on four days in April. Two maps appear for each day; one gives temperature, while the other gives pressure information. Areas of low pressure and high pressure are labeled with an L or an H on the pressure maps. Lines of temperature differences (fronts) and cloud cover are indicated by the symbols identified below.



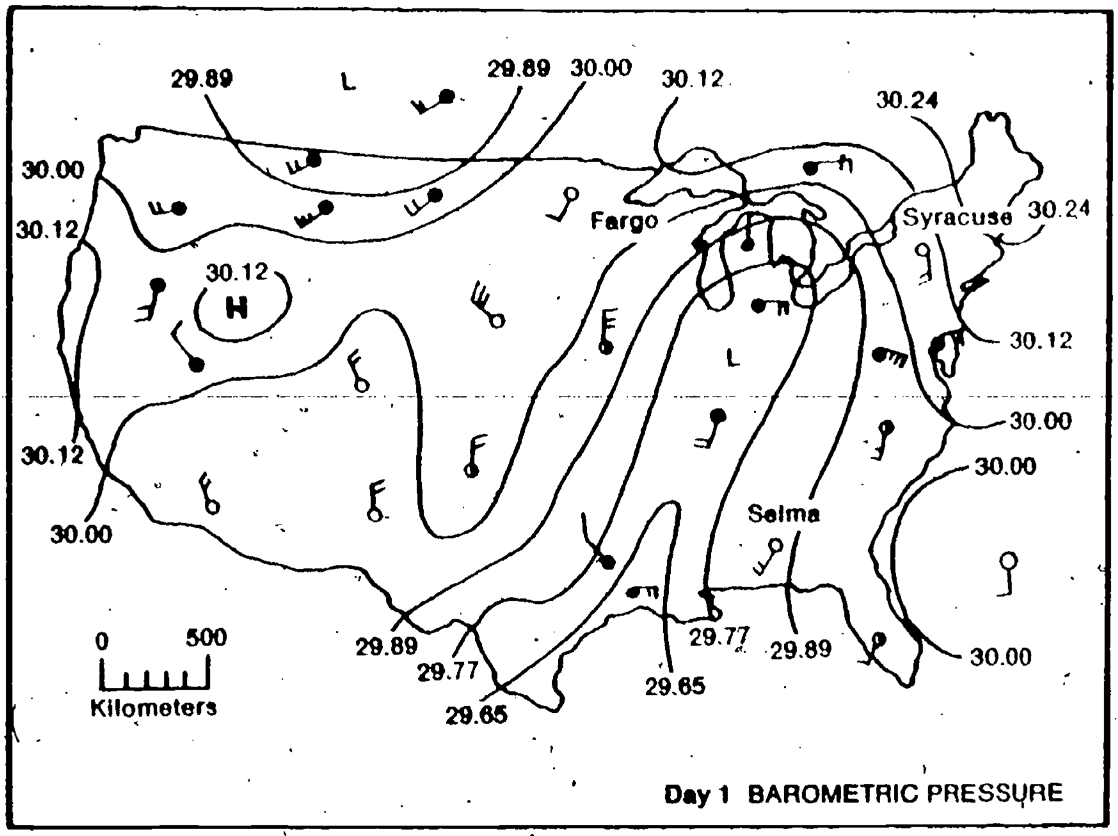


Figure 7-1a

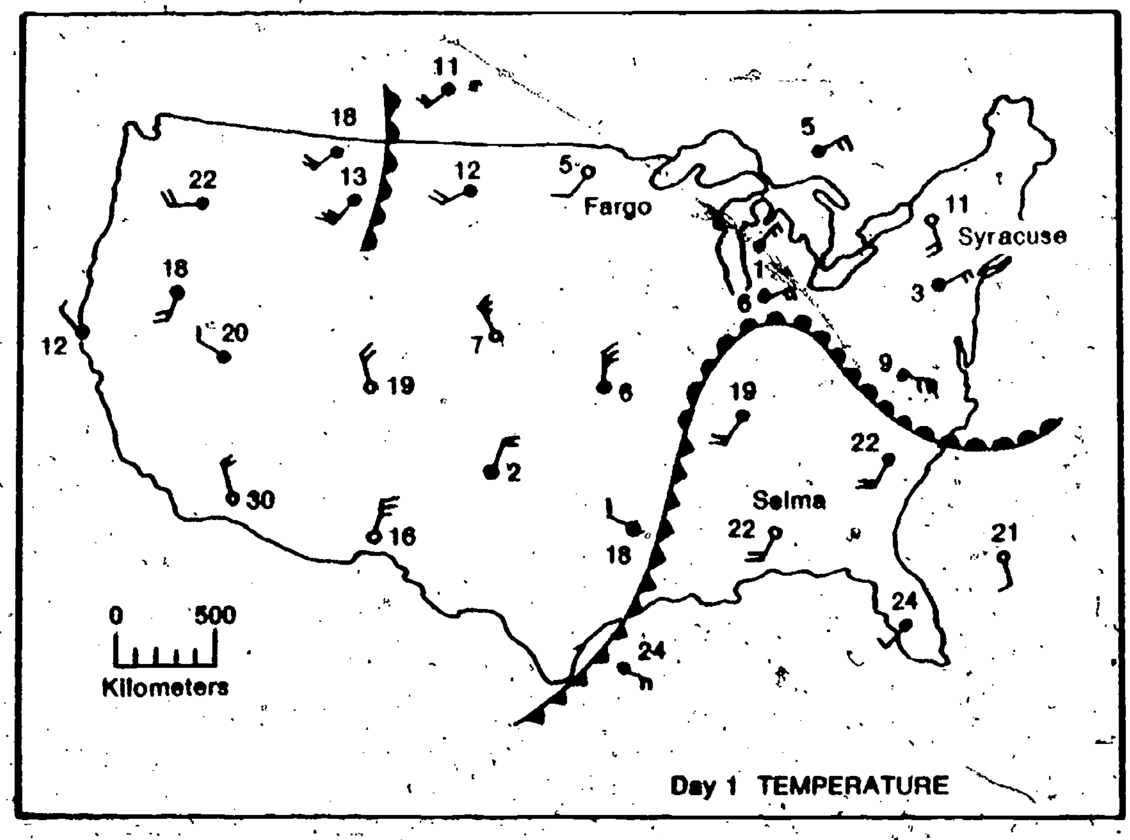


Figure 7-1b

Figure 7-2a

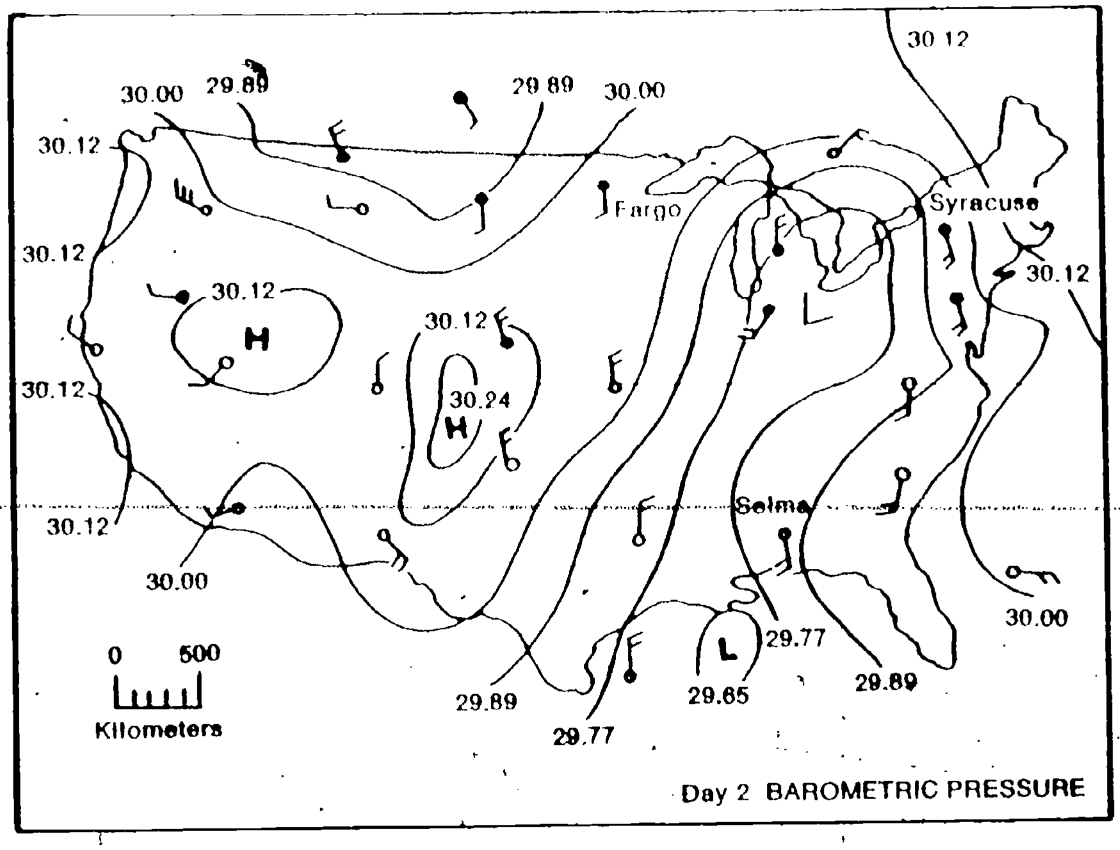
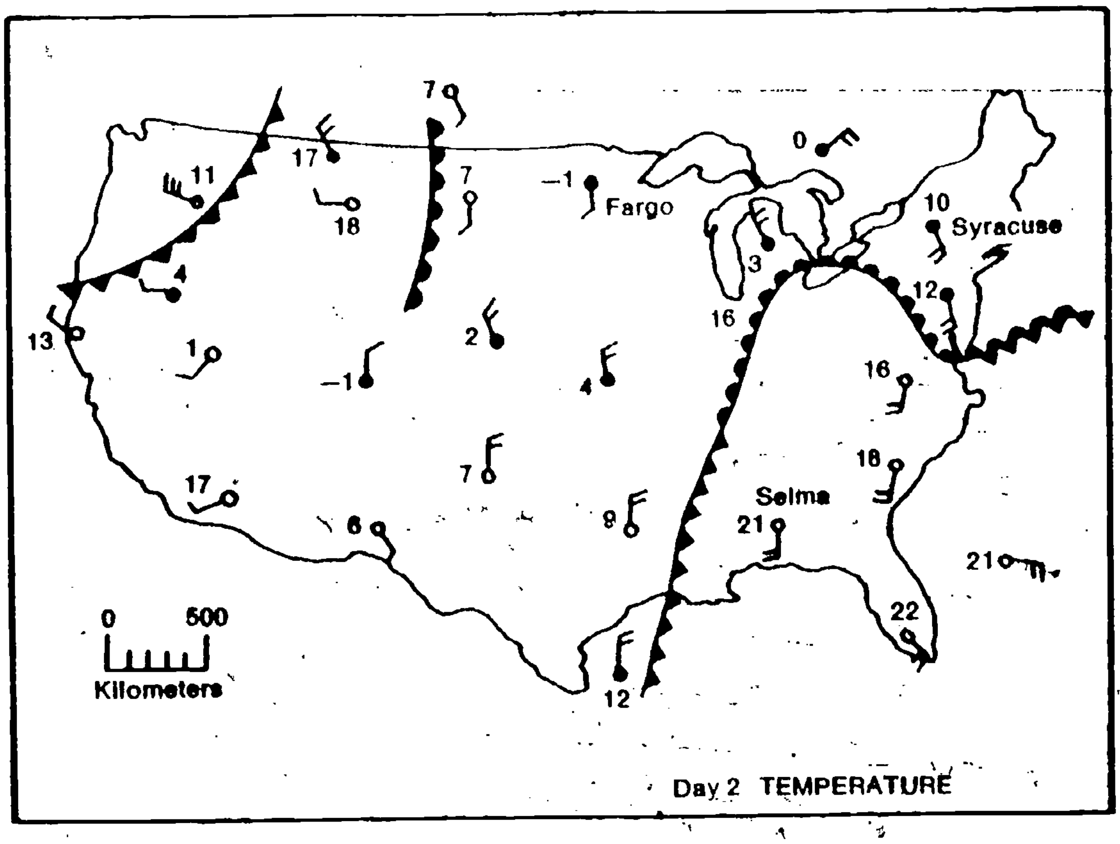


Figure 7-2b



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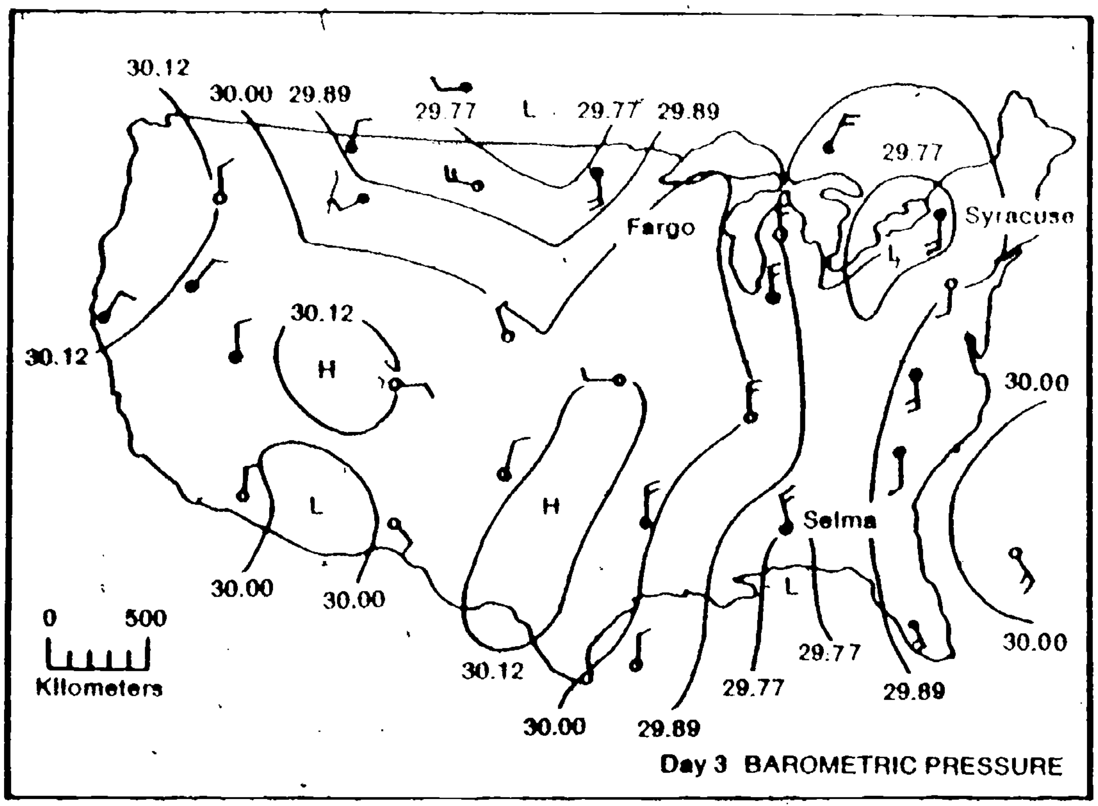


Figure 7-3a

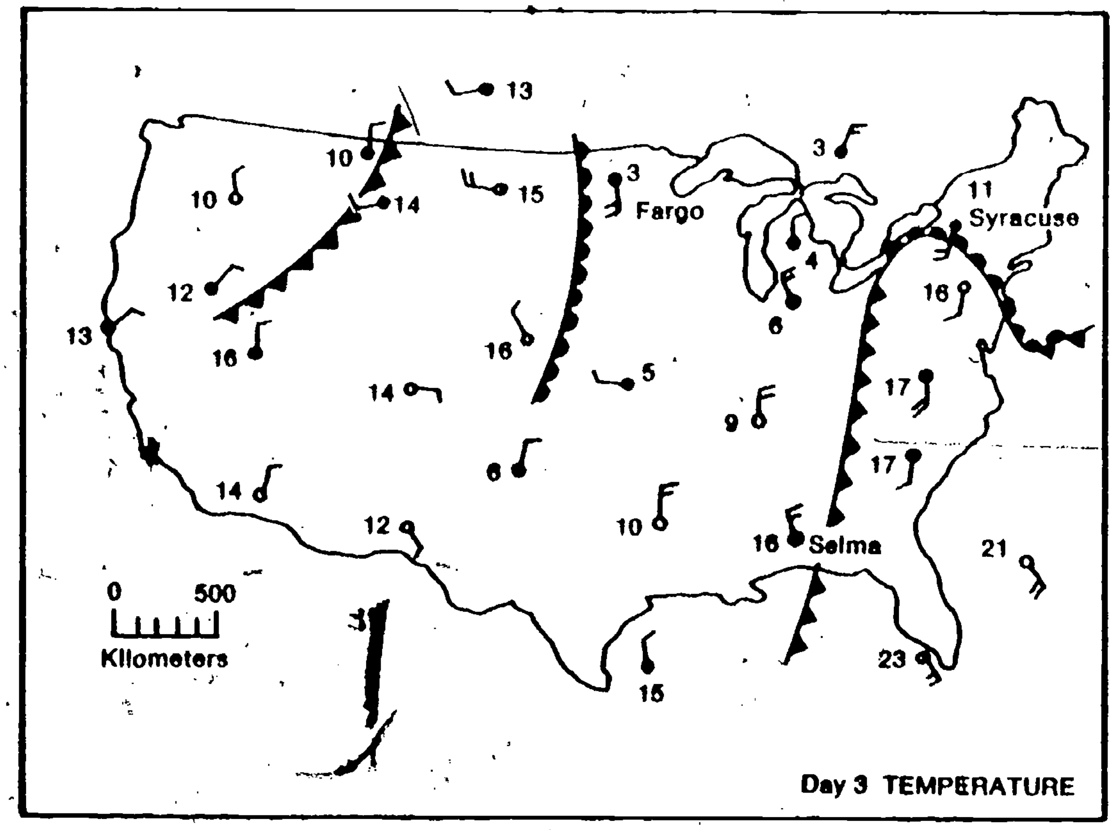


Figure 7-3b

98

Figure 7-4a

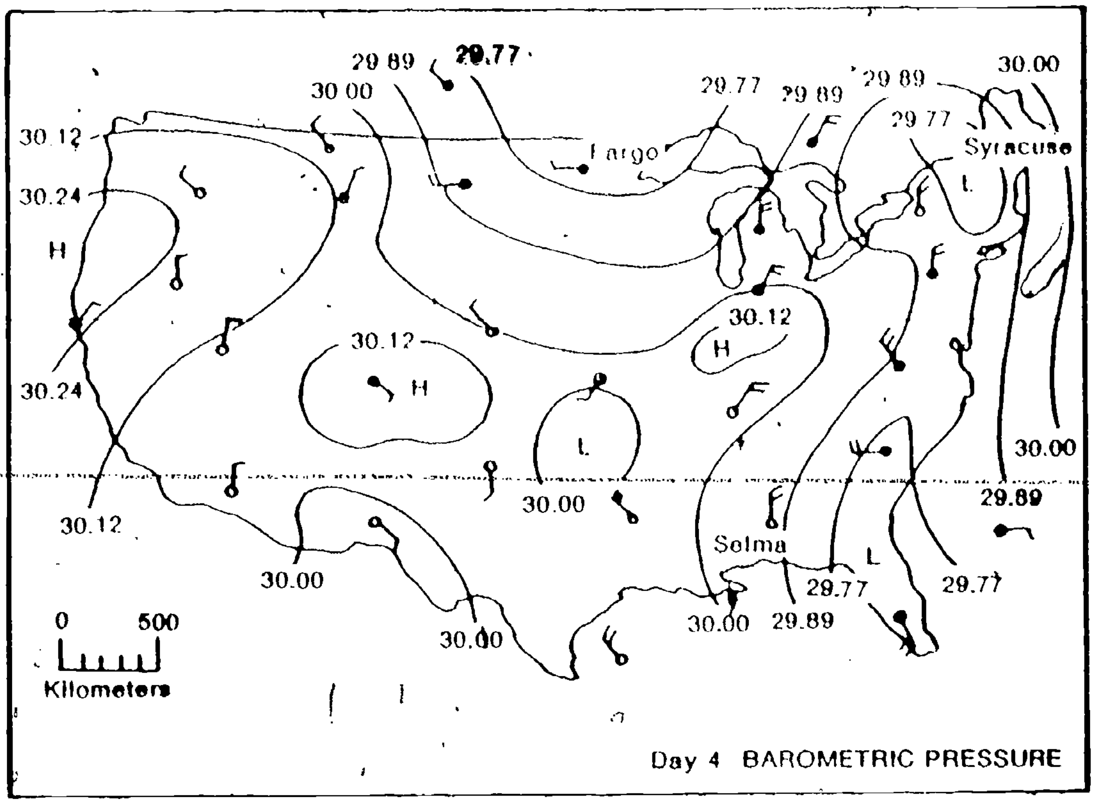
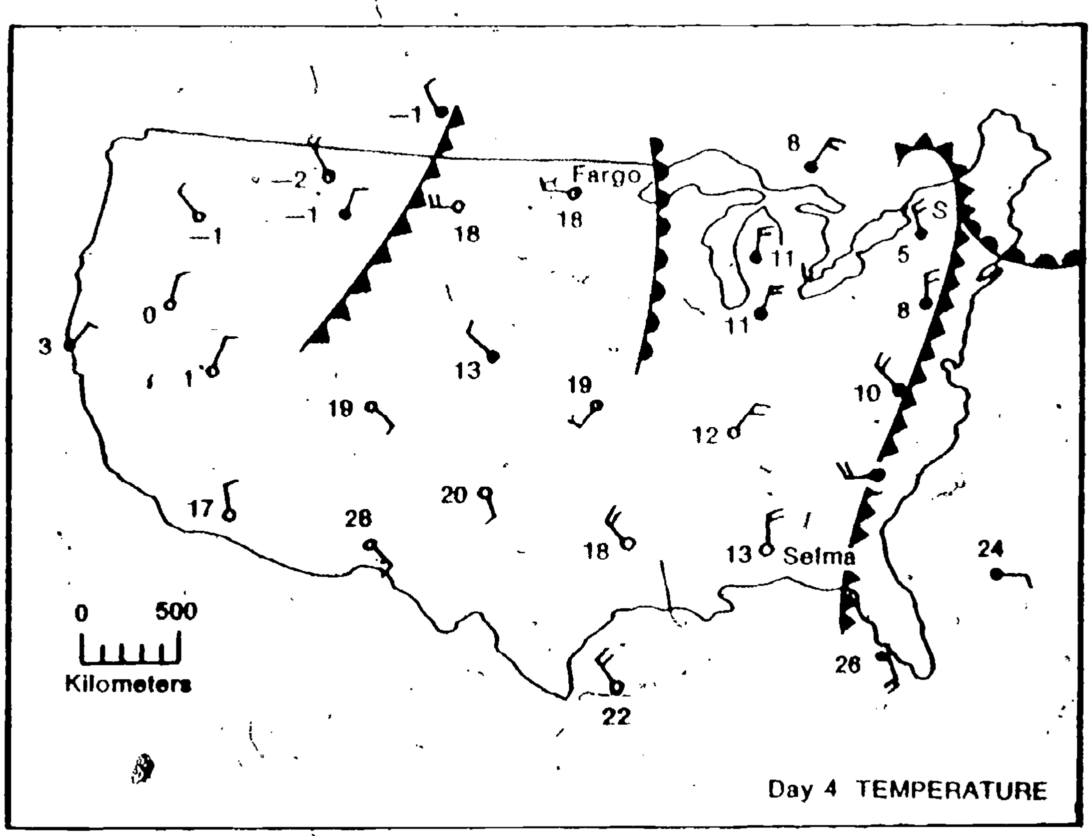
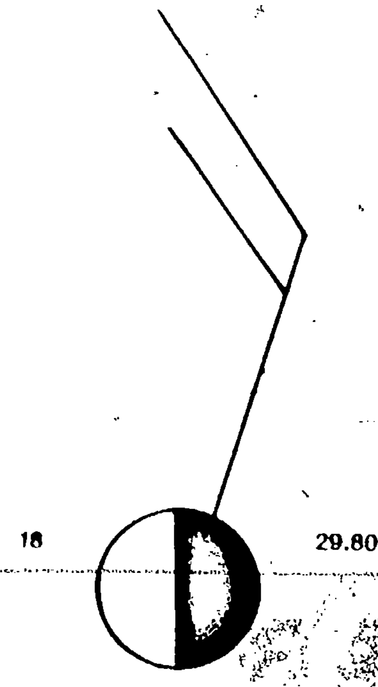


Figure 7-4b



☐**7-1.** Did the low-pressure areas, shown first in Figure 7-1a, move during the four-day period? If so, in what general direction?

☐**7-2.** Did the lines of temperature difference, shown first in Figure 7-1b, move during the four-day period? If so, in what general direction?



Both pressure areas and lines of temperature difference do move. Those on your maps wandered farther to the east during the four-day period.

The fact that cloud-forming agents move makes the job of weather prediction more difficult. You must find some way to guess in advance when one of these systems will come your way. Let's see if this can be done. First, we'll consider the problem of predicting the approach of a low-pressure system.

Suppose you were living in Syracuse, New York. On Day 1 of the data period (see Figures 7-1a and 7-1b), a low-pressure area would be lying to the west of you. Examine the data for Days 2, 3, and 4 and notice what happens in Syracuse as the low-pressure area approaches and then passes by.

☐**7-3.** What happened to the barometric reading in Syracuse as the system moved through (rose, fell, or remained the same)?

☐**7-4.** List the changes in the wind direction in Syracuse as the system moved through.

☐**7-5.** List changes in the cloud cover as the system moved through Syracuse.

☐**7-6.** What observations could have been used two days in advance to predict that the low-pressure area was moving into Syracuse?

Now let's look for signs that could be used to predict the approach and passing of lines of temperature difference. For this, you should study Figures 7-1b, 7-2b, 7-3b, and 7-4b.

Suppose you were living in Fargo, North Dakota, when the data on Figure 7-1b were collected. At that point, a line of temperature difference would be lying to the west of you.

[ ]7-7. Is the air behind the line (to the west) cooler, or warmer, than that in front of it?

Examine the temperature closely for Days 2, 3, and 4 and notice what happened to the weather in Fargo as the line of temperature difference moved through.

[ ]7-8. What happened to the air temperature as the line approached and moved through Fargo (rose, fell, stayed the same)?

[ ]7-9. List the changes in the wind direction as the line approached and moved through Fargo.

[ ]7-10. List changes in the cloud cover as the line approached and moved through Fargo.

[ ]7-11. What observation could have told you on Days 1 and 2 that a line of temperature difference was approaching Fargo?

Now consider the weather in Selma, Alabama. On Day 1, an approaching line of temperature difference lies to the west of that city, too. But it's different from the one you just examined. Look carefully to see how.

[ ]7-12. How does the line of temperature change approaching Selma differ from that approaching Fargo on Day 1 in Figure 7-1?

Look at the weather data for Selma over the four-day period.

[ ]7-13. List changes in the cloud cover in Selma as the line of temperature difference passed through.

[ ]7-14. List changes in the wind direction as the line passed through Selma.

[ ]7-15. What happened to the air temperature as the line passed through Selma?

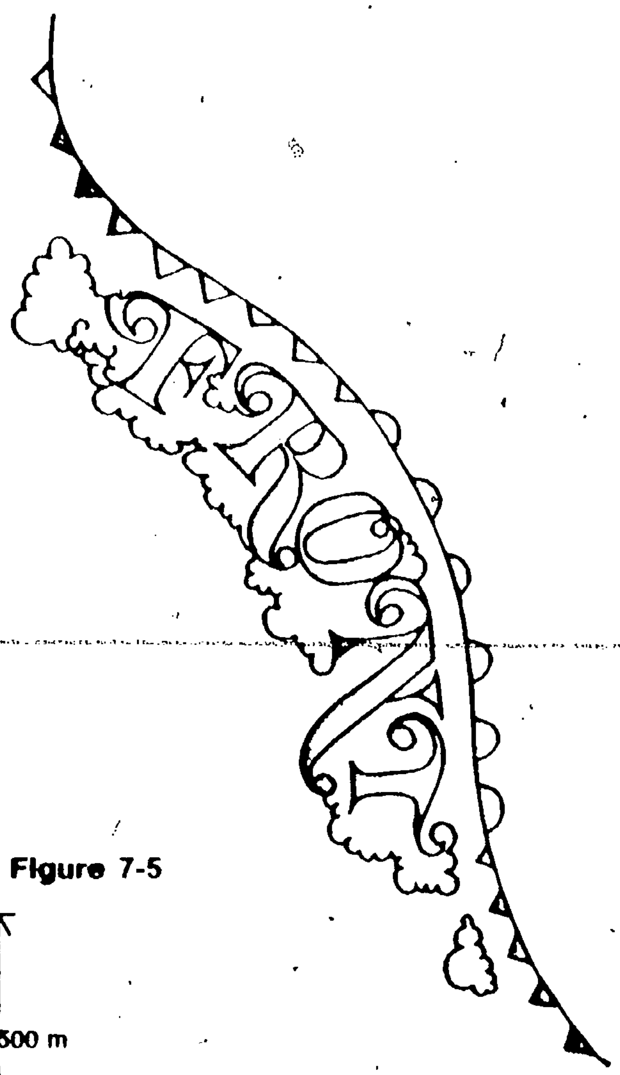
[ ]7-16. What happened to the barometric readings as the line passed through Selma?

□7-17. What observations could have told you in advance that this line of temperature difference was approaching Selma?

Perhaps you now see what "lines of temperature difference" really are. They are the edges of moving masses of warm or cold air. They are called *fronts.*

A *warm front* is a mass of relatively warm air that advances into a region that is relatively cold. As the warm air advances, the lighter, warm air is forced upward over the heavier, cold air. This process typically takes place over a large area. In a warm front, both the air masses are moving in the same direction. The advancing warm air mass is moving faster than the retreating cold air mass.

To visualize this motion, imagine that you are looking at the front from the side as it passes by. This side view (or cross section) would be what you would see if you sliced down through the front from top to bottom and laid it open. Figure 7-5 diagrams what a warm front would look like.



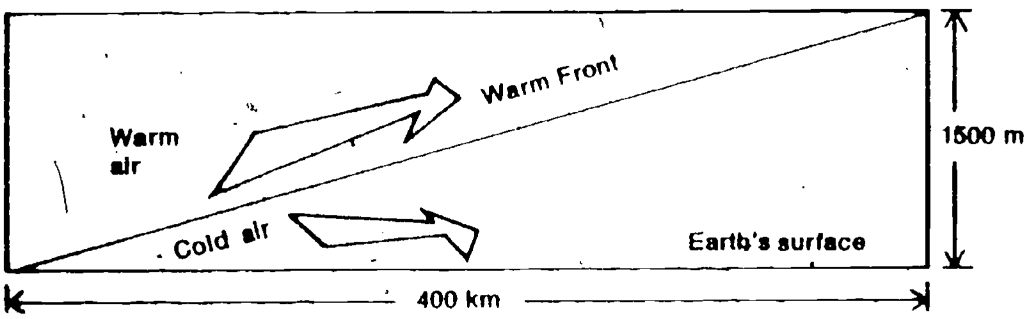


Figure 7-5

A *cold front* is a mass of relatively cold air that is displacing relatively warm, moist air. The warm air may be moved upward more quickly than it is in the usual warm front. Therefore, the slope of the cold front is steeper than that of the warm front. Figure 7-6 diagrams another side view of the frontal system. Study Figures 7-5 and 7-6 carefully so that you understand thoroughly the difference between warm fronts and cold fronts.

Figure 7-7 shows a different view of warm and cold fronts—as if you were looking down upon them from out in space. This is the view you get when looking at a weather map. Symbols used by meteorologists are shown in the figure.

