Chapter 3 **Air**

Precious atmosphere

The atmosphere is an envelope of gases nearly 500km thick, which surrounds the earth. 15 to 30km above the surface of the earth is a zone rich in ozone, which is formed when energy from sunlight splits an atom off one oxygen molecule and causes it to join another. Ozone (O_3) forms an invisible filter for some of the potentially harmful ultra-violet radiation from the sun. Above this the air is cloudless, thinner and colder.

Air has a fairly constant **composition**; it is a mixture of nitrogen (78%), oxygen (21%), inert gases like helium (1%) and carbon dioxide (0.05%) but with varying amounts of water vapour. It is in a dynamic equilibrium with the oceans and the land masses and holds heat close to the surface.

Weather occurs within the denser lower parts of the atmosphere, as a result of temperature, pressure and moisture differences within the air. Only about fifty per cent of the sun's energy which reaches the outer edges of the atmosphere actually penetrates through to the surface of the Earth, with the rest reflected from or absorbed by the clouds. The weather is like a huge, sun-powered machine evaporating water and differentially heating the Earth's surface.

Wind is produced by the **circulation** of air, caused by the way in which the surface of the earth is heated. Warm air rises at the equator, producing lower **pressure**, and drawing in air from the north and the south. At the poles, cool air sinks down producing higher pressure. In between there are other zones dominated by warm, rising air and zones of cooler, sinking air. Wind results from air movements between these areas of different pressure.

During the day, in coastal areas, air is warmed and rises from the land, but over the sea, air cools and sinks, causing wind to blow onshore. At night with the land cooling more rapidly, this process is reversed. The prevailing winds often also change with the season, for example monsoon winds from the SW in southern Asia herald the start of the rainy season.

Rainfall is a vital part of the water cycle. Air rises over hills and mountains, cools, and, unable to hold as much water, produces rain. Warm air rising over cold air at a weather front also leads to rain, and near to the sea moist air reaching warmer land rises and condenses as rain. Water can fall as sleet or snow and moist air cooling near to the ground condenses out as dew. It the temperature is low enough, this freezes to form frost.

Climate is the typical pattern of weather in an area over a long period of time. Some areas and seasons are characterised by low pressure systems and others by high pressure systems. A depression is formed when warm air meets colder air, producing a region of low pressure. The leading edge of the depression is a warm front. Rainfall can occur here and at the cold front trailing behind. A high pressure system, called an anti-cyclone, produces periods of clear, settled weather with very little wind. In some circumstances, at the boundaries between warm and cold air, the circulating vortices of air can become intense. Vast depressions with diameters of up to 500kms may be formed, resulting in water spouts or dust devils, tornadoes or violent tropical hurricanes.

Atmospheric pressures

Although there should be a balance between the water, air and biosphere circulating important components including nitrogen, oxygen, carbon and water, this balance is clearly under threat. For example, for every tonne of coal burnt, two tonnes of carbon dioxide are added to the atmosphere contributing to the greenhouse effect and potentially to global warming. Sulphur dioxide pours into the air from power stations and more complex chemicals like the CFCs (chlorofluorocarbons) escape from aerosol propellants, refrigerator coolants and from foam packaging. This cocktail of **air pollution** also includes potentially lethal carbon monoxide, unburnt hydrocarbons, and various oxides of nitrogen, all from vehicle exhausts, and dust particles from metals like lead and cadmium.

The weak acids resulting from the oxides of nitrogen and sulphur rot stonework, damage trees and pollute lakes and rivers, restricting the variety of plants and animals which are able to live there. This **acid rain** also affects the soil, leaching increasing amounts of toxic aluminium and removing calcium which leads to poor growth of trees and crops.

Ozone is now part of the photochemical smog present in many densely populated areas. In a temperature inversion, a ceiling of warmer air traps cool air, which condenses as a mist. Over cities, smoke from chimneys and car exhausts react with sunlight to produce low level ozone as a secondary pollutant. Ozone at ground level is relatively stable and can cause lung irritation and crop and tree damage over long distances.

While ozone at ground level is a pollutant, high in the atmosphere it is vital to protect the Earth from too much radiation, which would increase cataracts and skin cancers, affect plant growth and breakdown some plastics. The **ozone layer** is damaged by certain chlorine-containing molecules, particularly CFCs. The chlorine takes oxygen atoms from ozone and since these CFC gases are relatively stable and long lived, they are continuing to destroy the layer faster than it is being naturally replaced. Thinnings of this layer called ozone 'holes' are now developing, especially over wide areas centred on both of the poles, and this has been clearly related to the escape of CFCs into the atmosphere.

Basic concepts and issues	Air	Activities
Composition of air		3.1 Pressure gauges
Weather patterns		3.2 Wet and dry
Circulation and pressure		3.3 Blowing in the wind
Climates and microclimates		3.4 Wind patterns
Air pollution and acid rain		3.5 Hot and cold
Ozone depletion		3.6 When the cold wind blows
		3.7 Weather in miniature
		3.8 Acid drops
		3.9 Ozone holes
		3.10 Ozone game

3.1 Pressure gauges

Concept

The atmosphere is an envelope of gas molecules around the Earth. When these molecules collide with a surface they push against it creating pressure.

Context

Air pressure, which has a major effect on weather patterns, can alter from day to day and can be measured using a simple barometer.

Equipment

Barometer: *wide necked jam jar - balloon - scissors - thick rubber band - drinking straw - needle - sticky tape and glue - piece of card - plasticine*

Pressure demonstration: *2 wooden rulers - newspaper*

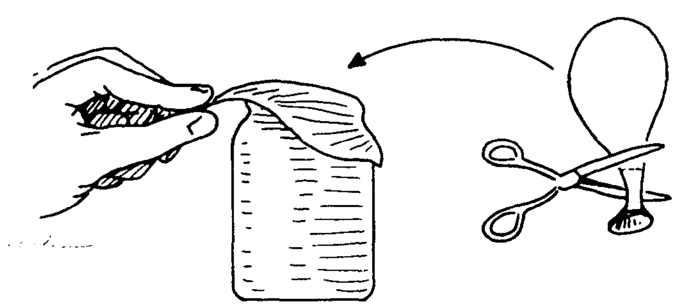
Air composition: *wide necked jar - straws or pipe - bowl or bucket of water*

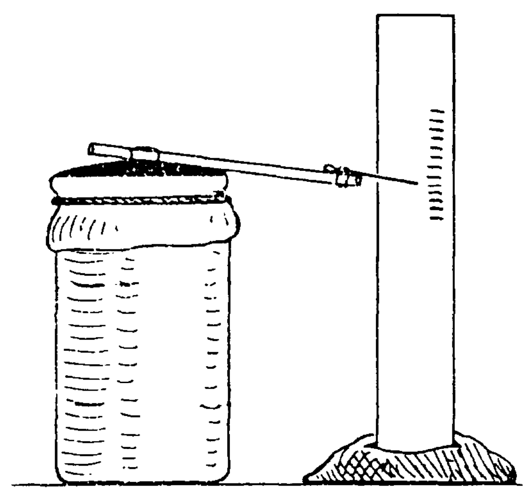
Making it

1. The barometer is made by cutting off the neck of the balloon and stretching the remainder tightly over the neck of the jar. Use the rubber band to hold it in place.

2. Fix the needle to one end of the drinking straw and stick the other to the balloon skin so that the edge of the jar acts as a pivot.

