Building A Weather Station
Michigan State University Cooperative Extension Service
4-H Club Bulletin
Weather Project Unit 2
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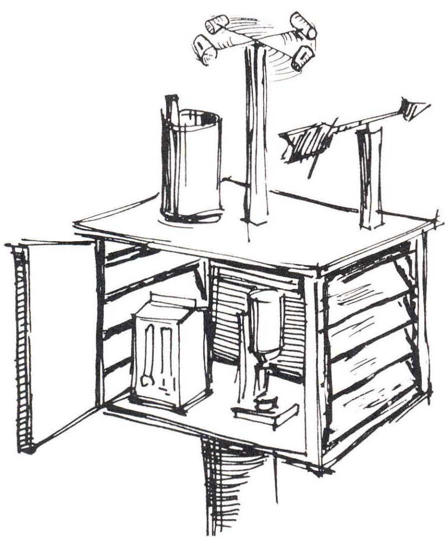
UNIT 2 4-H WEATHER PROJECT

BUILDING A WEATHER STATION



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Member's Guide

4-H—Youth Programs
and
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"It's not the heat, it's the humidity."

"It wouldn't be so cold if it weren't for this wind."

"You think this is COLD?
It gets down to 50 below in Alaska."

"Yes, but it's not so HUMID."

"Oh, for a breeze to cool off a little."

Sound familiar? Of course. We hear comments such as these all the time. We've probably used them a few times ourselves. What we're saying is that something more than temperature is involved in weather. Actually, our weather at any given time depends on four elements:

TEMPERATURE
AIR PRESSURE
WIND
HUMIDITY

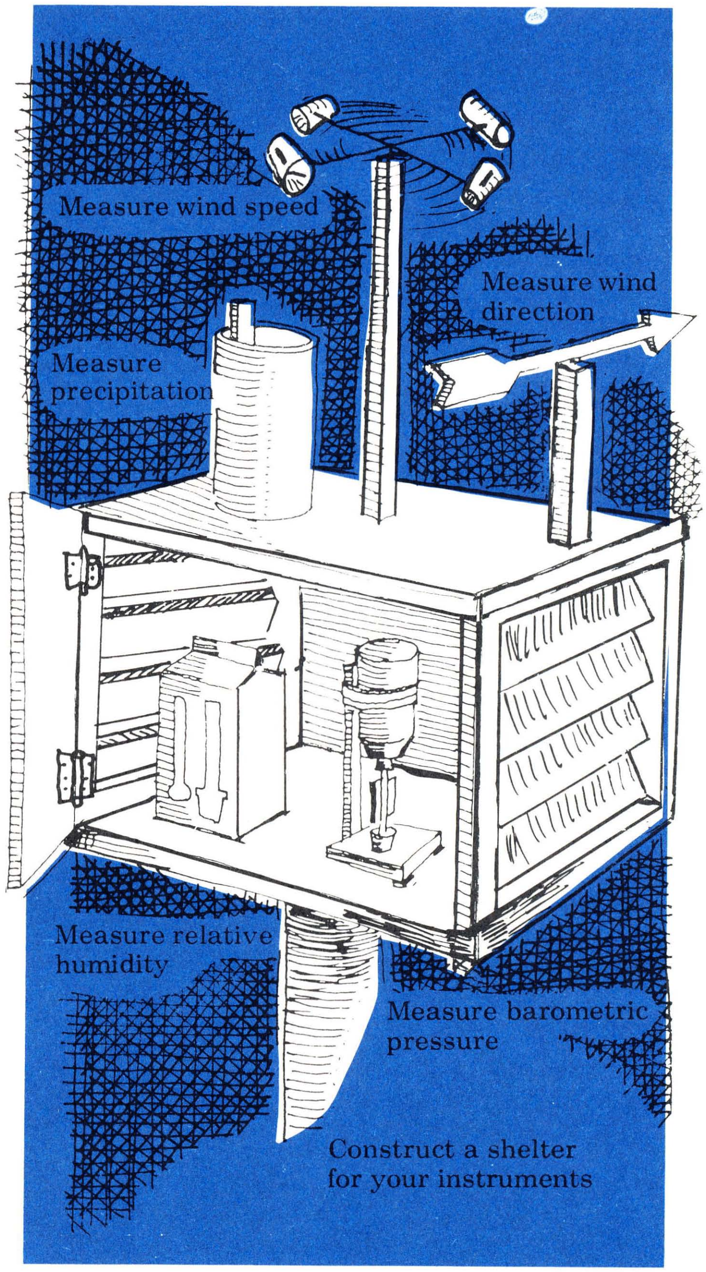
Change any of these elements and you have a change in the weather. Even the slightest variation can bring a weather change, and sometimes the change is violent.

Fortunately for those of us who like to plan ahead and want to know what the weather might be, each of these elements can be measured. The whole science of weather forecasting has developed from recording such measurements and observing their changes.

The most basic weather measuring instruments can be easily built. One purpose of this unit is to show you how to make them. The unit also explains how the instruments are read and what changes mean.

Your completed weather station will look very much like the one on the right. The instruments you will be making have been designed to fit inside or on the easy-to-build wooden shelter. The entire unit can be placed in your backyard.

By using the instruments to observe changes in the wind, temperature, air pressure and humidity—and then by keeping track of these changes in a daily weather "log" along with notes about the clouds, you should be able to predict future weather right from your own backyard.



CONTENTS

TEMPERATURE

The first question we're apt to ask about the weather is "What's the temperature?" Not only does the temperature affect how we feel and what we do, temperature also controls all other weather conditions. Without a change in temperature, there would be no change in pressure or wind, or humidity either. So—what's the temperature? Let's find out.

Obtain two outdoor thermometers. (You can use them later to measure relative humidity.) Hang one on the south side of your house and the other on the north.

Now compare the readings several times over the next day or so. One of the days should be sunny. Keep a careful record of the time and temperature at each location. Your notes might look something like this:

Date

	S. side	N. side
8 a.m.	________	________
12 noon	________	________
3 p.m.	________	________
8 p.m.	________	________

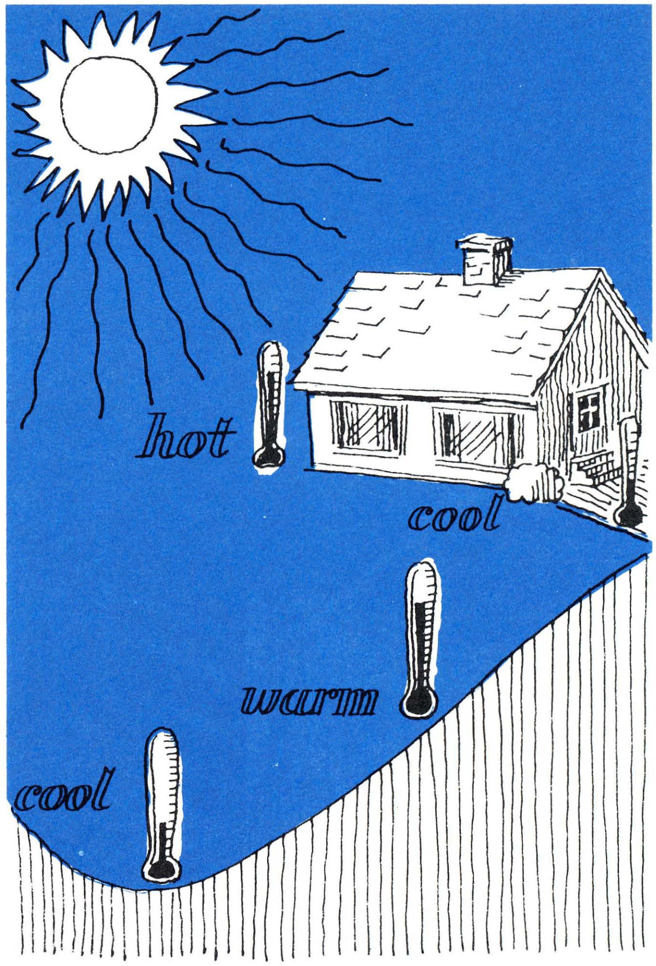
Next, if there's a slope to your street, hang one thermometer someplace at the bottom of the hill and another half way up.

Again check and record the readings, especially early in the morning and once or twice later in the day. Try another comparison if you'd like. Hang one thermometer in the wind. Set the other in a protected spot, where the air is rather still.

By now your readings should point out a surprising fact. Temperatures can vary as much as 10 or 20 degrees in just one neighborhood. The temperature can be affected by how the sun's rays hit a building, by the presence of wind and even by a slight dip in the land.

It's also obvious by now that you'll have to be careful where you place a thermometer to get an accurate reading. The weatherman suggests that a thermometer be placed:

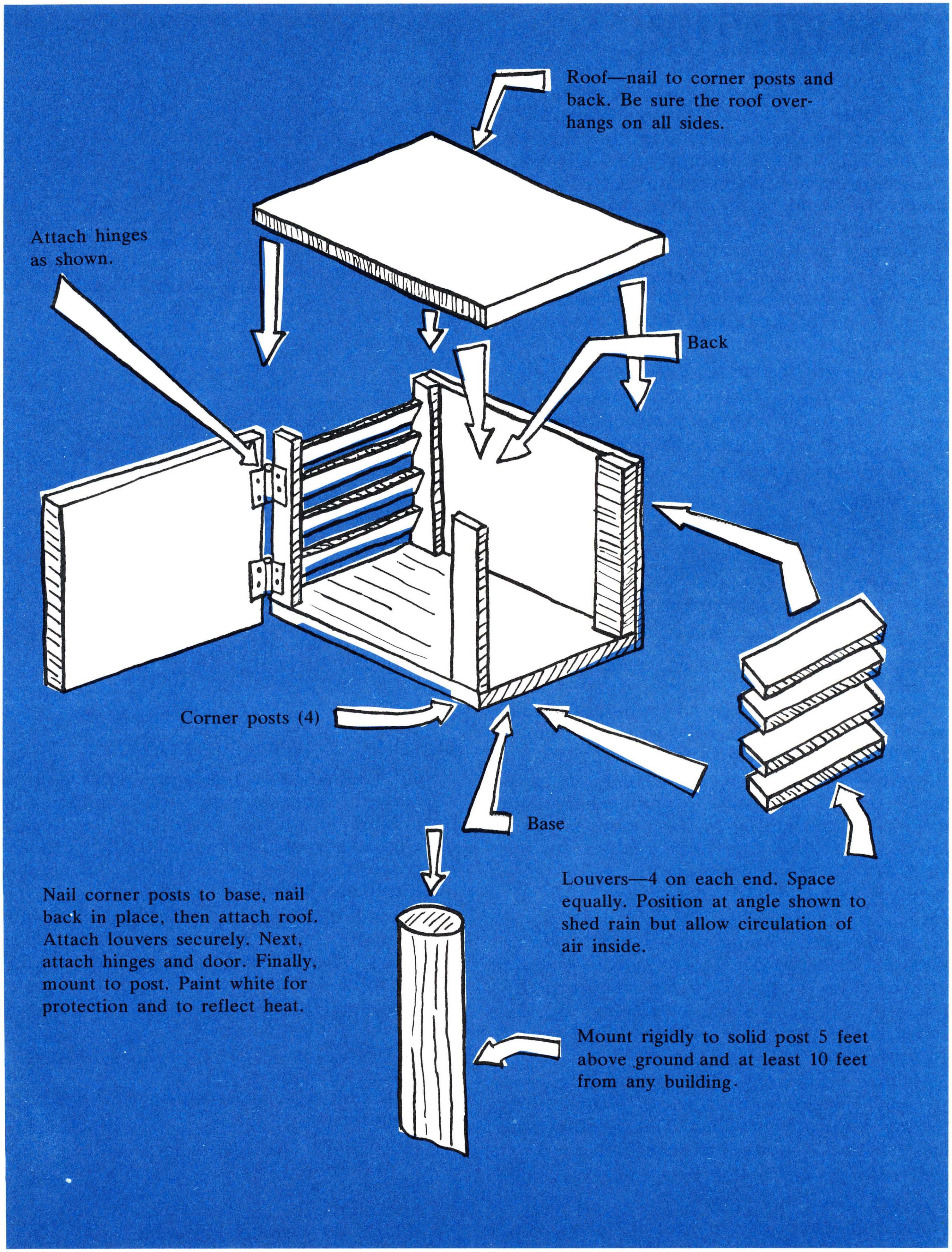
10 feet from any buildings
5 feet above the ground
Out of the direct rays of the sun
Where the air can circulate freely around it.