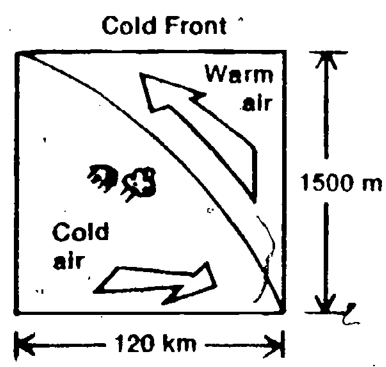
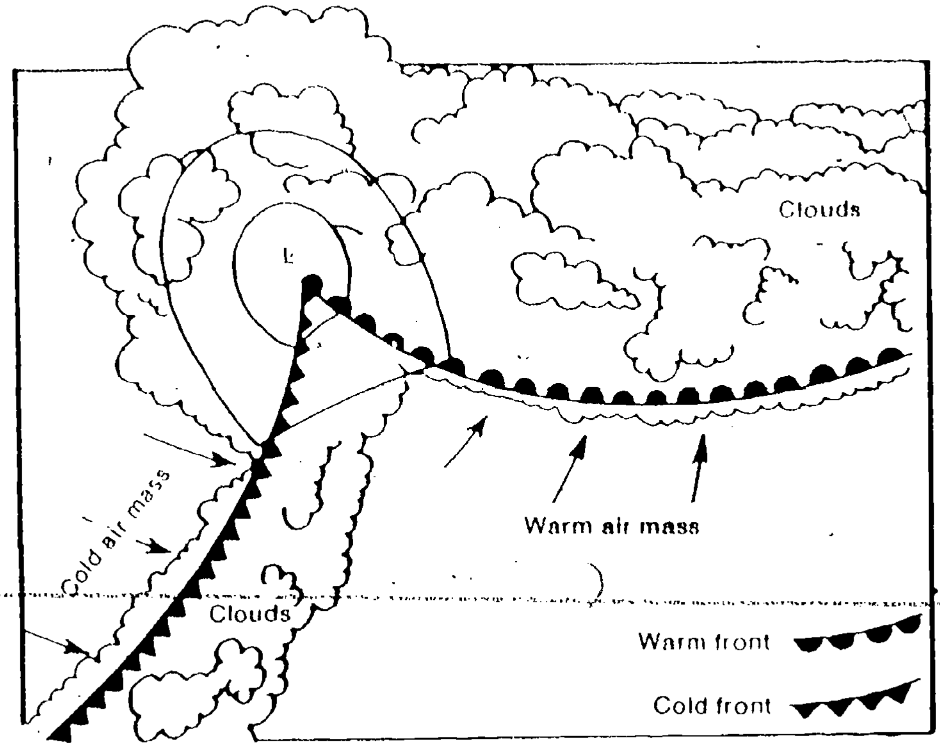


Figure 7-6

Figure 7-7



Notice the relationship of the fronts shown in Figure 7-7 to each other and to the low-pressure area. The general shape should be familiar to you. You've seen it on the weather maps you've been studying and in the photograph shown earlier and reproduced again in Figure 7-8.

Figure 7-8

In both Figure 7-7 and Figure 7-8 the two fronts and the low-pressure area actually form one large system. Look carefully once more at Figures 7-1 through 7-4. As you do, try to answer these questions:

□ **7-18.** Are the fronts on the temperature maps located in the same general areas as the low-pressure areas on the pressure maps?

□ **7-19.** Do the low-pressure areas move at roughly the same rate and in the same direction as any fronts near them?

Well, the pattern on the maps is not completely clear, but two things are apparent.

1. Fronts are always associated with low-pressure areas.
2. Fronts and pressure systems move across the country together.

At this point, you have the chance to stop and gather your wits. You are to look back over all the photographs, maps, and illustrations in the last chapter and this one. Build a picture in your mind (a model) as to what happens to the weather in an area as a large pressure system approaches and passes through. Take plenty of time for thought. It will be important to what you will do next. Use the questions below to guide you in your thinking. You should discuss these questions with others who are at about this point.

1. Approximately how wide is the band of cloudiness associated with a warm front? with a cold front? with a low-pressure area?
2. How far ahead of each type of front or pressure area does it extend? (See Figure 7-7.)
3. What is the pattern of winds around a low-pressure frontal system? (See Figures 6-4, 6-7, 7-1 and 7-2.)
4. How far do cold fronts, warm fronts, and low-pressure areas travel in a day? Do they all move at the same rate? (See Figures 7-1 and 7-2.)
5. How can you tell in advance when a low-pressure frontal system is approaching an area? (Refer to questions 7-2 through 7-17.)
6. What is the relationship of a high-pressure area to the movement and effects of a low-pressure frontal system? (See Figures 7-1 and 7-2.)

When you feel that you understand how passing fronts and low-pressure areas affect weather, you are almost ready to apply this knowledge to your local area. Before you try to do this, though, you need to consider two more subjects. The first is precipitation (rain, snow, sleet, and hail). The second is cloud type.

Precipitation

Why does rain or snow fall from one cloud and not from another? Why is this precipitation sometimes a downpour and sometimes only a sprinkle? Why does precipitation occur in so many different forms? These are not easy questions to answer. In general, it has been more difficult to explain how precipitation gets out of clouds than it has been to explain how clouds form in the first place.

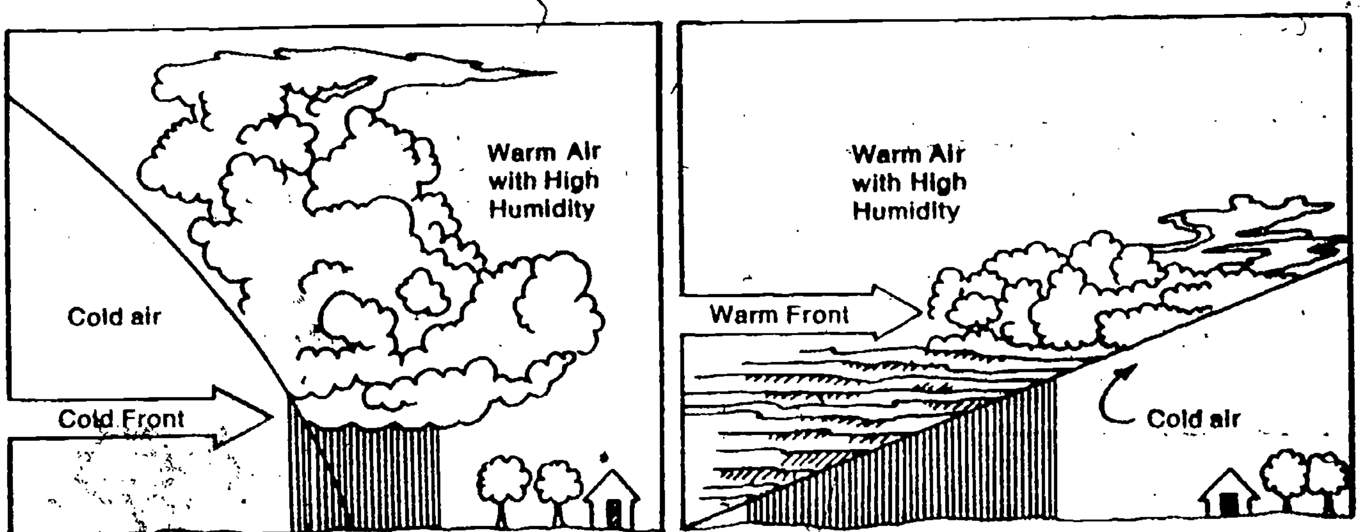
EXCURSION

If you are interested in learning how to make raindrops, see **Excursion 7-1,** "And the Rains Came Down."

In Chapter 4, you learned that water begins collecting on dust and salt particles when the temperature falls below the dew point. According to your model, this is what causes cloud formation. If the droplets combine into larger and larger ones, they become too heavy to stay aloft. Then they fall. Falling water (rain, snow, sleet, or hail) is called precipitation.

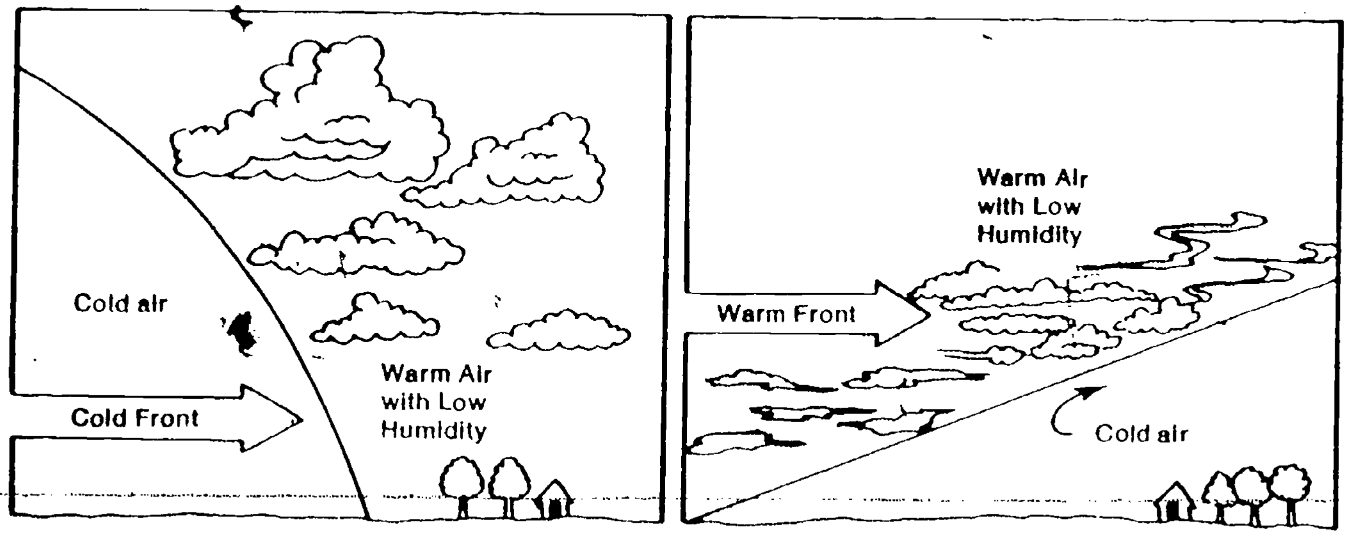
Along fronts, warm air slides up over cooler air. As it is lifted, the warm air cools below the dew points. If the warm air is quite moist (humidity is high) and/or the cooling is quite severe, precipitation is the likely result (Figure 7-9).

Figure 7-9



If the warm air is fairly dry (humidity is low) or if the cooling is not great, only a few clouds may form (Figure 7-10).

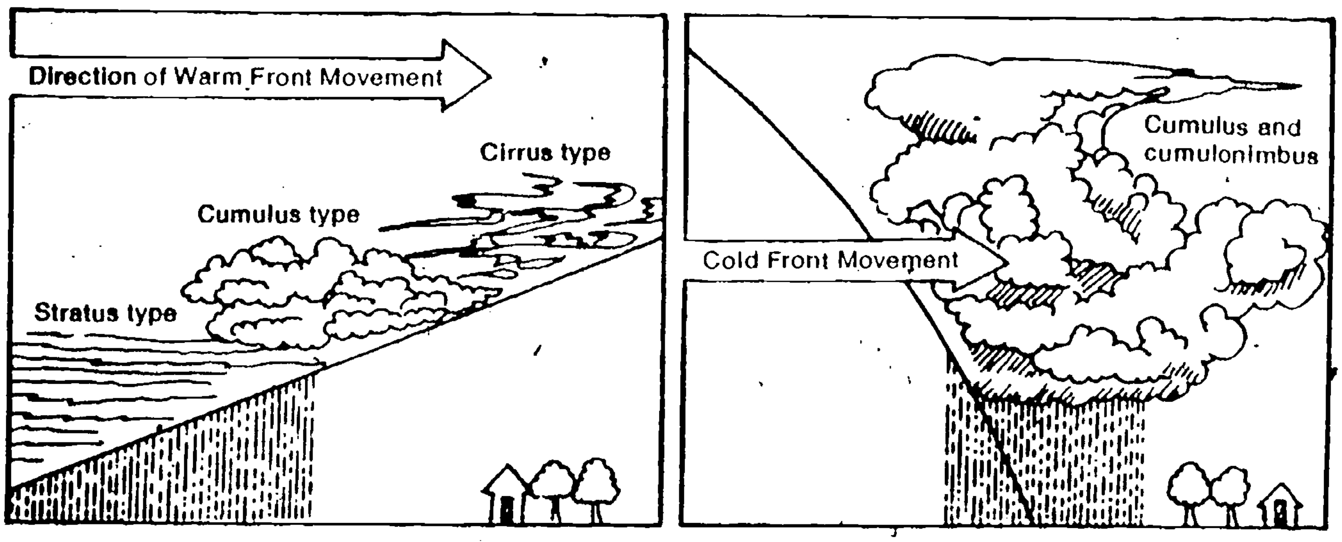
Figure 7-10



Back up to the clouds

The second subject we will discuss is cloud type. Over the years, meteorologists have studied the changes in cloud type as weather systems move through an area. They have found that the changes fall into the fairly consistent pattern shown in Figure 7-11.

Figure 7-11



Clouds are often spoken of as "billboards of the sky." A skillful observer can tell a great deal about forthcoming weather by studying the clouds.

☐**7-20.** List in order the cloud types you would expect to observe as a cold front approached your area.

[ ]7-21. List in order the cloud types you would expect to observe as a warm front approached your area.

Now let's try to summarize what you've learned about predicting the effects of frontal systems. Describe in Tables 7-1 and 7-2 the changes you would expect to occur with the warm and cold frontal systems.

Table 7-1

	COLD FRONT		
	Immediately Ahead of the Front	Along the Front	Immediately Behind the Front
Barometric reading			
Temperature			
Cloudiness			
Wind direction			

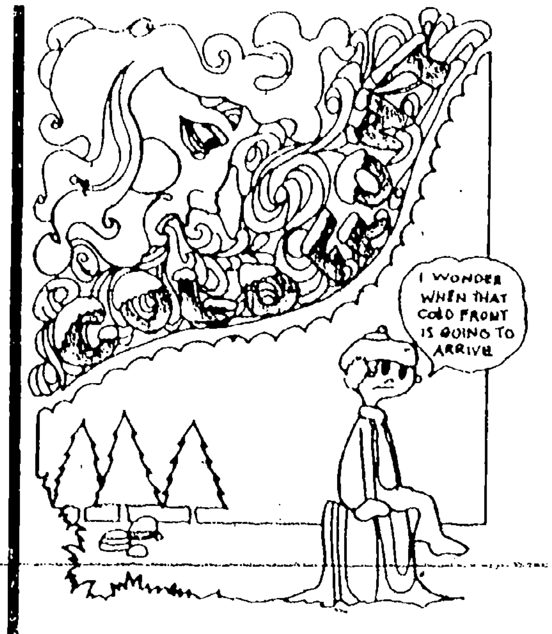
Table 7-2

	WARM FRONT		
	Ahead of the Front	Along the Front	Behind the Front
Barometric reading			
Temperature			
Cloudiness			
Wind direction			

You may have had trouble deciding how wind direction is affected by frontal systems. Predicting changes in wind direction requires that you know the direction before the front arrives. You would also need to know the direction of motion of the front. Neither of these bits of information is provided in Tables 7-1 and 7-2.

PROBLEM BREAK 7-1

You've been keeping a weather watch for quite a while now. You should have quite a collection of data for your area on variables such as barometric pressure, wind speed and direction, cloud cover, etc. Here's your chance to study that data and find out if the patterns in weather change for your area can be explained by the model you've been studying.



You should look for relationships between weather variables. For example, you may want to see if your data indicate that wind direction is related to barometric pressure, or to cloud type, or to dew point. Or you may want to find out if temperature change is related to humidity or to wind speed. Let's suggest one approach to getting answers to such questions.

Suppose you want to find out how pressure change affects temperature change. You could make a table like Table 7-3.

Table 7-3

Pressure Change from One Day to the Next	Prevailing Wind Direction for the 2nd Day of the 24-Hr Period			
	Northerly	Southerly	Westerly	Easterly
Rising				
Steady				
Falling				

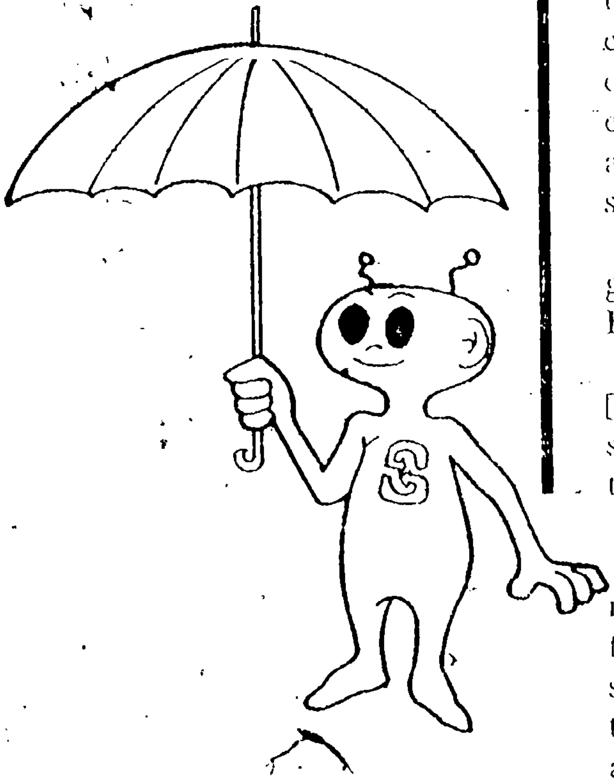
Tally the data from your weather watch in a table like 7-3. Each tally (mark) will represent one 24-hr period. After all tallies are made, you can judge the effect of pressure change on wind direction. You can even make some calculations. For example, you can calculate the likelihood that one kind of pressure change will produce a given wind direction. Suppose you want to know how often you can expect to see a southerly wind when the pressure is falling. Here's how you find out by using your data.

Sum up all the tallies in the entire table to get a grand total. Then divide this number into the number of tallies in the appropriate data box. Multiply your answer by 100 to get a percentage.

$$\frac{\text{No. of tallies in data box}}{\text{Grand total of tallies}} \times 100 = \%$$

This percentage (sometimes called probability) is a measure of the likelihood that falling pressure will produce southerly winds in your area. Of course, this percentage is based on limited data taken at one particular time of year. More extensive data might give you a different percentage for your answer. Even with such limited data, a percentage of this sort gives you more predicting power than you had before.

You should now select the variables you want to investigate. Record your findings and conclusions in your Record Book.



☐ **7-22.** What do you think the weatherman means when he says "The chance of rain today is 30%"? Discuss why you think he would make such a statement.

This unit of work was not designed to make you into a meteorologist. Its purpose was to introduce you to certain factors that affect weather and to help you put together a simple model for explaining those effects. You've seen that there would be no change in weather without movement of air. That's why this unit is titled *Winds and Weather*.

You've investigated many variables and seen how they affect the motion of air. You've learned something about the processes that form clouds. Perhaps you are still interested in learning more about old "cumulonimbus" mentioned in Chapter 1. If so, take a look at **Excursion 7-2**.

EXCURSION

Low- and high-pressure areas and frontal systems have also been studied a bit. You are on the verge of being able to predict simple weather changes in your own region. You can try your wings if you wish, by taking a look at **Excursion 7-3**, "Predicting Weather."

EXCURSION

Don't be disappointed if you aren't confident about your predictions. Weather is very complicated and often unpredictable. If you don't believe it, ask any weatherman.

Before going on, do Self-Evaluation 7 in your Record Book.

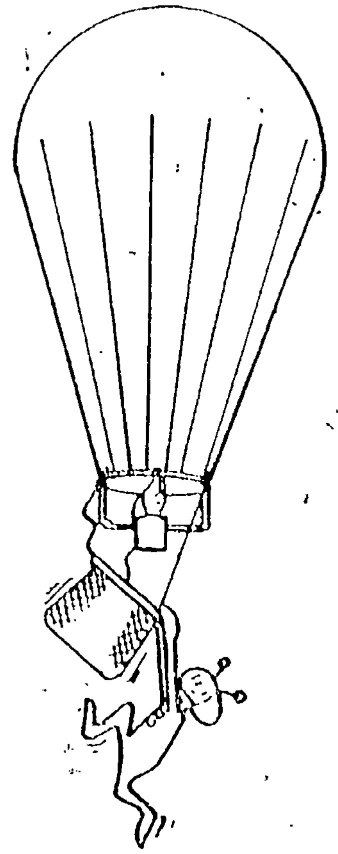
Excursions

Do you like to take trips, to try something different, to see new things? Excursions can give you the chance. In many ways they resemble chapters. But chapters carry the main story line. Excursions are side trips. They may help you to go further, they may help you go into different material, or they may just be of interest to you. And some excursions are provided to help you understand difficult ideas.

Whatever way you get there, after you finish an excursion, you should return to your place in the text material and continue with your work. These short trips can be interesting and different.

Hot Air Balloon

Excursion 1-1

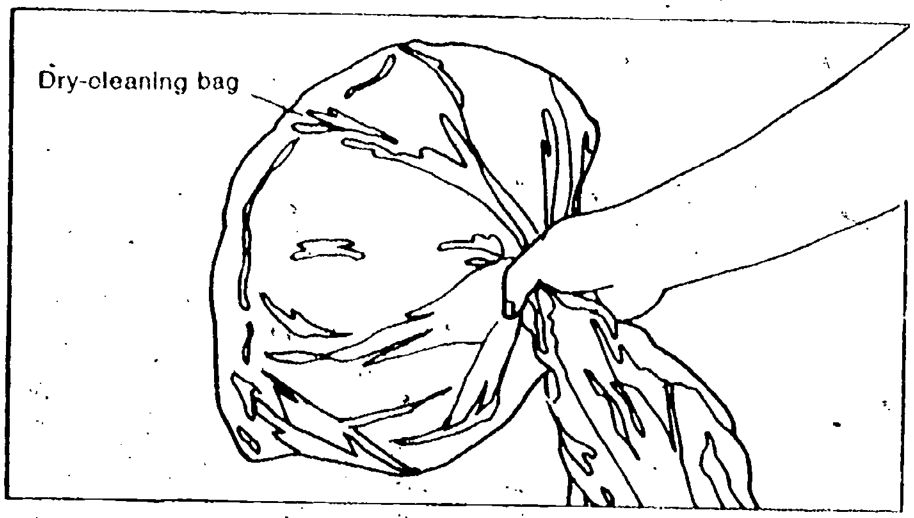


The basic equipment needed for a hot air balloon is an inflatable bag and a source of heat. Almost any size and shape of bag will work.

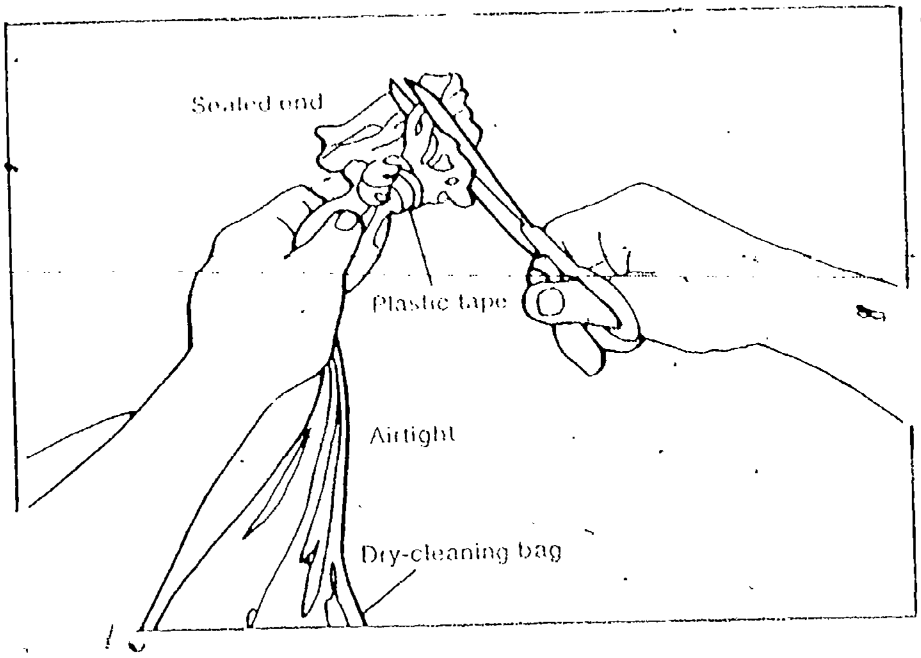
You can make your own balloon from a plastic dry-cleaning bag. The long dress-size bag will give the best results. Here is what you and a partner will need:

1 plastic dry-cleaning bag (dress-size)
Plastic straws
Plastic or cellophane tape
1 alcohol burner

ACTIVITY 1. You want to trap hot air in the bag, so check its sealed end for leaks. Do this by trapping some air in the end of the bag.

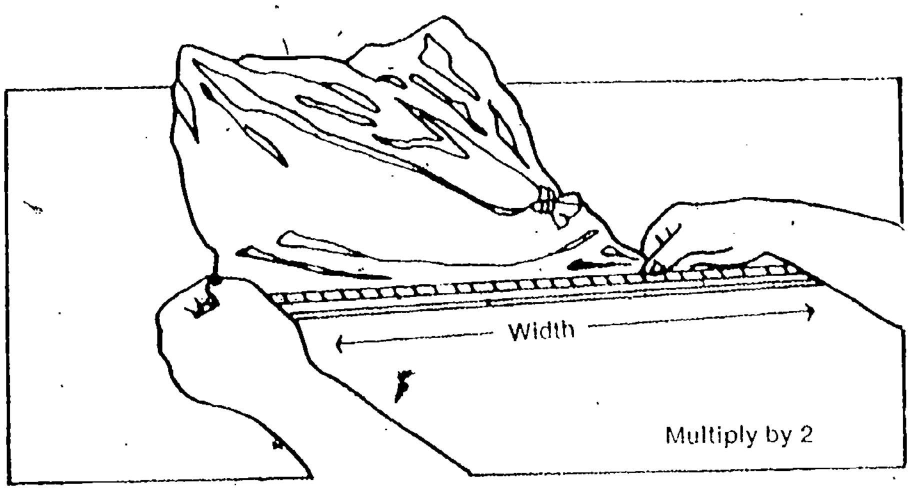


ACTIVITY 2. If the bag leaks, you should seal it with tape. Twist the closed end and tie a knot in it. Trim off the excess plastic with scissors.

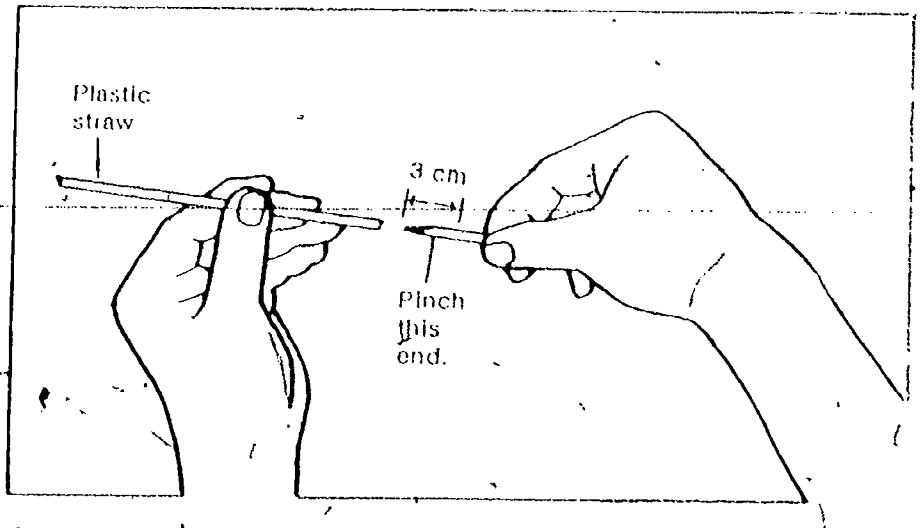


In order to collect hot air in the bag, you'll need to be able to hold the other end of the bag wide open. You can make a hoop or circle out of straws to do this. To find out how many straws to use, do the following activity.

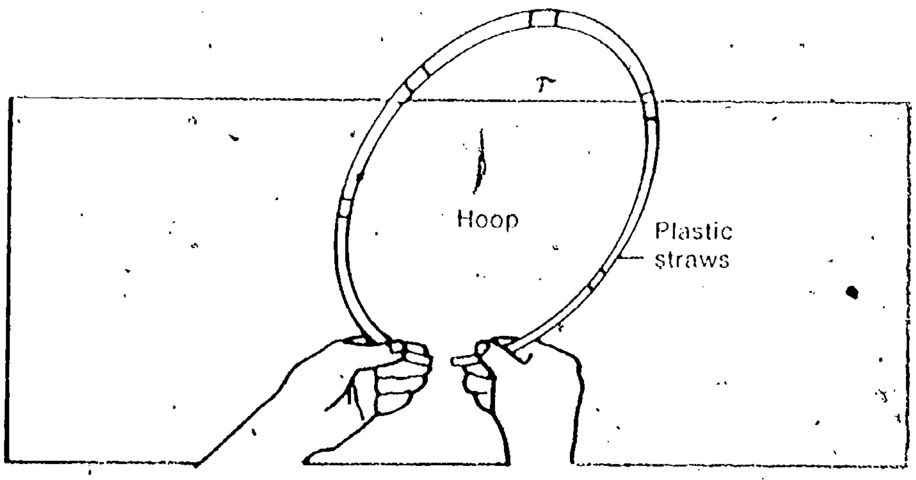
ACTIVITY 3. Flatten the bag out at its open end. Measure the distance across this open end. Multiply this distance (width) by 2. This will give you an approximate measure of the length of the bag's opening.



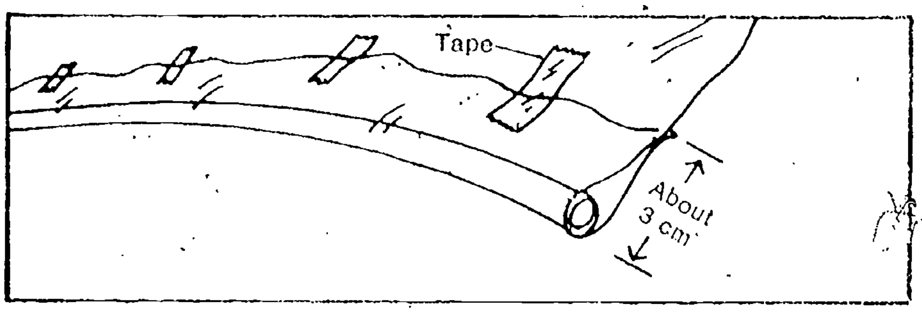
ACTIVITY 4. Place plastic straws together by pinching and folding one end of one straw and inserting it into another straw. (Overlap of the straws should be about 3 cm.) The total length of the straw chain should be equal to the approximate opening of the bag (as determined in Activity 3).

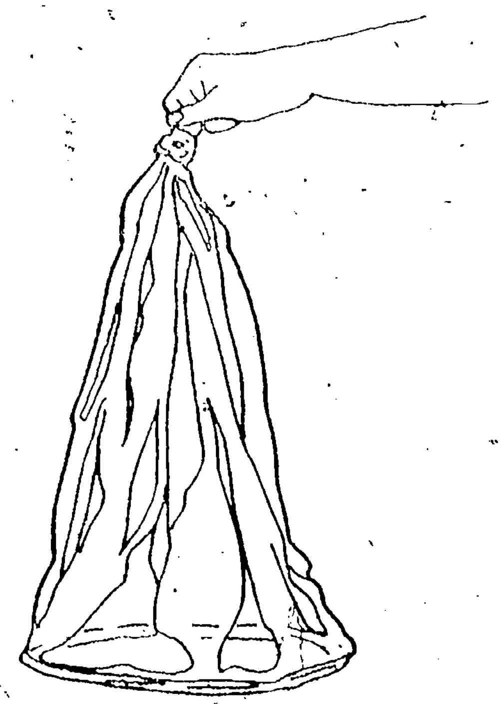


ACTIVITY 5. By putting the two end straws together, you can form a hoop.



ACTIVITY 6. Use a few short pieces of tape to hold the straw hoop inside the bag. Overlap the bag about 3 cm.