3. Push the card into the plasticine and adjust it so that the needle is pointing at the scale.





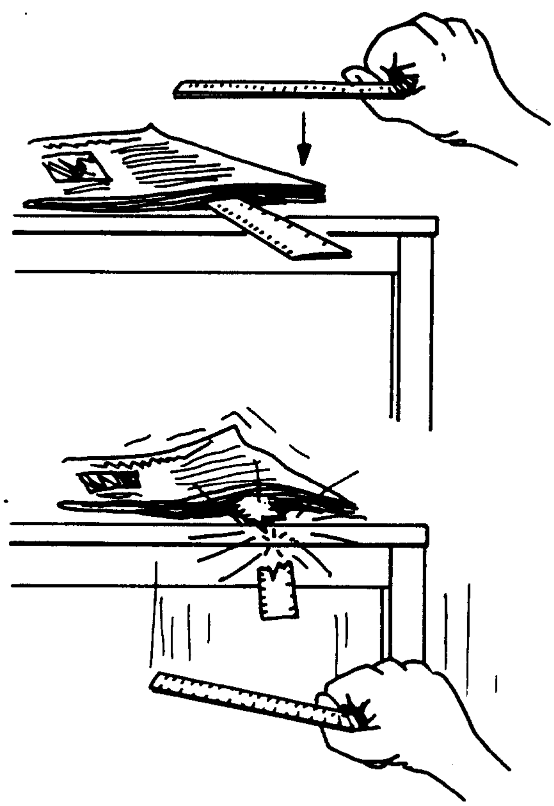
3. The needle should move as pressure alters. (NB: do not place the barometer out in the sun as this will heat and expand the air in the balloon).

Using it

Preliminary activities

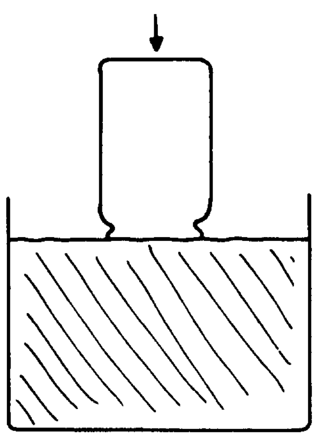
First start by demonstrating that air has weight and occupies space.

Position one ruler so that half of it overhangs the desk. Lay a flat piece of newspaper over the half of the ruler on the desk. Bring a second ruler down, hard, onto the half overhanging the desk. This ruler should break, the pressure of air on the newspaper preventing the half on the desk from flipping up.

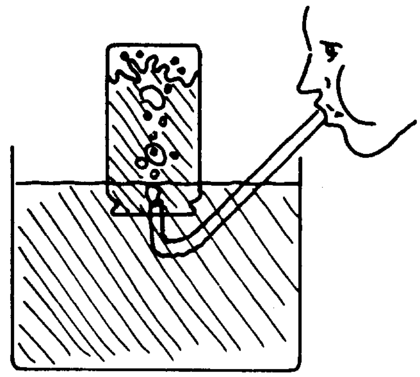


Now demonstrate that air is made of 'something'.

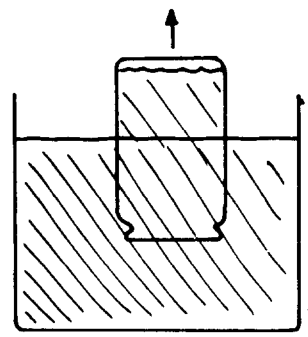
Ask a participant to invert the jar and push it down into a bucket of water. They will see that the jar does not fill with water indicating there is 'something' inside stopping it.



Next try filling the jar full of water keeping it inverted in the bucket. Place the end of the straw or pipe in the jar and ask the participant to blow air into the jar forcing the water out.



Try 'pulling the jar part way out of the water noting that the water does not fall out. This is due to the pressure of air on the surrounding water surface pushing down with enough force to keep the water in place.



Monitoring pressure changes

You can then start monitoring variations in pressure by making your own scale on the barometer card. If a commercially made barometer is available you can use this to calibrate your home-made scale. As pressure increases expect fine weather.

Adapting it

A barometer can also be made from a plastic bottle and a bowl (the thinner the bottle the more effective the barometer will be). Half fill the bottle with water and clamp it upside down into a small bowl of water. Mark the side of the bottle with a felt tip pen to show any changes in the water level indicating change of pressure.

3.2 Wet and dry air

Concept

The rainfall of an area can be related to the landscape, its proximity to the sea and the prevailing climate of high or low pressure systems.

Context

The amount of rainfall in any area varies tremendously and yet all plant, animal and human activity is dependant on it. Simple rainfall gauges are an important part of weather monitoring and the moisture content of the air (humidity) can also be simply measured using an hygrometer.

Equipment

Rain gauge : *large (2 litre) plastic bottle - smaller (1 litre) plastic bottle - modelling knife or scissors trowel - plasticine, blu-tac or similar - ruler and waterproof marker*

Hygrometer: *pieces of absorbent cloth, blotting paper or thick tissue - small stick - water*

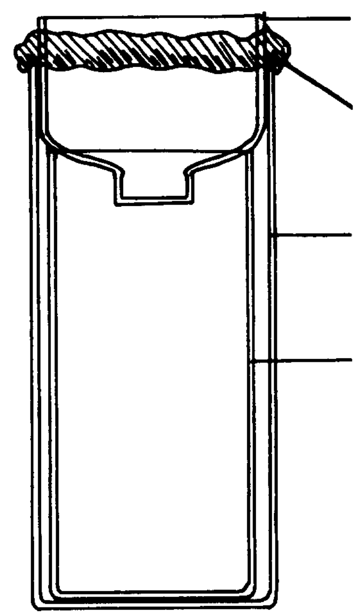
Making it

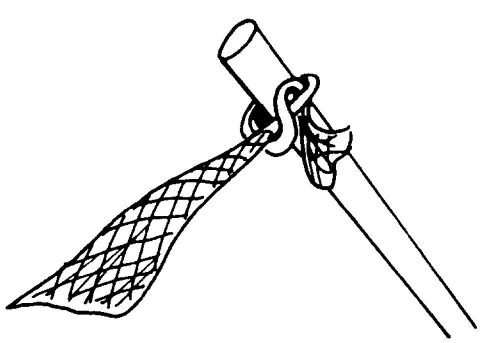
To make a simple but effective rain gauge

1. Carefully cut the top off the large plastic bottle, inverting it to form a funnel. The best bottles are those with thick, stable bases.

2. Measure the height from the base of the bottle to the bottom of the fitted funnel. Mark this height on the second bottle and cut at this point. The second, smaller bottle should now fit snugly inside the larger one. This is the collector.