BUILDING A WEATHER STATION

Your thermometer needs a shelter and so will several other weather instruments you'll be making and using. Some could be tipped over by the wind. The rain might ruin others. Here are directions for a shelter that can be built from scrap lumber. You'll need:

1 piece 3/4-in. plywood (12 in. x 20 in.) for bottom
1 piece 1/2-in. plywood (14 in. x 22 in.) for the top
2 pieces of 1/2-in. plywood (15½ in. x 20 in.) for the front and back
4 pieces of 1 x 2's (15-in. long) for the side posts
8 pieces of 1x2's (10¼-in. long) for the side louvers
1 pair hinges
1/2 in. flathead wood screws as needed for hinges
1 hook and eye
1/2 lb. of #8 (common) nails
White exterior paint



Roof—nail to corner posts and back. Be sure the roof overhangs on all sides.
Attach hinges as shown.
Back
Corner posts (4)
Base
Nail corner posts to base, nail back in place, then attach roof. Attach louvers securely. Next, attach hinges and door. Finally, mount to post. Paint white for protection and to reflect heat.
Louvers—4 on each end. Space equally. Position at angle shown to shed rain but allow circulation of air inside.
Mount rigidly to solid post 5 feet above ground and at least 10 feet from any building.

WHAT A DIFFERENCE A PLACE MAKES.

If you're wondering about those different temperature readings around your neighborhood, think back to a few weather facts from Unit I.

Direct rays from the sun are more powerful than slanted rays.

Rays hitting the south side of a house are more direct and therefore stronger. Since more heat builds up in the house and ground on the south side, the air there is warmer.

Cold air sinks.

In periods of calm or light wind, cold air settles to the bottom of a hill or in a depression or dip in the land. This can lower the temperature by several degrees. Sometimes these low spots are called "frost pockets."

Heat from the earth warms the air.

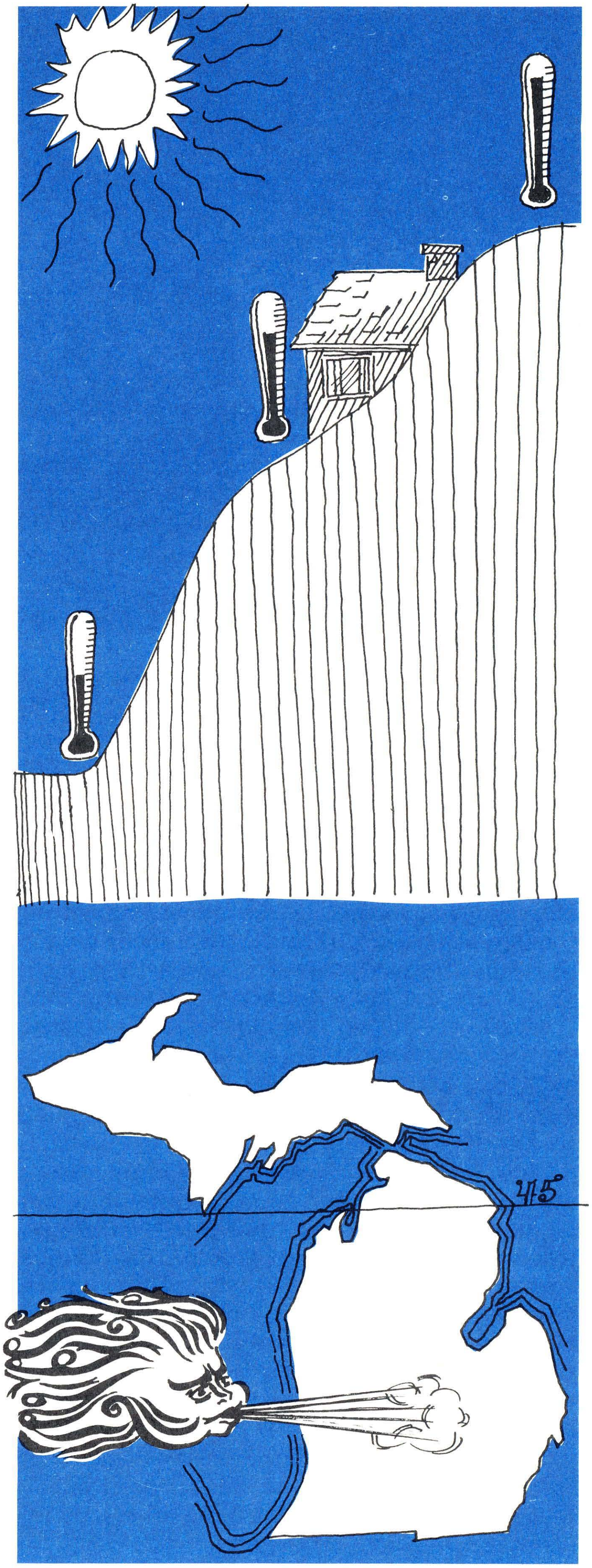
Air on the move does not have as great a chance to warm up as still air. Therefore, wind, by moving the air away from the earth, can keep the temperature lower.

WHY MICHIGAN TEMPERATURES VARY

Temperatures vary for many other reasons. Altitude is one. The higher up you go, the farther away you get from the earth's heat. The air becomes cooler. In mountainous regions, altitude is an important reason for temperature changes. Michigan has mountains—the Porcupines—but since these are concentrated in the northwest corner of the Upper Peninsula, altitude is not an important temperature-changer for our state as a whole.

Latitude is important, however. As you travel away from the equator toward the poles, the sun's rays shine at more of a slant. Temperatures become cooler. The effect of latitude is quite noticeable in Michigan. Traveling north from the southern part of the state to the Upper Peninsula, you can usually feel a temperature difference. You can see signs of it, too. For example, late in May, you can start in Lansing or some other "southern" spot where the trees are fully green and, traveling north, watch them grow bare. It's a little like traveling backwards in time. North of Clare, the trees will be just starting to leaf out. In the Upper Peninsula it could be still another week before much green will show.

The Great Lakes—and over 11,000 smaller lakes throughout the state—affect our temperature, too. All this water cools slower and warms slower than the land. Warmer air com-



ing off the lakes holds back the fall and takes the nip out of winter days. Cooler lake air delays spring and keeps our summer temperatures from soaring. Our winters are milder and our summers are cooler than in Wisconsin or other states of the same latitude. Places like Muskegon are spared many extremes of temperature because of a lakeshore location.

Where would you expect to find the coldest spot in Michigan? In the northernmost part of the Upper Peninsula? Guess again. Almost all of the climate in the Upper Peninsula is tempered by the Great Lakes. In fact, the growing season in the northernmost part of the Upper Peninsula along the shores of Lake Superior is as long as in most of southern Michigan. Hard as it is to believe, the coldest place in Michigan is in the northcentral part of the lower peninsula, inland, where the lakes' warming winds do not reach.

WHAT MAKES ONE DAY WARMER OR COLDER?

So far we've been considering temperature and why it varies from place to place. Now can you think of some of the reasons why temperature changes hour by hour and day by day?

The seasons, of course, bring a little change every day. June is warmer than May, May is warmer than April, April is warmer than March. Each month, as we move from spring to summer, we are tilting a little more toward the sun. The sun's rays are increasingly more direct. In the fall we start to tilt away from the sun. As the sun's rays slant, our days grow cooler.

We can also expect nights to be cooler than days. During the day we face the sun; at night we face away.

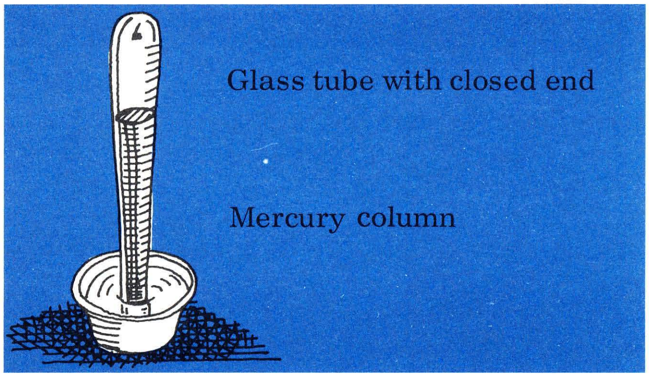
Changes such as these are predictable. Many other less predictable conditions have a profound effect on temperature. Once in Chicago, when the temperatures soared to 102 degrees, winds off Lake Michigan brought the temperature down 15 degrees in one hour. A blanket of clouds can trap the earth's heat and keep the night as warm as the day. Warm and cold air masses moving over us can give us 60-degree days in January and snow in June.

The fascination of weather study comes from trying to anticipate these "less predictables". Meteorologists start by keeping an eye on the air pressure. Let's do the same.

UNDERSTANDING PRESSURE

Galileo, the great seventeenth century scientist, invented the thermometer. Indirectly, he was responsible for the discovery of air pressure, too. Experimenting with vacuums, he tried to raise water through a pipe by suction. His idea was quite simple. He believed that nature abhors a vacuum. So he stuck a pipe in water, and with a machine, sucked the air out of the other end to create a vacuum. Water rose in the pipe. We do the same thing when we sip through a straw. His theory seemed to work, until a strange thing happened. The water in the pipe would not rise more than 34 feet. The mystery plagued Galileo for the rest of his life. He never found the solution. But the year after he died, a student of his did.

In 1643, Evangelisti Torricelli began to wonder if air pressure, rather than suction, might be forcing water up the pipe. Since mercury is about 14 times as heavy as water, Torricelli figured he would need about 2½ feet, or 30 inches, of mercury to get the same result as with 34 feet of water. He took a four-foot long tube, closed at one end, and filled it with mercury. Then he turned the tube upside down into a bowl of mercury. Some of the mercury flowed out, leaving a vacuum at the top. The rest of the mercury stayed in the tube at a height of 30 inches—just as Torricelli predicted.



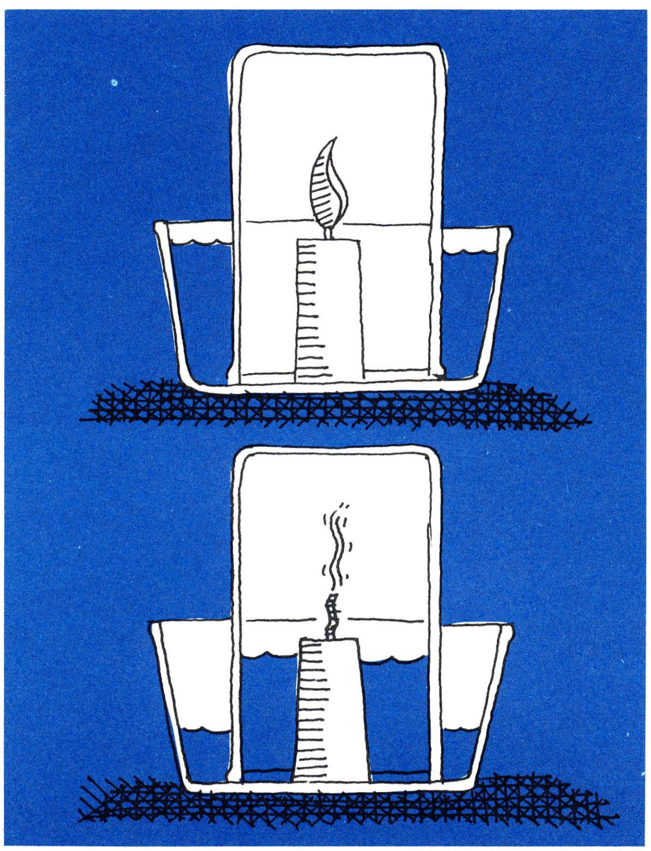
Torricelli noticed something else. The mercury in the tube did not always stay at 30 inches. Sometimes it stood higher, and sometimes lower. Torricelli reasoned that sometimes air was *heavier* and sometimes *lighter*. Again, he was right.