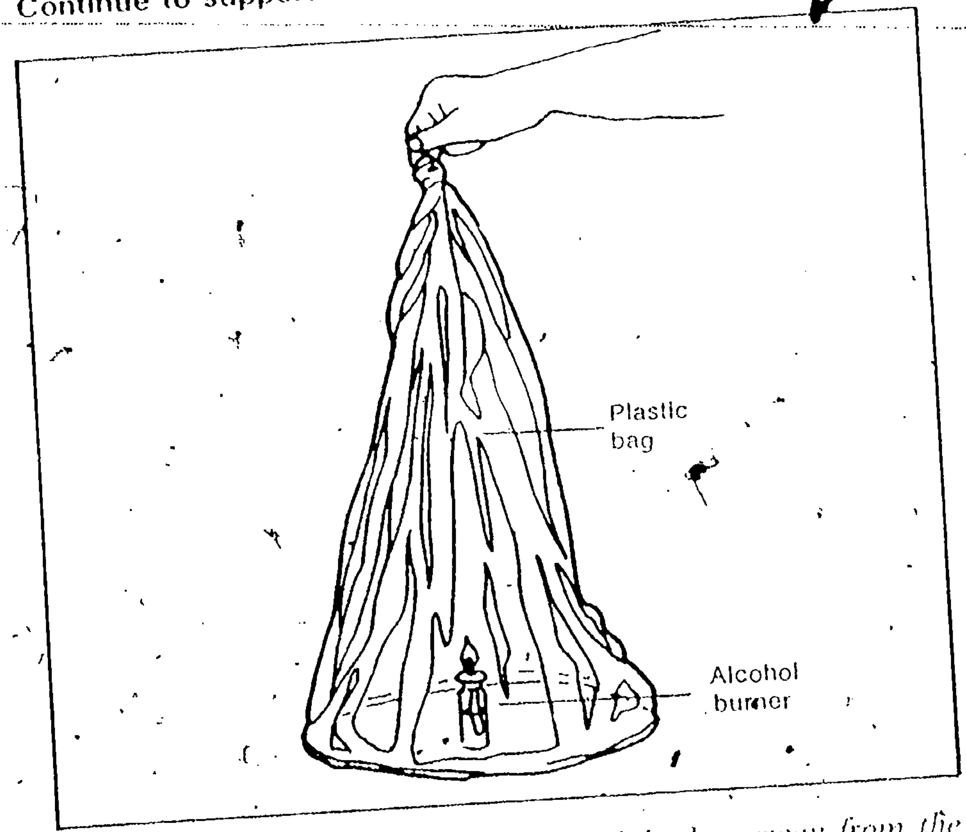




You are now ready to collect hot air in your bag.

Caution *The next part of this excursion should be done in an area designated by your teacher. Be sure to get his approval before beginning. Use caution in working with the alcohol burner. The plastic bag doesn't burn rapidly, but it will burn. Keep it clear of the flame.*

ACTIVITY 7. Hold the bag over the lighted alcohol burner. Continue to support the bag as the air inside is warmed.



Caution *Be sure to keep the sides of the bag away from the open flame.*

☐ **1.** Describe your observations of the bag as the air inside is heated.

☐ **2.** What would you have to do to keep the bag going up once it left the ground?

You may want to improve your balloon. That's okay. But don't try other experiments using flames without your teacher's permission.

Blowin' in the Wind

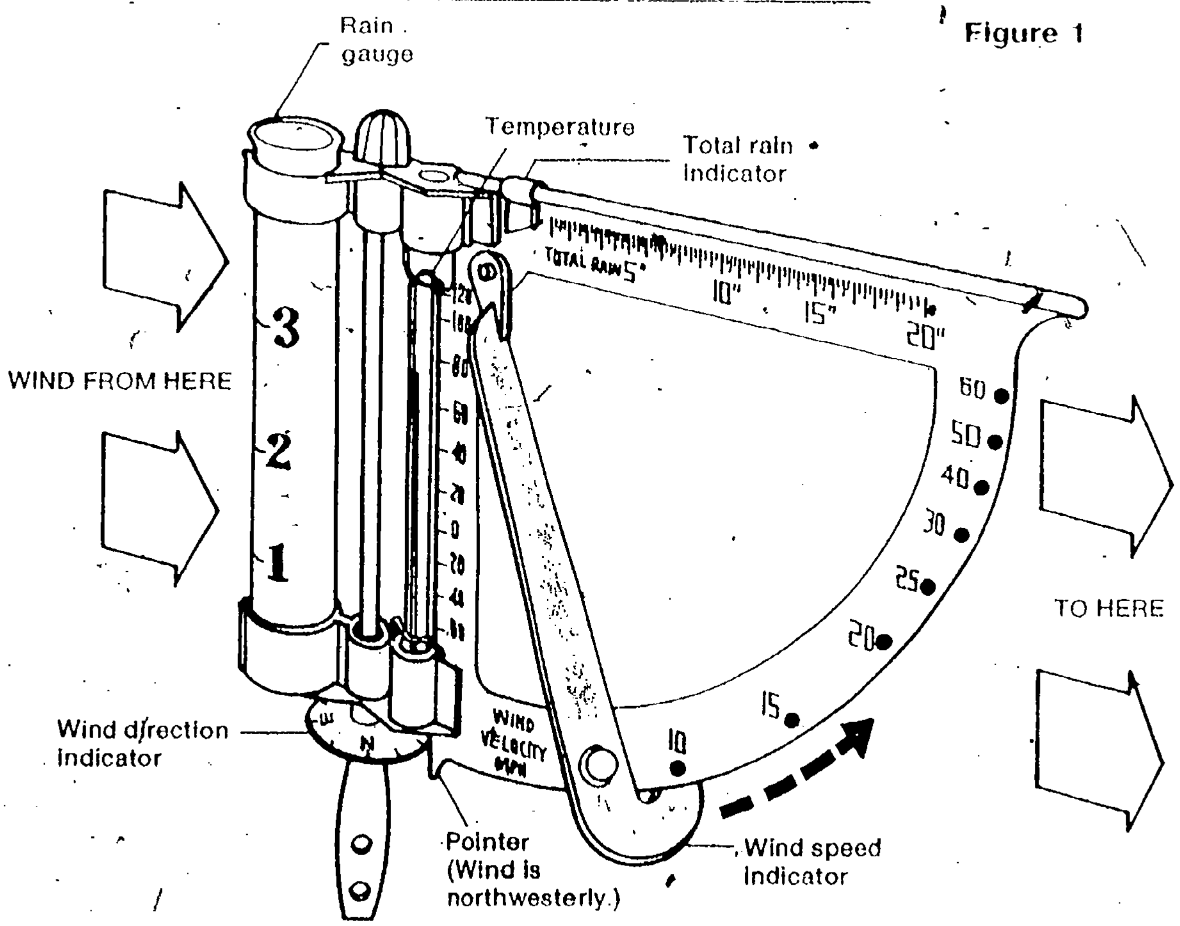
Excursion 2-1

Wind direction

In mounting the all-purpose weather instrument, the circular wind direction indicator should be positioned so that the north (N) symbol points toward true south. Then any pointer reading against this indicator disk will give the direction from which the wind is blowing.

The important point to remember is that wind direction is named according to the direction *from* which it blows.

Figure 1



Although it is possible to use up to 32 points of the compass to name the wind direction, you will use only 8. You can read the wind direction directly from the position of the movable pointer against the scale. A sketch of the 8 directions you may use appears in Figure 2.

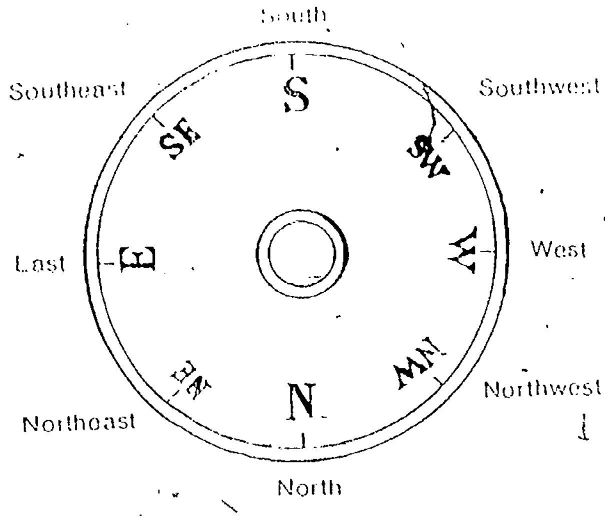
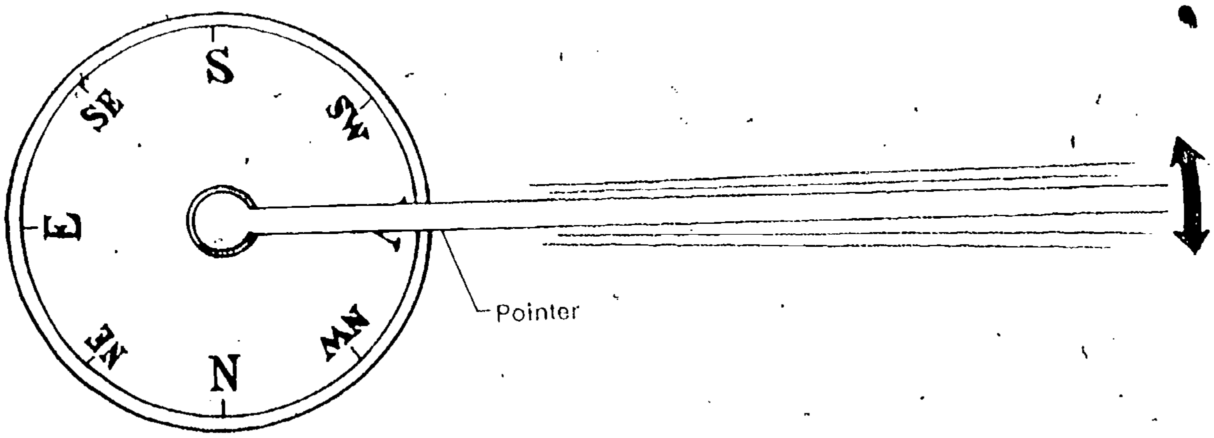


Figure 2

Usually, the pointer isn't stationary. It moves as the wind shifts back and forth. But you can still get an average reading. For example, if the pointer moves about as shown in Figure 3, the general direction of the wind is estimated to be *west*.

Figure 3



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Wind speed

The weather-station instrument also allows you to measure the wind speed. The principle behind the wind speed indicator should be obvious. In fact, you can easily build your own wind speed indicator if you are interested. See Figure 4 for hints on doing this. (You will have to furnish the common materials required.)

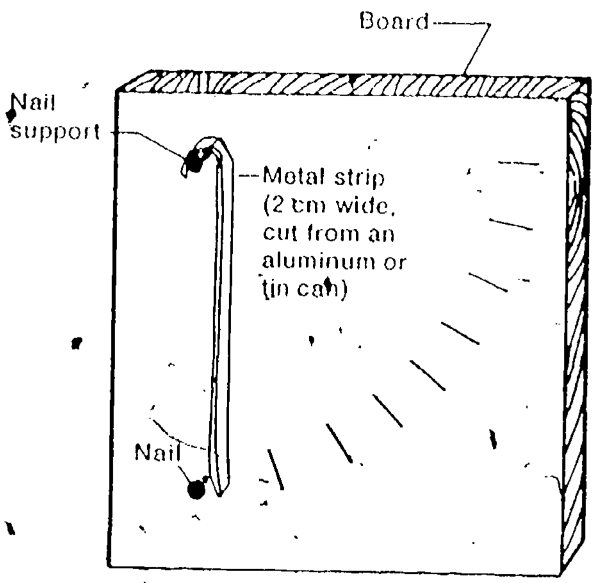
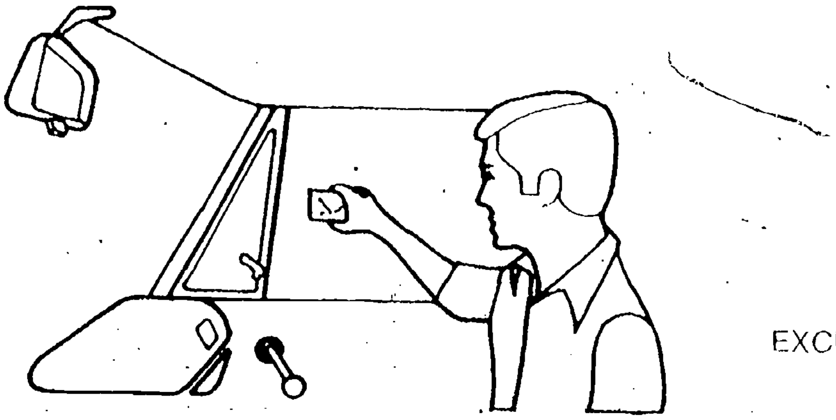


Figure 4

Your instrument will have to be calibrated in order to be useful in making your observations. To make the wind speed scale, wait for a calm day, then take your indicator for a car ride.

ACTIVITY 1. Hold the indicator out the window of the car that is moving. The moving air will move the speed indicator just as wind moving at the same speed does. Mark the scale at intervals of 5 mph.



In keeping your weather watch, there may be times (especially on weekends) when the weather station instrument is not available. If this is the case and you don't have your own instrument, you can estimate wind speed fairly accurately. Table 1 will help you do this. The table lists common events with the approximate wind speed associated with them.

Table 1

Wind Speed		Description of Behavior of Common Objects
mph	km/hr	
Less than 1	Less than 2	Smoke rises vertically.
1 to 3	2 to 5	Smoke drifts, but flags hang limp. Ordinary wind vanes useless.
4 to 7	6 to 11	Wind felt on face. Leaves rustle. Ordinary wind vanes move.
8 to 12	12 to 19	Leaves and twigs in motion. Light flags are extended.
13 to 18	20 to 29	Dust and loose paper raised. Small branches are moved.
19 to 24	30 to 39	Small trees begin to sway. Whitecaps form on lakes.
25 to 31	40 to 50	Large branches in motion. Wires whistle. Umbrellas hard to use.

Billboards of the Sky

Excursion 2-2

Since ancient times, men have watched the skies and tried to predict the coming weather by what they observed. Long before the clouds were given scientific names to identify them, they were described in terms of things that they resembled. Thus, statements like the following were commonly used:

"Mackerel scales and mare's tails
Make lofty ships carry low sails."

Figure 1 "Mackerel scales"

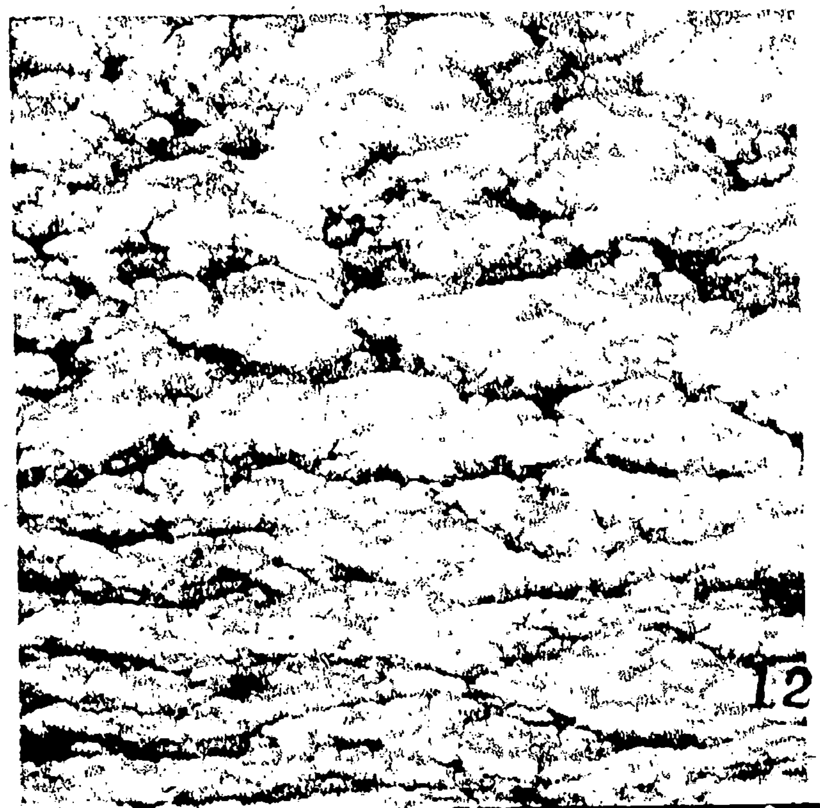
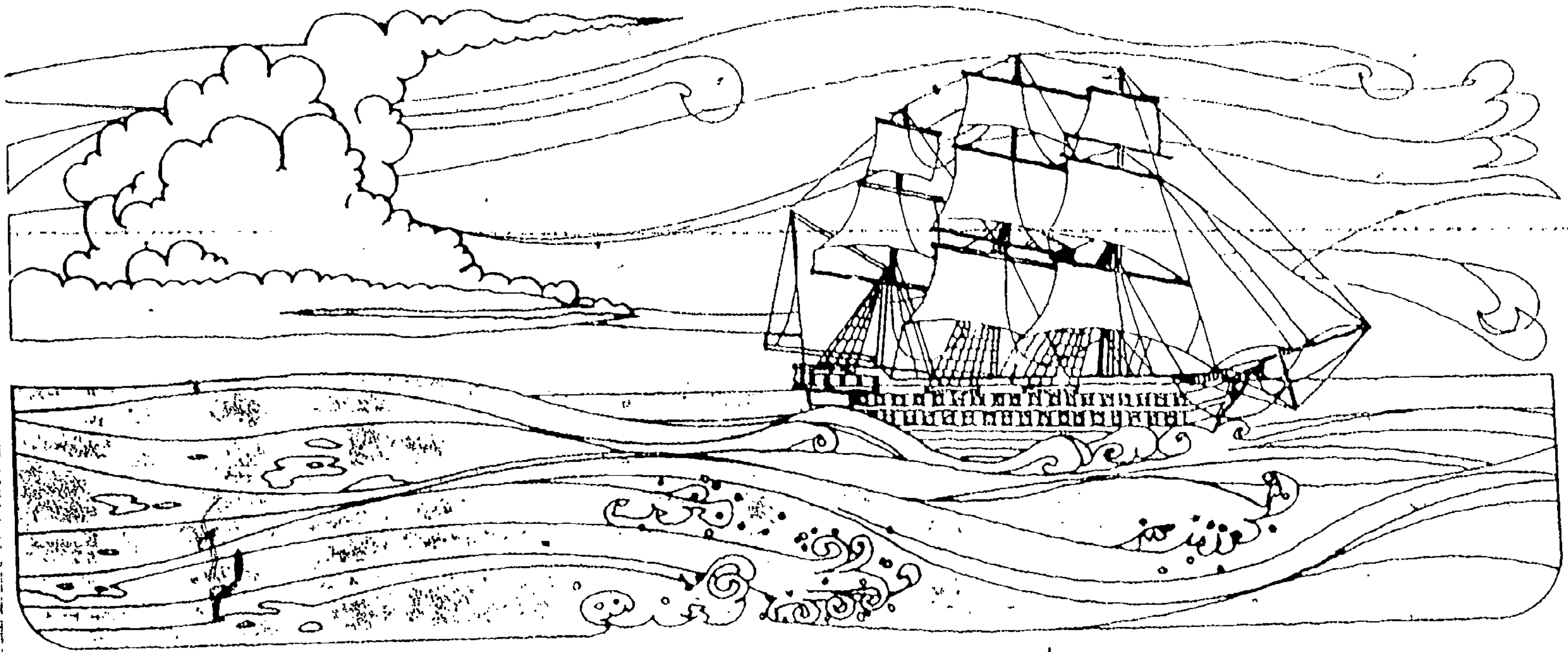


Figure 2 "Mare's tails"

The appearance of clouds as neat rows of small patches resembling the scales of a fish (Figure 1) or wispy filaments like the curling hair in a horse's tail (Figure 2) foretold a storm. Upon seeing these signs, sailors would lower their ship's canvas.



Of all the different elements of the weather that you will be studying, clouds and the forms of moisture that come from them are the only things that are generally visible. We can describe and name clouds by their appearance. You don't have to rely on an instrument for their description. If you learn the vocabulary of the cloud types, you can read them like a billboard. And you will also have some idea of coming events in the weather.

Much like people, clouds tend to be found in families. The three cloud names that you have used in Chapter 2 (cirrus, stratus, and cumulus) are really family names given to them by a nineteenth-century chemist named Luke Howard. *Cirrus* means "curl of hair," *stratus* means "spread out," and *cumulus* indicates a "pile." Also like people, there is often a combination of families. This means that there can be cirrus and cumulus combined, or cumulus and stratus, or stratus and cirrus. Thus, the mackerel scales (Figure 1) mentioned in the weather adage are really cirrocumulus, or "wispy piles."

All cirrus-type clouds are found at high altitudes, from 6,100 meters (20,000 feet) on up. At these heights, the temperature is so cold that the clouds are composed entirely of ice crystals. These crystals are very fine and delicate. This accounts for the hazy, filmy, and wispy appearance of the clouds. A cirrostratus cloud is just a high sheet of ice crystals spread out at one level above the earth. These clouds give the sky a filmy appearance and cause a ring, or halo, around the moon or sun. (See Figure 3.)

Cirrostratus Clouds (Wispy and spread out in a layer)

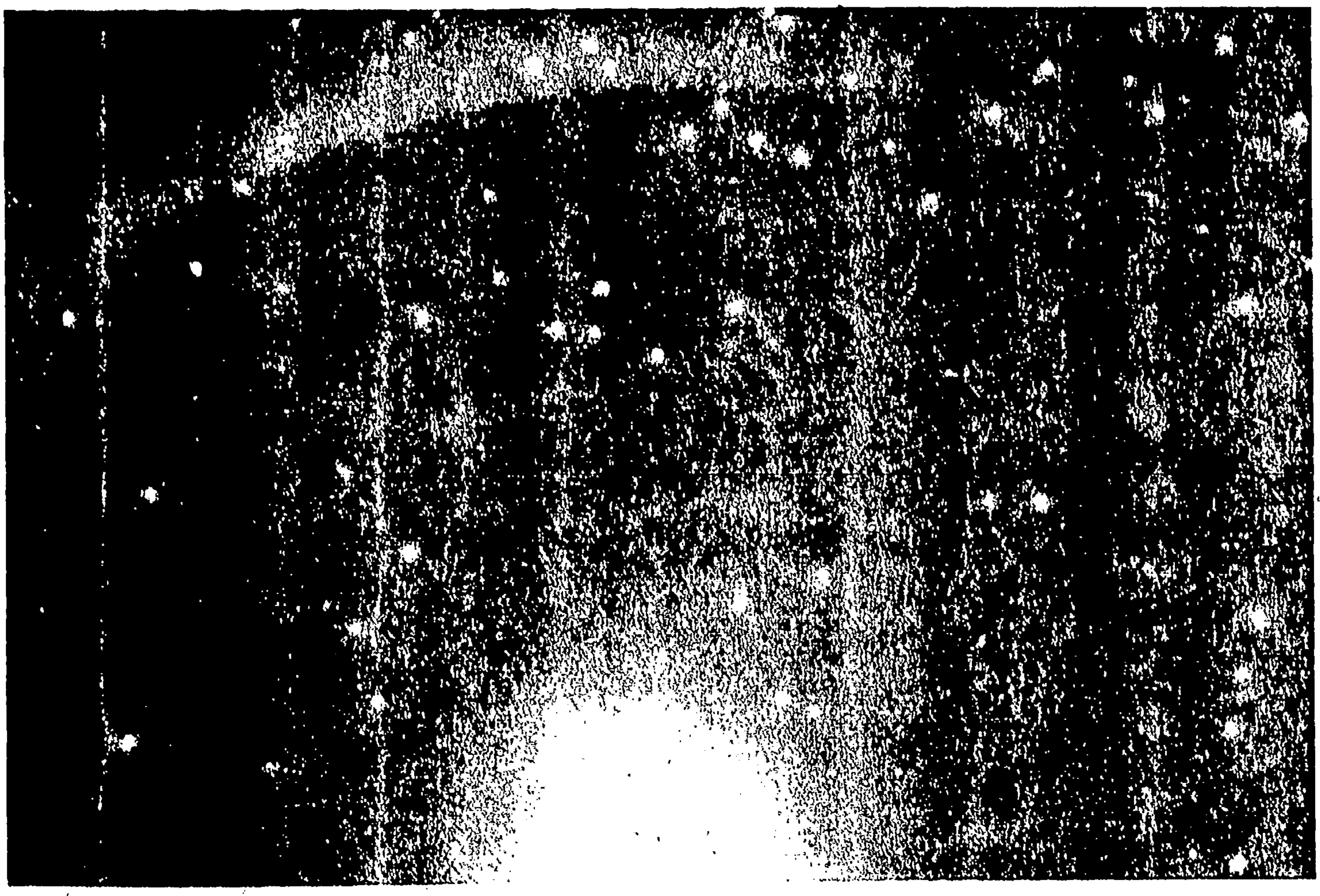


Figure 3

The three main categories of clouds often have other names added to them to further describe some of the variations. The prefix *alto* (meaning "high") can be added to the terms stratus and cumulus. To indicate a high, spread-out layer of clouds, the word altostratus is used. Clouds at high altitude and piled up are called altocumulus. They are found from 2,440 meters to 6,700 meters (8,000 feet to 20,000 feet).

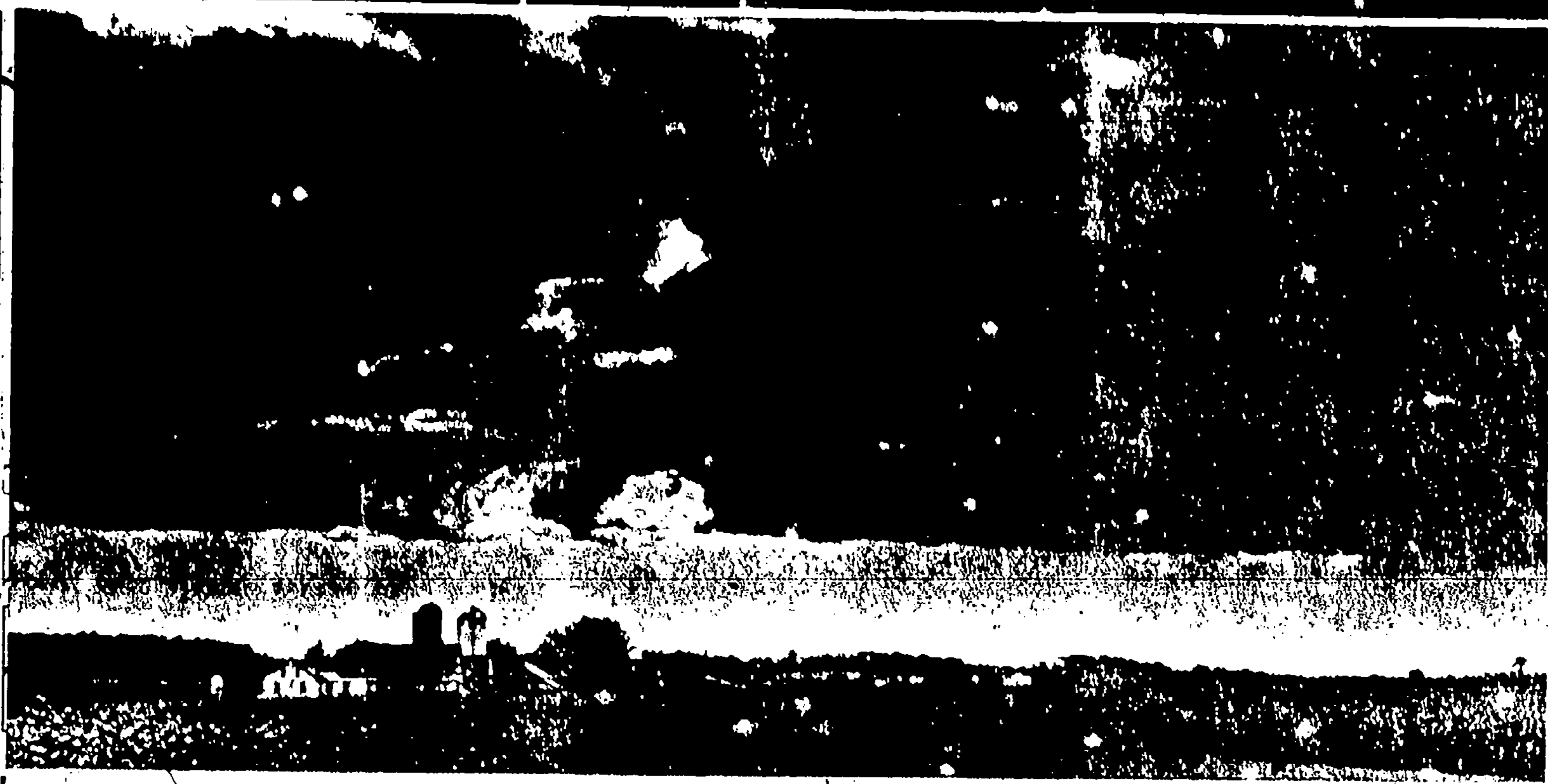


Figure 4 Altostratus

☐1. Why do you think there is *not* a cloud designated as altocirrus?