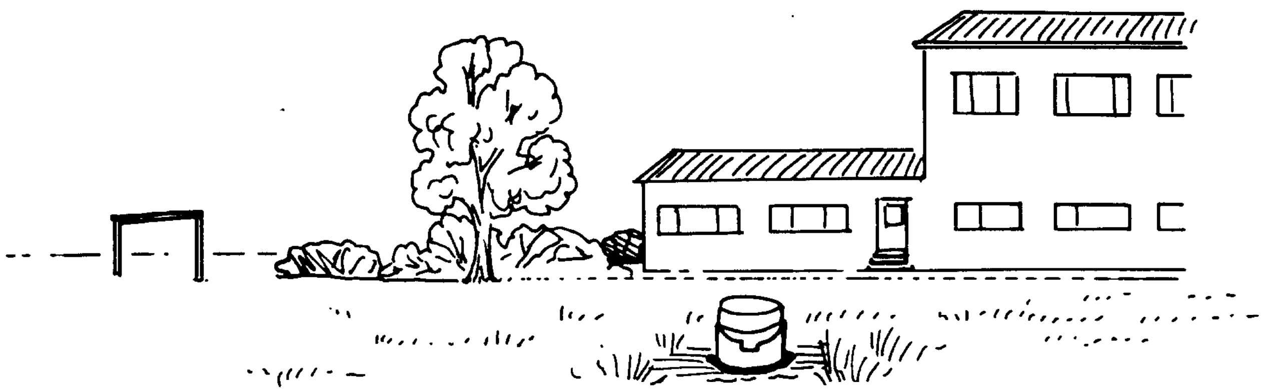
3. Secure the funnel in place with plasticine or similar so that it can be removed but so ensuring no rain can dribble around the edges into the outer bottle.





To make a simple hygrometer
(to test the moisture content of the air)

Cut a strip of absorbent cloth and tie it to a stick. (If you decide to make several of these ensure that the strips are of the same size). Before using your hygrometer soak it in water and squeeze out the excess until it doesn't drip, but is thoroughly wet.



Using the rain gauge

The rain gauge could be used straight away, or it could be calibrated so that the amount of water collected can be recorded.

1. The volume and height of water in the collector depends on the size (surface area) of the funnel and of the collector itself. Assuming that these are both round, the ratio of one to the other is a constant. Simply compare the square of the two radii, or just measure the diameters and square the values.

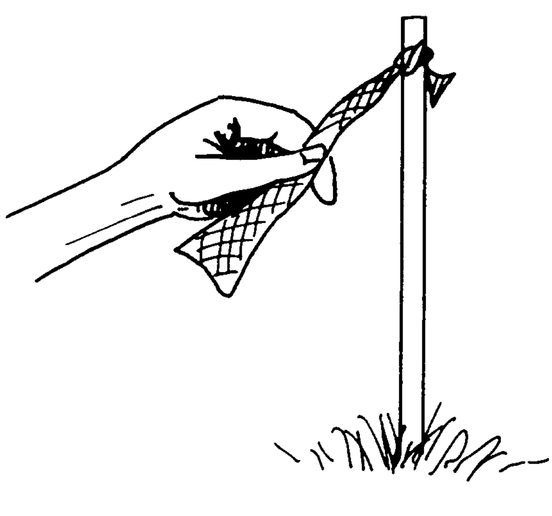
$$H = \frac{D^2}{d^2}$$

Where D= diameter of funnel in mm
Where d= diameter of collector in mm
Where H= height of the collector in mm for one mm of rain.

Mark the position on the collector for one mm of rain, then for 2, 5, 10 mm etc.

2. Put the rain gauge somewhere in the open, away from the effects of trees or buildings. If you have a number of gauges you could compare the rainfall in different places. (See also 3.7 and 4.2).

3. Check the rainfall at the same time each day. Like any weather recording, this information is only of interest if it is recorded regularly, allowing comparisons over time and between seasons.



Using the hygrometer

Push the stick into the ground keeping it away from buildings and trees to avoid possible interference. Record the time needed for the cloth to feel completely dry; obviously the drier the atmosphere the more quickly this will happen. It will also depend on the air temperature (warm air can hold more moisture) so record this in your weather station as well. (See also 3.5).

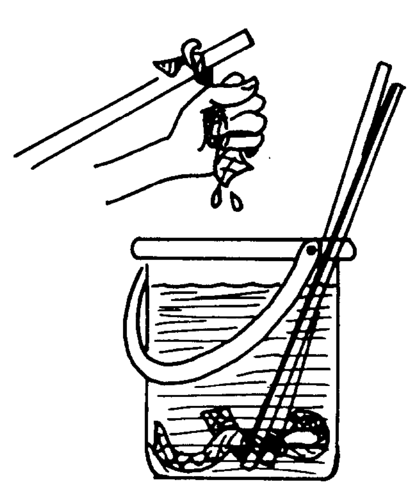
Adapting it

To calibrate the hygrometer, you will need access to a ***wet and dry thermometer.***

Record the air temperature and humidity from the tables provided with the thermometer and record the time taken for the cloth to dry.

Do this a number of times at different temperatures and when the air is both moist and dry. You can now use the table that you have made to say roughly how moist the air is, simply by timing how long the cloth takes to dry out.

If you are unable to borrow a wet and dry thermometer there are a number of natural ways to assess roughly the moisture in the air. For example, the cones from conifer trees open out in dry air, and seaweed (especially the brown oarweed ***Laminaria*** *spp), if hung up, will remain soft and moist or become dry, depending on the humidity.*



3.3 Blowing in the wind

Concept

Wind is caused by air movements in the atmosphere.

Context

Pressure differences in the atmosphere cause wind movements. Wind direction and strength can be measured at your weather station with a wind vane and an anemometer - equipment that gives plenty of opportunities for design work.

Equipment

Simple wind vane : *flat wooden board, piece of dowel or cane - hammer and nails - (size dependant on size of next item) - tube with closed end eg. cigar tube, empty biro, 'smarties' sweet tube - rubber band, scissors, glue - flat plastic carton, eg. milk, margarine - thick drinking straws or ice lolly sticks*

Anemometer: *long pole, eg. cane or broom handle - four identical plastic pots - thick straws or thin pieces of cane - hammer and nails - sticky tape - beads*

Making it

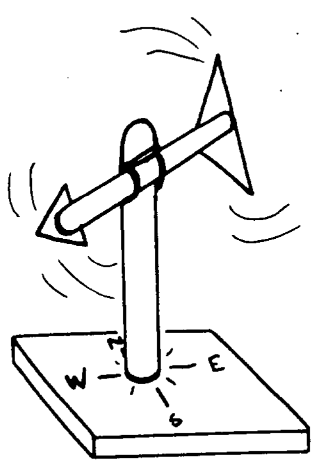
To make a simple but effective wind vane

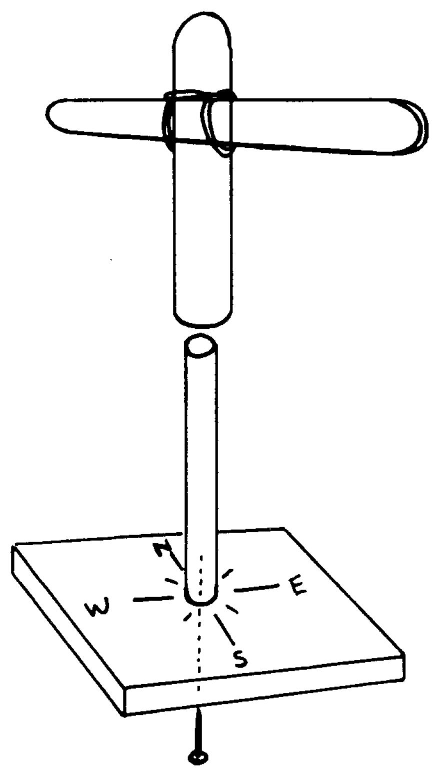
1. Pick the tube you are going to use and select either the nail size or piece of wood that fits most comfortably inside it. The tube should be able to spin freely. For example, a metal cigar tube will probably need a cane or piece of dowelling, while an old biro tube would require a thin long nail.

2. Fit the dowel upright on a firm wooden base as illustrated. Mark the points of the compass on the base and place the tube over the dowel.