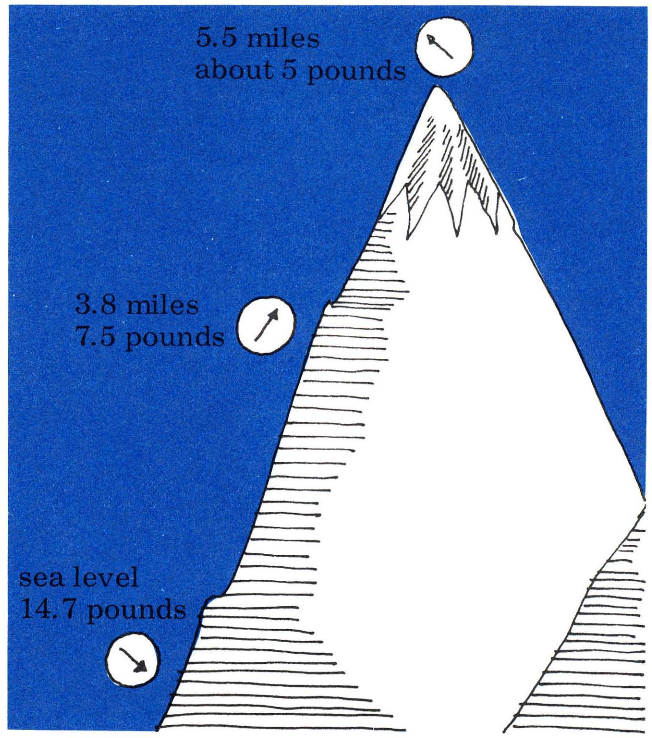
HOW A TORRICELLI BAROMETER MEASURES AIR PRESSURE

Air, pressing down on the mercury in the bowl, forces mercury up the tube, until the weight of the mercury remaining in the tube equals the weight of the air over a similar area outside. By weighing the mercury in the tube we can find out how much pressure the air is exerting. At sea level, standard air pressure is 14.7 pounds per square inch. When the air is heavier, more mercury is forced into the tube.

Torricelli's tube of mercury was the first barometer. It is still the most accurate barometer we have. If mercury were easier to obtain and safer to use, it would be quite simple to make a barometer at home like Torricelli's. Instead, let's try to show why his barometer works.

Light a candle and set it in a bowl of water. Quickly cover the candle with a jar. As the candle burns, it will use up all the oxygen—about 1/5 of the air in the jar. The jar now has a partial vacuum. What happens as the candle burns, then flickers out? The air outside the jar, pushing down on the water in the bowl, fills the vacuum with water.





WHY DOES AIR PRESSURE CHANGE?

Air pressure is the weight of all the air above us pushing down. As we go up higher, less air presses down against us. The air pressure decreases. Mountain climbers know this well. At the top of Mt. McKinley, 3.8 miles high, the air pressure is only 7½ pounds per square inch—about half of the pressure at sea level. At the top of Mt. Everest, 5.5 miles high, the air is so thin that climbers must carry oxygen with them. Air pressure there is only five pounds per square inch, or about one-third of the pressure at sea level.

Altitude is one reason why air pressure changes. But temperature changes are more important as far as weather is concerned. If we were to weigh equal containers of warm and cold air, we would find that the warm air has less weight than the same size container of cold air. Unequal heating of the earth's surface causes belts and pockets of warm air and cold air all over the world. Mountains and valleys, bodies of water and masses of land, dark soils and light soils heat the air overhead differently, and this means unequal pressures. As these different masses of lighter or denser air move over us, we can observe a change in the barometric pressure. With a change in the pressure comes a change in the weather.

HOW TO MAKE A BAROMETER

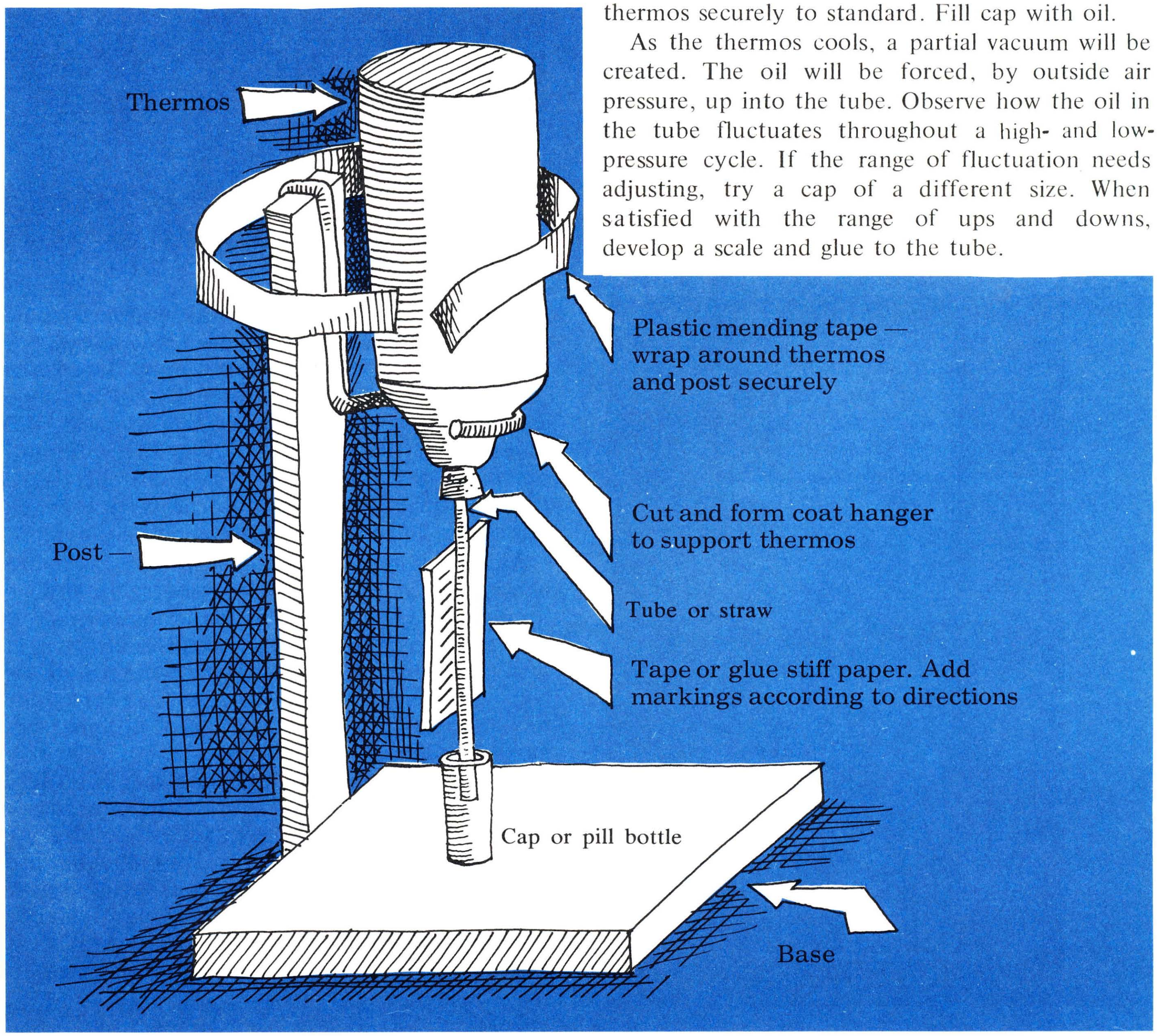
A barometer helps us anticipate weather changes by keeping track of these high-pressure and low-pressure air masses passing over us. To make a barometer, you'll need:

- Small thermos jug
- Cork or rubber stopper with a hole
- Glass tube or plastic straw (largest diameter available)
- Small, deep container (such as a pill bottle or bottle cap)
- Mineral oil
- 1 coat hanger
- 1 piece wood (1 x 2) 10 in. long for post
- 1 piece wood (4-in. square) for base
- Nails
- Plastic mending tape
- Paraffin or candle wax

Make an L-shaped standard with the two pieces of wood. Attach the thermos jug to the post with coat hanger wire, as shown. Be sure the entire assembly will fit inside the weather station. Also make sure that the cork fits the thermos and the tube fits the cork securely. Check to see that the tube will be long enough or can be adjusted to reach into the cap of mineral oil.

When all parts are ready for final assembly, rinse out the thermos with lukewarm water. Insert the cork and tube in the thermos. Seal the tube to the cork and the cork to the thermos with wax. Place the cap under the tube. Tape thermos securely to standard. Fill cap with oil.

As the thermos cools, a partial vacuum will be created. The oil will be forced, by outside air pressure, up into the tube. Observe how the oil in the tube fluctuates throughout a high- and low-pressure cycle. If the range of fluctuation needs adjusting, try a cap of a different size. When satisfied with the range of ups and downs, develop a scale and glue to the tube.



ANOTHER KIND OF BAROMETER

Air pressure today can also be measured without the use of a liquid. *Aneroid barometers* measure what happens when air pushes against a vacuum. Try this and you'll see why an aneroid barometer works:

Obtain a one-gallon metal can that can be closed tightly with a screw-on or snap-on top. Place about an inch of water in the can and heat until steam comes from the opening. Cap the can quickly and let it cool off. (Running cold water over the can will hasten the cooling.) Be prepared for a big surprise. Can you explain what happens?

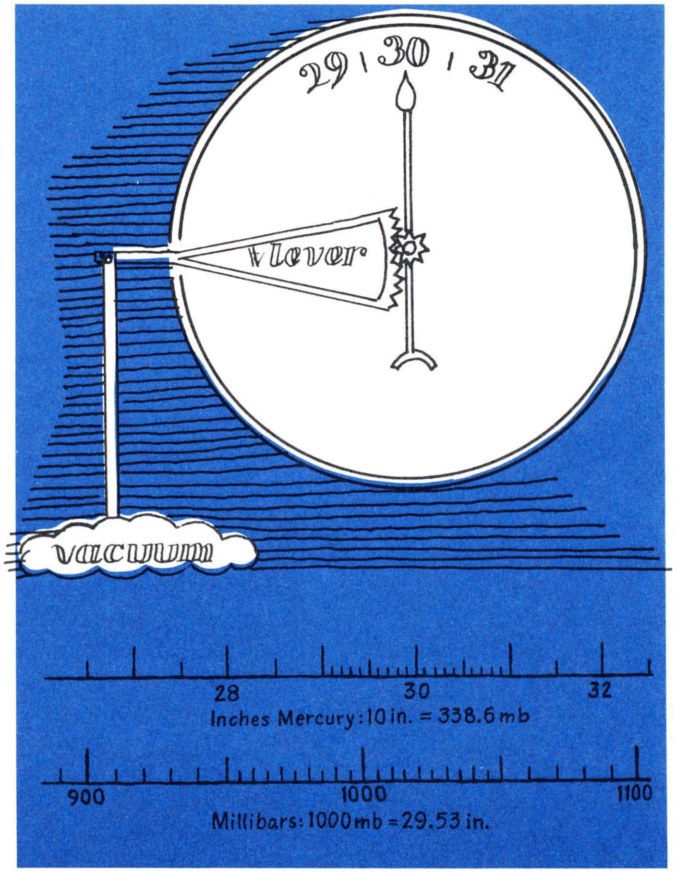
Steam in the can chases out the air. When the steam cools, it condenses, creating a partial vacuum. Air pushes against the vacuum on all sides with such force that it crushes the can. This force of the air against a vacuum is the principle behind an aneroid barometer.