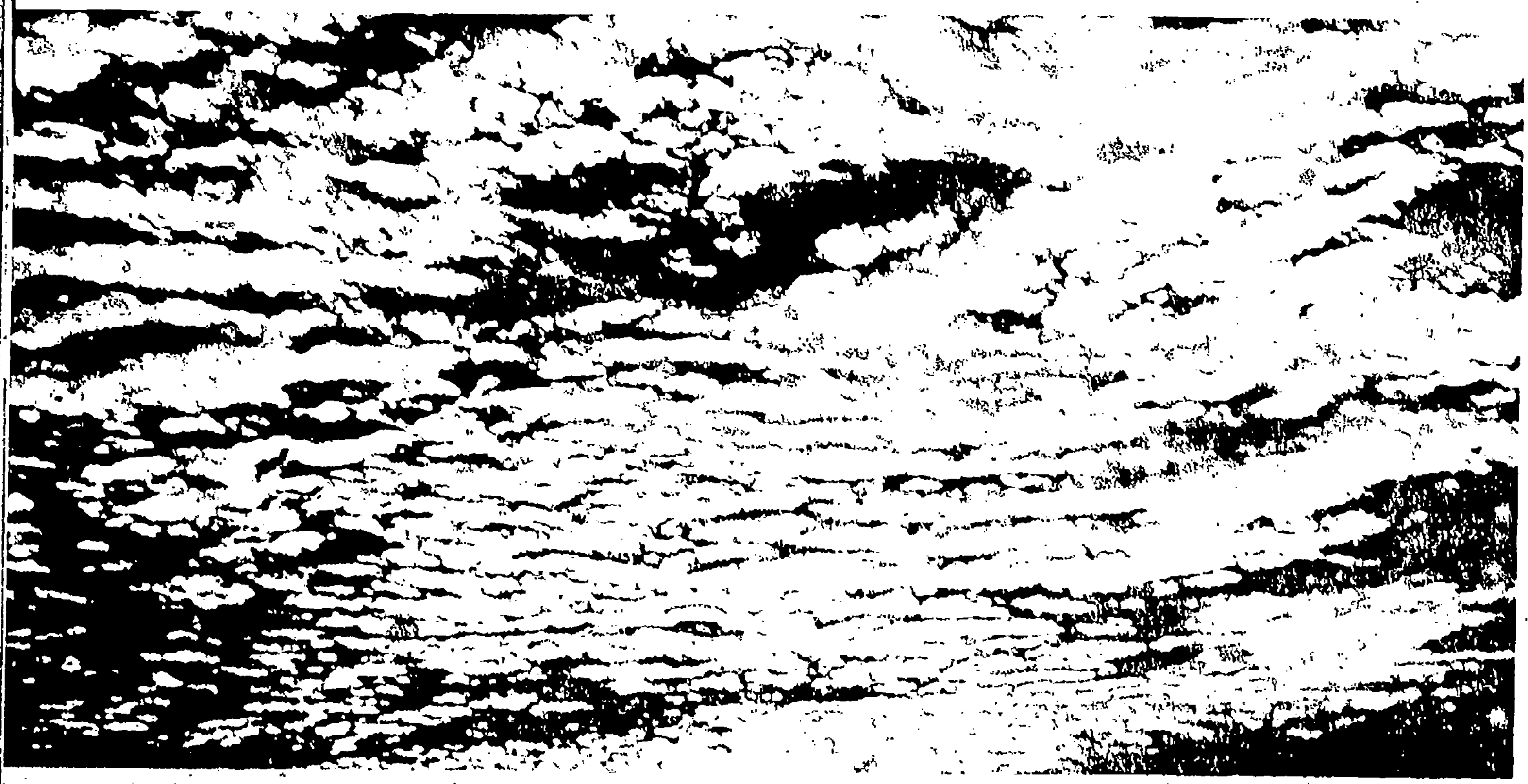
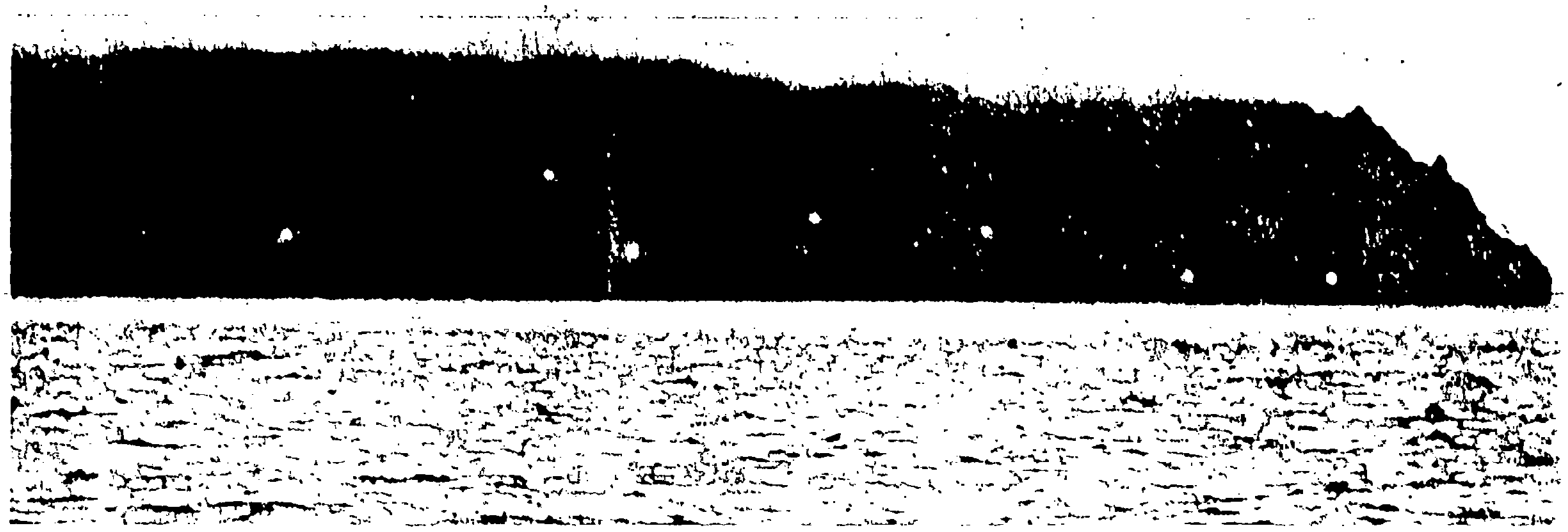


Figure 5 Altocumulus

The Latin word *nimbus*, meaning "rain cloud," is often used to indicate a cloud from which precipitation is falling. Thus, heavy stratus clouds from which rain or snow is falling are called nimbostratus. Stratus, stratocumulus, and nimbostratus are found below 2,440 meters (8,000 feet).



Stratus Cloud Fogging near the Top of a Mountain

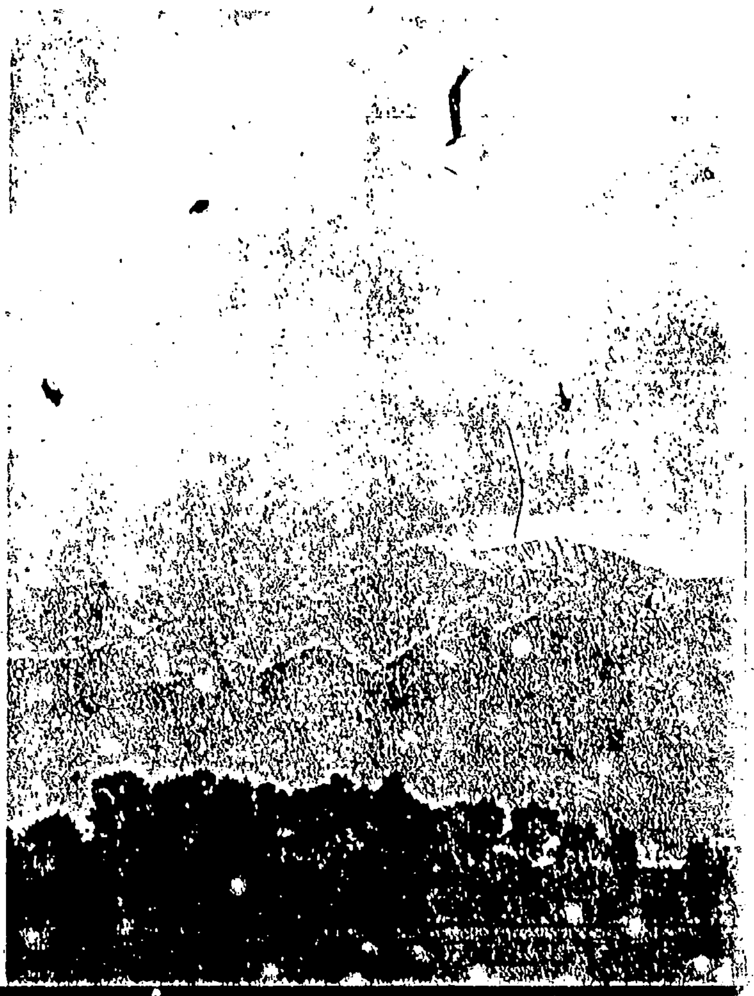
Figure 6

Stratocumulus
(Spread-out layer of piled-up clouds)

Figure 7

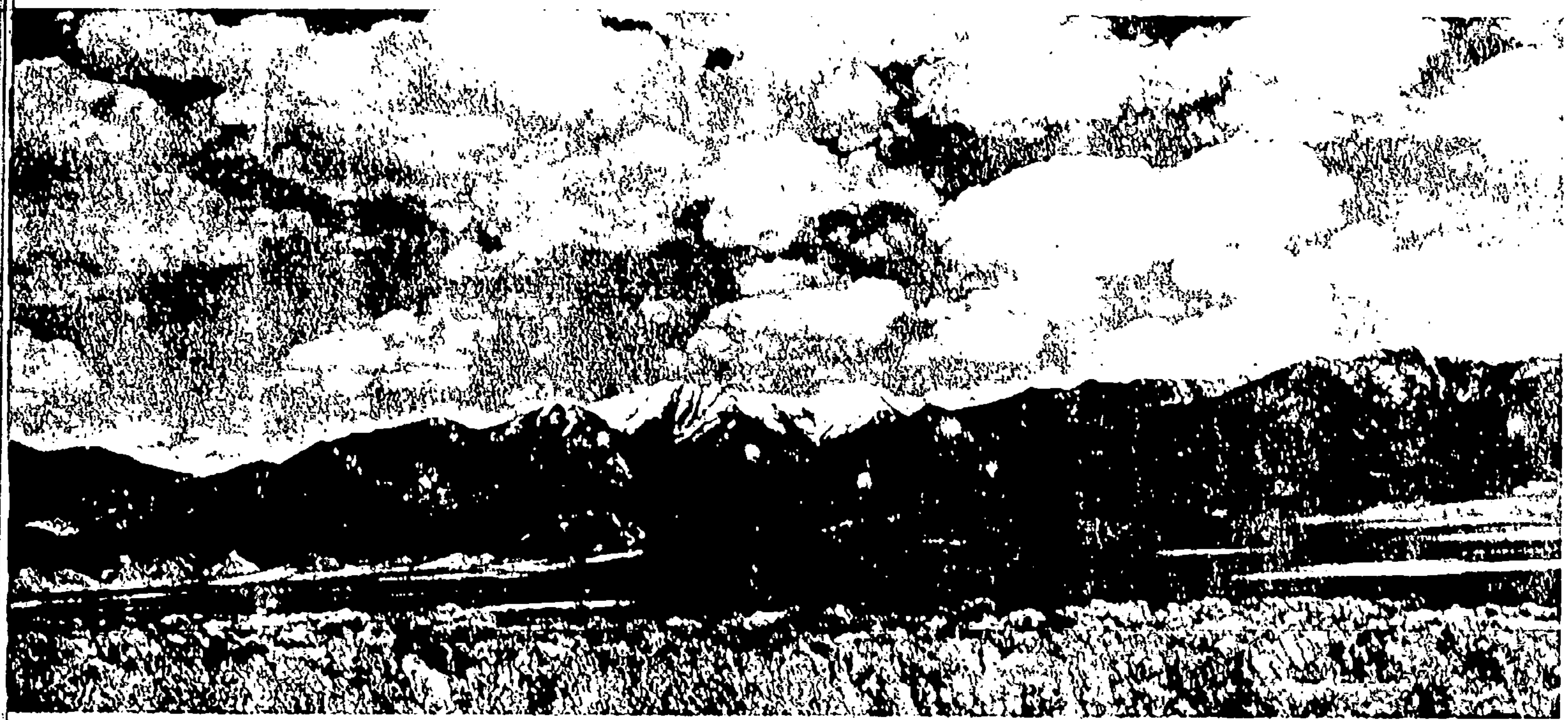
Nimbostratus
(Spread-out rain clouds)

Figure 8



Cumulus and cumulonimbus (thunderhead) clouds are found at all altitudes, from 2,440 meters (8,000 feet) to 18,300 meters (60,000 feet). The cumulus is the typical cloud of fair weather, resembling a fluffy white pile. A continuous growth of the cumulus cloud produces the fierce cumulonimbus of the thunderstorm. This cloud is the one associated with our most vicious weather, including tornadoes and hailstorms.

Cumulus (Piled-up clouds) **Figure 9**

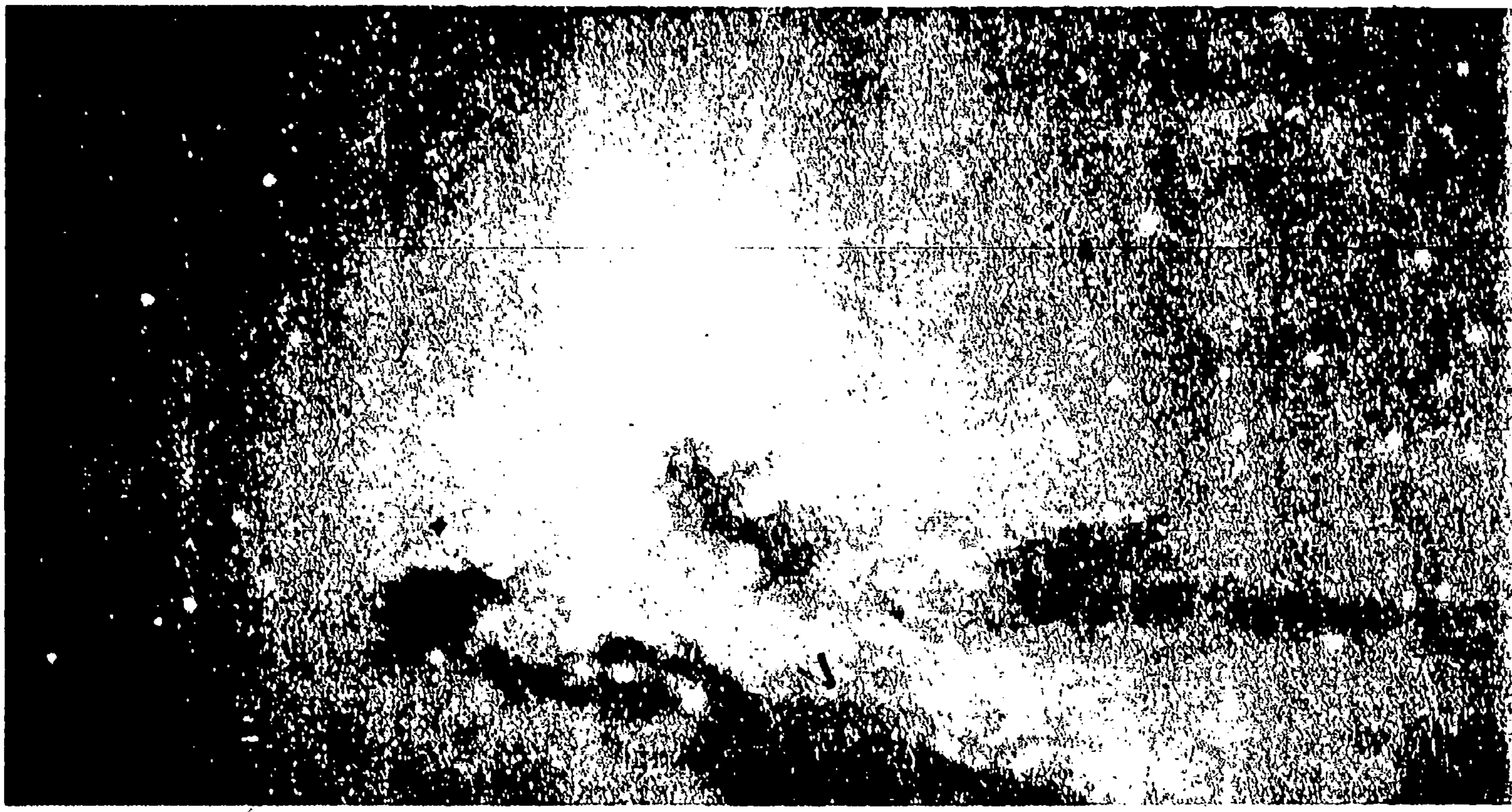


☐**2.** Now see if you can identify some of the ten varieties of clouds that have been mentioned. Don't look back to the descriptions unless you have to.

Cumulonimbus (Piled-up rain clouds) **Figure 10**

A. A high sheet (2,400 6,100 meters) that makes the sun appear as if you were seeing it through tissue paper

Figure 11



B. A low cloud (below 2,440 meters) that looks like a layer of rolls or twists.

Figure 12

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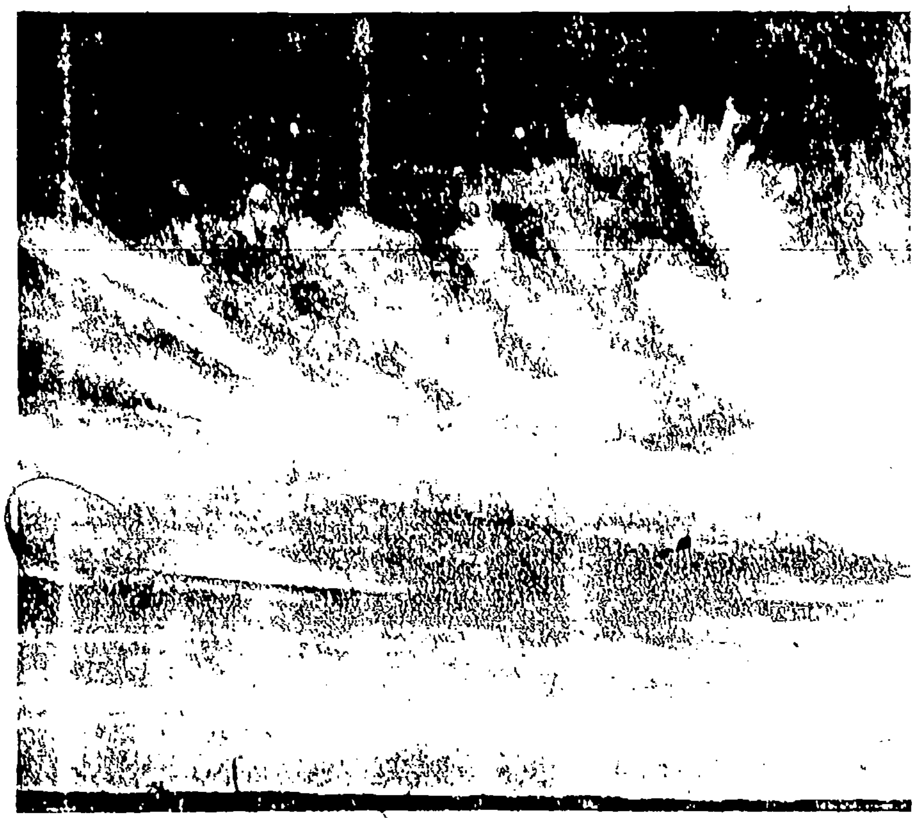
Figure 13 C. "Thunder sky, Not too long dry."

Figure 14 D. The cloud that gives the all-day drizzle.

E. What cloud type is called a fog when it is right down on the ground?

F. "Feathery sky."

Figure 15



G. These are called sheep clouds. They are woolly packs, 2,440 to 6,100 meters high.

Figure 16

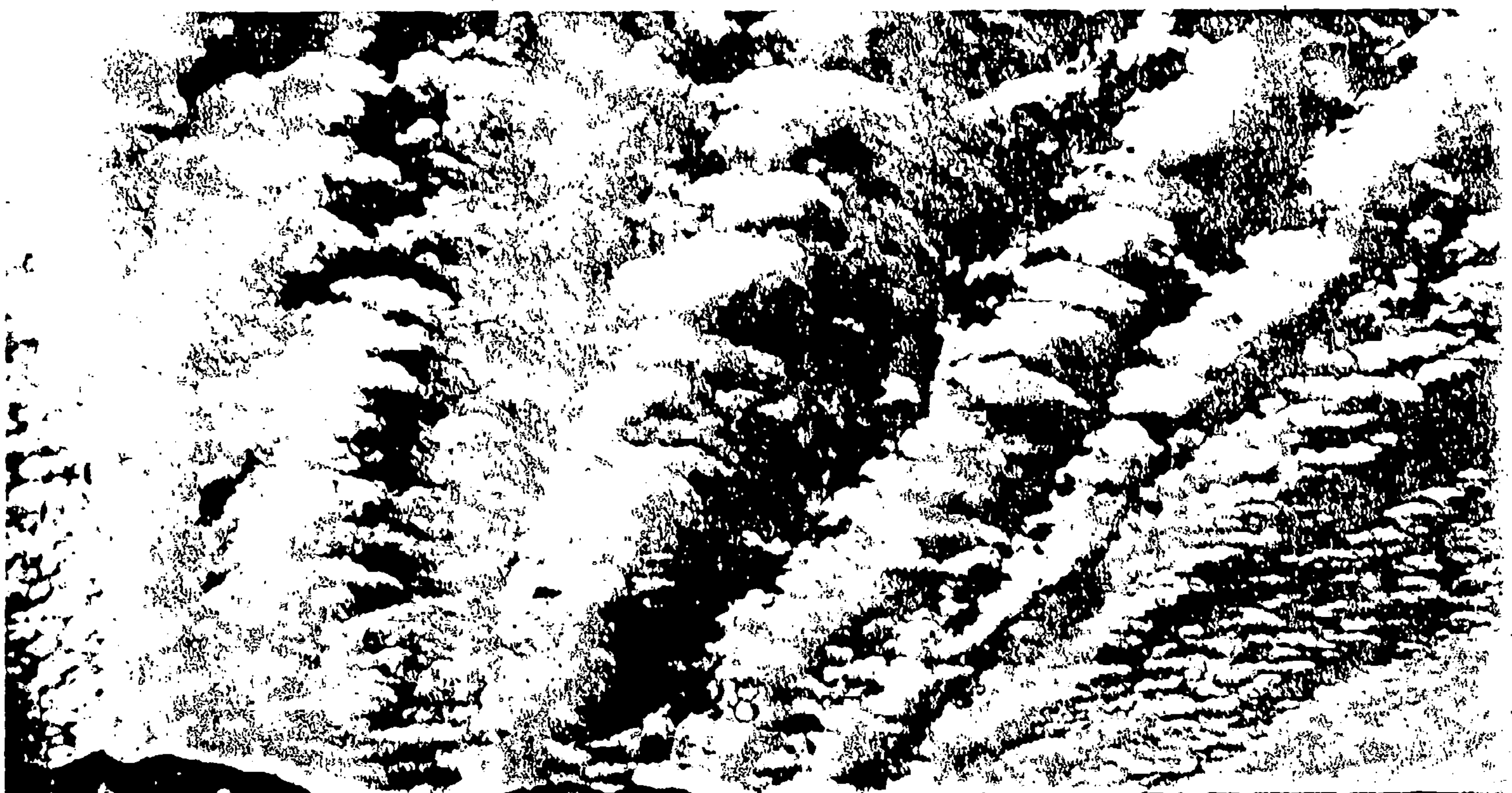


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Figure 17 H. "In the morning, mountains, In the evening, fountains."

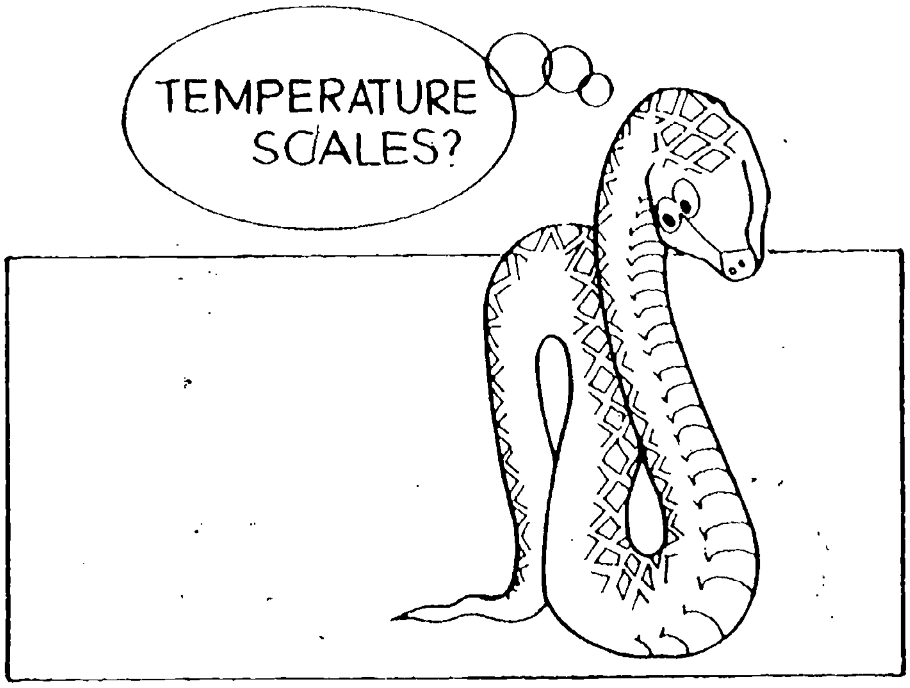
Figure 18 I. "Curdled sky, Not 24 hours dry."

Check the answers below to the ten cloud types. Then, as you go through the rest of the unit, see if you can determine why the weather adages give a clue to the coming weather in terms of the model that you develop.

A. Altostratus	B. Stratocumulus	C. Cumulonimbus
D. Nimbostratus	E. Stratus	F. Cirrus
G. Altocumulus	H. Cumulus	I. Cirrocumulus

The Conversion Excursion

Excursion 2-3



Temperature

So far in the ISCS course, you have measured temperature in Celsius units. On the Celsius scale, the freezing point of water is 0°C, and the boiling point of water is 100°C. The temperature on a warm spring day might be something like 24°C. However, when temperatures are given in a newspaper, radio, or TV weather report, these temperatures are usually given in Fahrenheit degrees. When recording your own weather information in this unit, you may also use Fahrenheit degrees. How are the Fahrenheit and Celsius temperature scales related?

Figure 1 shows how the same thermometer would look if marked in degrees Celsius (a) and in degrees Fahrenheit (b).

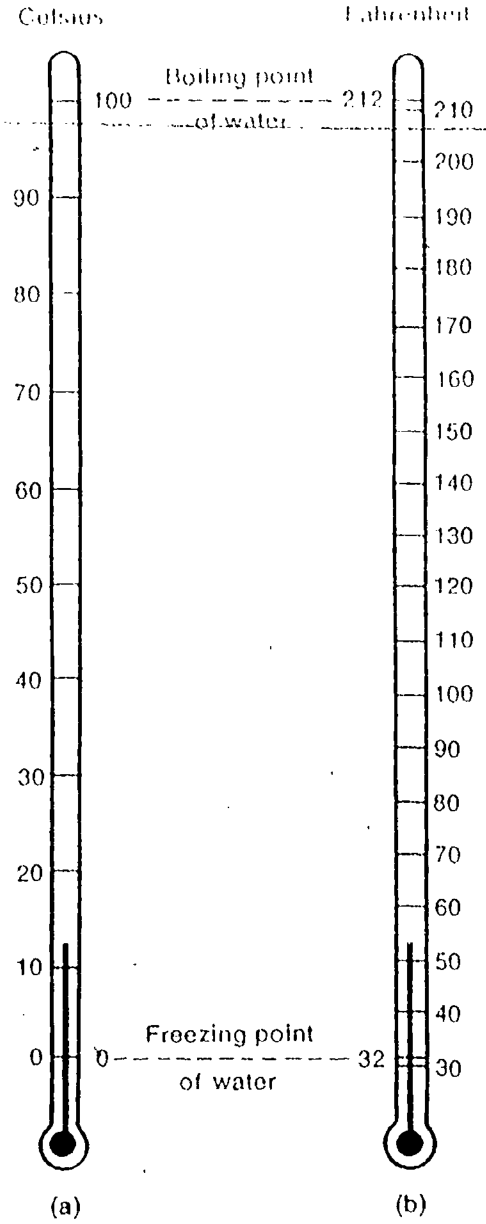


Figure 1

☐**1.** How many degrees separate the freezing point and the boiling point of water on the Celsius temperature scale?

☐**2.** How many degrees separate the freezing point and the boiling point of water on the Fahrenheit temperature scale?

☐**3.** Which is the higher temperature, 50°C or 50°F?

☐**4.** Which is the bigger temperature *change*, 10 degrees on the Celsius scale or 10 degrees on the Fahrenheit scale?

Table 1 can be used when you need to make a quick conversion from one scale to the other. You may want to round off the Fahrenheit temperatures.

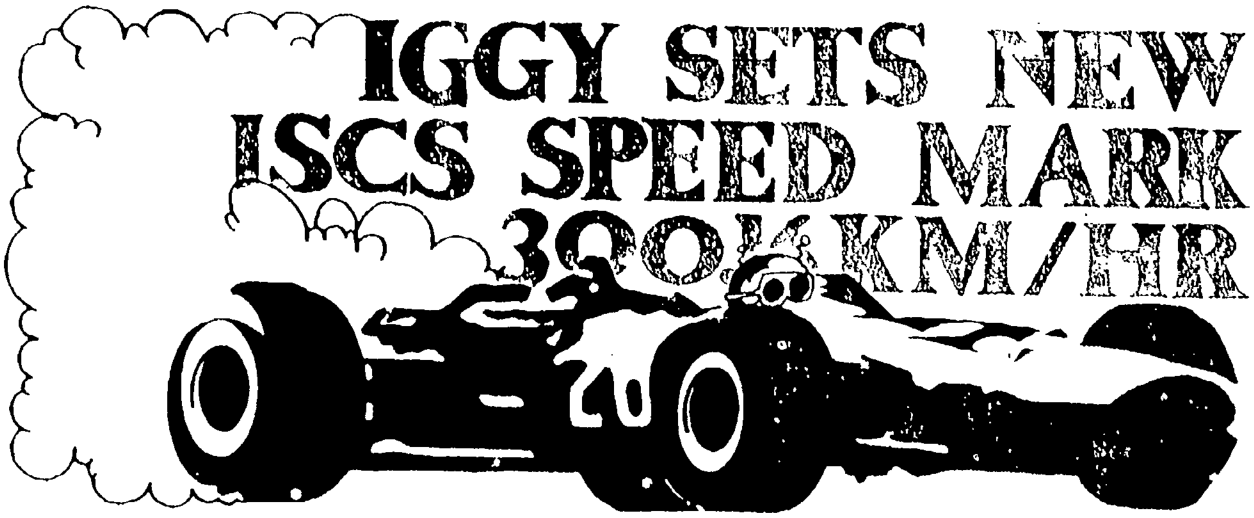
Table 1

°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
49	120.2	31	87.8	13	55.4	-5	23.0	-23	-9.4	-41	-41.8
48	118.4	30	86.0	12	53.6	-6	21.2	-24	-11.2	-42	-43.6
47	116.6	29	84.2	11	51.3	-7	19.4	-25	-13.0	-43	-45.4
46	114.8	28	82.4	10	50.0	-8	17.6	-26	-14.8	-44	-47.2
45	113.0	27	80.6	9	48.2	-9	15.8	-27	-16.6	-45	-49.0
44	111.2	26	78.8	8	46.4	-10	14.0	-28	-18.4	-46	-50.8
43	109.4	25	77.0	7	44.6	-11	12.2	-29	-20.2	-47	-52.6
42	107.6	24	75.2	6	42.8	-12	10.4	-30	-22.0	-48	-54.4
41	105.8	23	73.4	5	41.0	-13	8.6	-31	-23.8	-49	-56.2
40	104.0	22	71.6	4	39.2	-14	6.8	-32	-25.6	-50	-58.0
39	102.2	21	69.8	3	37.4	-15	5.0	-33	-27.4	-51	-59.8
38	100.4	20	68.0	2	35.6	-16	3.2	-34	-29.2	-52	-61.6
37	98.6	19	66.2	1	33.8	-17	1.4	-35	-31.0	-53	-63.4
36	96.8	18	64.4	0	32.0	-18	-0.4	-36	-32.8	-54	-65.2
35	95.0	17	62.6	-1	30.2	-19	-2.2	-37	-34.6	-55	-67.0
34	93.2	16	60.8	-2	28.4	-20	-4.0	-38	-36.4	-56	-68.8
33	91.4	15	59.0	-3	26.6	-21	-5.8	-39	-38.2	-57	-70.6
32	89.6	14	57.2	-4	24.8	-22	-7.6	-40	-40.0	-58	-72.4

Speed

The wind speed indicator on the weather-station instrument is calibrated in the English system (miles per hour). You may want to convert English miles to the metric system (kilometers per hour.)

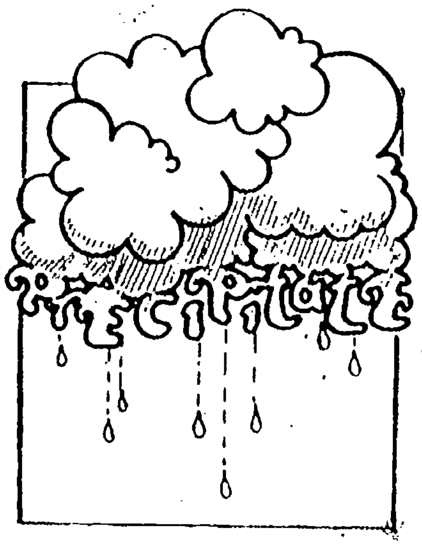
In a mile, there are about 1,600 meters, or 1.6 kilometers (abbreviated km). Thus, if the number of miles is multiplied by 1.6, the answer will be in kilometers.



☐5. What is the wind speed in km/hr if it is blowing at a rate of 10 mph? 20 mph? 25 mph?

☐6. Wind is considered to be of hurricane force if it's speed is 75 mph or above. How fast in km/hr would this be?

☐7. A breeze of 64 km/hr has what speed in mph?