3. Fasten a thick straw, lolly stick or similar with a rubber band across the top of the tube.

4. Cut an arrow shape for the front and a tail 'fin' for the rear from the plastic and glue into position.

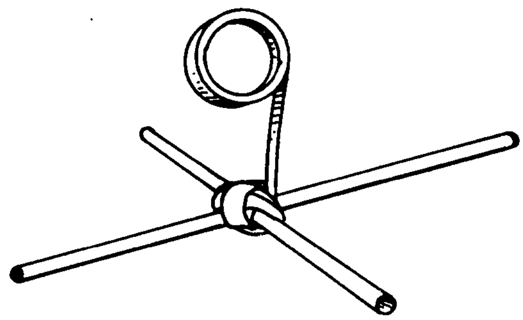




To make the anemometer

1. Make holes in the plastic pots, so that the straws or canes ('arms') fit through tightly. Secure the arms at right angles to each other with tape. Make a hole through the centre of both arms to take a nail.

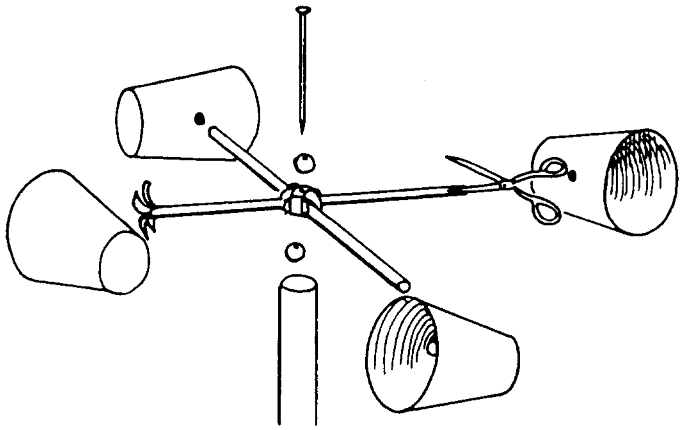
2. Thread the nail through a bead, the arms, another bead and then hammer into the upright pole. Push the pots onto the arms and balance them, before taping them on securely, all facing in the same direction. The meter should move fairly smoothly.

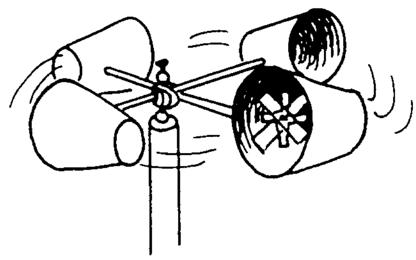


Using it

*Put both instruments out in the open as part of your weather station. You will need to orientate the base of the weather vane to north/south before taking any readings. The anemometer can be pushed into the ground. Try sinking a short plastic tube as a sleeve for the pole, which can then be taken in after use. You might like to calibrate the anemometer against observations of the wind (the **Beaufort Scale**). Can the participants devise a way of counting the revolutions when, in a strong wind, it is going round very fast?*

Can participants relate their observations of wind to temperature, rain, season or any daily cycles?

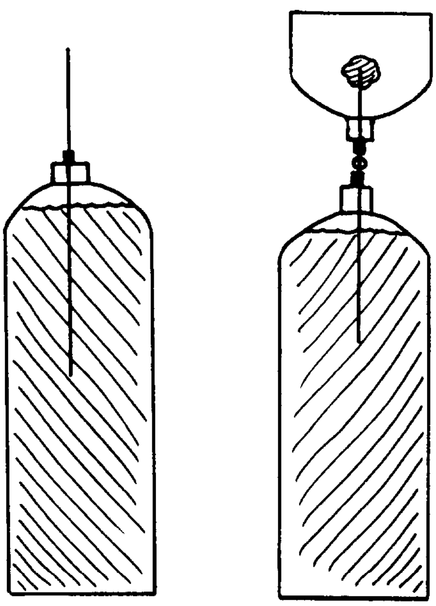




Adapting it

A more robust 'mark two' weather vane

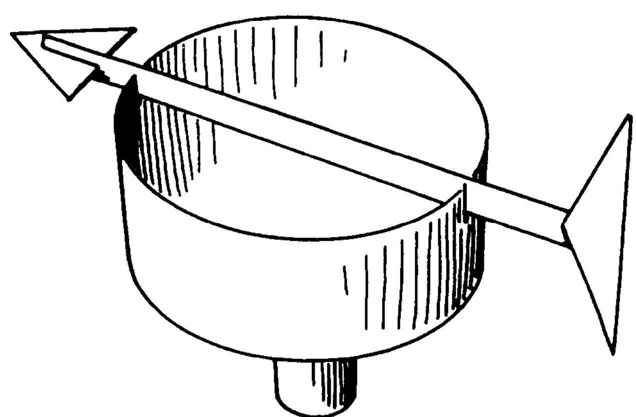
1. Fill an empty washing-up detergent bottle (or similar) with water. Cut off the cap and insert a length of thin wire, (eg. from a coathanger) so that it fits tightly and protrudes a few centimetres straight from the top.



2. Cut a second detergent bottle just below the top, discarding the bottom. Cut a slit through as shown, to take a long thick straw or a thin piece of wood.

3. Put a bead on the protruding wire, then push this into the top of the second bottle, adding a second bead if necessary and then a lump of plasticine or similar to prevent the top from flying off.

4. Fix an arrow shape and a tail fin to the arm as before. Check that the vane moves freely. The water should help to anchor it but you might prefer to cut a hole in the base and slip the bottom bottle over a post.



3.4 Wind patterns

Concept

Winds are produced by the circulation of air and are an important part of the weather. The patterns of weather within an area, characterised by pressure differences, lead to daily and seasonal differences in wind direction and strength.

Context

To record the direction of the wind, a simple compass is required. A fun way to 'feel' the wind and investigate wind resistance is to make and use kites and parachutes.

Equipment

Compass: *small transparent round plastic pot with lid (the lid doesn't need to be transparent) - card - glue - scissors - waterproof pen - half of a bottle cork (or small piece of polystyrene) - sewing needle - small magnet - ruler - protractor - water - washing detergent*

Kites: *thin polystyrene sheet or light sturdy card - buttons - thread - string*

Parachutes: *thin plastic sheet (polythene bags) -thread - cotton reels*

Making it

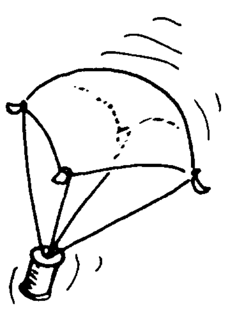
*1. For the **compass** cut a small circle of card to fit into the lid of the pot. Draw on lines at 90°, 180°, 270° and 360° and mark with E(ast), S(outh), W(est) and N(orth). Stick this into the lid and then place the pot on top. You should now be able to read the positions through the base of the transparent pot.*

2. Cut a slit across the cork or polystyrene. Magnetise the needle by stroking it with the magnet in one direction. Carefully push the needle into the slit.

3. Put some water into the pot and add a drop of detergent to stop the cork or polystyrene drifting over and sticking to the edges of the pot. Float the cork or polystyrene on the water.