Aneroid barometers are not always as accurate as a mercury barometer, but they have their advantages. They can be carried around much more easily than a 2½-to 3-foot tube of mercury. And they can be much more sensitive. Almost all barometers sold in the stores are aneroid barometers.

An aneroid barometer is a shallow metal can with some of the air removed. A strong spring or corrugated metal keeps the sides of the can from collapsing but still they move. When air is heavy, the sides are pushed in. When the air pressure lifts, the sides move back. On most aneroid barometers, a lever mounted on the can is attached to a pointer. As the lever dips and rises, the pointer indicates the amount of pressure.

POUNDS, INCHES, OR MILLIBARS?

How will you measure air pressure? In pounds? In inches? In millibars? It doesn't really matter. Standard air pressure at sea level can be described as 14.7 pounds, 29.92 inches, or 1013.2 millibars. Pounds are easiest to understand. They refer to the actual weight of the air per square inch. Most barometers, however, are marked in inches and millibars —and this can be confusing. Inches, even in an aneroid barometer, refers to inches of mercury. Millibars is a measure used by weather bureaus all over the world. Approximately 34 millibars equal an inch of mercury. Since tiny fractions of a point or inch can trigger a



big change in the weather, millibars have the advantage of measuring the smallest changes more exactly.

WHAT DOES A PRESSURE CHANGE MEAN?

A pressure change brings a change in the weather. By observing the direction and speed of the change, we can have a general idea of what's about to happen, and how soon.

Keep in mind that the trend of fluctuation—whether rising, falling or holding steady—is much more important than the actual pressure at a given time.

Is the barometer falling? We may be due for bad weather. Is the barometer rising? Fair days may be ahead. To make sure, we need to know what other conditions are developing at the same time—for example, the wind. If we know the direction of the wind—whether it's blowing from a warm, moist area, or from a cold, dry one, we can start to make predictions with our barometer.

Where's the wind coming from? Let's find out next.

UNDERSTANDING THE WIND

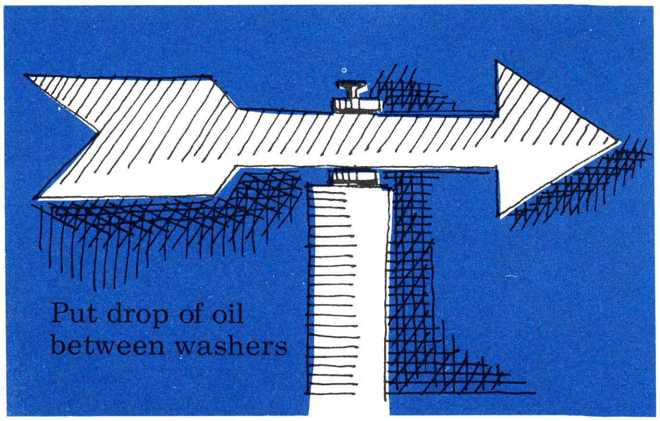
"Northwest is by far the best;
Northeast is bad for man or beast."
—an old proverb

Long before weathervanes or wind measuring instruments had been thought of, early weather watchers recognized that wind direction was important. They didn't understand why, but they knew that wind from one direction generally brought fair skies while wind from another brought rain. So they watched the trees sway and the smoke drift for a sign of wind direction. Or they licked a finger and stuck it in the wind to see which side felt cool.

MAKING A WEATHERVANE

We can be more accurate with a weathervane. Here is an easy one to make. You'll need:

A piece of wood for an arrow about one foot long, ½-inch thick, and 3-inches wide
A mounting stick about 3/4 inch x 3/4 inch x 1 foot
A nail or screw for attaching the arrow to the mounting stick
Two washers



Cut out the arrow. Drill a hole through the balance point of the arrow shaft. (Balance the shaft on your finger to find the right spot.) Mount the arrow on the stick with a screw or nail, placing the washers as illustrated. Attach your weathervane to a pole where it has access to the wind from all directions. The arrow will point in the direction *from* which the wind is blowing. (If the arrow points west, it means the wind is coming from the west.) Be sure one side of the mounting stick faces north. Label the stick with appropriate compass points.

WHERE THE WINDS COME FROM

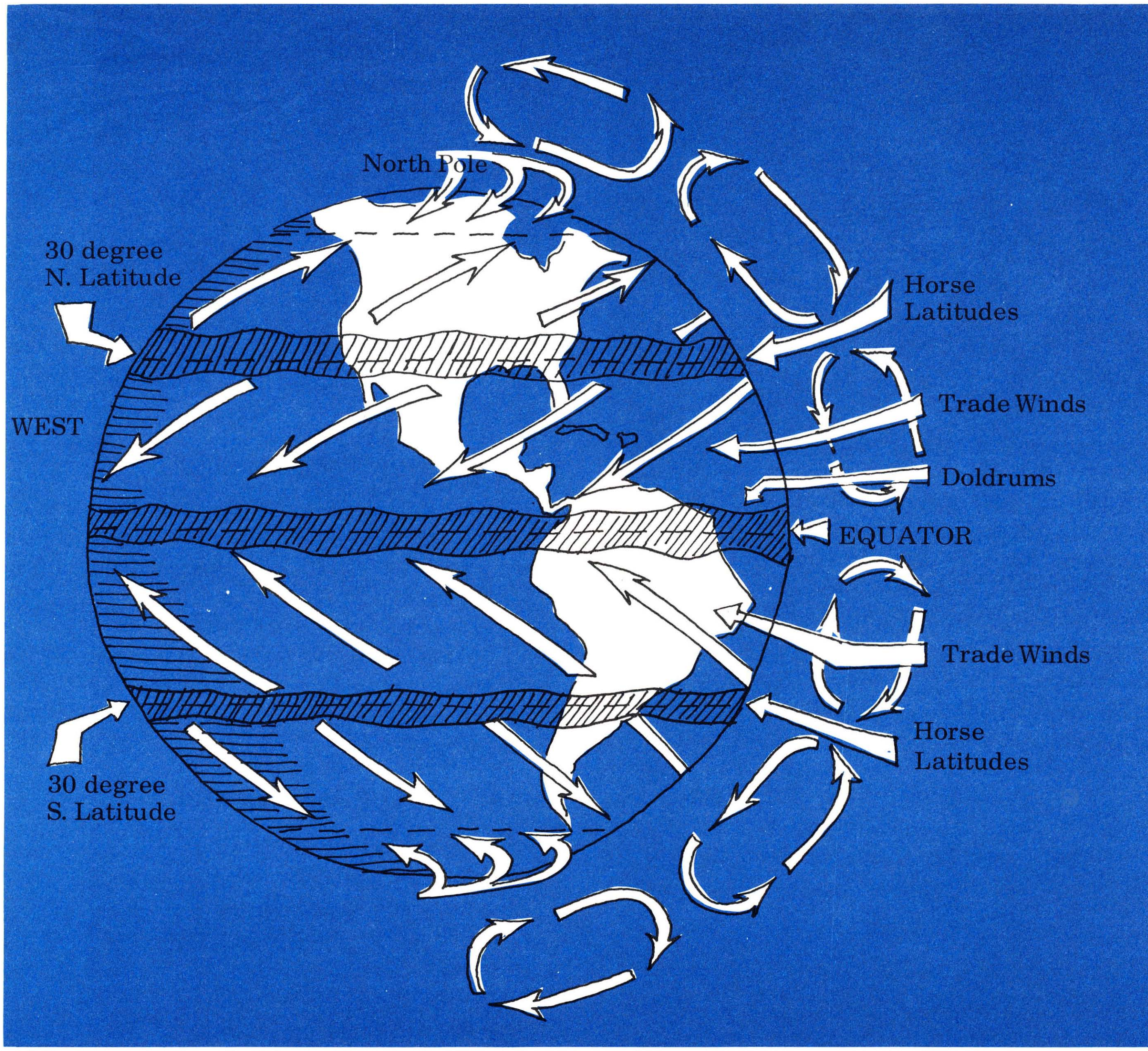
Wind is caused by air moving from a high pressure to a low-pressure area. Whether the "wind" is a small gust of air whirling up the dust on a city sidewalk, or a great wind that always blows from the same direction, the cause is always the same. Air that is under pressure is trying to escape or balance itself and heads for the nearest area of lower pressure. The greater the difference in pressure for a given distance between a high-and a low-pressure area, the stronger the wind. Where the pressure difference is small for a given distance, the winds will be light.

The sun sets the stage for the world's great winds. At the equator, where the sun each day shines relentlessly, warm air rises in a mighty stream. The constant heat and the light form a low pressure belt of rising air known as the "*doldrums*."

As air rises from the doldrums, it cools and drifts toward the poles. Some of it falls in the *horse latitudes*, around 30 degrees latitude, and, piling up, creates a belt of high pressure. The constant pressure of the doldrums and horse latitudes make these regions of calm or very light winds. But in between them, air is on the move. Rushing from high pressure to low pressure, the air flows back toward the equator as the strong and steady northeasterly *Trade Winds*.

Some of the air that rises from the equator continues on to the poles. There it sinks, becomes compressed and rushes out toward the 60-degree latitude (the *Sub-Polar Low*). These icy blasts from the poles are the *Polar Easterlies*. When the Polar Easterlies dip into the middle latitudes, they bring us blizzards and Florida snow.

While the Polar Easterlies and the Trade Winds blow toward the equator, something quite different happens to the air in the middle latitudes, between the Horse Latitudes High and the Sub-Polar Low. Still rushing from high to low pressure, winds here blow back toward the poles. These are the major winds of the United States and European countries and are called the *Prevailing Westerlies.*



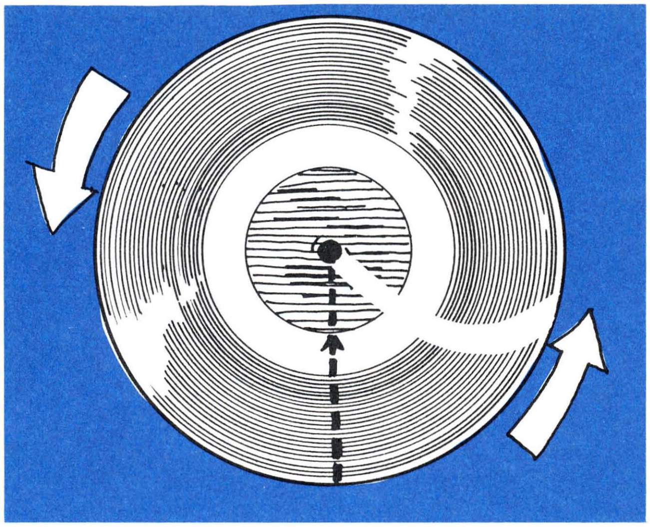
The Doldrums. Sailors of old dreaded the equatorial calm where days and weeks would go by without the slightest wind to fill their sails. Sweltering in the muggy heat, without even a breeze to cool them, they named this region the "doldrums."

The Horse Latitudes. Sailing ships carrying horses from Spain to the New World would languish for weeks without sufficient wind in the latitudes around 30 degrees. The story is that as food and water become scarce, they threw the horses overboard. From the waters strewn with carcasses came the name "horse latitudes."

The Trade Winds. So steadily do the winds blow north and south of the equator that they became a popular route for traders. They soon became known as the "trade winds."

WHY OUR WINDS BLOW EAST OR WEST

If the earth were perfectly still, these great winds would blow north and south. Instead, the earth spins, bending the winds to the right in the Northern Hemisphere and to the left in the Southern. Try this and you'll see why:



Take a phonograph record and rotate it counter-clockwise on a phonograph spindle. This represents the way the earth turns as seen from the north pole. (Rotate the record clockwise for the effect in the Southern Hemisphere.) With a piece of chalk, try to draw a straight line from the spindle to the outer edge of the record. What happens? All you can draw is a curve.