Precipitation

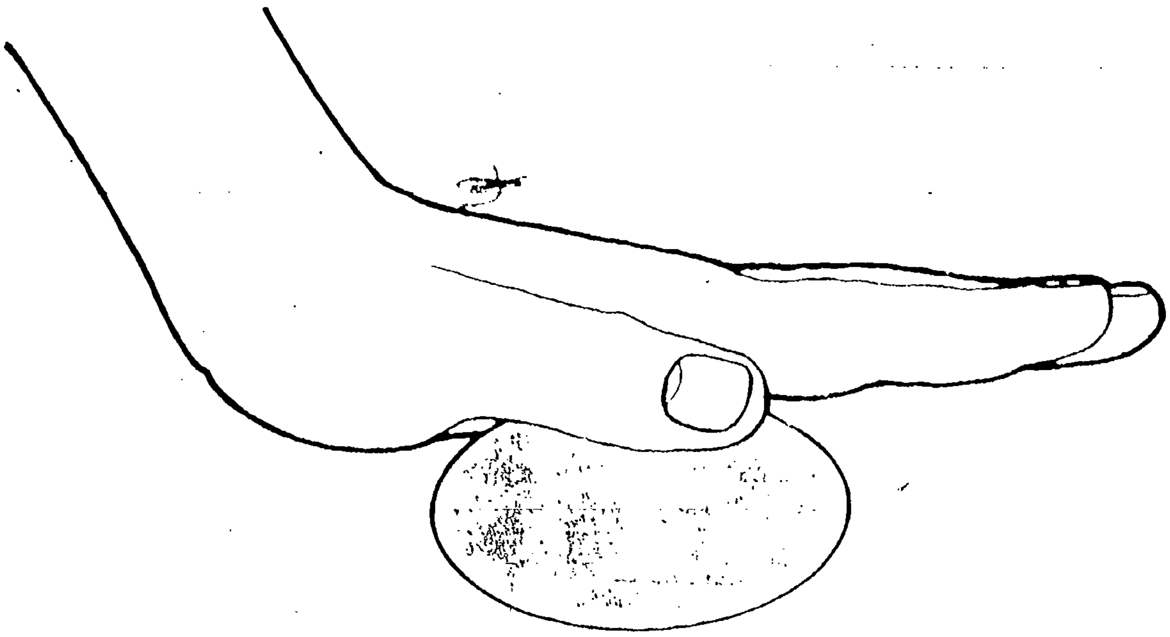
The precipitation gauge on the weather-station instrument is calibrated in inches. Precipitation figures given in the news media (newspapers, radio, TV) are also usually in inches. It is an easy task to convert inches to centimeters.

There are 2.54 centimeters in each inch. Therefore, if the number of inches is multiplied by 2.54, the answer will be in centimeters.

☐8. Suppose the rain gauge shows that 2.5 inches fell last night. How many centimeters of rain fell?

The Pressure's On

Excursion 3-1



The term *pressure* will be used many times in this unit. Do you understand what it means? Test yourself with the following checkup. When you have finished, check your answers at the end of this excursion, If you get both answers 100% correct and are satisfied that you fully understand pressure, skip the rest of this excursion.

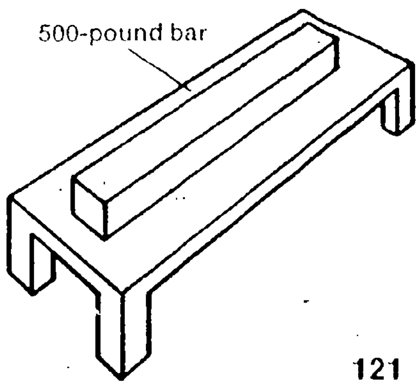
If you are less successful or have any doubts, stay with it.

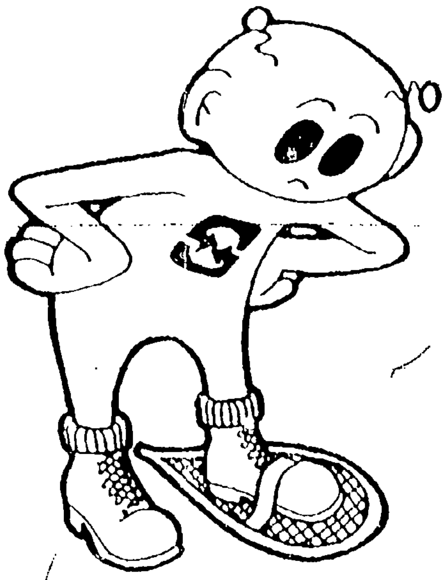
CHECKUP

1. In your Record Book place a check by any of the following that could be a measure of pressure.

a. 7 pounds (__)
b. 9 newtons (__)
c. 6 pounds per square inch (__)
d. 4 square inches (__)
e. 8 newtons per square meter (__)

2. A 500-pound metal bar is lying on a bench. The area of the bottom of the bar is 50 square inches. What is the pressure of the bar on the bench? (______)

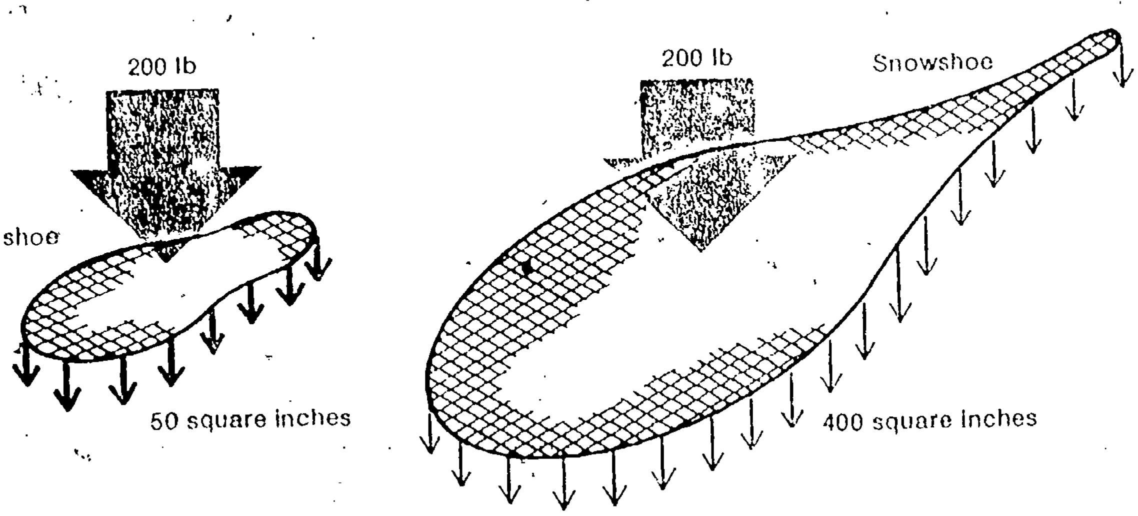




A 200 pound man walks across soft snow. He sinks into the snow up to his knees. After putting on a pair of snowshoes, he leaves only a shallow footprint as he walks across the same snowfield. Certainly the man doesn't weigh any less after he puts on snowshoes. (In fact, the weight of the snowshoes would increase his total weight.)

[ ] 1. Why don't the man and his snowshoes sink as deeply into the snow?

In answering question 1, you probably used the idea that snowshoes spread the man's weight over a bigger area. This idea is the key to understanding pressure. Whether the man is wearing snowshoes or not, his feet push on the snow with a force of 200 pounds (his weight). When he wears snowshoes, this force is spread out over a bigger area. The term *pressure* is used to describe how concentrated a force is (how much force there is on each unit of area). One of the common ways that pressure is measured is in pounds per square inch. Suppose the man takes a walk with one shoe and one snowshoe. To make the calculations simple, let's suppose the total area of the man's shoe is 50 square inches, while the total area of a snowshoe is 400 square inches.



Thus, the force exerted by each square inch of the shoe is

$$200 \text{ lb}/50 \text{ sq in.} = 4 \text{ lb/sq in.}$$

This force per square inch is the pressure exerted by the man on the snow under his foot. All the man's 200 pounds is spread over 50 square inches of snow.

The force exerted on the snow under the snowshoe can be calculated in the same way. Each snowshoe has an area of 400 square inches. It is pushed into the snow with a force of 200 pounds if the man is putting all his weight on one foot.

☐2. Calculate the force exerted on each square inch of the snowshoe.

We can use this idea of pressure to explain why the man does not sink into the snow when wearing snowshoes:

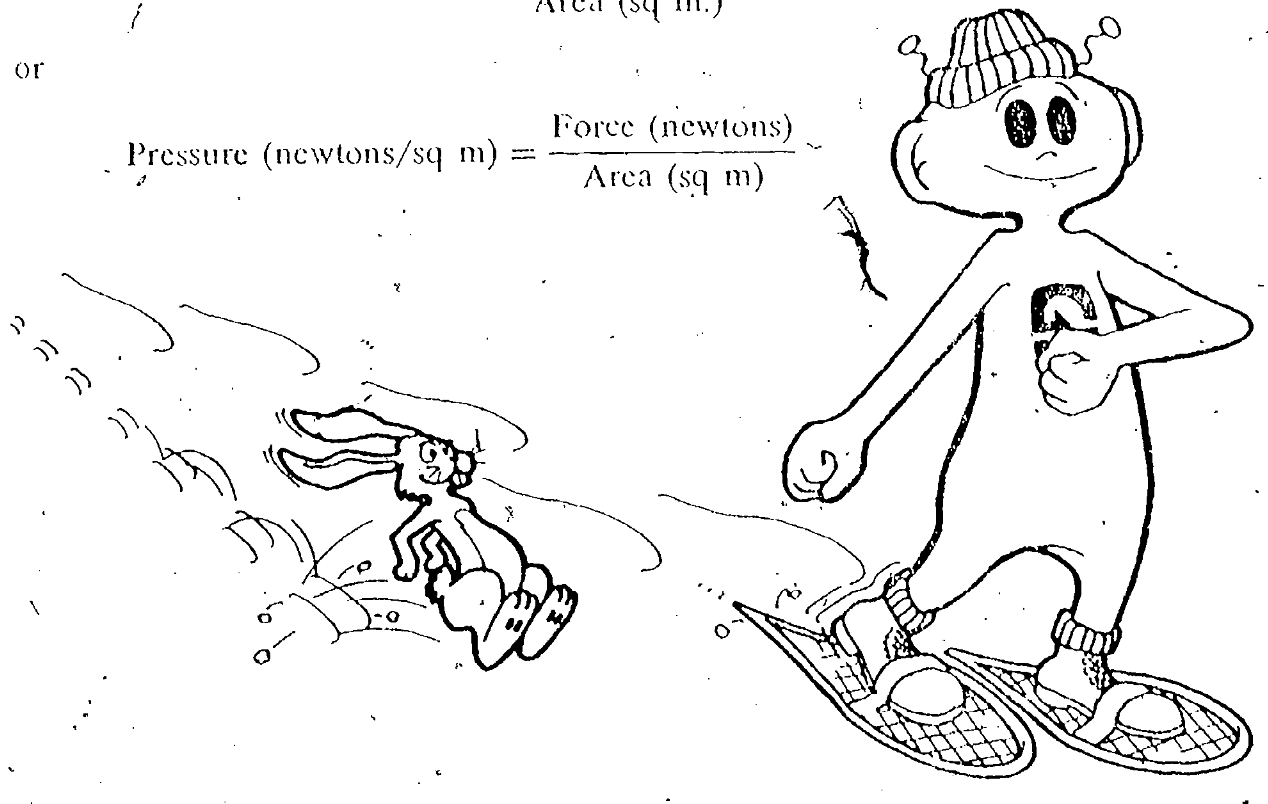
> When wearing shoes, the pressure of the shoe on the snow is four pounds per square inch. When wearing snowshoes, the pressure of the snowshoe on the snow is less, only 0.5 pound per square inch.

Pressure, then, measures the concentration of a force. It can be operationally defined by this formula:

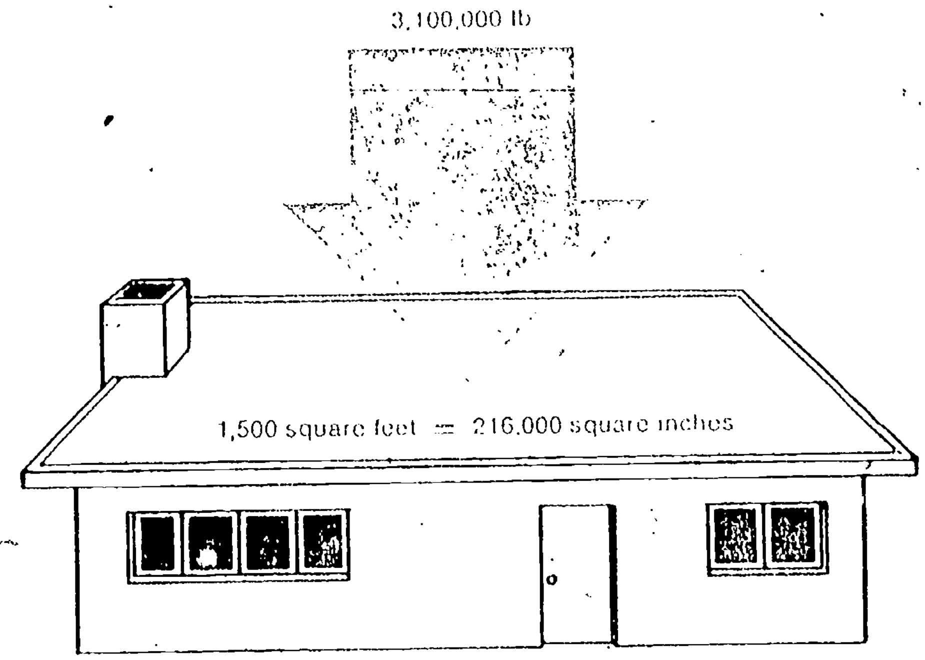
$$\text{Pressure (lb/sq in)} = \frac{\text{Force (lb)}}{\text{Area (sq in.)}}$$

or

$$\text{Pressure (newtons/sq m)} = \frac{\text{Force (newtons)}}{\text{Area (sq m)}}$$



But what about air pressure? Like the man, air has weight. In fact, the air above your house or apartment (assume the roof of the house to have an area of 1,500 square feet) is about 1,550 tons (3,100,000 lb)! Air is not light! But what about the pressure? Since the 1,550 tons exerted by this great weight is spread over the total area of your house, you can determine the air pressure on it.



If we apply the operational definition that pressure = $\frac{\text{force (lb)}}{\text{area (sq in)}}$, then the air pressure on the house would be

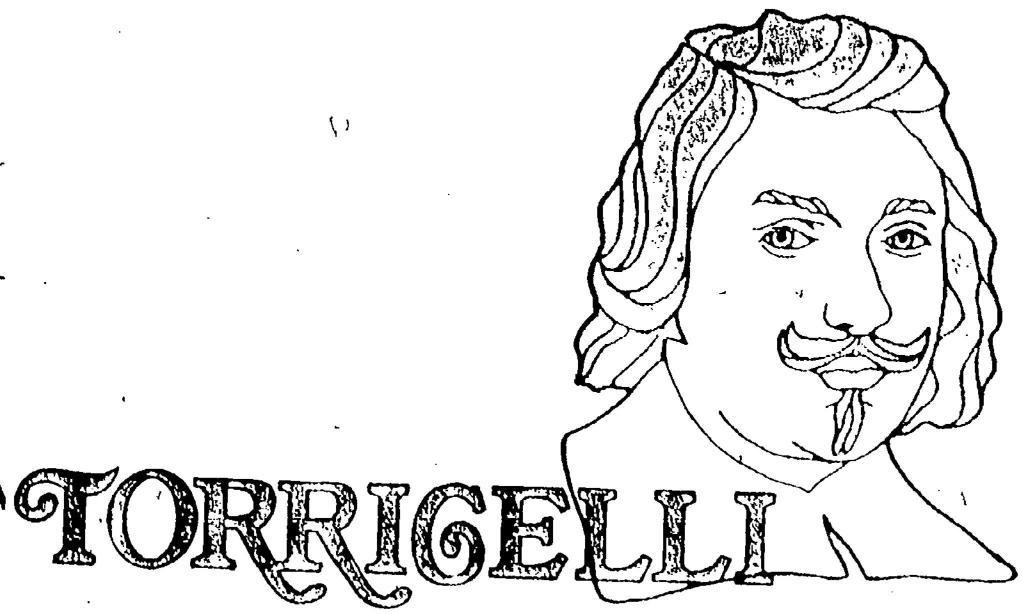
$$\text{air pressure} = \frac{3{,}100{,}000 \text{ lb}}{216{,}000 \text{ sq in.}}$$
$$= \text{about } 14 \text{ lb/sq in.}$$

Every square inch of roof has 14 lb of air weight on it. For answers to the checkup, invert the page.

Answer to Checkup on page 121
1. (c) and (e); 2. 10 lb/sq in

Measuring Air Pressure . . . in Inches?

Excursion 3-2



What does it mean to say that the atmospheric pressure is 30 inches of mercury? What has the length of mercury got to do with pressure?

The first person to use the length of a column of mercury to measure air pressure was Evangelista Torricelli, an Italian who died at age 39 in 1647. Rather than describe Torricelli's experiments to you, we will give you the chance to read some of his own words. The letter that appears on the following pages is part of a longer letter written by Torricelli in 1644. We found this old document of great interest and hope you may, too. A few marginal notes have been added to help you understand it.

THE BAROMETER*

(To Michelangelo Ricci in Rome)

Florence, June 11, 1644

MOST ILLUSTRIOUS SIR AND
MOST LEARNED PATRON

Torricelli tells Ricci that he has constructed an instrument to measure changes in air pressure.

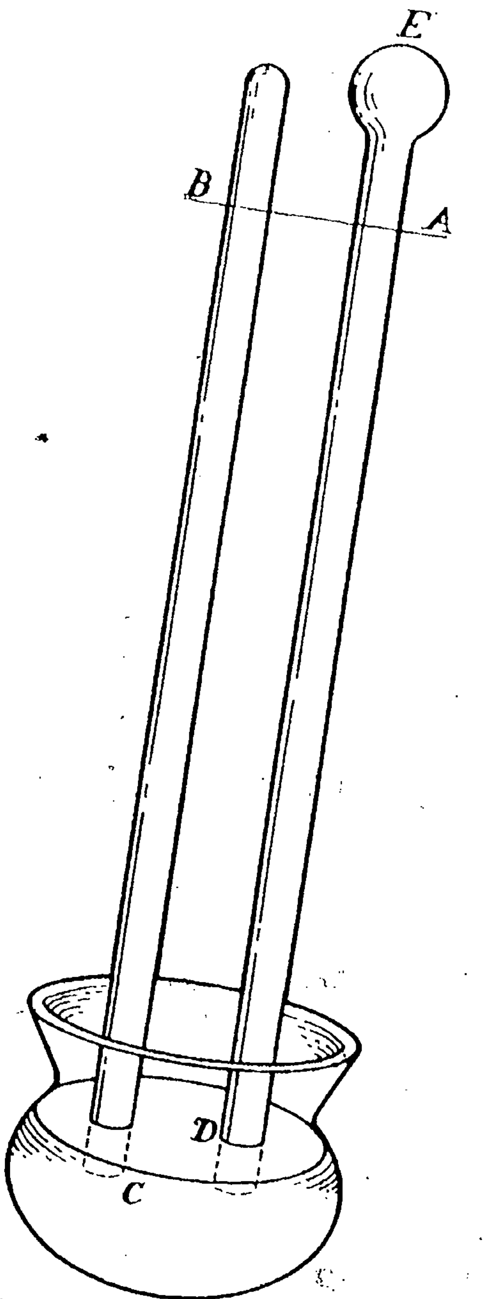
I have already called attention to the fact that there are in progress certain philosophical experiments, relating to vacuum, designed not simply to make a vacuum but to make an instrument which will show the changes in the atmosphere, as it is now heavier and more gross and now lighter and more subtle.

Air pressure is due to the weight of a column of air 50 miles high. The air is most dense near the earth's surface and much less dense at higher altitudes.

We live immersed at the bottom of a sea of elemental air, which by experiment undoubtedly has weight, and so much weight that the densest air in the neighborhood of the surface of the earth weighs about one four-hundredth part of the weight of water. Certain authors have observed after twilight that the vaporous and visible air rises above us to a height of fifty or fifty-four miles. But I do not think it is so much, because I can show that the vacuum ought to offer a much greater resistance than it does, unless we use the argument that the weight which Galileo assigned applies to the lowest atmosphere, where men and animals live, but that on the peaks of high mountains the air begins to be more pure and to weigh much less than the four-hundredth part of the weight of water.

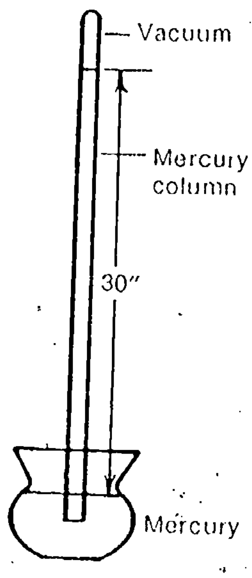
*Adapted from pages 945–948 of *A Treasury of World Science*, edited by Dagobert D. Runes, copyright 1962, Philosophical Library, Inc.

We have made many vessels of glass like those shown as A and B (Fig. 1) and with tubes two cubits long. These were filled with quicksilver, the open end was closed with the finger, and they were then inverted in a vessel where there was quicksilver C; then we saw that an empty space was formed and that nothing happened in the vessel where this space was formed. The tube between A and D remained always full to the height of a cubit and a quarter and an inch over.



A glass tube about three feet long was filled with mercury (quicksilver) and inverted in a bowl of mercury.

The level of mercury in the tube fell until it was about 30 inches above the level of the mercury in the bowl. The space above the mercury column was essentially a vacuum.



The column of mercury is supported by air pressure.

Air pressure will support a column of water about 34 feet high.

Torricelli did not choose to use the instrument to measure air pressure because he considered the height of the column to depend also upon temperature. This effect is actually very small and is usually ignored.

I asserted that the force which prevents the quicksilver falling down is external and that the force comes from without. On the surface of the liquid which is in the bowl there rests the weight of a height of fifty miles of air; then what wonder is it if into the vessel CE, in which the quicksilver has no inclination and no repugnance, not even the slightest, to being there, it should enter and should rise in a column high enough to make equilibrium with the weight of the external air which forces it up? Water also in a similar tube, though a much longer one, will rise to about 18 cubits, that is, as much more than quicksilver does as quicksilver is heavier than water, so as to be in equilibrium with the same cause which acts on the one and the other.

I have endeavored to explain by this principle all sorts of repugnances which are felt in the various effects attributed to vacuum, and I have not yet found any with which I cannot deal successfully. I know that your highness will perceive many objections, but I hope if you think them over they will be resolved. My principal intention I was not able to carry out, that is, to recognize when the atmosphere is grosser and heavier and when it is more subtle and lighter, because the level AB in the instrument EC changes for some other reason (which I would not have believed) especially as it is sensible to cold or heat, exactly as if the vessel AE were full of air.

Your devoted and obligated Servant,
E. TORRICELLI

Instead of using a mercury barometer to measure air pressure, you will be using an *aneroid* barometer. It is called aneroid, meaning "without fluid," because it uses, instead of fluid, a small disk-shaped box from which most of the air has been removed. The disk can be seen in most aneroid barometers by looking through the hole in the dial. The disk will look something like the one drawn in Figure 1.

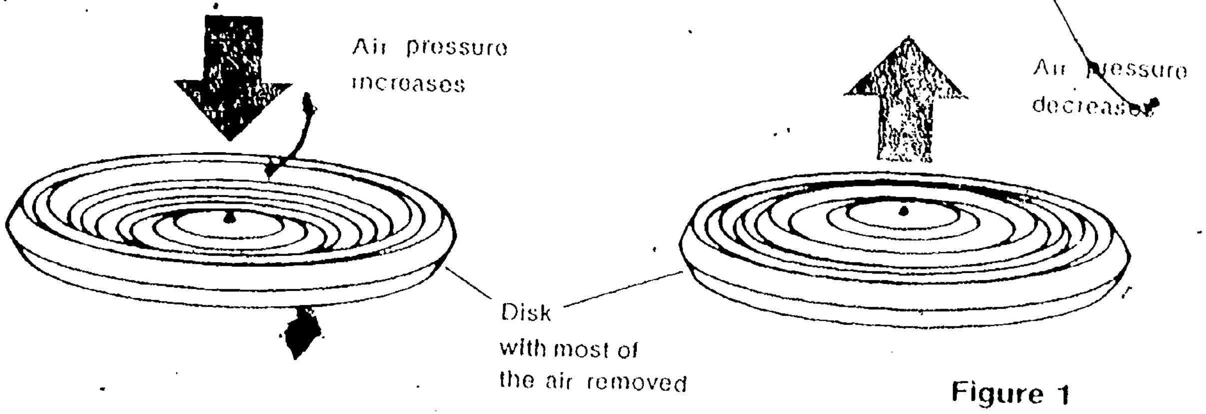
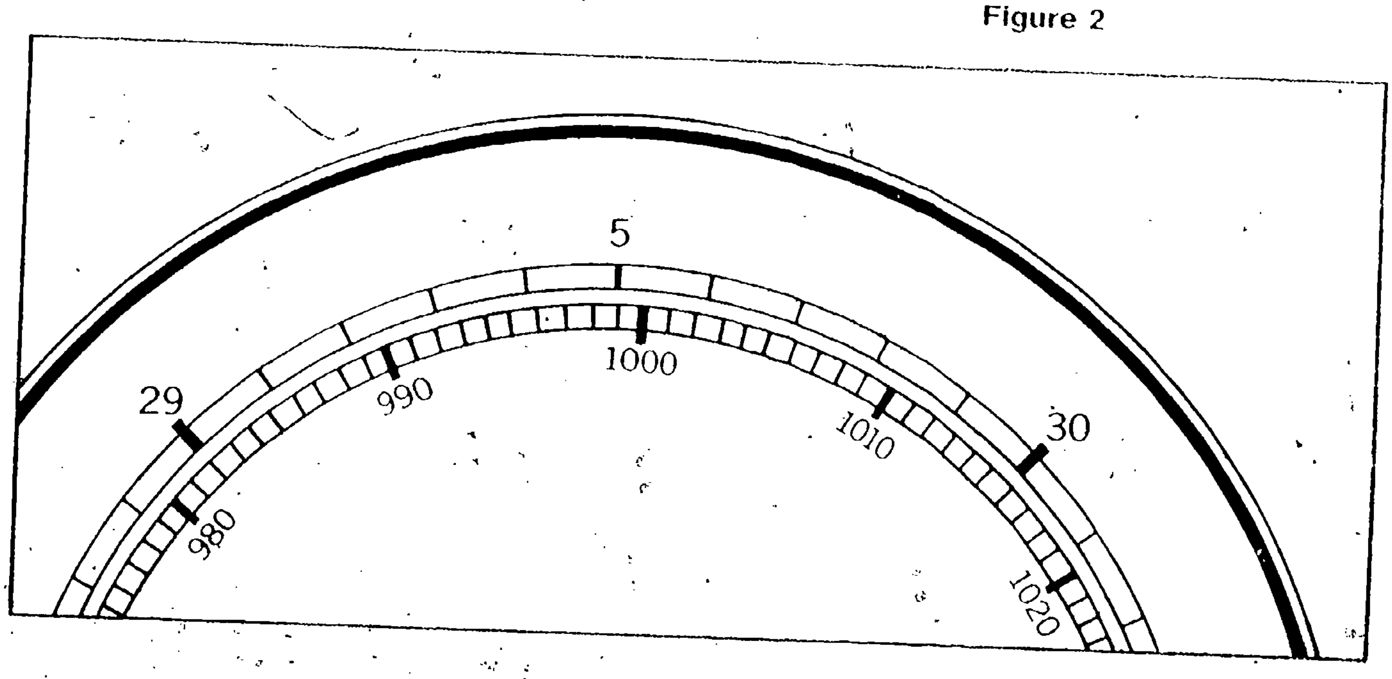


Figure 1

As the air pressure on the disk changes, the top and bottom are squeezed together or expand, causing levers and springs to move the pointer.

You will notice that there are two circular scales on the barometer face (Figure 2).

Figure 2



The top scale tells you the height in inches to which a column of mercury can be supported by the pressure of the air. Remember that Torricelli found this to be about 30 inches.

The bottom scale records the air pressure in millibars (mb). A millibar is a measure of pressure. Remember that pressure can be expressed as the amount of force per area (see **Excursion 3-1**, "The Pressure's On"). One millibar of pressure is the same as 0.0145 pound per square inch. The air pressure needed to support a column of mercury 30 inches high is 1,016 millibars.

EXCURSION

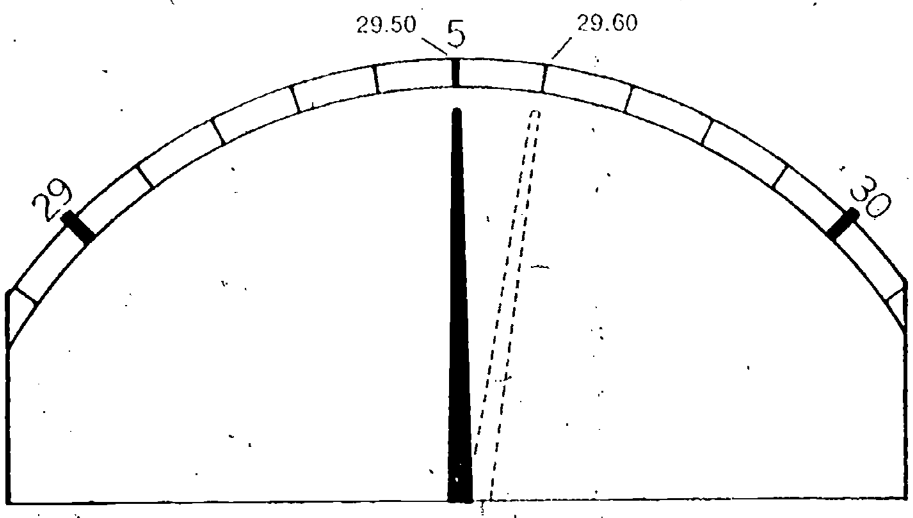
☐ **1.** What air pressure in pounds per square inch is required to support this mercury column of 30 inches?

☐ **2.** How many pounds per square inch of pressure are required to support a 29-inch mercury column?

For your weather watch, you should record the barometric pressure in inches; thus, you can ignore the millibar scale.

Now let's find out how to operate the aneroid barometer. Notice that halfway between 29 and 30 on the barometer scale is the numeral 5. If the black needle were directly on that line, the reading would be 29.50 inches (Figure 3). If it were on the dark line just to the right of the 5, the reading would be 29.60 inches.

Figure 3



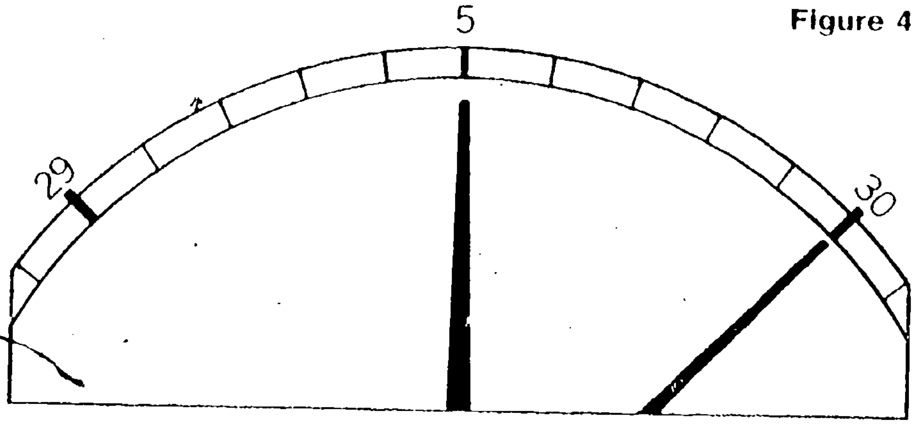
☐3. Go to where the aneroid barometer is located in your room (or in the weather station) and record the air pressure in inches.

Before continuing, check your reading with your teacher.

You will notice that there is a silver needle on the barometer. This needle can be used as a marker to help you keep track of how air pressure changes from one reading to the next. By setting the silver needle directly over the black needle, you can see how much, if any, the black needle has moved when a later reading is made. You can move the silver needle by turning the knob on the face of the barometer. This will be very useful because you can immediately tell if there was a rise or fall in the pressure since the last reading.

☐4. Figure 4 shows the position of the black needle about twelve hours after its position was marked with the silver needle. How much has the barometer reading changed in the twelve hours?