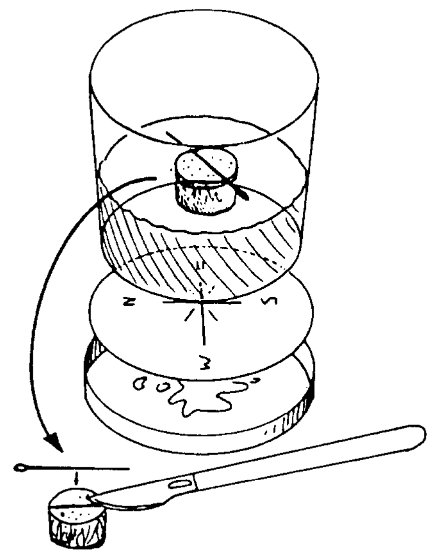
*4. A **kite** can be made from a 50cm square of thin polystyrene sheet such as a ceiling tile. First find the centre and mark it. Then mark a spot 12cm above the centre as shown in the diagram. Make holes at both of these points. Thread string through each hole and fasten the end to two buttons. Fix a line to the thread; (if you wish you can fix paper streamers to the base of the kite).*

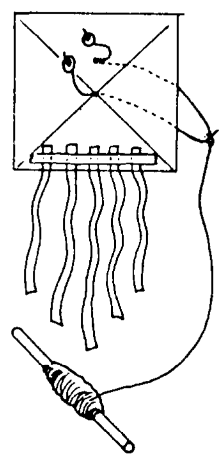
*5. **Parachutes** can be made using squares of thin plastic to make a canopy. Tie a thread to each corner, then thread each piece in turn through the centre of a cotton reel and tie off the ends.*

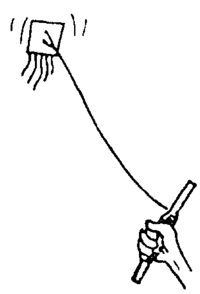


Using it

*To use the **compass** place the pot on a level surface. When the needle is still, carefully turn the lid with the direction signs until the needle matches the north/south line seen through the base.*







*You can fly **kites** and experiment with different length of tails. It can be a fun way of working out which direction the wind is coming from and going to.*

***Parachutes** work as air collected in the canopy pushes against it. You can experiment with different loads and canopy sizes to see how this affects the rate at which the parachute falls.*

3.5 Hot and cold

Concept
Measuring the temperature of the air is an indirect way of finding out how much energy is in the atmosphere at a particular time.

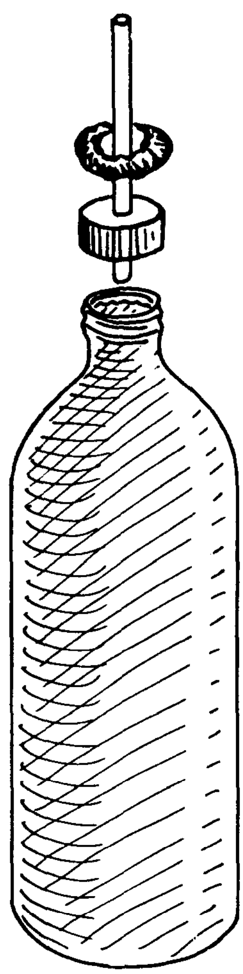
Context
A simple thermometer can be made to allow comparison of temperature at different sites.

Equipment
Bottle with a screw top - coloured water - drinking straw - plasticine (or clay or candle wax) - card and tape - thermometer or other simple temperature measuring devices (eg. liquid crystal strips)

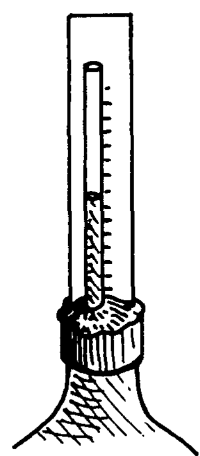
Making it
1. Fill the bottle completely to the top with the coloured water.

2. Make a hole in the bottle's lid just big enough for the straw to go through.

3. Screw the lid back on and push the straw through the hole. Fix the straw in place and make a water tight seal using the plasticine.



4. Tape the card to the upper part of the straw and mark a scale on the card; (if possible try to calibrate the scale with a commercially made thermometer).



Using it
This thermometer will give you a rough guide to how much hotter or colder the air temperature has become. For daily monitoring, try positioning it in a shady area and checking it three times a day.

Also try putting it in a small hole made in the soil. Are the temperatures any different?

As for other recordings of weather, this information is only of significance if the readings are taken regularly, enabling comparisons to be made over time and between seasons.

3.6 When the cold wind blows

Concept

Climatic differences produce seasonal changes to which plants and animals must adapt. For example, the seasons affect the timing of reproduction and the availability of food. When conditions are unsuitable, some animals migrate, while others enter a dormant state like hibernation where the body temperature falls and an energy-saving period of inactivity occurs.

Context

This activity simulates some of the conditions experienced by mammals during the winter, and investigates how they respond.

Equipment

An area outside where participants can find a range of natural materials, eg. leaves, feathers etc. - clean empty food cans - small plastic tubes (eg. film canisters) - access to hot water - thermometer or other simple temperature measuring device (eg. liquid crystal strips)

Using it

Participants might be introduced to this activity after a habitat investigation. For example they might have discovered that small mammals are present within an area, (see 5.6) and have some idea of seasonal changes from weather observations and measurements.

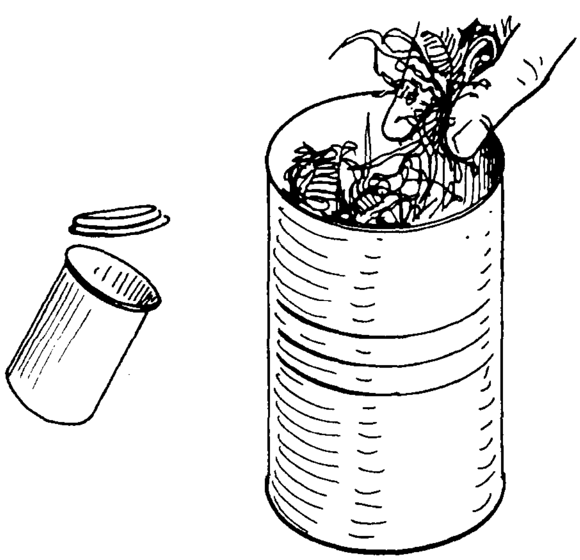
1. Split the participants up into groups, each of which has two tins (NB check that there are no sharp edges) and two plastic tubes. Suggest that each tube represents a small animal (for instance a mammal such as a mouse) and the tin represents the hole and nest site. They might like to personalise the tubes by drawing a face on them to represent a particular mammal!

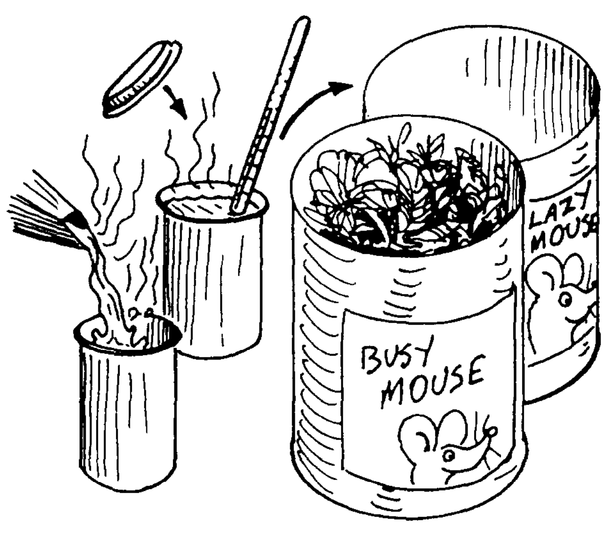
2. Ask each group to hunt for nesting material for one of their 'animals'; anything found on the ground can be used. Participants will need to decide what might be best (eg. moss, feathers, grass) and how tightly to pack it around the tube.