This is called the "Coriolis effect." The spin of the record deflects your mark just as the spin of the earth deflects the winds. Trade Winds and Polar Easterlies, blowing toward the equator, are deflected toward the west. The Prevailing Westerlies, blowing toward the equator, are deflected to the east.

LAND AND SEA BREEZES

Many local winds are set up because the earth heats unequally. For example, there's almost always a breeze at the lake. Do you know why? And have you ever noticed that it blows one way during the day and the opposite way at night? During the day, the land heats faster than the water. Cooler, heavier air from the water blows toward the land. At night the land cools faster than the water. Now the warmer, lighter air is over the water. The cool, heavier land air blows toward the lake.

MOUNTAIN WINDS

If you've ever been to the mountains, you may have wondered about another special set of winds. During the day these winds blow up the mountain. At night they come whistling down. Can you figure out why?

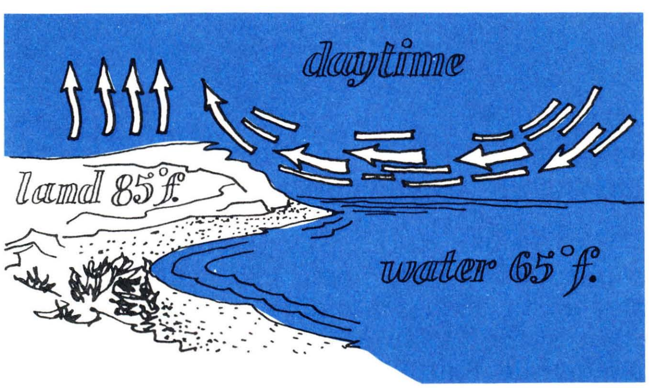
HOW FAST IS THE WIND BLOWING?

The speed of the wind tells us how great the pressure difference is between two masses of air. To measure wind speed, we can use a scale set up by Admiral Beaufort of the British Navy in 1805, or an anemometer. While the Beaufort scale (on page 14) is a handy guide, either a cup or flap anemometer would be fun to make and easy to use. Our weather station wouldn't be complete without one.

MAKING A CUP ANEMOMETER

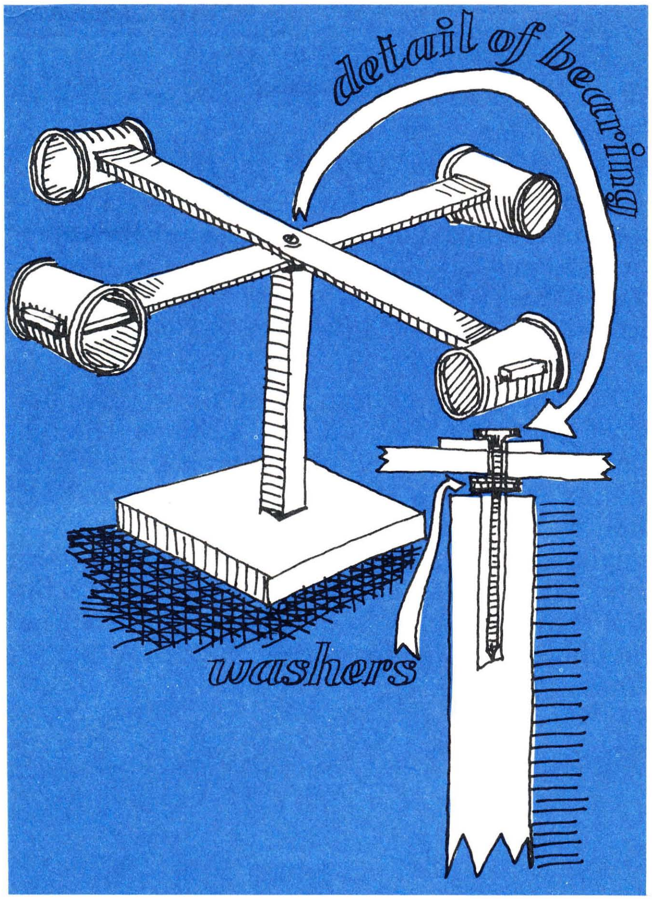
To build a cup anemometer you'll need:

- A block of wood for the base (about 3 inches square and ¾ inch thick)
- A stick about 1 inch x 1 inch and 12 inches long for post
- A yardstick cut in half
- 4 paper cups
- Three 10-penny nails
- Two small washers
- Two ¾-inch wire brads



Day Breeze

Night Breeze



Cup Anemometer

To make the spinner, cross the yardstick pieces and fasten together through their exact centers with a ten-penny nail. Hold the spinner arms at right angles with two wire brads. Cut slits through the paper cups being careful that they are centered. Slip a cup over the end of each yardstick arm as shown. Drill a hole into the end of the post a little deeper than the length of a ten-penny nail and slightly larger in diameter. Nail the opposite end of the post to the base. Attach the spinner to the post using the two washers as illustrated. Put a drop of oil between the washers. Paint all parts for protection. Paint one cup a different color.

To calibrate, hold the anemometer outside the car. Ask Dad to drive at 1, 5, 10, 15, 20 and 25 miles per hour. At each speed count the revolutions for 30 seconds. Keep a record of these numbers.

Mount your anemometer on top of your weather station or on a post about four feet off the ground and in a place where the wind can reach it freely. When you want to know wind-speed, count the revolutions for 30 seconds and check your record.

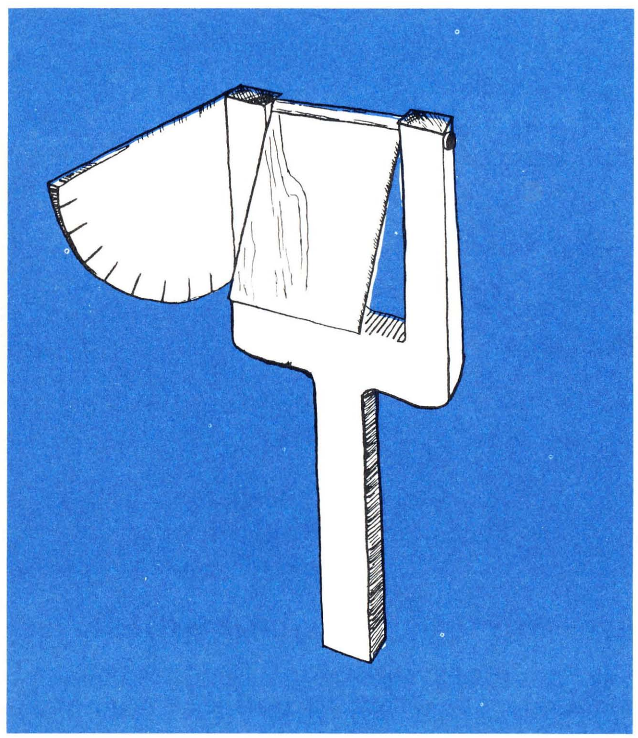
MAKING A FLAP ANEMOMETER

To make a flap anemometer you'll need:

A piece of ½-inch plywood, 4 in. x 10 in.
A piece of thin metal, 3 in. x 4 in. (such as from the bottom of a "heat and serve" roll pan)
4-in. nail or piece of coat hanger
A thin piece of wood, metal, or plastic, 3 in. x 3 in., for a scale

Cut a U-shaped slingshot from the wood. The inside of the U should be about 4½ inches deep. Pound in the nail or secure the coathanger wire to form a bar across the top of the U. Now roll one edge of the metal around the nail or wire so that the flap will swing freely yet hold securely.

Cut around one end of the remaining piece of wood, metal, or plastic to form a quarter circle. Attach one edge of the quarter circle to an arm of the U to form a right angle. The remaining edge should be on a line with the nail.



Flap Anemometer

To calibrate, hold the anemometer outside a car window and mark on the scale the angle of the flap at speeds of 1, 5, 10, 15, 20, and 25 miles per hour (more if desired). To use the anemometer, hold it in the wind and note the speed indicated on the scale. The anemometer can be kept inside the weather station when not in use.

THE BEAUFORT SCALE

Description	Speed, MPH	Observation
Calm	less than 1	Smoke rises straight up. Trees are still, water is mirror calm.
Light air	1-3	Smoke drifts in direction of wind. Leaves on trees move slightly.
Light breeze	4-7	Wind can be felt on face. Leaves rustle.
Gentle Breeze	8-12	Leaves in constant motion. Light flags flap.
Moderate breeze	13-18	Small branches move, dust is stirred up.
Fresh breeze	19-24	Young leafy trees sway. Dust stirred up in clouds. Crested wavelets on lakes, ponds.
Strong breeze	25-31	Tree boughs swing. Wind whistles through telephone wires.
Moderate gale	32-38	Tree trunks swing. Difficult walking against the wind.
Fresh gale	39-46	Walking requires effort. Small branches break.
Strong gale	47-54	Slight damage to buildings, signs, windows.
Whole gale	55-63	Trees blown down. Considerable damage to buildings. (More often experienced at sea.)
Storm	64-74	(Rare) Wide damage.
Hurricane	75 or more	Great damage, wide destruction.

WHAT THE WINDS CAN MEAN

As you observe the wind for direction and speed, do you start to notice any special weather patterns? Here are a few that apply to many parts of the United States. See if they hold true where you live:

Winds from the north, northwest, and west: Generally bring dry and cooler weather. They blow from cooler masses of air to the north and drier masses of air to the west.

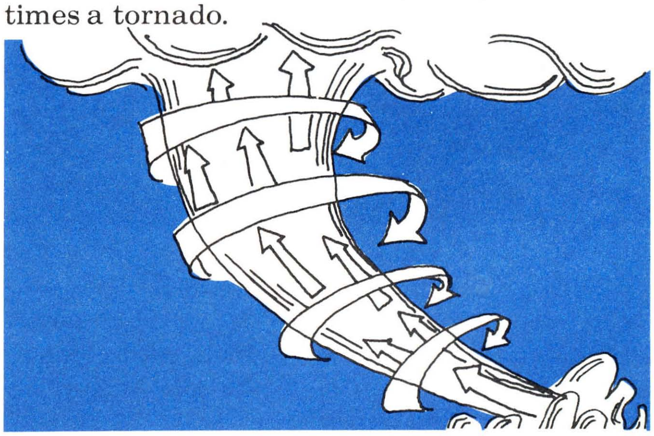
Winds from the west, southwest, and south: Generally bring fair and warmer weather. They blow from warmer land.

Winds from the east, southeast, and northeast: Generally bring rain. They blow from the ocean.

WHAT ARE THE UPPER WINDS DOING?

Winds in the upper levels of the atmosphere are sometimes very different from those we feel around us. The difference can be important. When they are much faster and are bringing in colder, drier air, we could be in for a violent storm.

On a hot, muggy day, moist air streams upward from near the earth's surface. Though it cools as it rises, it may still be warmer than the air around it. If so, it continues to rise. If this warmer air current then reaches the height of the fast-moving wind and colder, drier air, its instability increases. The result is a rapid churning of the atmosphere and a likelihood of thunderstorms, hail, and sometimes a tornado.



Differences of pressure, temperature, and wind speeds must be extreme for a tornado to form. When a tornado does form, the pressure of the rising air in the middle of the funnel is so low that houses literally explode as it passes over them. Thinking back to earlier discussions of pressure, can you explain why?

Would you like some idea of the direction and speed of the upper winds? Line up a cloud with a tree or the edge of a building and then watch how it travels across the sky within your field of vision.

High above the cloud levels are waves of wind called jet streams that travel at more than hurricane speed. They were discovered by B-29 bomber pilots during World War II when they flew higher than ever before possible. Since then, meteorologists have been able to chart these jet streams and have found that weather is always more changeable under them.