Figure 4



☐5. Does the change in pressure represent a rise, or a fall, in air pressure?

Here is a good technique to use when reading an aneroid barometer. Gently tap the glass of the barometer before taking the reading. This will force the needle bearing if it is sticking slightly—a common occurrence in many aneroid barometers. Try it and see.

If you are not sure of your ability to "read" the aneroid barometer, test yourself with the three problems in the following checkup. You can check your answers at the end of the checkup.

CHECKUP

1. Move the silver needle on the aneroid barometer (by turning the knob) so that it points to 29.20.
2. Move the silver needle so that it points to 29.85.
3. What is the barometric pressure, in inches, shown in Figure 5?

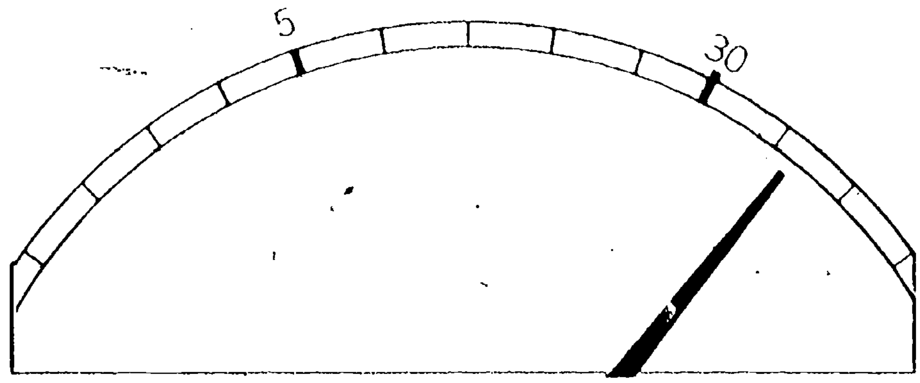
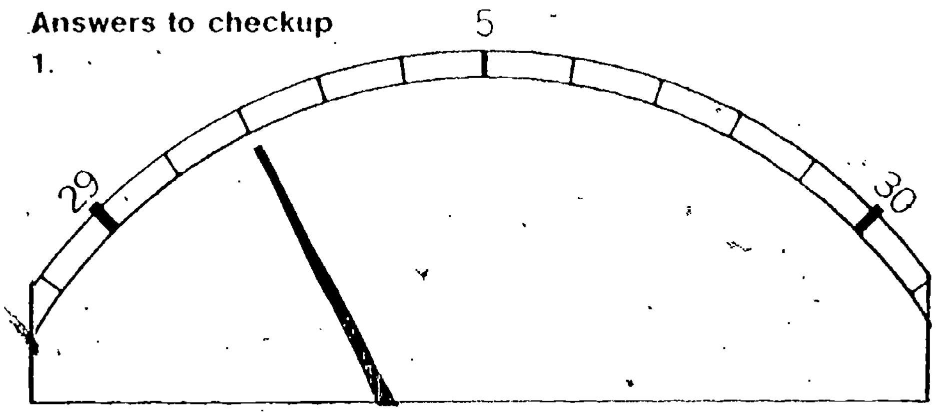


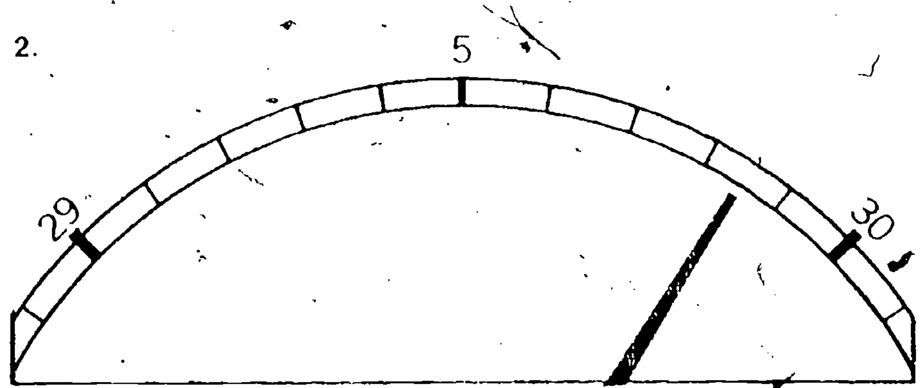
Figure 5

Answers to checkup

1.



2.



3. **30.12, or 30.13, or 30.14**

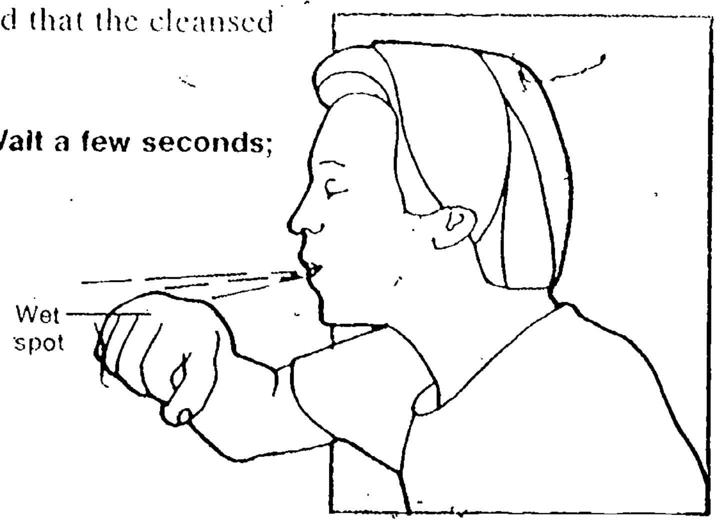
If you missed any of these, and don't understand why the answers given are correct, talk it over with your teacher.

The Shivering Thermometer

Excursion 4-1

Try to remember your last vaccination. Was alcohol used to clean your arm? If so, you probably noticed that the cleansed spot on your arm felt cold. Why?

ACTIVITY 1. Lick the back of your hand. Wait a few seconds; then blow across the wet spot.

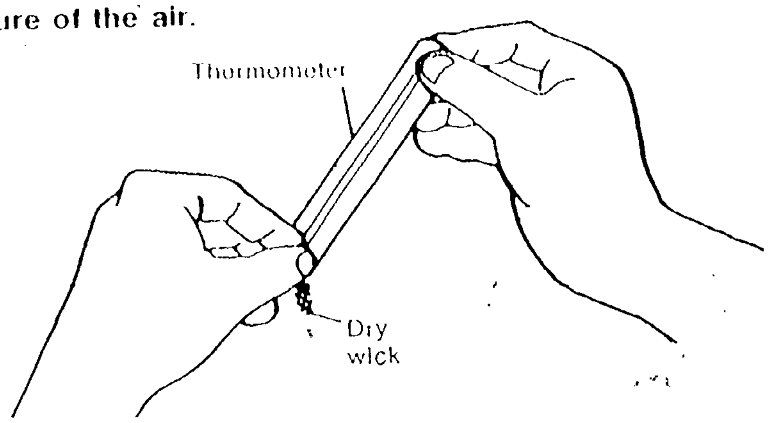


☐**1.** Describe how the wet spot felt before you blew across it, and then while you blew across it.

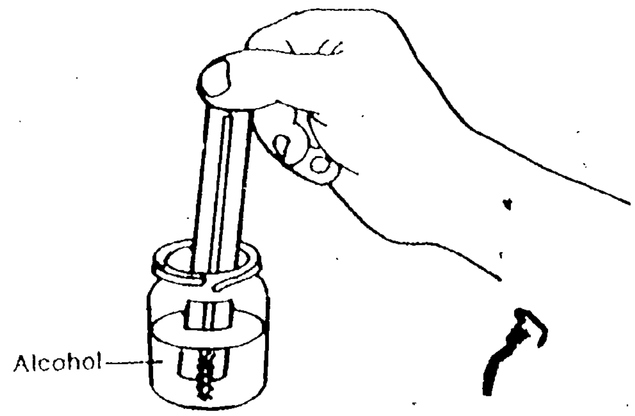
Let's find out more about this cooling. You will need the following materials:

1 thermometer
1 4-cm piece of wick
Baby-food jar half-filled with alcohol

ACTIVITY 2. Place a dry wick over the end of a thermometer. In doing this, your fingers will probably touch the bulb and cause the temperature to rise. When the temperature returns to normal, record it as Temperature A in Table 1. This is the temperature of the air.



ACTIVITY 3. Place the thermometer in the jar of alcohol. Record the temperature of the alcohol as Temperature B in Table 1.



ACTIVITY 4. Remove the thermometer from the alcohol and wave it around for about 15 seconds. Record the temperature as Temperature C in Table 1.

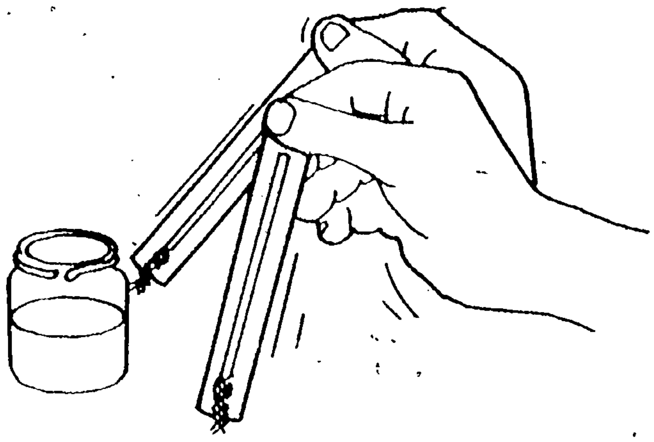


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Table 1

	Temperature (°C)
Temperature A	
Temperature B	
Temperature C	

☐2. What is the difference between Temperature A and Temperature B?

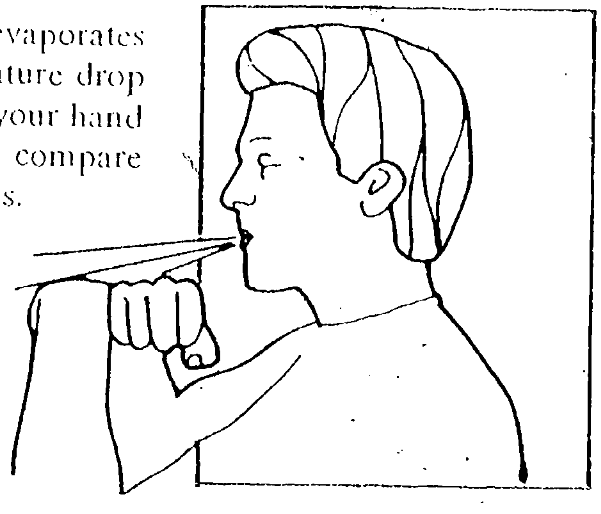
☐3. What is the difference between Temperature B and Temperature C?

☐4. How do you explain these differences in temperature?

You probably found that the air temperature (A) and the alcohol temperature (B) were very similar. However, Temperature C was much lower.

☐5. What happened to the alcohol as the temperature dropped?

Alcohol was used in this activity because it evaporates rapidly. This evaporation is related to the temperature drop that you observed. Blowing across the wet spot on your hand speeds up the evaporation of the liquid. You can compare the cooling effect of evaporation of the two liquids.



ACTIVITY 5. Put a small amount of alcohol on the back of one hand. Then lick the back of the other. Now blow across both hands at the same time. Continue blowing until one of the liquids disappears.

[ ]6. Which hand felt cooler as you blew across it?

[ ]7. Which liquid evaporated the faster? (You may want to devise another way to compare the evaporation rate of the liquids.)

You may recall from Volumes 1 and 2 of ISCS that energy is absorbed by a liquid when it changes to a gas. This energy (usually heat) is absorbed from the surroundings.

[ ]8. Explain the fact that the backs of your hands felt cool while the liquids were evaporating.

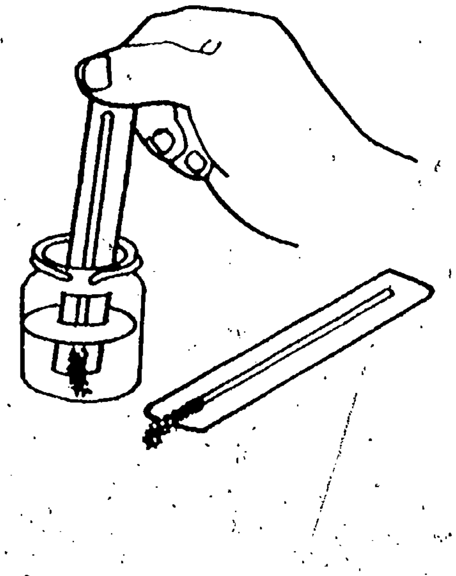
[ ]9. Why did the alcohol make the hand feel cooler than the other liquid did?

Wet- and dry-bulb thermometers

Recall how you determined the relative humidity and dew point by using the sling psychrometer. You found that the temperature of the wet-bulb thermometer was lower than that of the dry-bulb thermometer. What you know about cooling and evaporation should help explain this difference. The energy needed to evaporate the water from the wick was taken from the wet-bulb thermometer. As a result, the thermometer cooled down.

But why did you have to twirl the sling psychrometer around? Why wasn't the difference between the dry- and wet-bulb thermometers always the same? Let's try an experiment to help find the answers to these two questions. You and a partner need these materials:

1 thermometer
1 wick
1 baby-food jar half-filled with alcohol

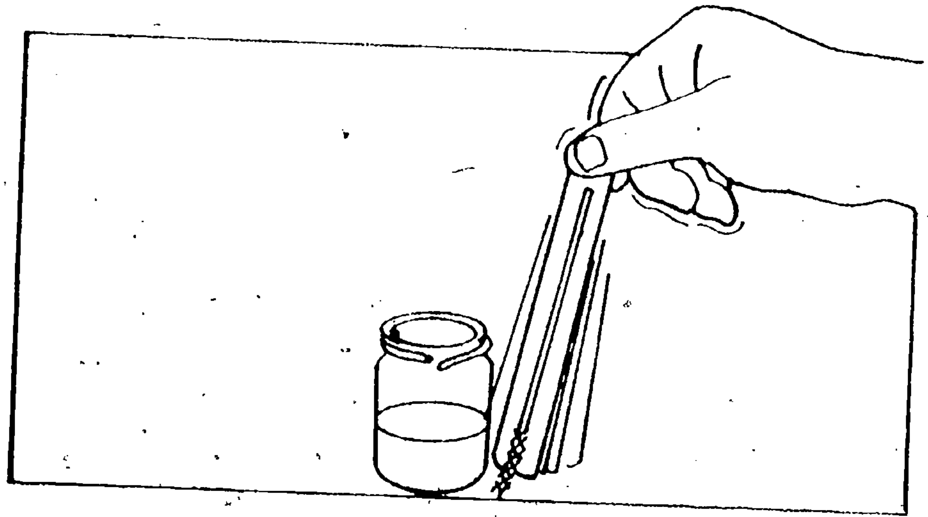


ACTIVITY 6. Place the wick over the end of the thermometer. Dip the thermometer into the alcohol and remove it. Place it on the table and read the temperature at 15-second intervals. Record the readings in row 1 of Table 2.

Table 2

Condition	Temperature (°C)			
	After 15 sec.	After 30 sec.	After 45 sec.	After 60 sec.
1. Thermometer (on table)				
2. Thermometer (waved around)				

ACTIVITY 7. Again place the thermometer and wick into the alcohol. Remove it, and wave it around steadily, stopping at 15-second intervals to read the temperature. Record the readings in Table 2.



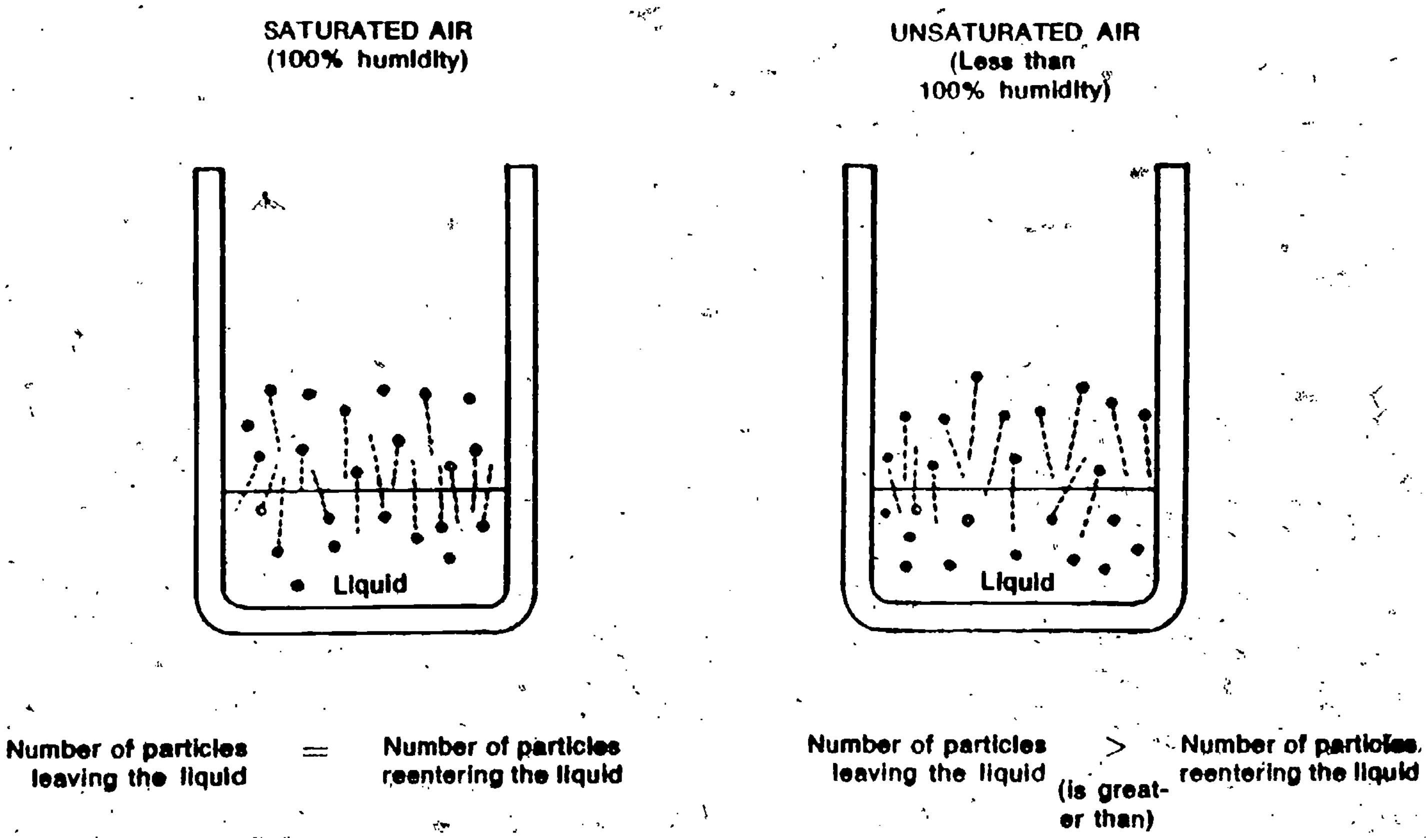
☐**10.** Using your particle model, explain why the moving thermometer cooled off more rapidly. (You may want to use the ISCS Volumes 1 and 2 particle model in your explanation.)

The particle model for matter says that this energy speeds up moving particles. The fast-moving particles may leave the liquid to become part of the gaseous air. However, collisions between gaseous water particles directly above the liquid may knock some particles back into the liquid again. It is also possible for particles to return to the liquid just because they are moving in that direction.

When will the number of particles of evaporated liquid returning to the liquid be the greatest? It will be when the air above the liquid is saturated with particles from the liquid. Saturated means the air has all the evaporated liquid it can hold. A sponge is saturated with water when it is holding all the water it can.

Suppose, for example, the evaporating liquid is water. The greatest return of water particles to the liquid would occur when the air is saturated with water vapor; in other words, when the humidity is 100%. The number of particles leaving the liquid would be balanced by the number of evaporated liquid particles returning. This idea of particle balance is illustrated in Figure 1.

Figure 1



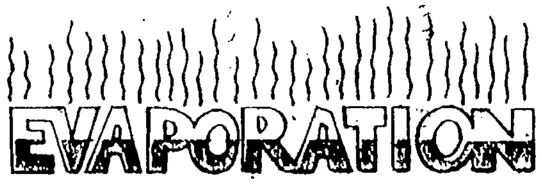
☐**11.** Suppose the particles leaving the liquid were removed from above the liquid (blown away, for example). How would this affect the evaporation of the liquid?

Perhaps you can see why you "sling" the psychrometer. (The same reason explains why wet clothes dry faster on a windy day than on a day when the air is calm.) The air immediately next to the wet-bulb thermometer may be saturated with water. However, by swinging the thermometer around, you constantly bring the wet surface into regions where the air is not saturated.

☐ 12. Suppose the humidity in your classroom is 100% (saturated air). How would the temperature of the wet- and dry-bulb thermometers compare?

When the air is not saturated, particles will evaporate from the wet-bulb thermometer. The drier the air, the faster the evaporation. Thus, the better the cooling and the greater the difference between the wet- and dry-bulb readings.

In summary, in humid (moist) air, the difference in temperature between the two thermometers is slight, if any. In very dry air, the wet-bulb thermometer gives a much lower reading than does the dry-bulb thermometer. This should help explain the figures in Table 4-2 of Chapter 4.



Condensed condensation

The particle model is also useful in explaining condensation. It is the opposite of evaporation. In condensation, a gas becomes liquid. Condensation occurs with cooling. As the gas cools, its particles lose energy and move more slowly. The forces of attraction between the particles are sufficient to bring these slower moving particles together.

You have seen moisture gather on the outside of a container of cold liquid. (This is similar to the way you determined dew point.) The air close to the cold container is cooled as the container absorbs heat from it. The particles in the air lose some of their energy. With reduced motion, gaseous water particles join together to form the visible liquid droplets.

How High Are the Clouds?

Excursion 5-1

Many warm summer days begin with a cloudless sky. By noon, however, puffballs of cumulus clouds may have appeared. Heat from the earth's surface has lifted moist air up, forming clouds. Usually these clouds have flat bottoms.

☐1. How do you account for the flat bottoms when the cloud tops aren't flat at all?

That isn't an easy question, but you may be closer to the answer than you think. As moist, warm air rises, it gradually cools. Eventually it gets high enough and cool enough so that the water vapor condenses. This condensing (cloud formation) happens just when the temperature of the air is the same as the dew point. This occurs at a specific height above the earth. (Of course, this height varies from day to day.)

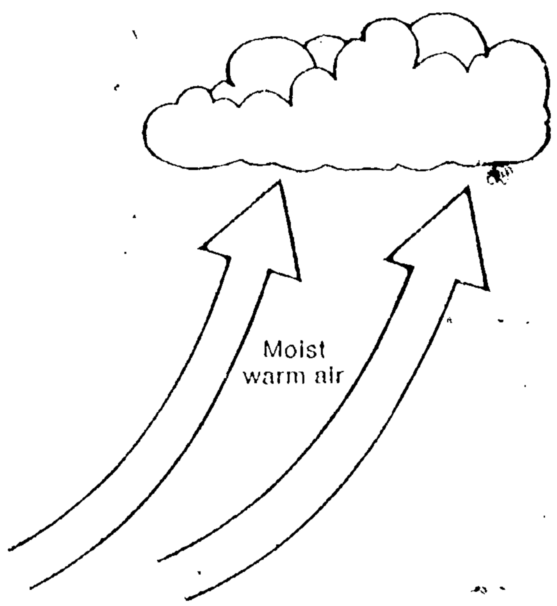


Figure 1

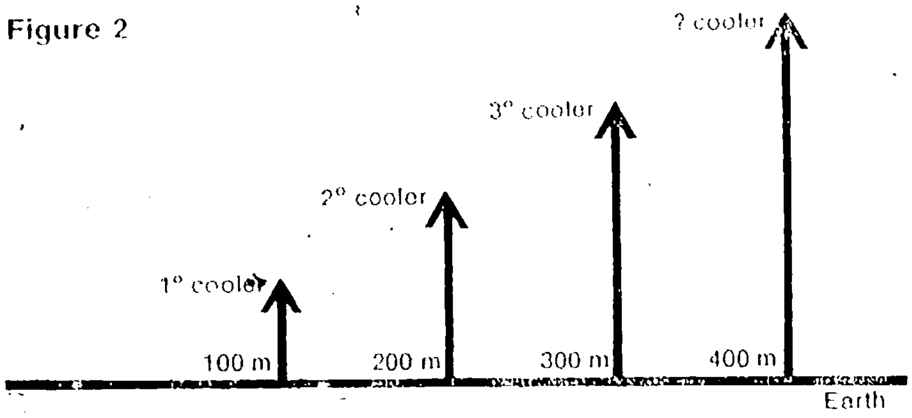
☐2. What part of the cloud is the first to form, the top or the bottom?

☐3. Can you now explain the flat-bottomed clouds?

As air rises, it cools at an average rate of about 1°C per 100 m.

[ ]4. How much cooler would the air be at 400 m than at ground level? (Figure 2)

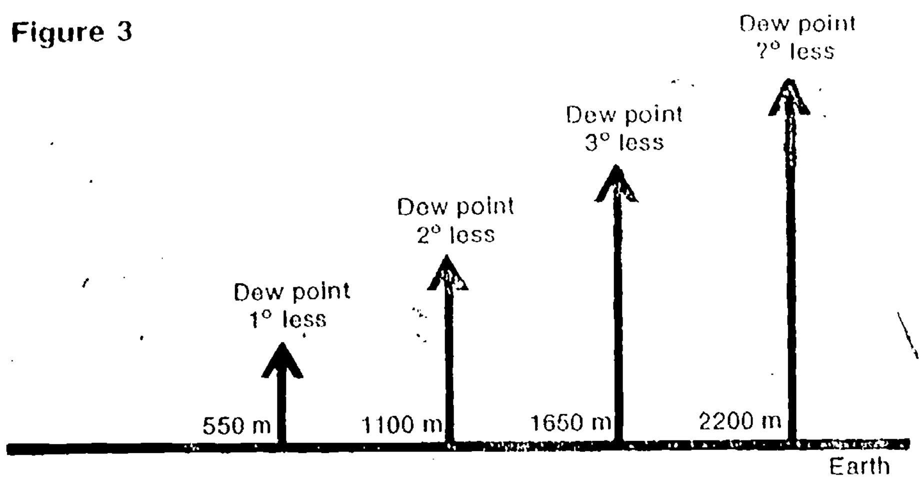
Figure 2



The dew point of air decreases at an average rate of 1°C per 550 m.

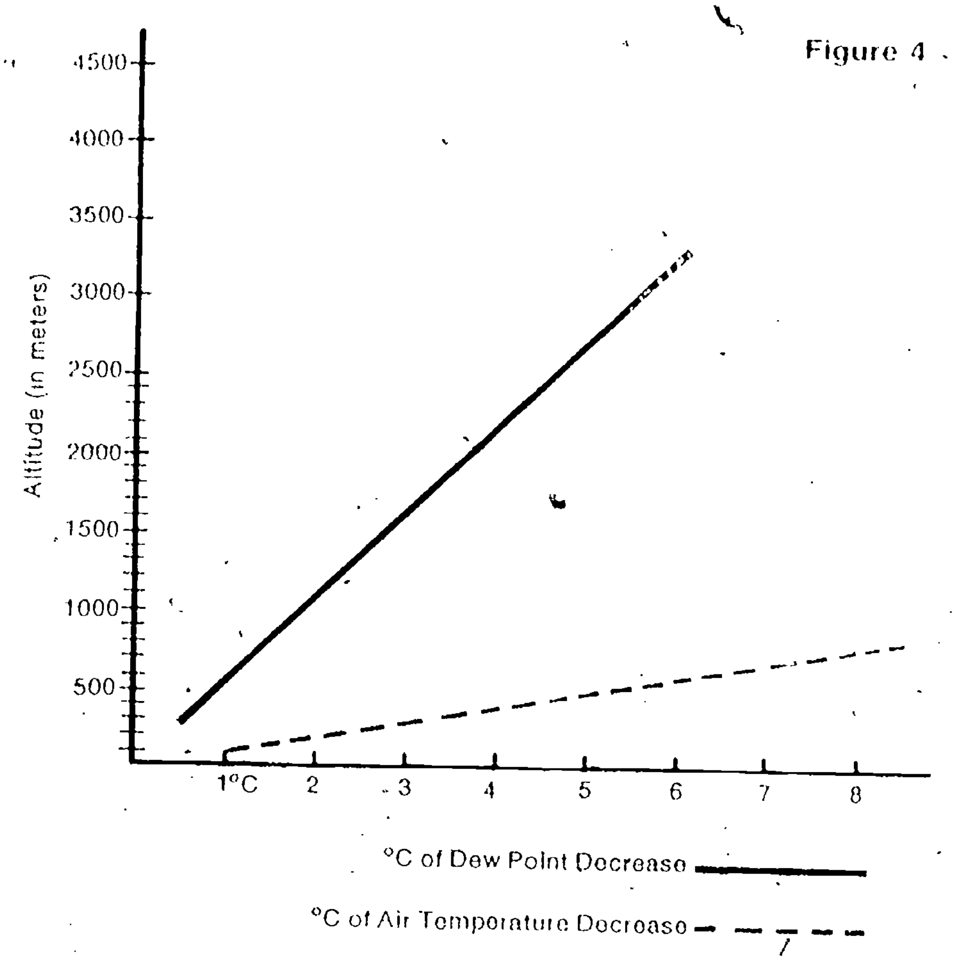
[ ]5. How much less would the dew point of air be at 2,200 m than at ground level?

Figure 3



[ ]6. Which decreases faster with altitude, the air temperature or the dew point?

Figure 4 may help you with your answer to question 6.



As altitude increases, the air temperature falls faster than the dew point. Therefore, at some specific altitude, the air temperature will be equal to the dew point. At that altitude, clouds will begin to form. Since cloud bottoms form first, all of them will be flat at that height. (The rest of the cloud forms as the warm air continues upward. What do you think causes some clouds to stop getting larger?)

Your problem is to find the height of the base of clouds. Assume that the temperature at the base of the cloud is at the dew point.

Calculating the height of the cloud base involves two steps.

1. Find the air temperature and dew point at ground level.
2. Find the height at which the air temperature (getting lower by 1°C each 100 m) and the dew point (getting lower by 1°C each 550 m) are equal.

Figure 5 shows a sample problem on a day when the temperature at ground level is 26°C and the dew point is 8°C.