3. Suggest that the second animal decides not to make a nest; provide no nesting material for this one.

4. Fill each tube with hot water, measure the temperature and quickly replace the lid and any bedding. If you do not have a thermometer, a hand around the tube can give a good impression of the starting temperature. Ask the groups to hide the 'nests' somewhere on the ground; some participants may find holes or additional layers of insulation.

5. After a period of time (dependant on the size of the tubes) retrieve the 'nests' and take (or feel) the temperature again.





- ☞ *Which stayed the warmest; the 'mouse' who made a nest or the 'lazy' one?*
- ☞ *Which group managed to keep their 'mouse' the warmest? Now look at the nesting material; are there any clues as to why this 'mouse' retained the most heat?*
- ☞ *In real life how would a warm-blooded mammal keep temperature constant? (for instance animals grouping together; curling up; moving; eating to provide energy; additional fat and thicker fur etc).*

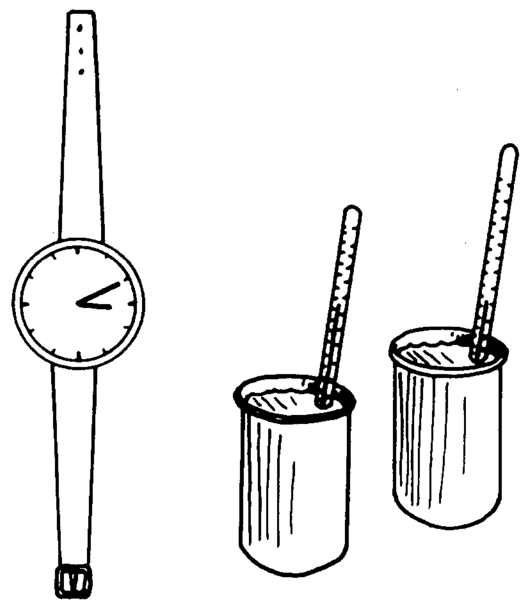
Adapting it

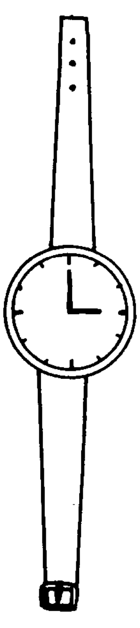
Try using 'animals' of different sizes. (The rate of heat loss from mammals depends on their surface area and smaller mammals have a larger surface area to volume ratio).

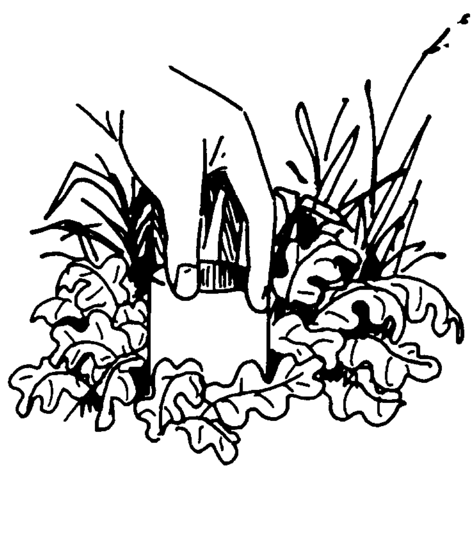
Can you think of a similar activity which could be developed to illustrate the problems of retaining water in warm, dry climates, or of keeping cool?

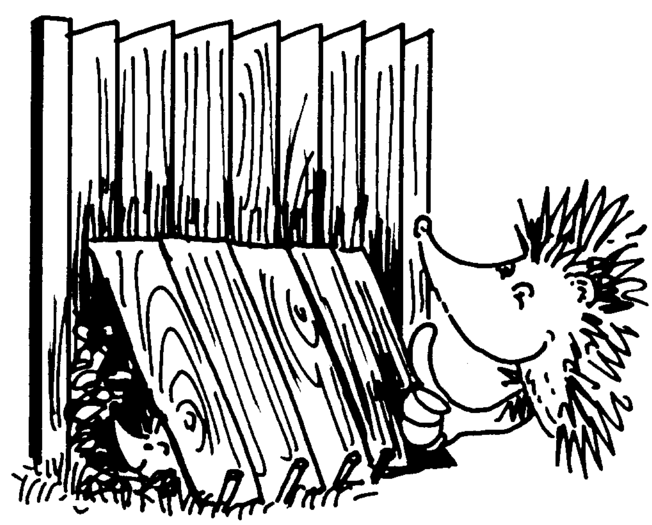
Many mammals in cold winters still maintain an active existence, while others will migrate and some truly hibernate. This activity should stimulate further discussion. Hibernators generally require an insulated nest to provide a fairly constant environment. Groups might like to provide suitable hibernating sites in colder countries for animals such as bats or hedgehogs.

This activity can also lead on to role play, where participants identify the needs of specific animals and look for their ideal home.









3.7 Weather in miniature

Concept

Changes in microclimate are caused by vegetation affecting winds and water vapour and by cities which are warmer than the surrounding countryside. Buildings slow the wind in some places but increase the speed or create turbulence in others.

Context

While weather operates on a global level, local conditions produce differences in microclimate. These are easier to investigate and are often very relevant - for example the importance of shelterbelts in protecting crops from the wind and of trees in reducing soil erosion by rainfall. Some ideas are suggested.

Equipment

To demonstrate shelter: *hairdryer or fan - toy windmill - plasticine or similar (or ribbon-o-meter as below) - pot plants*

Ribbon-o-meter: *flat piece of wood as base - short piece of dowelling or cane - plasticine (or hammer and nails) - thin coloured ribbons (or paper streamers)*

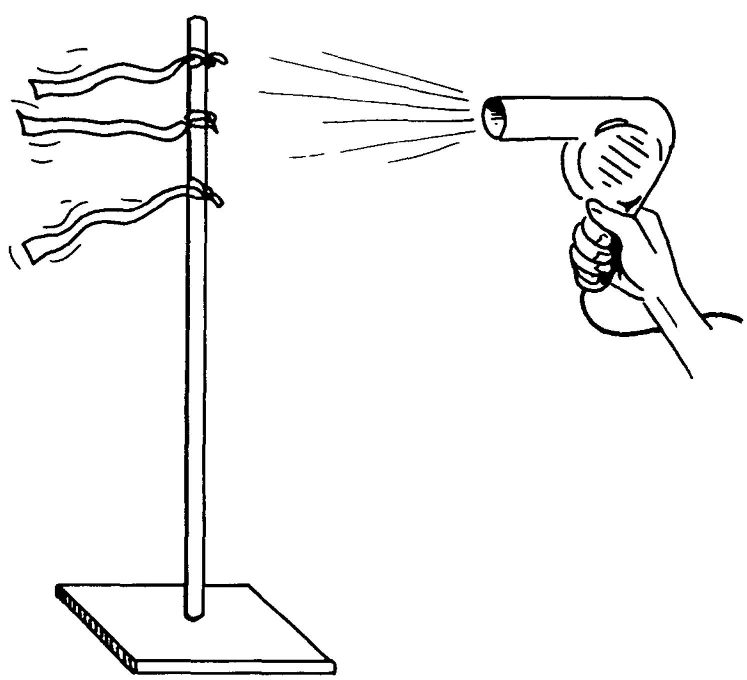
For other measurements: *thermometers (see 3.5) - cloth hygrometers and rain gauges (see 3.2) - compass (see also 3.4)*

Making it

To prepare a simple wind indicator or 'ribbon-o-meter' (direction and strength) :

1. Nail the dowel or cane firmly to its base.

2. Tie a group of streamers or ribbons at the top of the post. As you will need a number of these, make sure that each is the same height and that the 'tassles' are of the same material and there are similar numbers on each 'meter'.