UNDERSTANDING HUMIDITY

Humidity refers to the amount of water vapor in the air. On a hot,muggy day we say the humidity is high. The air is holding just about all the water it can. On a really hot day, as much as four percent of the air around us could be water vapor. By comparing how much water vapor is in the air to how much vapor the air can hold, we get a percentage, and this is the relative humidity.

When the relative humidity reaches 100%, we say the air is *saturated* or has reached the *dewpoint*. Now if the temperature cools even more, or if more water evaporates and tries to escape into the air as a gas, the moisture that the air cannot hold is forced out as drops of water. These could be in the form of dew, or frost, or fog, or clouds, depending on where and when the change is taking place.

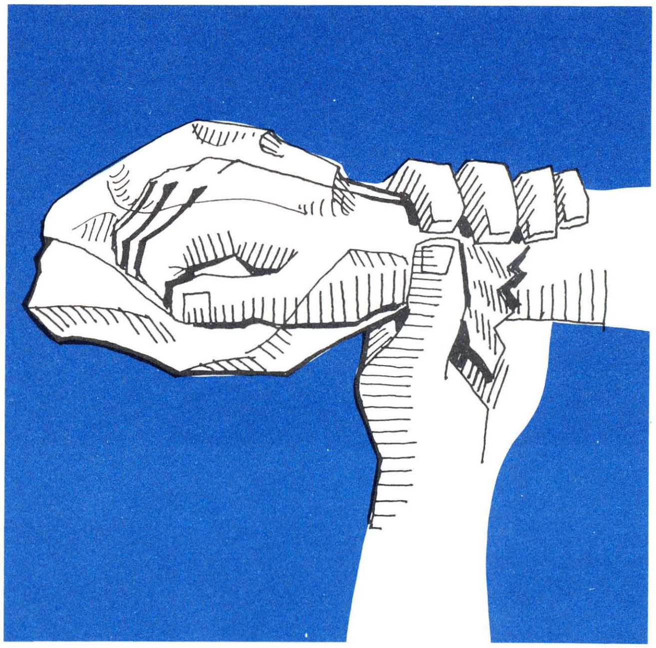
FEEL WARM? FEEL COLD? COULD BE THE HUMIDITY.

Relative humidity has a lot to do with how comfortable we feel. Place your hand in a plastic bag and close the bag snugly at your wrist. Keep your hand in the bag for about 10 minutes. Now take it out. Do you know where the moisture comes from? We aren't aware of it, but our bodies give off moisture all the time. When the relative humidity is a comfortable 50 percent or 60 percent, the water vapor from our bodies escapes into the air. As the relative humidity nears 100 percent the moisture from our bodies cannot escape so easily. It clings to us and we see it and feel it as perspiration.

If the relative humidity is fairly high and the air is very still, we can feel very uncomfortable. The water vapor from our bodies can't move very far away from us. It saturates the air all around us. This is what happens on a muggy day when we long for a "breath of fresh air." We all know a breeze will make us feel better—but do you know why?

Moving air cools us by carrying away the water vapor that has built up around our bodies. Moving air also cools us by evaporating the water or perspiration clinging to our bodies. A great deal of heat is required to change a drop of water back to a gas. This heat is taken from our bodies and we feel cooler.

In the summer, we're glad to get rid of all the body heat we can. In the winter, we try to hold on to it. Again, relative humidity holds the key. On a winter day, the amount of moisture in the air inside and out, can be exactly the same—but the relative humidity will be very different. Inside—unless a humidifier or steamer adds moisture to the air—the humidity is extremely low. The thirsty air robs our bodies of moisture and heat, and we feel cold. Turning up the heat only makes the air thirstier. Would you like to know the best way to warm up in a hurry? Put a kettle on to boil. The steam adds moisture to the air, thereby increasing the relative humidity.



MEASURING HUMIDITY

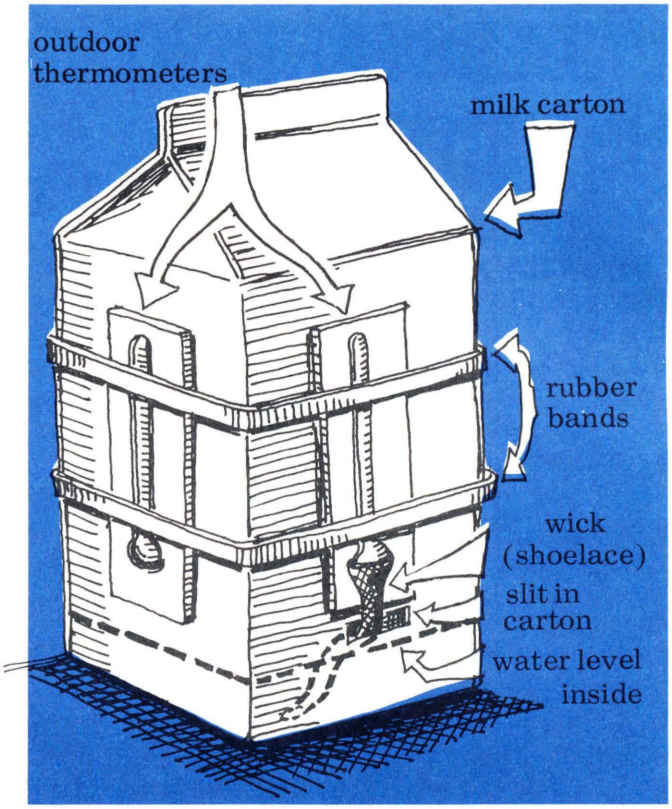
Relative humidity can be measured in two ways—with a *psychrometer* or a *hygrometer*. Your weather station should include one of them.

A psychrometer is essentially two thermometers. The bulb of one is kept dry. The second bulb is wet and then fanned so that the moisture will evaporate as much as possible. As we've seen, evaporation is a cooling process. When the humidity is lower, more water can evaporate. Therefore, the wet-bulb cools off more and reads lower.

MAKING A PSYCHROMETER

To make a psychrometer, you'll need:
A milk carton
Two outdoor thermometers that give the same reading
A white shoelace
Two rubber bands

Cut the tips from the shoelace. Boil the shoelace and rinse well to remove any impurities. Attach the thermometers with rubber bands to adjacent sides of the milk carton. Cut a slit in the carton under one of the thermometers. Pour water in the milk carton, perhaps an inch deep but below the slit. Wet the shoelace. Feed most of it through the slit into the water in the carton. Slip the remaining end of the shoelace tube over the thermometer bulb. To find the relative humidity, fan the shoelace until the temperature reading will drop no further. Compare the dry- and wet-bulb thermometer readings and check the humidity chart below for the relative humidity percentage.



RELATIVE HUMIDITY CHART

Dry-bulb thermometer reading	Difference between Dry-bulb and Wet-bulb Thermometers (degrees)																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
35	91	81	72	63	54	45	36	27	19	10	2														
40	92	83	75	68	60	52	45	37	29	22	15	7													
45	93	86	78	71	64	57	51	44	38	31	25	18	12	6											
50	93	87	80	74	67	61	55	49	43	38	32	27	21	16	10	5									
55	94	88	82	76	70	65	59	54	49	43	38	33	28	23	19	11	9	5							
60	94	89	83	78	73	68	63	58	53	48	43	39	34	30	26	21	17	13	9	5	1				
65	95	90	85	80	75	70	66	61	56	52	48	44	39	35	31	27	24	20	16	12	9	5	2		
70	95	90	86	81	77	72	68	64	59	55	51	48	44	40	36	33	29	25	22	19	15	12	9	6	3
75	96	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24	21	18	15	12	9
80	96	91	87	83	79	75	72	68	64	61	57	54	50	47	44	41	38	35	32	29	26	23	20	18	15
85	96	92	88	84	81	77	73	70	66	63	59	57	53	50	47	44	41	38	36	33	30	27	25	22	20
90	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49	47	44	41	39	36	34	31	29	26	24
95	96	93	89	86	82	79	76	73	69	66	63	61	58	55	52	50	47	44	42	39	37	34	32	30	28
100	96	93	89	86	83	80	77	73	70	68	65	62	59	56	54	51	49	46	44	41	39	37	35	33	30

Try out your psychrometer upstairs and in the basement of your house. Is there a difference? Why?

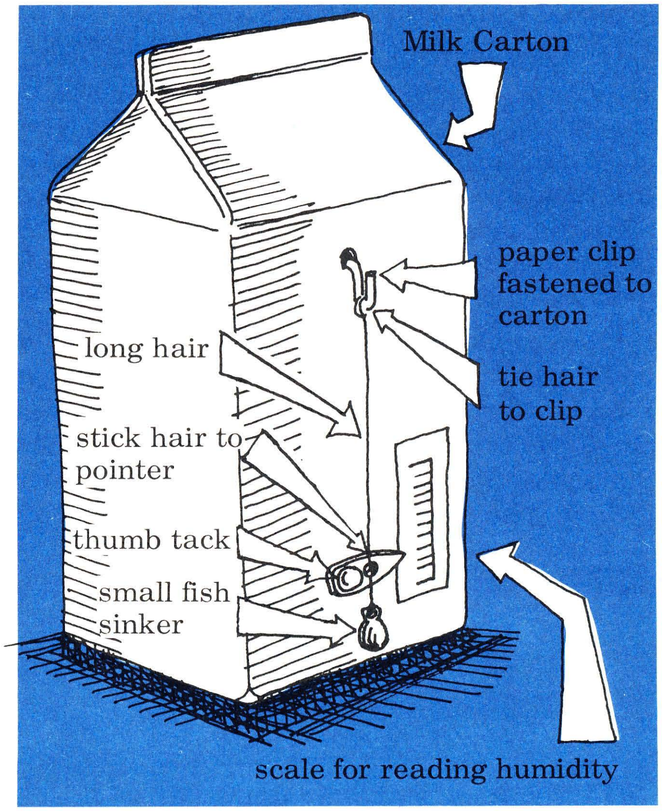
MAKING A HYGROMETER

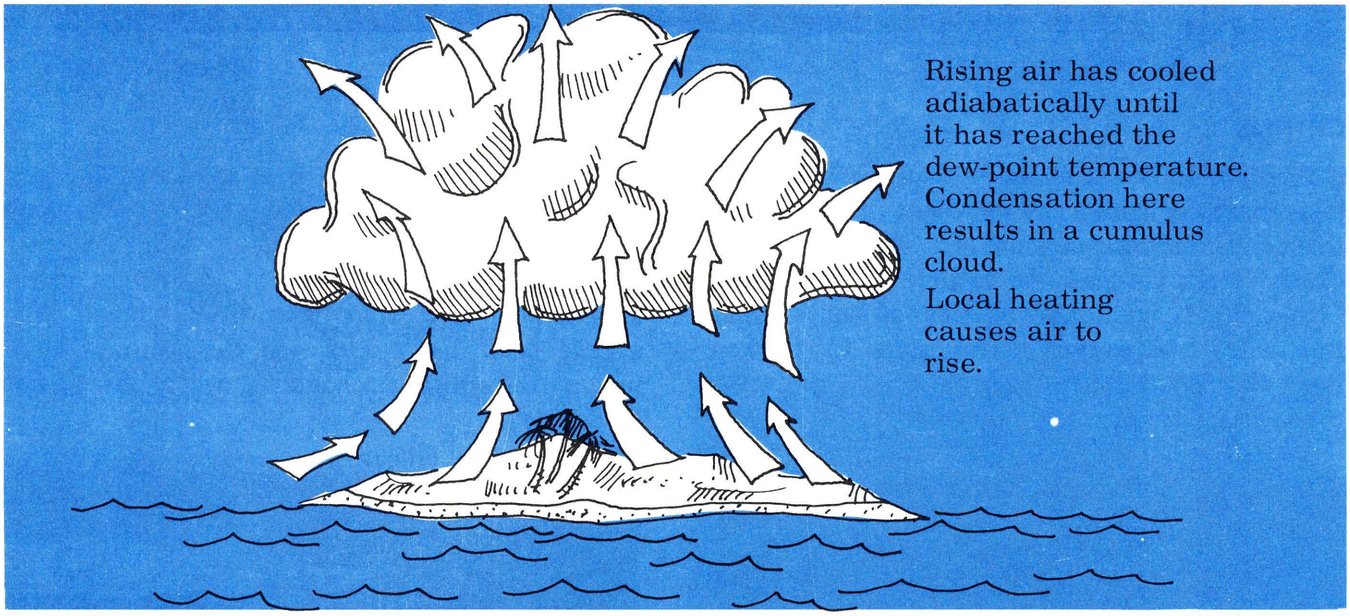
A *hygrometer* is little more than a scale and a single strand of hair with a pointer attached. In dry weather, the hair tightens up and becomes shorter. As the humidity increases, the hair becomes longer.