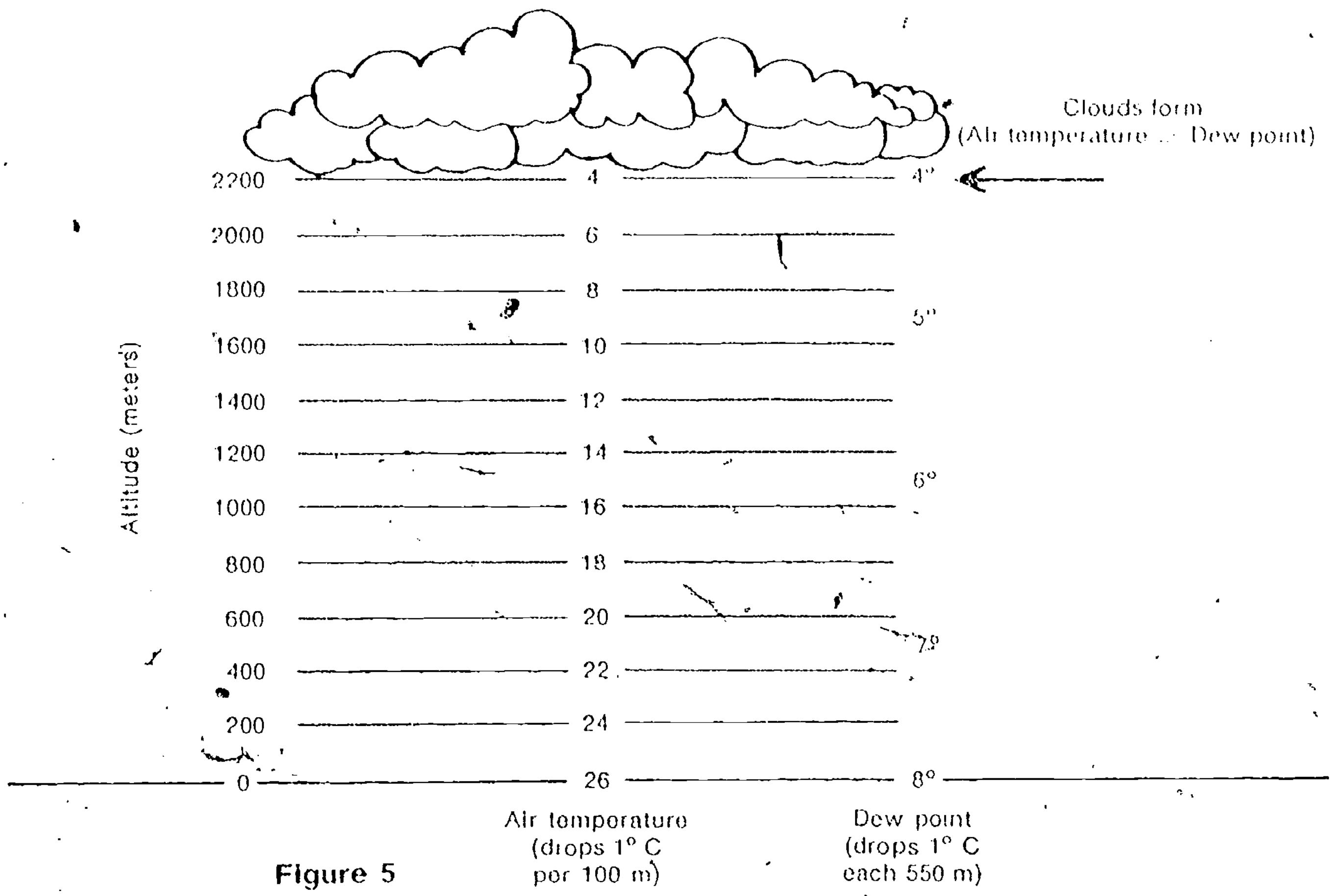


Figure 5

An easier solution than the one shown in Figure 5 involves using a simple formula. Here it is:

$$\text{Height of cloud bottom in meters} = 122(T_{air} - T_{d.p.})$$

T_{air} = ground level temperature of air

$T_{d.p.}$ = ground level dew point

☐ **7.** Using the formula, check the sample problem of Figure 5.

☐ **8.** Calculate the height at which clouds could form today. (Record your method, data, and conclusions in your Record Book.)

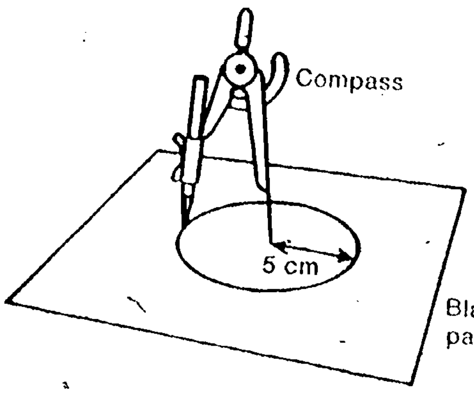
☐ **9.** (Optional) Can you derive the formula given for this type of problem?

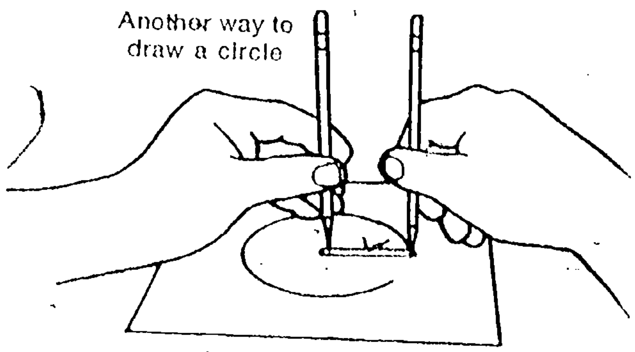
Building a Nephoscope

Excursion 5-2

A nephoscope is a device you can build and use to measure the forward motion of a cloud. You will need the following materials:

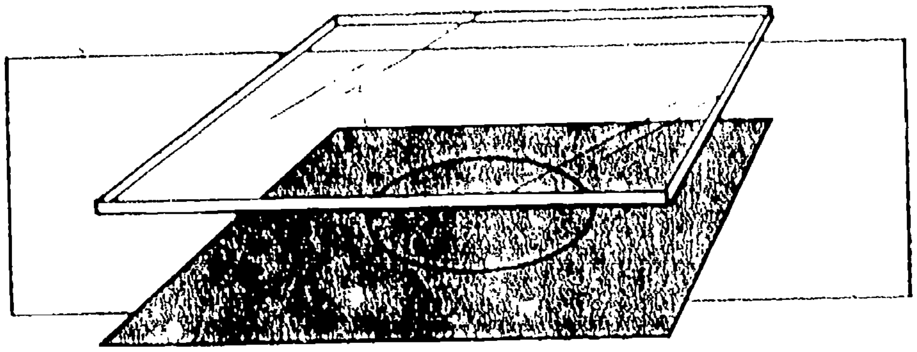
1 pane of window glass, approximately 21 cm × 21 cm
1 sheet of black paper, cut to the same size as the glass pane
1 centimeter ruler (or meterstick)
1 watch, with sweep second hand
1 strip of masking tape (about 20 cm)
1 marking pen (fine point)
1 drawing compass



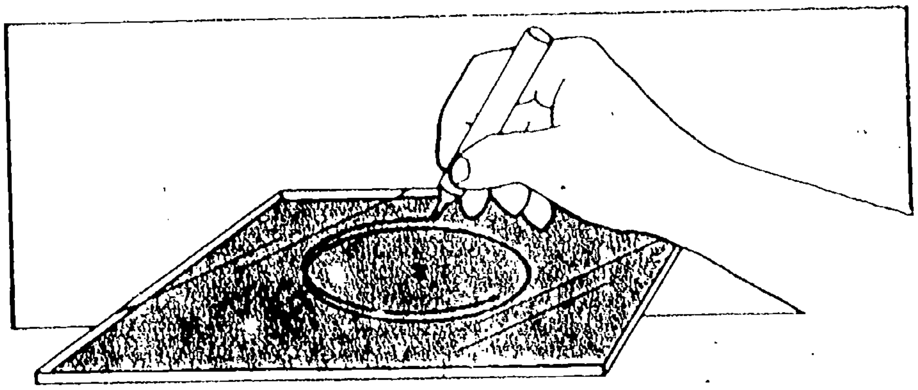


ACTIVITY 1. Clearly mark a point near the center of the black paper. With this point as center, use a compass to draw a circle of 5-cm radius.

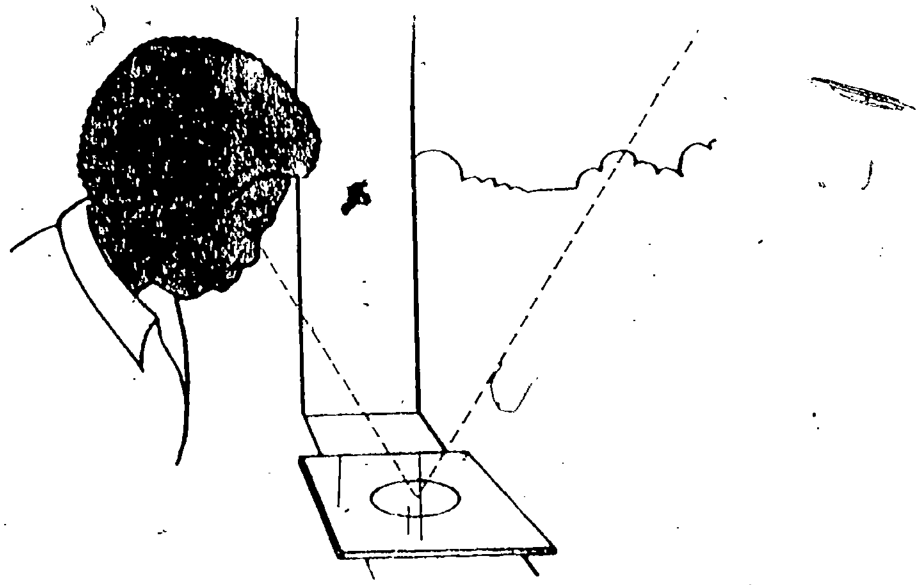
ACTIVITY 2. Tape the black paper with the pencil markings next to the glass. They should be visible through the glass.



ACTIVITY 3. With the marking pen, trace over the pencil markings so that the glass sheet is marked like the black paper.

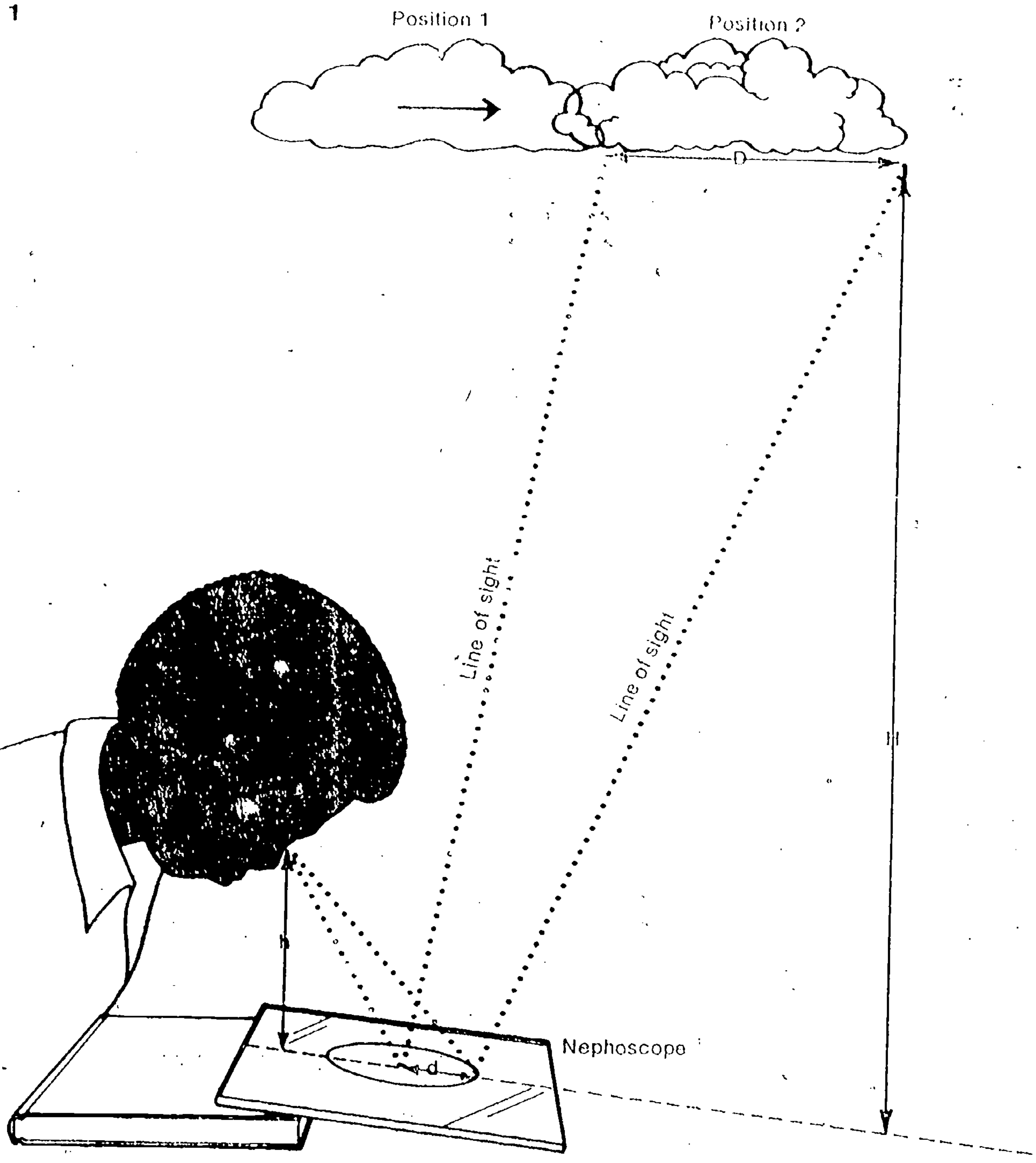


ACTIVITY 4. Place the nephoscope as near a window as possible, or in the open where you have a clear view of the sky.

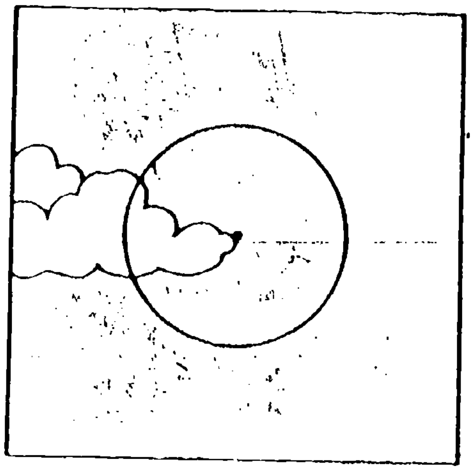


Choose some clouds as nearly overhead as possible. Stand beside the nephoscope in a position from which you can see the reflection of the clouds. You may need to prop one edge of the nephoscope on a book. Once you have this set up (Figure 1), you are ready to make measurements. You will need the help of a partner.

Figure 1

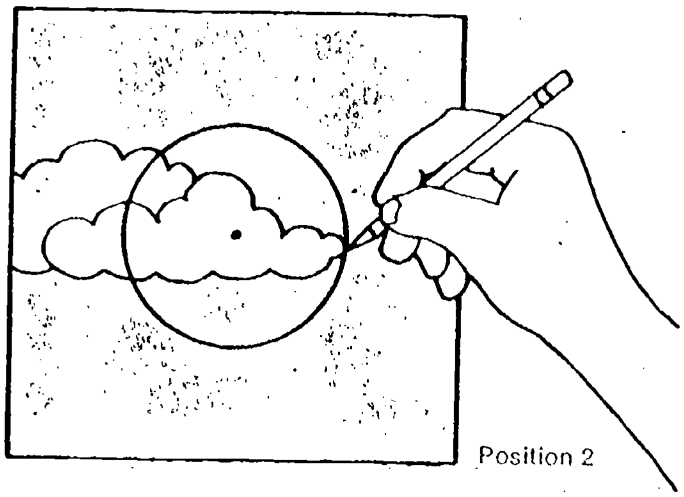


ACTIVITY 5. First, select a clearly identifiable point on the edge of a cloud. Position yourself so that the reflection of this point is at the center of the nephoscope.



Position 1

ACTIVITY 6. Then, without changing your position, have your partner time the movement of the reflection. Record how many seconds it takes your chosen point to move from the center to the rim of the circle. Don't change the position of your body until your partner measures the height of your eye above the nephoscope. (See Figure 1.) Record your data in Table 1.



Position 2

Table 1

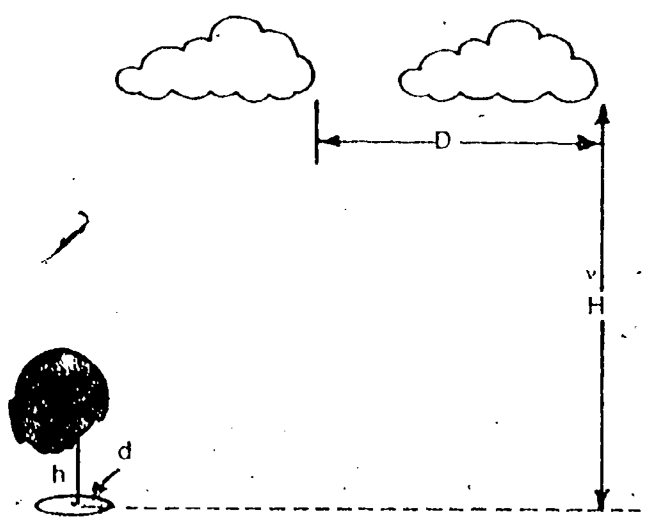
Distance moved by reflection (d)	0.005 meter
Time to move 5 cm (t)	seconds
Height of eye above nephoscope (h)	meters
Estimated height of clouds (H) (See **Excursion 5-1.**)	meters

Do not forget to change your measurements of h and d from centimeters to meters.

With a formula from geometry, you can use the measurements you have just made to calculate the distance traveled by the clouds.

$$D = \frac{H \times d}{h}$$

D = Actual distance traveled by cloud
H = Estimated height of cloud
d = Radius of nephoscope circle
h = Height of eye above nephoscope



[ ]1. What is the distance moved by the cloud?

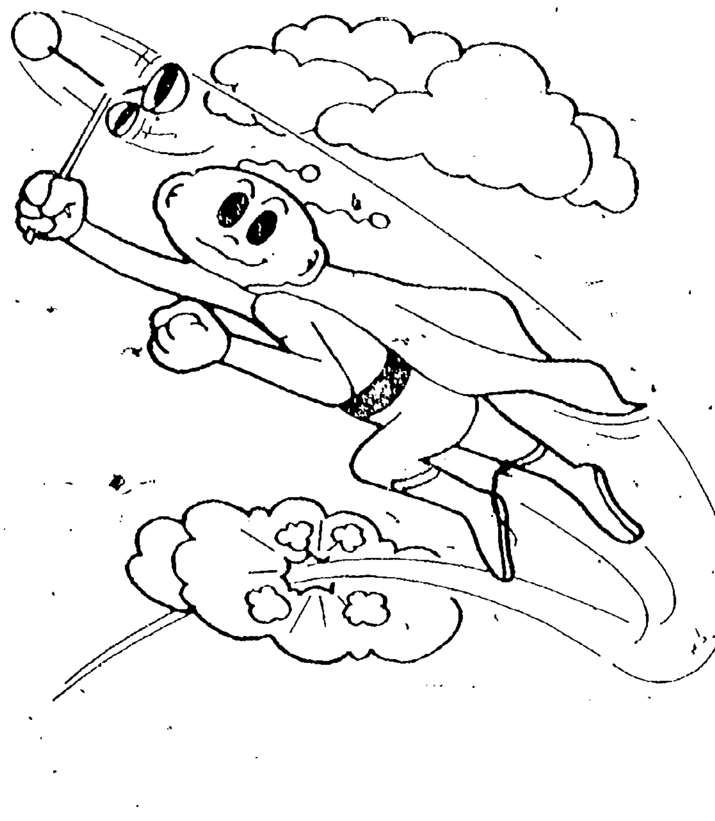
[ ]2. Suppose the estimated height (H) is 2,000 meters. What distance would the cloud have moved if all your other measurements were the same as before?

[ ]3. How fast did the cloud move in meters/sec?

$$\left(\text{Speed} = \frac{D}{t}\right)$$

[ ]4. Suppose you wanted to use this method to measure the speed of a jet aircraft. What would you need to know?

[ ]5. How could you improve this method of determining cloud speed?



And the Rains Came Down

Excursion 7-1

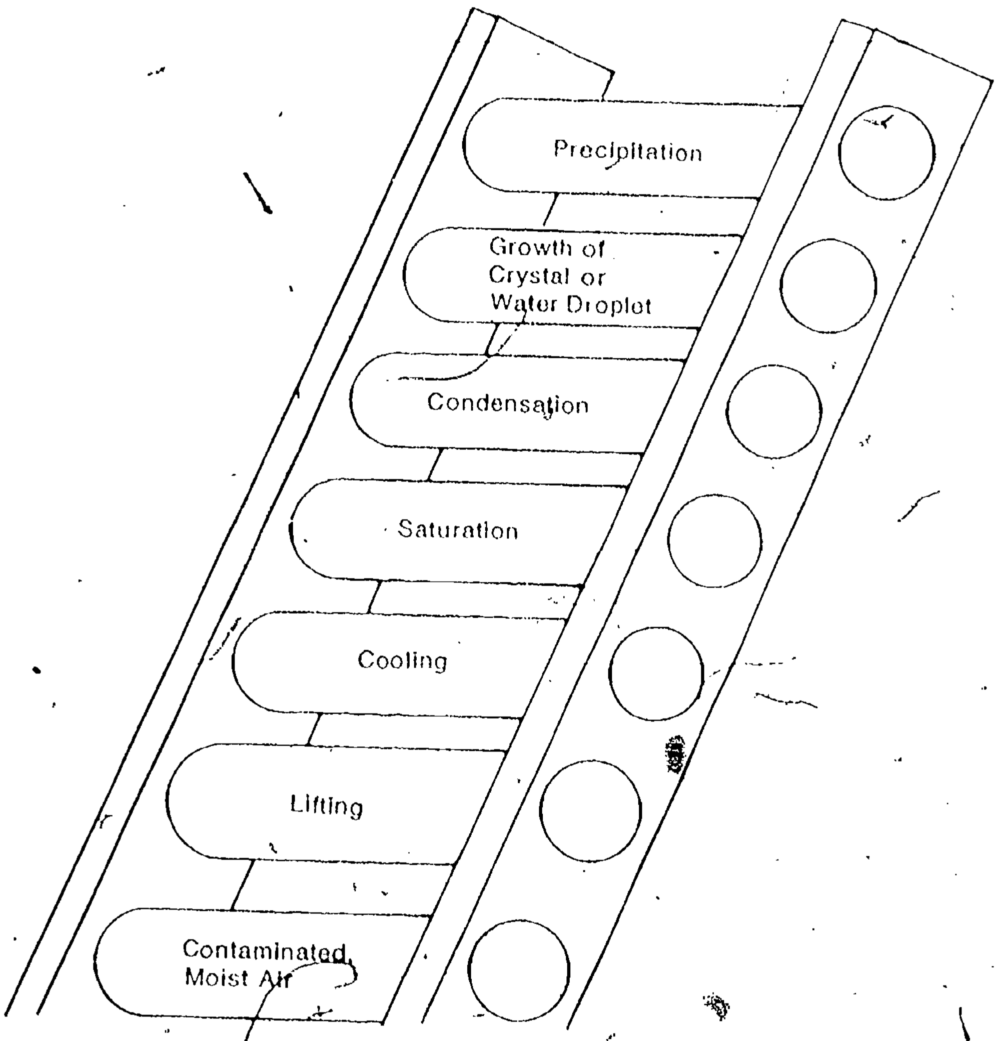


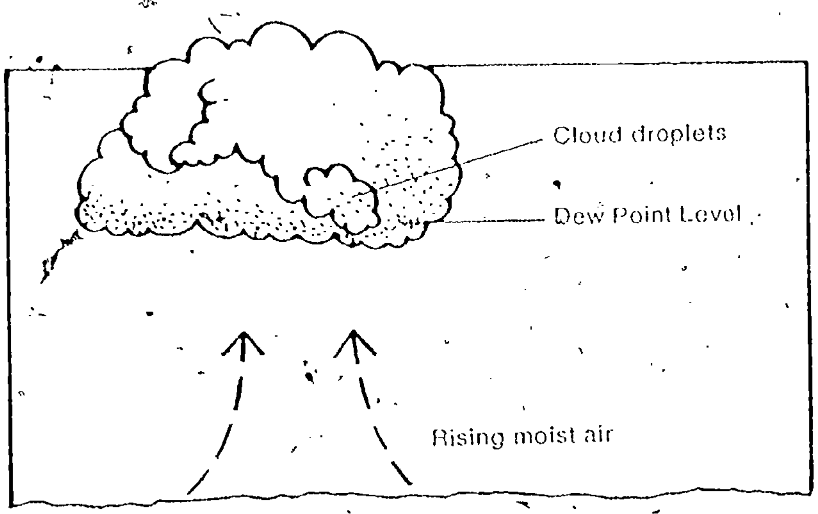
Figure 1

You have been studying a number of events that take place in the atmosphere. All these events can lead to one other occurrence that we associate with weather—precipitation. This precipitation can be in the form of drizzle, showers, snow, sleet, or hail. It all depends on the temperature and other conditions.

Precipitation might be considered the top rung of a ladder of events that occur in the air (Figure 1).

Let's climb to rung 5, Condensation. You have found that air must contain water vapor and some solid particles for condensation to take place. When the temperature of the air reaches the dew point, the water vapor will condense on the particle surfaces (dust, smoke, salt particles). Figure 2 illustrates the formation of a cumulus cloud. Moist air is lifted and then cooled. The cloud forms when the dew point is reached and water begins to condense on small particles (condensation nuclei).

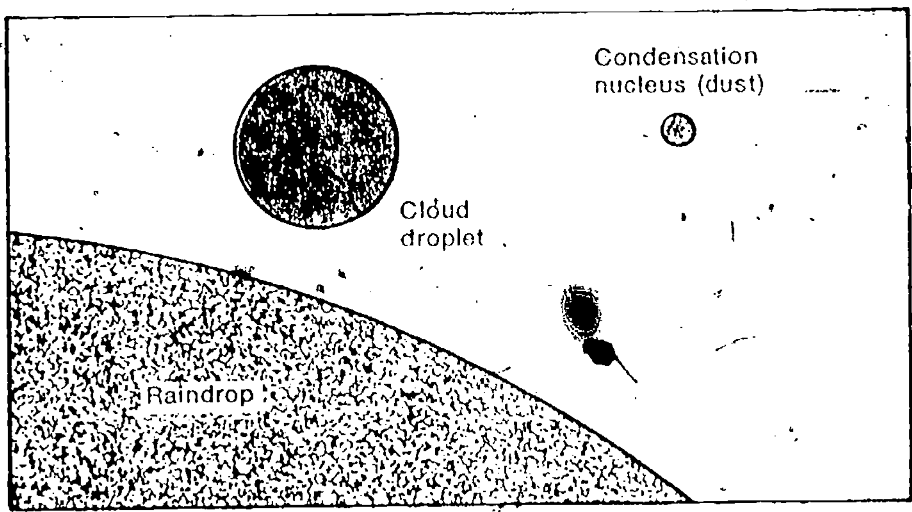
Figure 2



The cloud consists of very tiny droplets, which we'll call "cloud droplets."

Figure 3 compares the sizes of a condensation nucleus (dust or salt), a cloud droplet, and an average-size raindrop. An average raindrop is so large compared to the droplet and condensation nuclei that we can only show part of it.

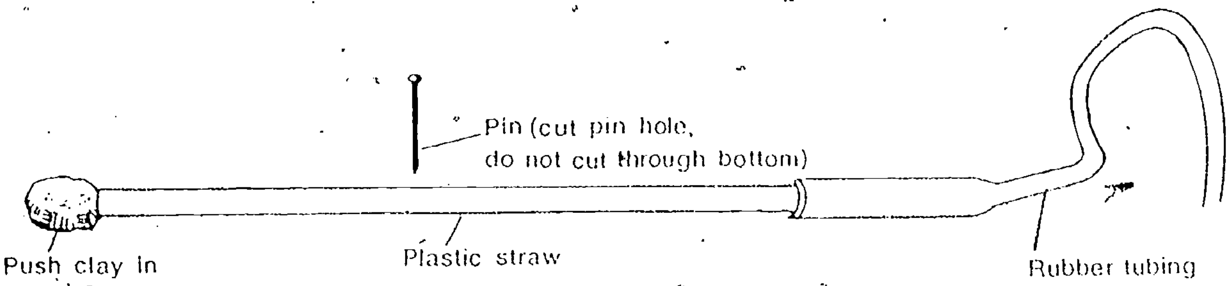
Figure 3



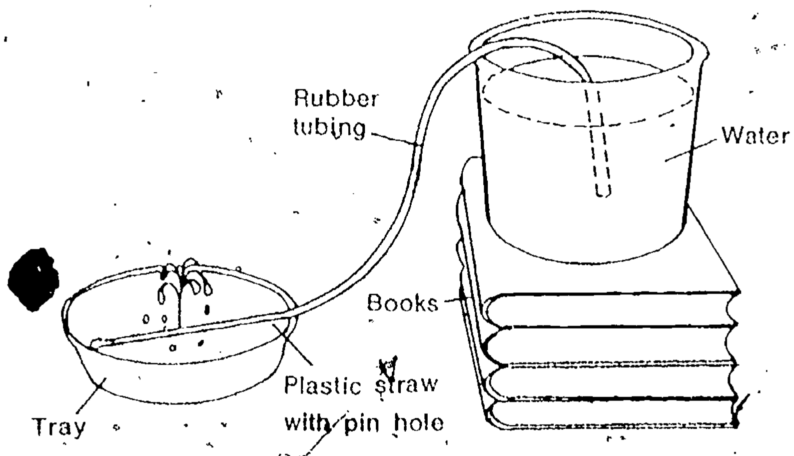
Now glance back at the ladder in Figure 1. In order to go up from rung 5, Condensation, to rung 7, Precipitation, Growth (rung 6) of the "cloud droplets" must take place. About one million cloud droplets are needed for a small raindrop to form! How does this happen? To find out, you and a partner will need the following:

1 plastic straw
Rubber tubing, 2-foot length
1 pail
1 comb
Scotch tape or clay
Flat aluminum pie pan

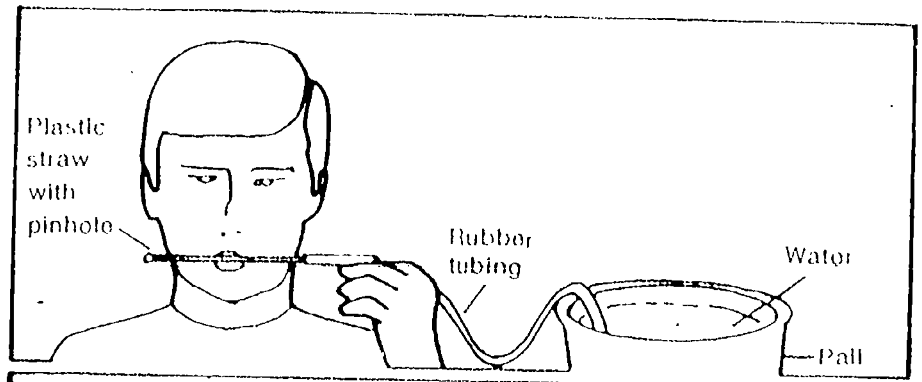
ACTIVITY 1. Carefully punch a pinhole on one side only of the plastic straw. Block up one end of the straw with clay or tape. (The end *must be* watertight.) Fasten the open end of the straw to the rubber tubing.

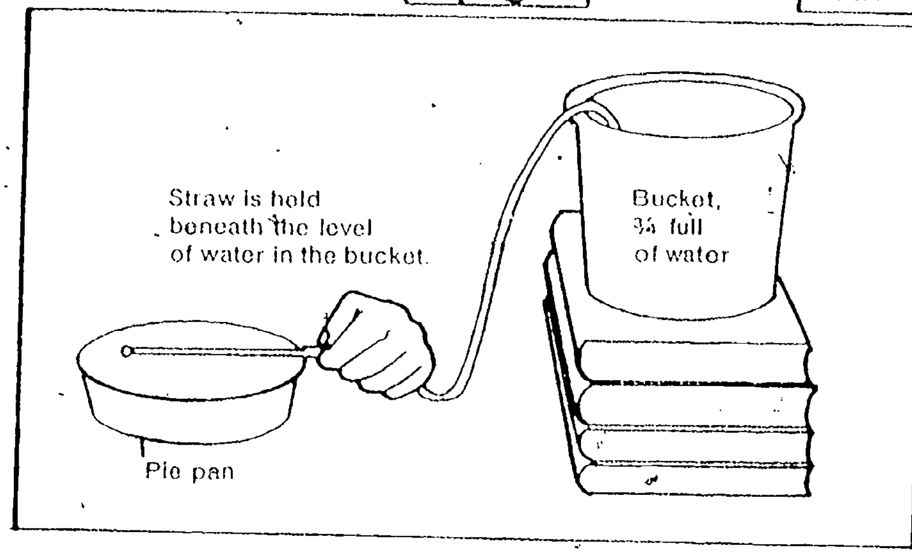


ACTIVITY 2. Set up the apparatus as shown. The top supply bucket should be about $\frac{3}{4}$ full.