Using it

To demonstrate the effect of a building or trees on the wind:

1. On a flat indoor surface set up a 'ribbon-o-meter' or firmly anchor a toy windmill into a block of plasticine.

2. Turn on the dryer or fan and direct it at the ribbons or windmill. How far can you move the 'wind' away before the ribbons or windmill stop blowing?

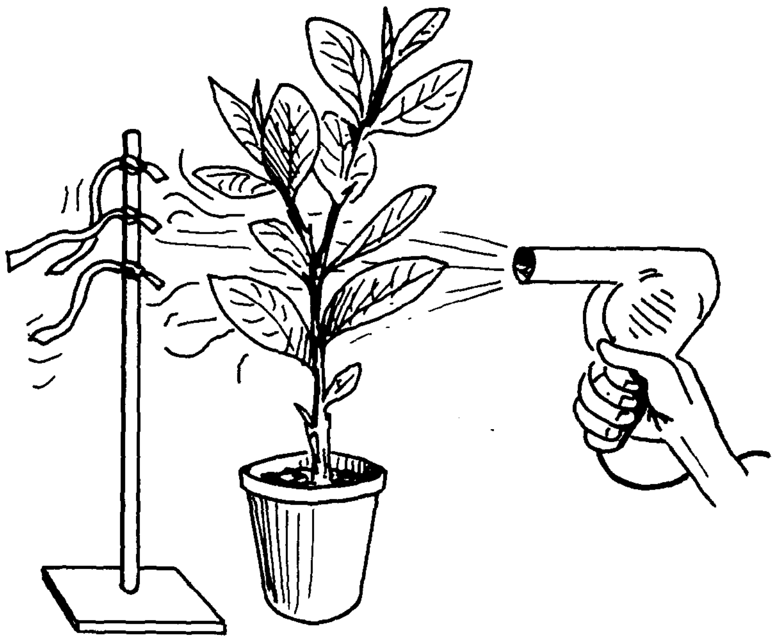
3. Now put the plant or plants in the way. How close does the 'wind' need to be to get through? Do different plants have different effects?

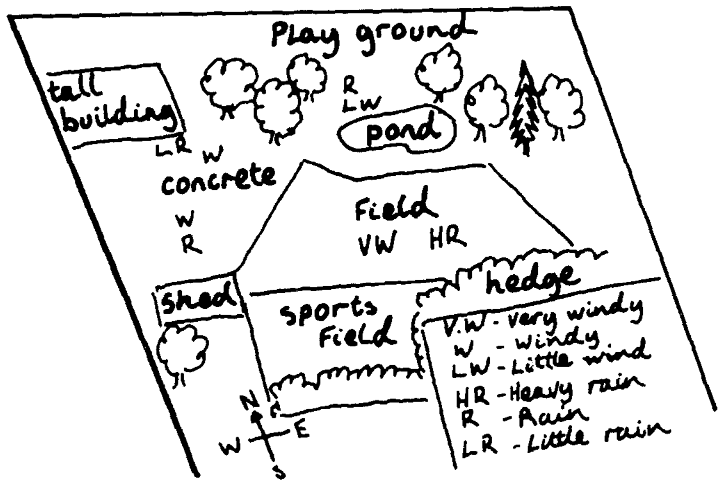
To monitor the microclimate around buildings (for example a school):

1. Ask the participants to look carefully at a plan of an area with buildings with which they are already fairly familiar. Use the compass to mark the main directional points on the plan. Discuss with them the direction in which the sun rises and sets. They might also note which are the tallest buildings or even go out and measure them. (See 5.13)

2. Ask the participants to 'guess' where the wind will be strong or weak; where the air will be warmest or coldest; where the water collected in rain gauges will be greatest and where it is likely to be most or least humid.

3. Now test these ideas with the equipment already developed. Use the 'ribbon-o-meters' to give an approximate idea of prevailing direction and relative strength.





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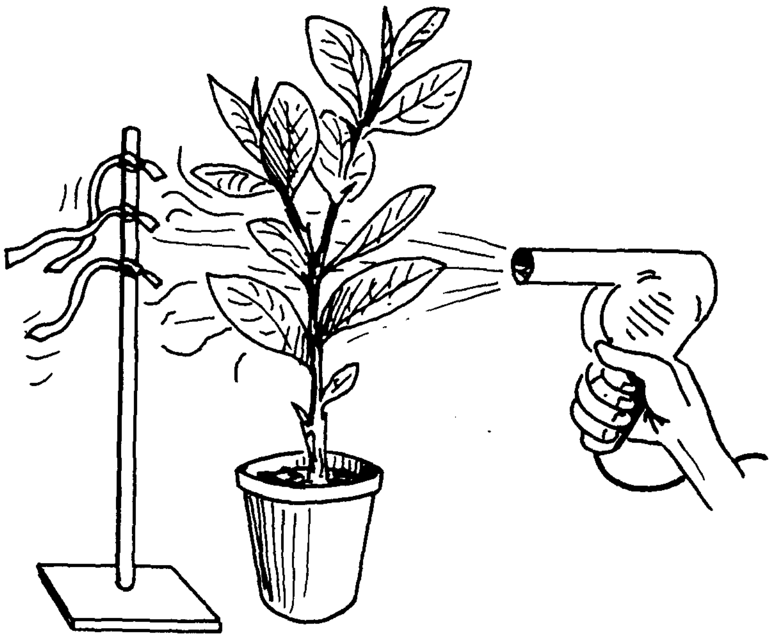
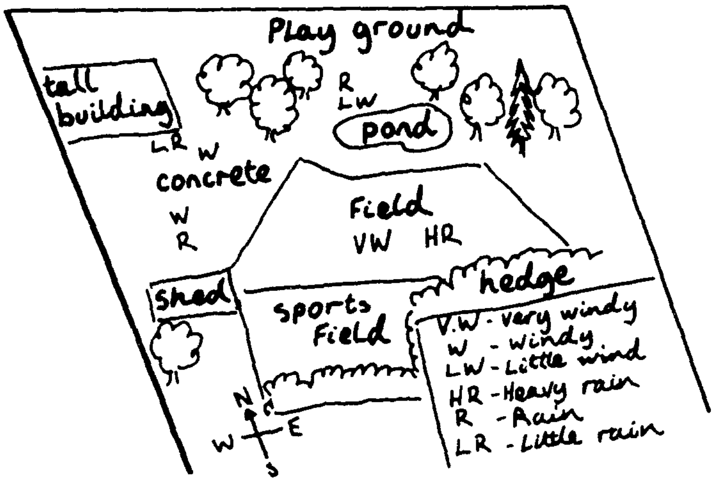




3.8 Acid drops

Concept

Rain water is naturally slightly acidic (pH5 to 6) due to the presence of carbon dioxide and sulphur and nitrogen compounds from bacteria, volcanoes etc. Primary pollutants from the burning of fossil fuels (like the oxides of nitrogen which form a dilute nitric acid and also sulphur dioxide), acidify the rainfall further and it falls as acid rain.