To make a hygrometer, you'll need:

- A milk carton
- Small piece of heavy paper
- A long hair (wiped with cleaning fluid to remove oils)
- A paper clip
- One thumbtack
- A lead sinker (size of BB shot)

Make a heavy paper pointer and thumbtack it to the milk carton about two inches from the bottom. Make a scale and attach it to the milk carton at the end of the pointer. Tie the sinker to one end of the hair. Tie the other end of hair to the paper clip. Attach the paper clip to the milk carton so that the hair hangs over the middle of the pointer. Hold the hair to the pointer with a spot of glue or wax. Make sure the pointer is free to move with any change in the length of the hair.





HOW A CLOUD IS FORMED

When a gas or liquid is released from a compressed state, it expands and cools. Have you ever wondered why your finger may feel cold while using a can of spray paint or other pressurized spray? This is the reason. The escaping spray expands and cools. The same thing happens when warm air rises. As air escapes from the higher pressure at the surface of the earth, it expands and cools. The higher the air goes, the more it cools.

We call this *adiabatic cooling.* Rising air, loaded with water vapor, cools adiabatically about 5½ degrees for each 1,000 feet until the dewpoint is reached. At this point, the water vapor condenses, clings to particles of dust in the air and forms a cloud.

SIGNPOSTS IN THE SKY

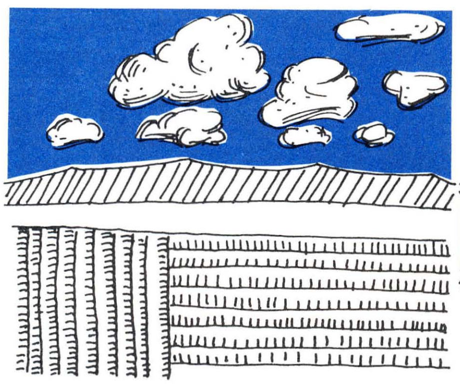
If clouds seem a jumble to you, look again. Their varied shapes actually fall into families or categories that can be easily identified. More important, the reasons why they have taken a particular form, high or low in the sky, are clues to the weather.

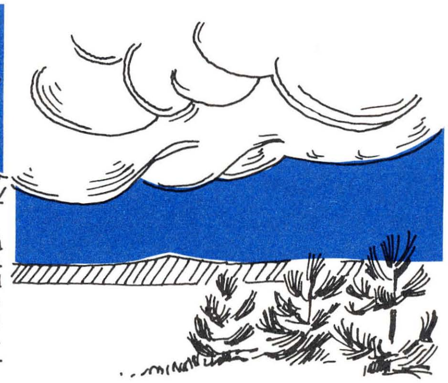
CUMULUS

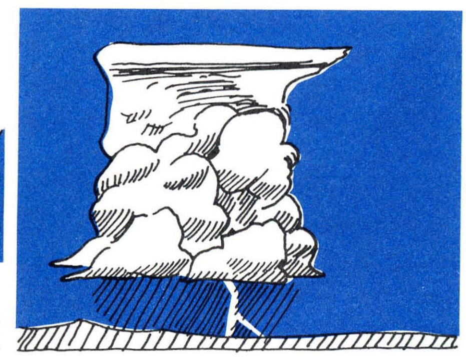
Cumulus clouds are the flocks of billowy white puffs, so familiar in the summer sky. They are always formed by rising and cooling columns of air. Cumulus generally are fair weather clouds. But should they grow into dark, towering thunderheads *(cumulonimbus)*, watch out. The turbulence within them will soon erupt into a brief but violent thunderstorm, and possibly into a tornado.

Like all clouds the cumulus is a signpost in the sky. Cumulous clouds often mark some spot on the earth's surface below that has warmed up faster than the surrounding terrain. To the pilot, a puff of cumulus, (1) often means a plowed field below. To the sailor, it signifies land. A mass of cumulus, resembling cauliflower (2) may be the signal that colder weather is approaching.

Colder, denser air moving in nudges under the warmer air and lifts it until clouds form. Cumulonimbus thunderheads (3) may rise 5 miles or more in the sky.

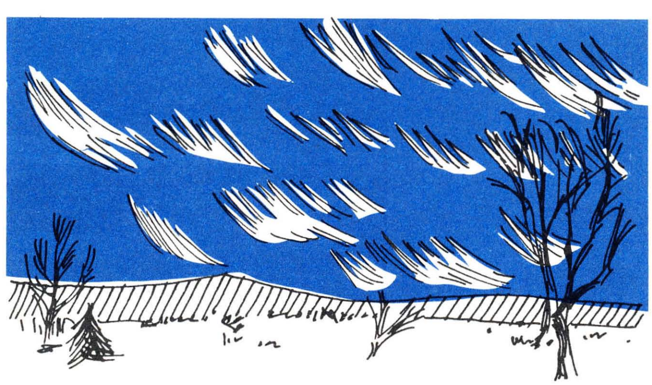






CIRRUS

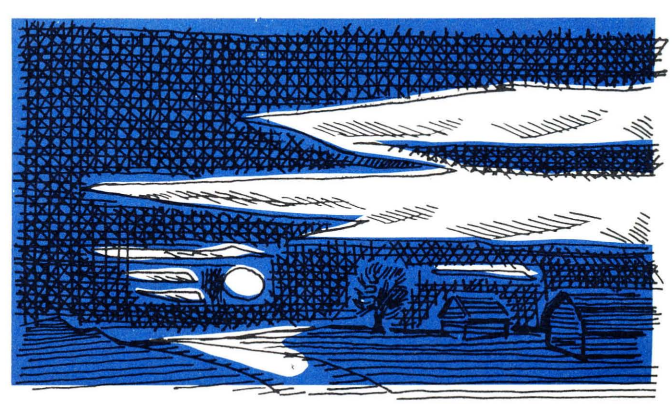
Cirrus clouds are feather-like and wispy. They take shape high in the sky, where the air is very thin and temperatures are far below freezing. Cirrus clouds are made up entirely of icy crystals. Cirrus clouds are usually a sign of fair weather. But when stratus-type cirrus start to thicken, they can be the first sign that rain, snow, or other bad weather is on its way.



STRATUS

Stratus clouds lie like a sheet across the sky. They form when air moving horizontally cools below the saturation point.

Stratus clouds may form at any height in the atmosphere. Low, dark, stratus-type clouds, after a cold spell, are a sure sign that warmer air is moving in, bringing a good chance of steady rain or drizzle.



HOW HIGH IS A CUMULUS?

Would you like to figure out how high above you the base of a cumulus cloud may be? It's easy with your psychrometer and the dewpoint chart below. Notice the difference in degrees between the wet-and dry-bulb thermometers. Then, using the chart, find the dewpoint temperature. Since air from the surface is cooling 5½ degrees for each 1000 feet of rise, figure out how high the air must rise to reach the dewpoint and condense. For example, let's say the temperature of the air around us is 85 degrees and the dewpoint is 74 degrees. The air must cool 11 degrees to reach the dewpoint. This will happen if it rises about 2000 feet (5½ degrees per 1000). The base of the cumulus cloud, then, must be 2000 feet above us.

DEWPOINT CHART

Air Temp.	Difference between wet- and dry-bulb thermometers (degrees)																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
35	33	30	28	25	21	17	13	7	0	-11	-41														
40	38	35	33	30	28	25	21	18	13	7	-1	-14													
45	43	41	38	36	34	31	28	25	22	18	13	7	-1	-14											
50	48	46	44	42	40	37	34	32	29	26	22	18	13	8	0	-13									
55	53	51	50	48	45	43	41	38	36	33	30	27	24	20	15	9	1	-12	-59						
60	58	57	55	53	51	49	47	45	43	40	38	35	32	29	25	21	17	11	4	-8	-36				
65	63	62	60	59	57	55	53	51	49	47	45	42	40	37	34	31	27	24	19	14	7	-3	-22		
70	69	67	65	64	62	61	59	57	55	53	51	49	47	44	42	39	36	33	30	26	22	17	11	2	-11
75	74	72	71	69	68	66	64	63	61	59	57	55	54	51	49	47	44	42	39	36	32	29	25	21	15
80	79	77	76	74	73	72	70	68	67	65	63	62	60	58	56	54	52	50	47	44	42	39	36	32	28
85	84	82	81	80	78	77	75	74	72	71	69	68	66	64	62	61	59	57	54	52	50	48	45	42	39
90	89	87	86	85	83	82	81	79	78	76	75	73	72	70	69	67	65	63	61	59	57	55	53	51	48
95	94	93	91	90	89	87	86	85	83	82	80	79	78	76	74	73	71	70	68	66	64	62	60	58	56
100	99	98	96	95	94	93	91	90	89	87	86	85	83	82	80	79	77	76	74	72	71	69	67	65	63

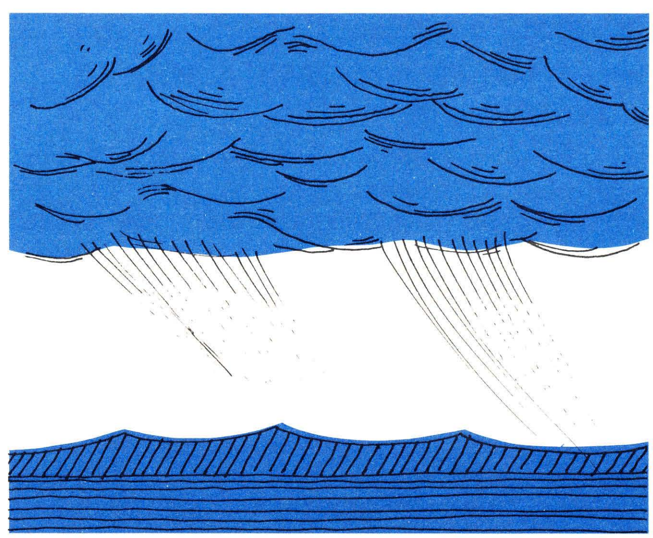
WILL IT BE RAIN, SNOW, HAIL, OR SLEET?

Cloud droplets must grow enormously before rain can fall. An average raindrop contains a million times as much water as a cloud droplet. While cloud droplets have little weight and are easily carried by the air, raindrops are too heavy and precipitate or fall.

Clouds that form in freezing temperatures are made up of ice particles instead of water. When the ice particles grow too heavy, they also fall as ice crystals or as snowflakes. Whether they reach the earth as snowflakes or melt into rain will depend on the temperature in the lower levels of the atmosphere.