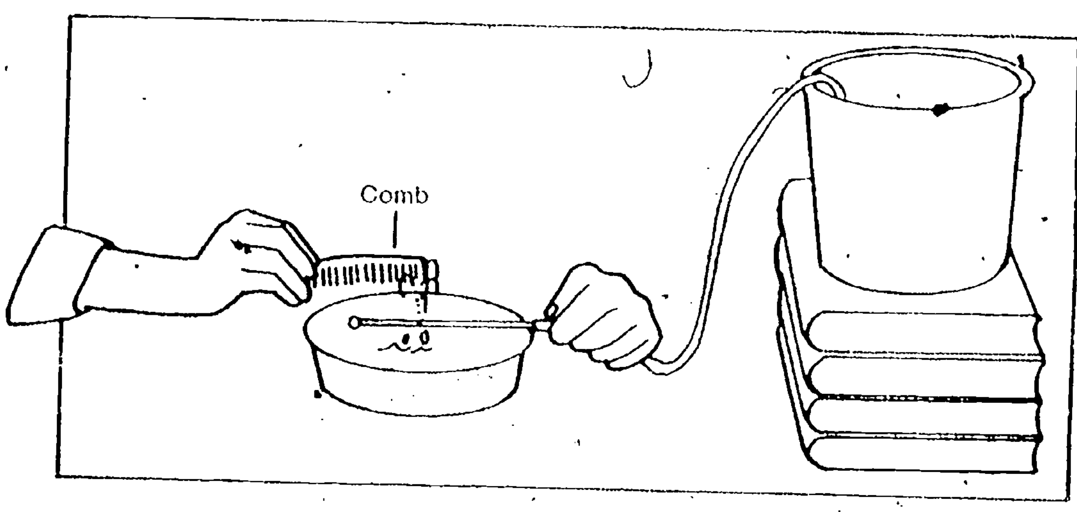


ACTIVITY 3. Hold the straw lower than the water level in the bucket. Suck on the pinhole until water starts to flow. Hold the straw in the pan so that the fountain is vertical.





ACTIVITY 4. Observe the spray of water carefully. Pay particular attention to the size of the droplets. Now, while you hold the straw, have your partner run a comb several times through his hair, and then move the comb close to the spray. Move the comb in and out several times.



[ ]1. What did you observe happening when the comb was brought close to the spray?

[ ]2. What happened to the size of the droplets when the comb moved toward and away from the spray?

[ ]3. Give your explanation of why the comb affects the water spray?

[ ]4. Does this investigation suggest what might cause tiny cloud droplets to combine to form raindrops? Explain your answer.

The friction that results when a comb is run through dry hair produces an electric charge on the comb and the hair. This charge has been described in detail in Volume 2 of ISCS. Electric charge can produce a force of attraction between objects. As you brought the charged comb near the water spray, the droplets probably increased in size. It is reasonable to assume that this charge was caused by the charge on the comb. Tiny droplets were attracted to each other and combined into larger ones. Electric charge also exists in clouds. Therefore, it is reasonable to think that this charge may cause the formation of raindrops.

There is another factor in raindrop formation that some meteorologists think is even more important than the presence of electric charge. This factor is the presence of ice crystals in clouds. Figure 4 shows how the temperature in a cloud may vary. In large clouds extending to high altitudes,

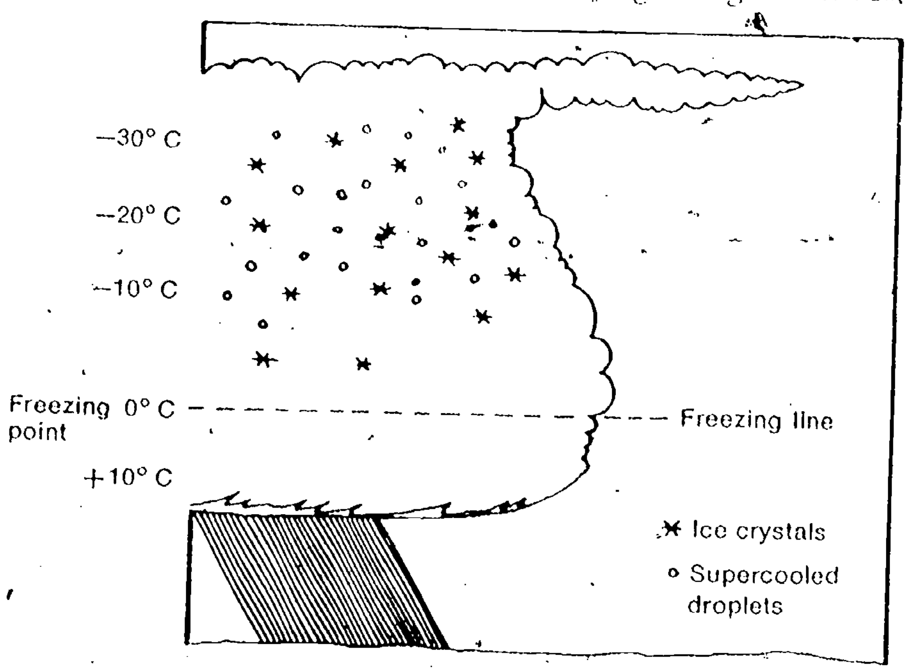


Figure 4

the temperature may be well below the freezing point of water. The water droplets at altitudes above the freezing line will be colder than the freezing point of water, and still be liquid. These droplets are called "supercooled" droplets. Some ice crystals will also exist in the cloud. If a droplet collides with an ice crystal, the supercooled droplet will immediately freeze on the surface of the ice crystal. If this process continues, the ice crystal may become heavy enough to fall through the cloud. If the crystal falls through warm air, it may melt and reach the ground as a raindrop. If the crystal falls through air that is below freezing, the precipitation may be in the form of snow or sleet.

EXCURSION

If you are interested in finding out how hail forms, take a look at **Excursion 7-2**, "Cumulonimbus."

Cumulonimbus

Excursion 7-2

This excursion should be done on a day when there are cumulus clouds. Figure 1 shows a typical display of cumulus clouds.

Figure 1

ACTIVITY 1. Go outside, lie on the ground, pick out a single cumulus cloud, and observe it for at least three minutes. Then select another cloud, and again, observe it for three minutes.

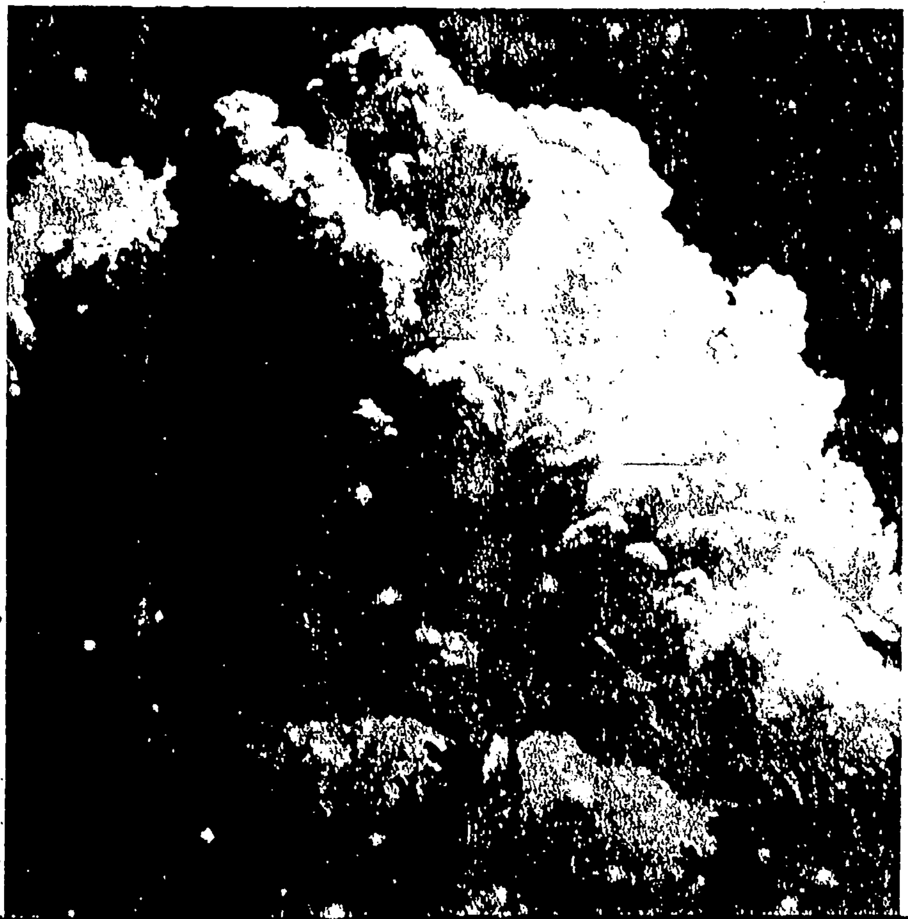
[ ]1. List the changes you observed for the two cumulus clouds.

[ ]2. Compare and contrast the behavior of both clouds.

You learned earlier in this unit that if warm, moist air rises, it will cool. The water vapor will condense on tiny solid surfaces, forming a cloud. Cumulus clouds, with their puffy, heaping appearance, are formed where updrafts of moist, warm air occur. You might have noticed that the clouds you observed changed quite dramatically. Perhaps the cloud moved horizontally, broke apart, faded away, or grew larger. Generally these clouds don't last too long because the air surrounding them is usually quite dry. This dry air causes the cloud droplets to evaporate and become invisible water vapor.[1]

Some cumulus clouds, however, are huge and may last long enough to produce violent weather. Examples of these clouds are shown in Figures 2 and 3.

Figure 2



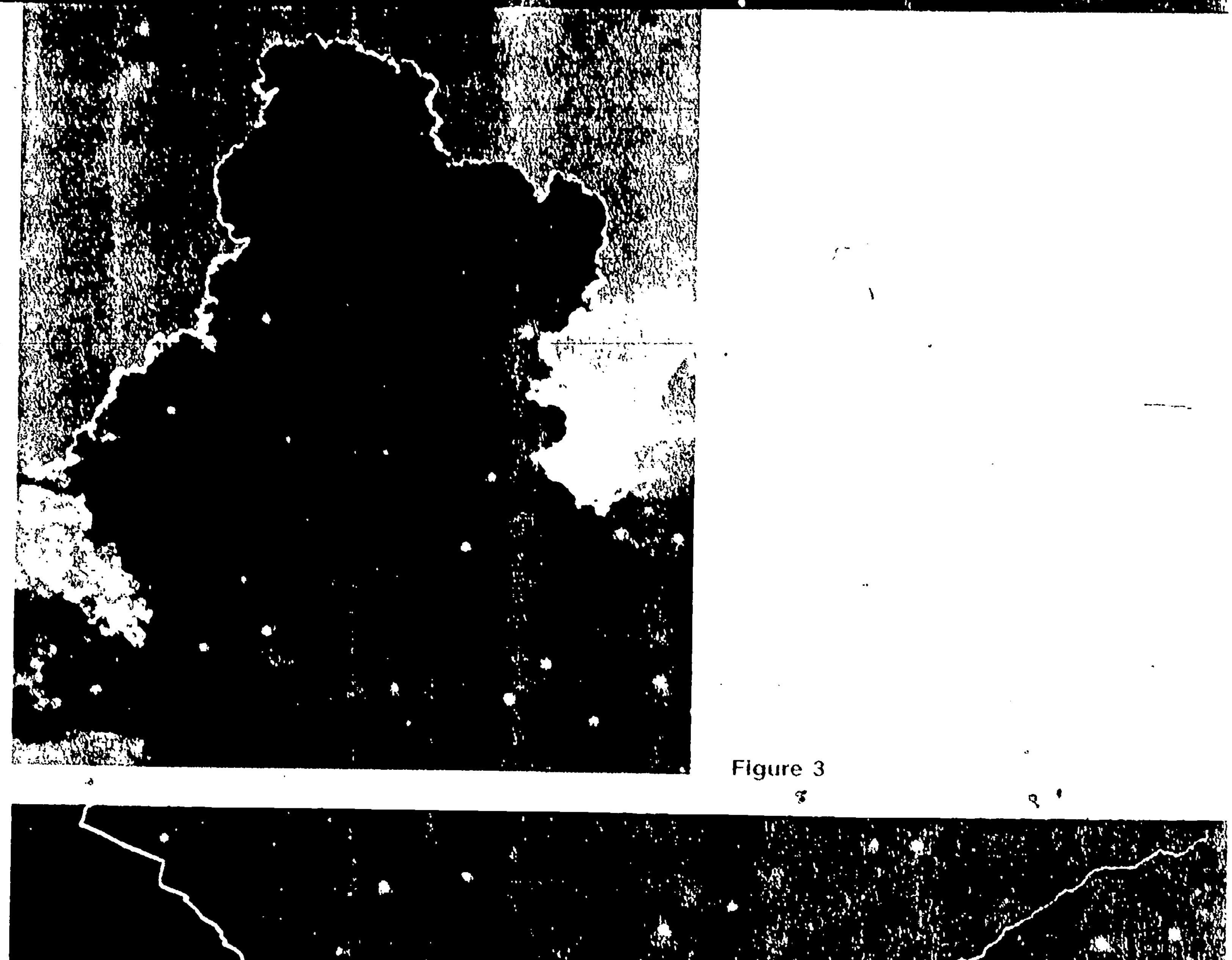


Figure 3

You probably know that the clouds shown in Figures 2, and 3 are cumulonimbus clouds. Perhaps you have seen one recently. You may remember that wind, thunder, lightning, rain, and perhaps even hail may have been associated with it. How does a cloud get so big? What happens inside these clouds to produce a violent thunderstorm?

ACTIVITY 2. Figure 4 shows drawings of the same thundercloud at different times. Using the vertical scale shown in the photographs, determine the height, in feet, of the cloud at each time.

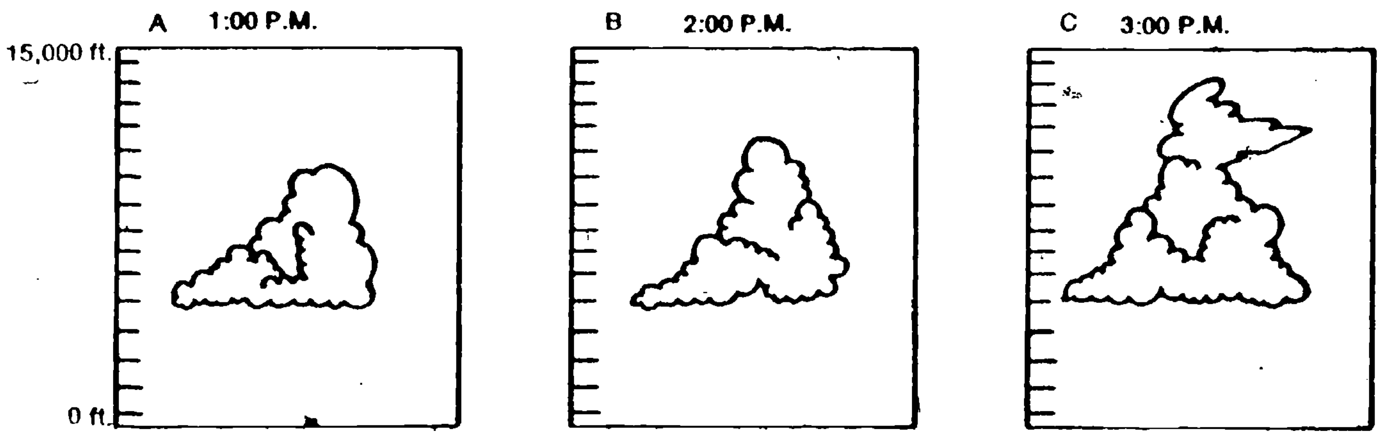


Figure 4

☐**3.** How tall (from bottom to top) was the cloud at each time interval?

☐**4.** What was the rate of growth of the thundercloud? (Hint: How many feet did it "grow" per hour?)

Rising air in some thunderclouds may have upward speeds of 60,000 to 100,000 feet per hour. At such speeds the air may climb above the condensation level very rapidly. If the surrounding air is relatively high in humidity, the cloud may grow to 40,000 feet or more!

Inside the cloud, air moves violently up and/or down. Figure 5 shows the nature of the air motion in a cumulonimbus cloud.

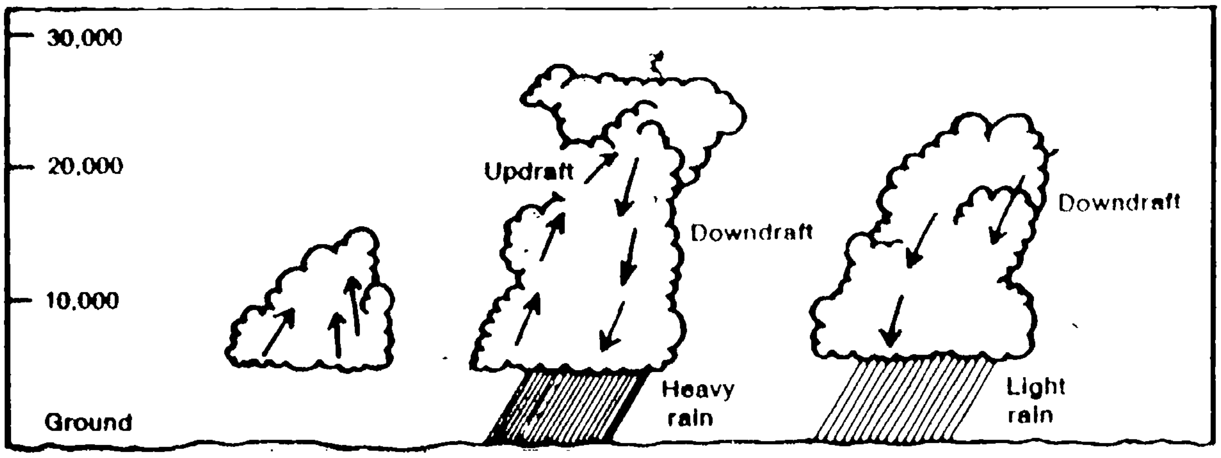
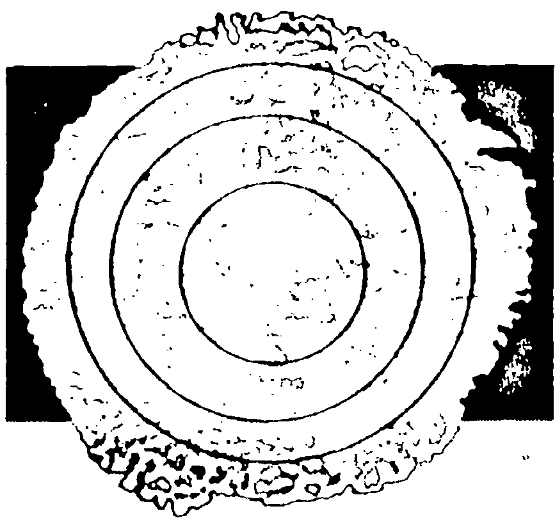


Figure 5

Notice that at first the air motion is predominately an updraft. During maximum development of the cloud, the air moves both in violent updrafts and in downdrafts. Finally, the upward motion, which supplies the moisture, ceases, and the cloud consists only of downdrafts.

Let's examine one important effect of the ups and downs of air in a cumulonimbus cloud. This effect is called hail. Although most hail is about pea size ($\frac{1}{4}$ inch), some hailstones may be as large as tennis balls ($2\frac{1}{2}$ to 3 inches in diameter). A close inspection of hailstones reveals that they consist of a series of layers of ice in concentric shells. See Figure 6.

Figure 6



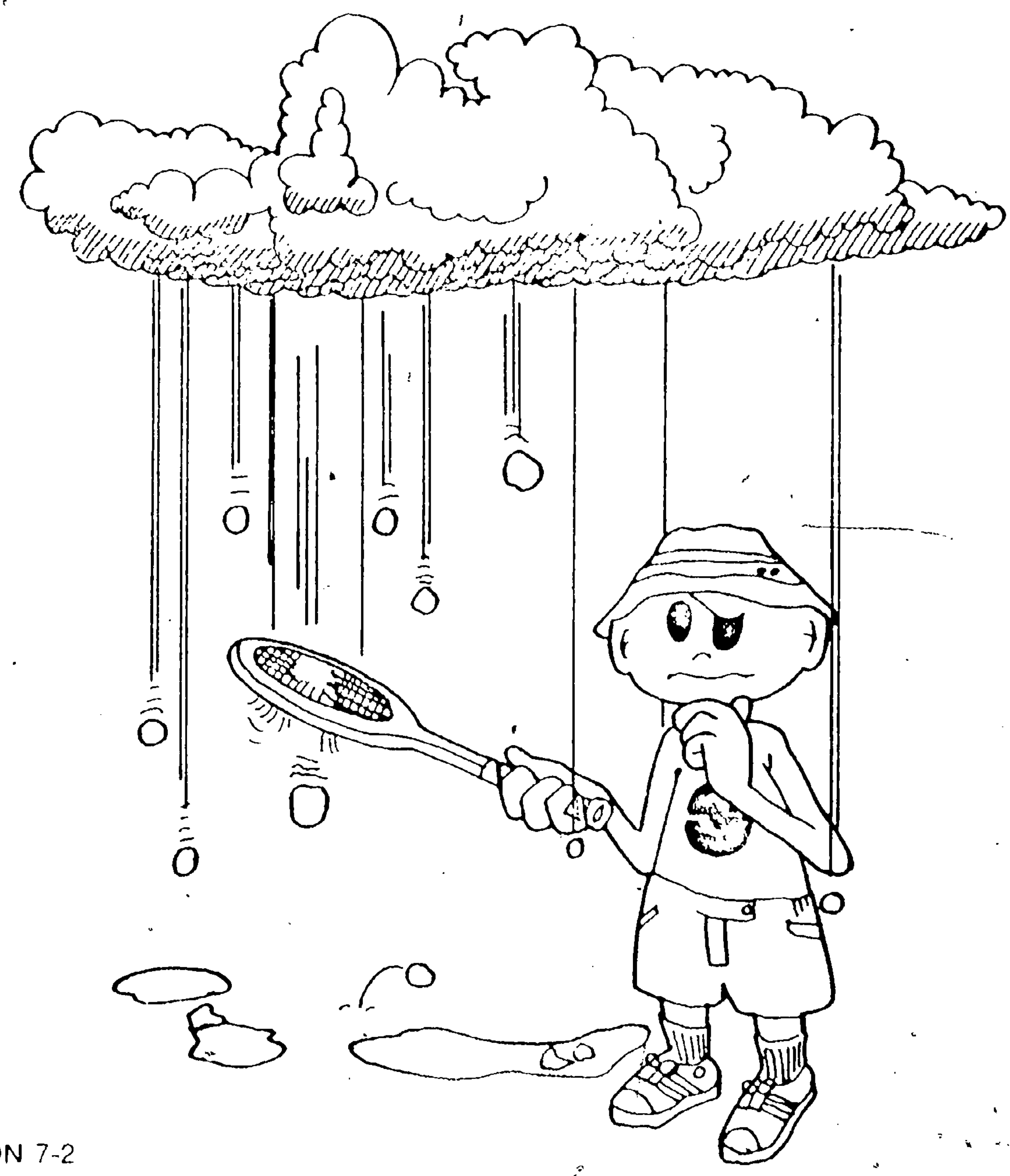
The formation of these ice layers requires the presence of strong updrafts.

☐**5.** Why do you think strong updrafts are necessary in forming hail?

If an ice crystal falling through the cloud is caught in an updraft, it can collect more droplets on its surface. The crystal then enlarges. Near the top of the cloud, the force of the updraft decreases. The now larger crystal falls again, collecting more ice on its surface. If it is hurled upward again by the updrafts, still more ice collects.

[ ]6. What would cause the hailstone to finally fall to the earth?

Imagine how strong the updrafts must be to produce hailstones the size of tennis balls!



Weather Prediction and Forecasting

Excursion 7-3

Have you been wondering how meteorologists can predict the weather from data like that shown in Table 1? How can they combine several kinds of information to interpret and forecast the weather?

Table 1

Day	Time	Temp.	Wind Dir.	Wind Speed	Cloud Type	Cloud Cover	Precip.	Bar. Pres.	Rel. Hum.	Dew Point
20	1:30	17°C	S	8–12	Stratus	○	—	29.90	55%	13°C
21	2:05	20°C	S	8–12	Stratus	⦶	—	29.88	83%	18°C
22	1:50	10°C	N	25–31	Cumulonimbus	○	1.5 cm	29.81	100%	10°C
23	1:45	5°C	N	8–12	Clear	○	—	29.92	29%	−9°C
24	—	—	—	—		—	—	—	—	—

How well can you interpret the data in Table 1? Can you predict what the next day's weather will be? Notice that the data is for a four-day period. Data for a fifth day (the 24th) is not included. You will try to predict this data. Study the patterns in each column before trying to answer the following questions.

[ ]1. What kind of front is moving across this area?

[ ]2. If you knew that the center of high pressure was due to arrive on the 24th, predict what would happen to each of the following quantities just after it arrives. (Complete that part of Table 1 in your Record Book.)
TEMPERATURE (Drop greatly; drop slightly; no change; rise slightly; rise greatly?)
HUMIDITY (Drop; stay the same; rise?)
CLOUDS (Stay clear; get cloudy; if so, what types?)
WIND (None; strong; light?)
PRECIPITATION (None; some?)

Fortunately, the weather pattern shown by the data in Table 1 is a fairly clear-cut case of frontal movement. The air pressure dropped slightly and then rose rapidly just before the first part of the high-pressure area arrived. The drop in temperature shows that the high-pressure area was the result of an advancing cold air mass. As the cold mass moved into the area, the relative humidity rose, water vapor condensed into clouds, and rain fell. After the cold air mass replaced the warm air, the air was clear, cold, and fairly still.

Most weather predictions, or forecasts, are for less than 48 hours. They are called short-range forecasts. Careful analysis of the daily weather map (which you can obtain from a daily newspaper) coupled with the observations you make of temperature, pressure, humidity, and cloud type, will enable you to make 48-hour forecasts.

Table 2 describes signs to look for when making short-range (48-hour) forecasts.

ACTIVITY 1. For the next three days, continue to gather weather-watch data. Each day, study your observations and make a forecast of the next day's weather. In addition to making your own observations, consult the daily weather map posted in your room, or look in your newspaper.

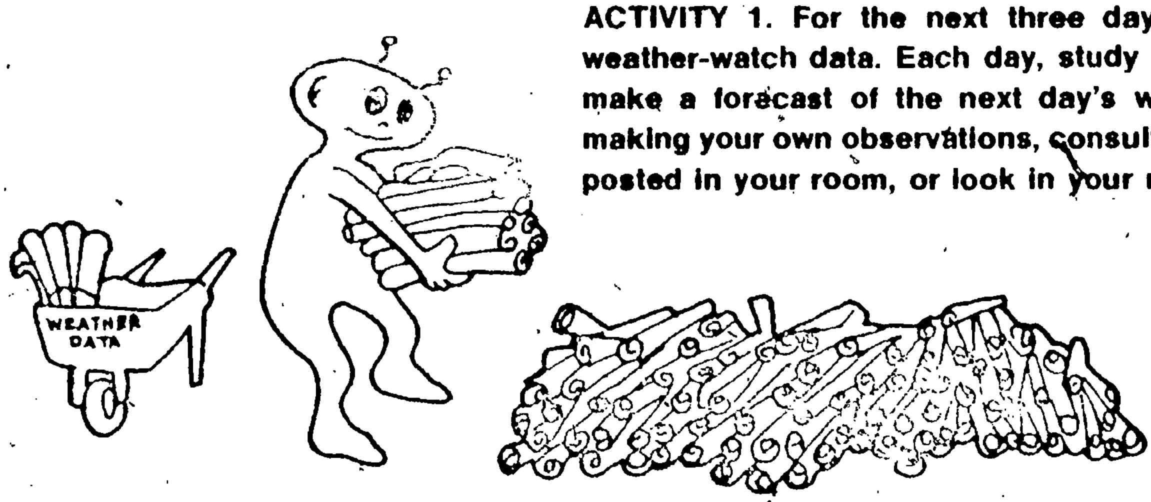


Table 2

Weather Element	Sign	Probable Change in Weather
Air Pressure	Rapid drop	Front approaching—rain or snow
	Rapid rise	Front moving out—clearing and fair
	Steady	Weather remains same.
Clouds	Puffy, scattered cumulus	Fair weather
	Afternoon cumulonimbus clouds	Thunderstorms
	Altostratus	Warm front—no rain unless cloud type changes
Miscellaneous	Cool, clear day with little wind	High pressure over region—weather will probably remain fair.
	Sudden change in wind direction	Advancing or receding front

Your forecast should be recorded in your Record Book and you may also want to post it on the chalkboard or bulletin board. Try to include predictions of the following in your forecast:

1. Cloudiness (increase, decrease, remain the same)
2. Probable wind direction
3. Probable wind speed
4. Barometer reading (fall, rise, remain the same)
5. Probable cloud types
6. Probable temperature range
7. Precipitation expected (amount and type)

As each day passes, also make a note of your success. Even with computers, abundant data, and numerous observers, professional weather predictors often have a "batting average" of only 60%-70%. If your predictions are correct even half the time, you are doing pretty well.

You can do your forecast work at the same time that you are beginning the next unit. Try not to let newspaper or television weather forecasts affect your own predictions! The object of this activity is to test how well *your* model works for predicting, not to make perfectly accurate forecasts.

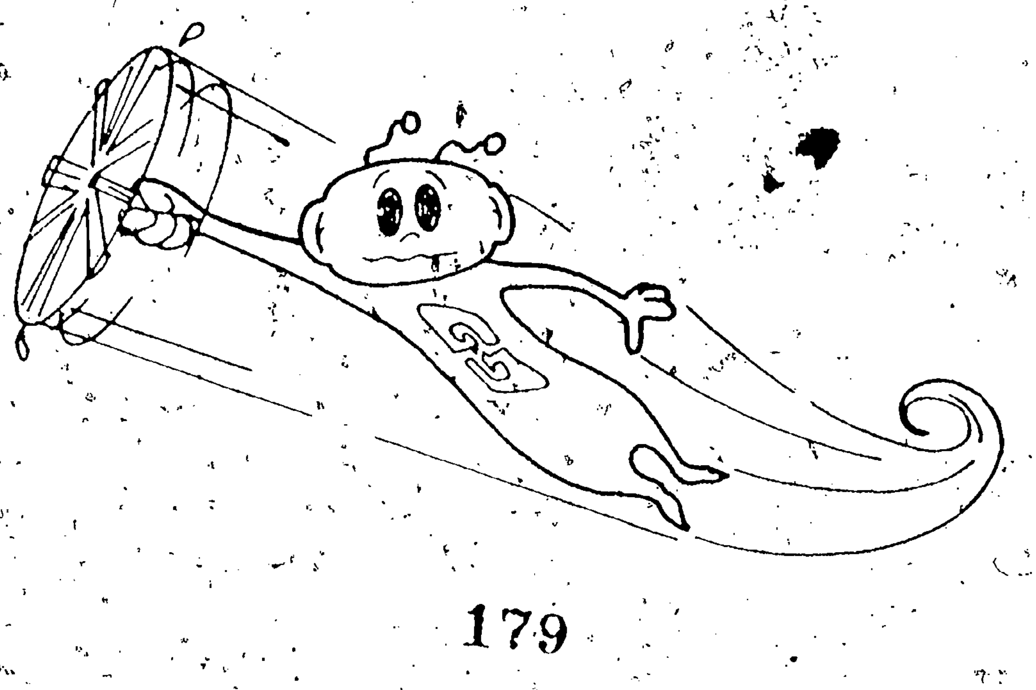
ACTIVITY 2 (Optional). If you are interested, try making an extended forecast. An extended forecast is usually a weather prediction up to about a week in advance. Extended forecasts are general forecasts. Therefore, you should not be concerned with details as you were for the short-range forecast. For the next week, predict what you believe the outlook will be for your area in terms of the following.

Temperature (warmer or colder than normal for that time of year)

Precipitation (More rainy or less rainy than normal for that time of year)

Movement of fronts through your area

In order to give a general forecast, you may want to find out what the normal temperatures and precipitation amounts are for your local area. You may also want to look at weather-satellite photographs of the clouds over the earth's surface. We'll leave that up to you!



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