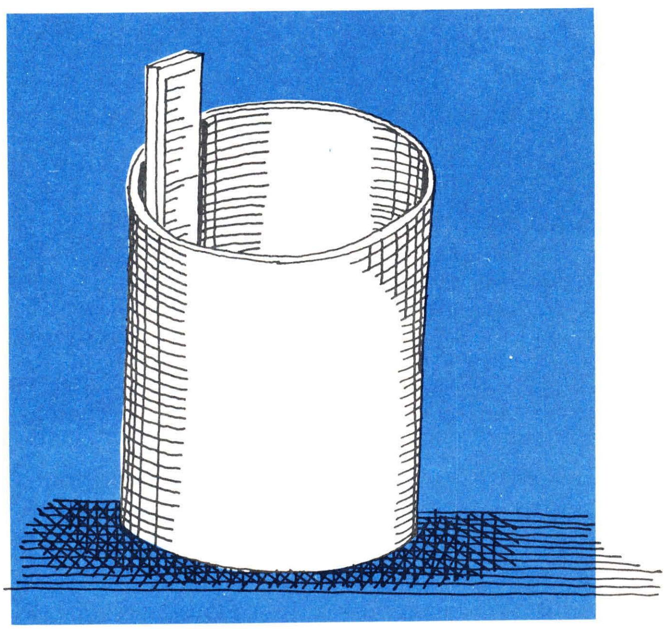
Hail and sleet both start out as raindrops, but there the similarity ends. Can you find out what happens to make them so different?

Sometimes, when the air at lower levels is very dry, raindrops or snowflakes evaporate before they ever reach the ground. The rain, falling in the upper levels, gives the appearance of a gray tail hanging from the cloud. The effect is known as *virga* and is often mistaken for a tornado.



MAKING A RAIN GAUGE

Measuring rain or a snowfall is easy. All you need is a straightsided can or bottle to collect the precipitation and a marked-off stick for measuring. Set the can in an open area away from buildings and trees and at least two feet off the ground. On top of your weather station would be fine. Be sure the can is level. To measure the depth of the rainfall, mark off a straight stick into inches with a pencil or waterproof pen and then divide each inch into ten equal parts. After each shower, measure and record the precipitation to the nearest tenth of an inch. Then empty the can. Melt snow to get the rainfall equivalent. Under ordinary conditions, it takes about 10 inches of snow to equal an inch of water.



WHAT MAKES MICHIGAN A WINTER WONDERLAND?

Michigan receives more snow than almost any other state east of the Rockies. The prevailing westerlies blowing over the Great Lakes pick up moisture until the air is saturated. Forced upwards when it reaches hilly land, the moist air condenses into clouds and then, in the winter, falls as snow. Heavy snow, plus milder weather from the lakes, gives Michigan the perfect combination for winter fun. The next time you go skiing, or tobogganing, or otherwise enjoy our "winter wonderland," think of the lakes and the unique weather they bring.

Summing Up...

Now that you have your own weather instruments . . . . KEEP YOUR WEATHER EYE OUT. Observation is the key to successful weather forecasting. Almost all the clues you need to forecast the weather are in the air around you. Check your instruments twice a day and keep a careful record of:

TEMPERATURE

BAROMETRIC PRESSURE

WIND SPEED AND DIRECTION

HUMIDITY

PRECIPITATION

CLOUDS

Like the pieces of a puzzle, your records will form a picture of what's happening now and what's going to be.

WHAT'S SO SPECIAL ABOUT MICHIGAN? Weather, for one thing. Find out all you can about the unique Michigan weather that has made us a great fruit-growing, resort, and industrial state. Your leader's kit has some information. Your local weatherman can tell you more. Then amaze and inform your friends with an exhibit of what you've learned.

BE A WEATHER PROPHET. Check your weather records on the rule-of-thumb weather guide which follows and you can start to forecast the weather from your own backyard. A sample Weather Log is included to help you with your forecast. Then, if you want to learn more about weather forecasting, turn to Unit III where you'll find out how to "read the skies" and plot the weather on a map, just as your weatherman does.

Meteorologists use symbols on their weather maps to describe the type of weather observed at each station around the country. Here are just a few of them. You can begin to learn them right now by using them in your weather log.

CLOUDS	
	Fair weather cumulus
	Towering cumulus
—	Fair weather stratus
- - -	Rain-bearing stratus
	Cirrus filaments
	Milky cirrus veil

PRECIPITATION			
•	Rain	,	Drizzle
*	Snows	≡	Fog
▽	Showers		Thunderstorm

BAROMETRIC TREND (Since previous reading)			
/	Rising	—	Steady
∧	Rising then falling	\	Falling steadily
	Rising then steady	∨	Falling then rising

WEATHER LOG *Prepared by* ____________ *club* ______ *age* ___

DATE	TIME	PRESSURE	HUMIDITY	WIND DIRECTION	WIND SPEED	CLOUD TYPE	CLOUD AMOUNT	PRECIP. TYPE	PPECIP. AMOUNT	TIME PRECIP. STARTED	TIME PRECIP. ENDED	NOTES
5/4	4PM	30.27	60%	S	5		10%	NONE	–			
5/5	8AM.	30.01.	80%	SSE	5	—	100%	NONE	–			
5/5	4PM.	29.91	90%	SE	3	- - -	100%	,	LIGHT	2PM.		
5/6	8AM.	29.81	90%	E	5	- - -	100%	•	HEAVY			
5/6	4PM.	29.8–	80%	SW	10		50%	NONE	–		10AM.	

RULE-OF-THUMB WEATHER GUIDE

WIND DIRECTION	SEA-LEVEL BAROMETRIC PRESSURE (Inches)	WEATHER INDICATED
SW to NW	30.10 to 30.20, steady	Fair with little temperature change for 1 to 2 days
SW to NW	30.10 to 30.20, rising rapidly	Fair followed within 2 days by rain; warmer
SW to NW	30.20 and above, steady	Continued fair, no marked temperature change
SW to NW	30.20 and above, falling slowly	Fair with slightly rising temperature for 2 days
S to SE	30.10 to 30.20, falling slowly	Rain within 24 hours
S to SE	30.10 to 30.20, falling rapidly	Wind increasing, rain within 12 to 24 hours
SE to NE	30.10 to 30.20, falling slowly	Rain in 12 to 18 hours
SE to NE	30.10 to 30.20, falling rapidly	Increasing wind, rain within 12 hours
E to NE	30.10 to 30.20, falling slowly	(Winter) Rain within 24 hours (Summer) With light winds, rain may not occur for several days
E to NE	30.10 and above, falling rapidly	(Winter) Rain or snow, with increasing winds (Summer) Rain probably within 12 to 24 hours
SE to NE	30.00 or below, falling slowly	Rain will continue 1 to 2 days
SE to NE	30.00 or below, falling rapidly	Rain with high winds, followed in 36 hours by clearing, cooler
S to SW	30.00 or below, rising slowly	Clearing within a few hours, fair for several days
S to E	29.80 or below, falling rapidly	Severe storm soon, followed within 24 hours by clearing and, in winter, colder
E to N	29.80 or below, falling rapidly	Severe NE gale and heavy precipitation. (Winter) Heavy snow, followed by cold wave
Going to W	29.80 or below, rising rapidly	Clearing and colder

ADIABATIC—(Pronounced - A-de-ah-BAT-ic) The warming or cooling of air due to changes in atmospheric pressure. For example, when air is warmed over a sandy beach, it rises. As it rises, atmospheric pressure decreases with altitude permitting this parcel of air to expand. As the air expands, its temperature drops. Air forced up the side of a mountain will cool in this manner. This same air will then be warmed again as it slides down the opposite side of the mountain where it is again compressed by the higher pressure of lower altitudes.

ANEMOMETER—An instrument for measuring the speed of wind. Usually consists of small cups attached to arms, which whirl about a center shaft. The shaft is connected to a dial, either mechanically or electrically, so that wind speed can be read directly as miles-per-hour.

BAROMETER — An instrument used for measuring atmospheric pressure.

BAROMETRIC PRESSURE—The ocean of air which surrounds the earth has weight which is measured as barometric pressure in terms of pounds per square inch, inches of mercury, or millibars.

CONDENSE—The changing of a gas to a liquid. Water vapor in the air condenses when it forms a cloud, fog, snow, or rain.

CORIOLIS — (Pronounced - Cor-e-O-lis) A French engineer and mathematician who, about 1835, discovered this force described in the experiment which bears his name. The Coriolis Force applies not only to the movement of air over the earth, but to ocean currents and the firing of artillery. It is especially important to our astronauts when they plan the landing spot for their space ships.

DEWPOINT —The temperature at which condensation takes place.

DOLDRUMS—A belt of low-pressure air circling the earth in the vicinity of the equator.

HEAT—The amount of energy from the relative motion of molecules in a substance. At absolute zero, about 273° degrees centigrade below zero, molecules stop moving. As heat is applied, the molecules begin moving and their movement increases steadily as more heat is applied. It is this motion which causes solids to melt into liquids or boil into gases as they become hotter.

HORSE LATITUDES—A belt of high-pressure air circling the earth, usually located at the 30th parallel of latitude, both above and below the equator.

HUMIDITY—Refers to the amount of water vapor suspended in the air.

HYGROMETER—An instrument used for measuring Relative Humidity. Often made with a strand of fine human hair attached to a pointer mechanism, which gives a direct reading of humidity. The amount of moisture in the air causes the hair to either stretch or shrink, which changes the reading of the pointer.

JET STREAM — Bands or ribbons of extremely high-altitude winds which move at very high speeds, usually between the Horse Latitudes and the Sub-Polar Low. Jet Streams are seldom wider than a hundred miles. They are usually located above 40,000 feet altitude. Their speeds often reach as much as 300 miles-per-hour.

LATITUDE—Imaginary lines around the earth, parallel to the equator. The equator is known as zero degree latitude. The North Pole is 90 degrees latitude North. Latitude lines are sometimes called parallels. Michigan is centered on the 45th parallel (of latitude).

MILLIBAR—The term commonly used by weathermen to express atmospheric or barometric pressure. About 34 millibars is equal to one inch of mercury. All weather maps show pressure in millibars.

POLAR EASTERLY — Almost constant winds out of the East and Northeast, lying in an area between the Sub-Polar Low and the North and South Poles.

PRECIPITATION—When the temperature of air is cooled below a given point, the water vapor will condense and turns into rain, snow, hail, etc. This liquid or solid form of water falling to the ground is called precipitation.

PREVAILING WESTERLIES—The almost constant winds blowing from the West and Southwest and lying in the area between the Horse Latitudes and the Sub-Polar Low.

PSYCHROMETER—An instrument used for measuring Relative Humidity. Usually consists of two thermometers. One thermometer shows the actual temperature of the air and is called the dry-bulb thermometer. The second thermometer usually has a cloth wick over its bulb which is saturated with water. This is called the wet-bulb thermometer. As water on this wick evaporates, it causes the wet bulb thermometer to indicate a lower temperature. By comparing the readings of these two thermometers to a chart, the Relative Humidity can be determined.

RELATIVE HUMIDITY — The amount of water vapor actually contained in the air when compared to the maximum amount the air can hold at a given temperature and pressure. Usually expressed as a percent. For example, a Relative Humidity of 50% means that the air contains one half the amount of water vapor it is capable of holding.

SATURATION—When the Relative Humidity reaches 100%, the air is said to be "saturated". In other words, at that particular temperature and pressure, it cannot absorb any more water vapor. If the temperature or pressure should drop just the slightest amount, condensation will occur.

SUB-POLAR LOW—A belt of low-pressure air surrounding the earth usually lying near the 60 degree parallel of latitude.

TEMPERATURE—The amount of heat in a substance. Usually expressed in degrees fahrenheit or degrees centigrade.

TORNADO—A small, violent, whirling wind usually appearing as a funnel shape which sometimes accompanies severe thunderstorms. Tornados are extremely destructive because their winds rotate or spin at speeds from 200 to 500 miles per-hour. In addition, a vacuum-like condition inside the whirling funnel often causes buildings to literally explode because of the rapid change of pressure as the tornado passes overhead. Tornados are sometimes incorrectly called Cyclones. (Cyclones are described more completely in Unit III)

TRADE WINDS — The almost constant winds which flow out of the East and Northeast in the area between the Doldrums and the Horse Latitudes.