Context

Monitoring the acidity of rainfall makes it possible to investigate the relationship with wind direction and other weather variables. Acid indicator can be made from plant extracts and the effects of acid rain can be demonstrated by making acid rain in a miniature model of the atmosphere.

Equipment

To make an indicator: *red cabbage or similar coloured vegetable - pan and source of heat - water and small plastic bottle (look for one with a small nozzle) - lemon juice, milk, vinegar etc*

To collect acid rain: *clean plastic bags, rubber bands - large (two litre) plastic bottles - wooden post*

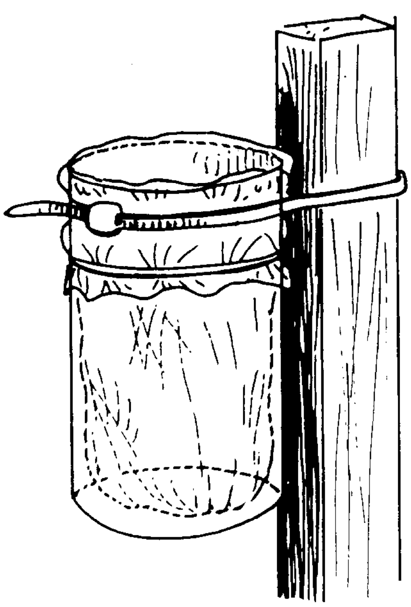
To illustrate acid rain being formed: *large screw top glass jar - litmus paper or home made indicator (see above) - distilled water if possible (from a fridge) - matches - crushed chalk*

To illustrate the effects of acid rain: *two large, clean plastic tubs - small plastic pot and some water - campden tablets (for brewing/wine making) - plastic bags and large bands, or 'cling-film' - fast germinating seeds eg. cress - two lid tops or similar for germinating trays - cotton wool*

To investigate dry deposition: *filter funnel (can be made from the top of a washing up liquid bottle) and paper - double-sided sticky tape on pieces of card or wood (or white tiles)*

Making it

*1. To make an **acid rain collector**, cut the top off the plastic bottle and using the plastic bag as a glove, fit it inside, securing with an elastic band as shown. Use a larger thick band to attach to the pole.*



*2. Boil red cabbage in a small amount of water. The water will become purple. By using only a little water, the dye is concentrated. Allow it to cool and then store in a dispenser. This **indicator** will not store for very long.*

3. Prepare for an illustration of the effects of acid rain by germinating seeds such as cress on small trays of cotton wool.

Using it

The indicator you have made can be used to test for acidity:

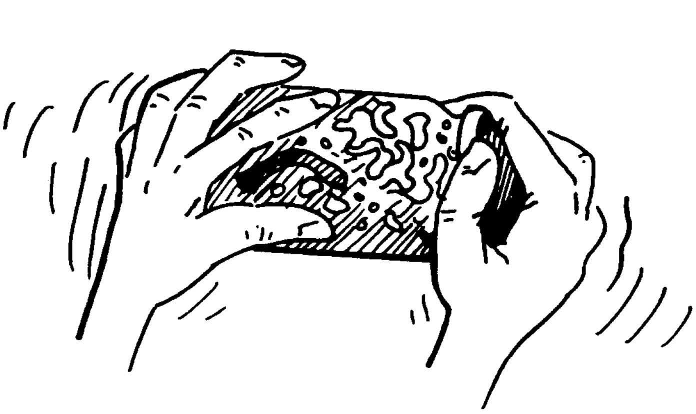
1. Put your wooden post out in the open and collect some rain in the plastic bag. Put a little indicator in with the rain water and note the colour. Can you notice any differences in acidity on different days? Litmus paper will give more precise results, but because rain is poorly buffered, it is better to obtain a specialised indicator.

2. Mix a small amount of the indicator with vinegar or lemon. Note the colour changes. Can participants find any other substances which will reverse this? Can you discover any other plant extracts that will act as acid/alkali indicators? Some blue flowers eg. ***Campanula*** *species will change to red in colour if put in strong acid. Try agitating an ant's nest with a flower head, as they may squirt formic acid onto it!*

To simulate acid rain:

1. Quarter fill the glass jar with water (distilled if possible), and add a litmus paper. Light a number of matches over the water, and when the heads have finished burning, blow them out and quickly secure the lid.

2. Shake the jar to absorb the fumes in the water. What happens to the litmus paper? Add some crushed chalk to the water, shake and see what happens now.



To see how acid rain might affect plants:

1. Put one campden tablet into the small pot of water (this will produce sulphur dioxide fumes). ***Wash off any spilt liquid with plenty of water immediately.*** *Put the pot inside one large tub and secure with a plastic cover.*

2. Put one of the trays of germinated cress inside the 'sulphur' chamber, and another inside a second tub, without the fumes . Leave for a few hours. What happens? Try different plants; how do they react?

Try some fieldwork to find out about dry, sooty material in the air:

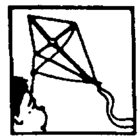
1. Pick some evergreen leaves and wash them thoroughly in a little water. Filter the water; what is left behind?

2. Leave out some white tiles, or pieces of double-sided sticky tape on strips of card or wood. Compare different areas; in the open, next to roads etc. Look for the build up of dry pollution deposits from the air.

Adapting it

Lichens (simple plants formed by a beneficial relationship between a fungus and an alga) and mosses, have been shown to be especially sensitive to sulphur dioxide levels. In a similar way to the use of water minibeasts as pollution indicators (see 4.10) the presence of lichens on trees and buildings can be used to characterise air quality. In general terms, there is a continuum from no lichens (suggesting high pollution levels), through crusty species and leafy species to shrubby, dangling types which prefer air with little or no sulphur dioxide (and therefore indicate low levels of pollution).

3.9 Ozone holes



Concept

Oxygen molecules are made up of two oxygen atoms. Sunlight energy powers a reaction that splits an atom off one molecule and forces it onto another. This new molecule made up of three oxygen atoms is ozone. The ozone splits again as the molecule is unstable and the extra atom of oxygen is removed and goes back to join another oxygen atom. The natural cycle of 'making' and 'breaking' of ozone in the stratosphere is disturbed by the presence of CFC gases. One CFC molecule can destroy tens of thousands of ozone molecules, forming chlorine monoxide.

Context

The reaction occurring in the upper atmosphere can easily be demonstrated using role play.

Equipment

cloth - card - paint

Making it

Introduce the following symbols to the group: a sun; oxygen gas; and a 'nasty' CFC. Ask them to use the materials to make costumes representing these.

Using it

Using a story format, the group in their costumes can play out the following points:

1. "There was a stable couple of oxygens that lived together in the air above our heads" (participants hold hands in pairs of oxygen atoms to represent an oxygen molecule).

2. "In the morning as the sun came out they would both get very excited and go off to work". (At this point designated oxygens stop being joined and go off to form groups of three oxygens.) "They worked as ozone molecules, filtering out harmful radiation".

3. "At night they stopped working and formed their partnership again" (this cycle can be continued until the CFCs arrive). Now oxygens that break up are captured by the CFC molecules and taken away. These are the 'nasty' intruders that take away oxygen atoms! The result is that less ozone is formed.

Adapting it

This approach can be adapted to many chemical reactions such as photosynthesis and acid rain production. Participants other than younger children can be given the elements of the story and left to make up their own play.

3.10 Ozone game

Concept

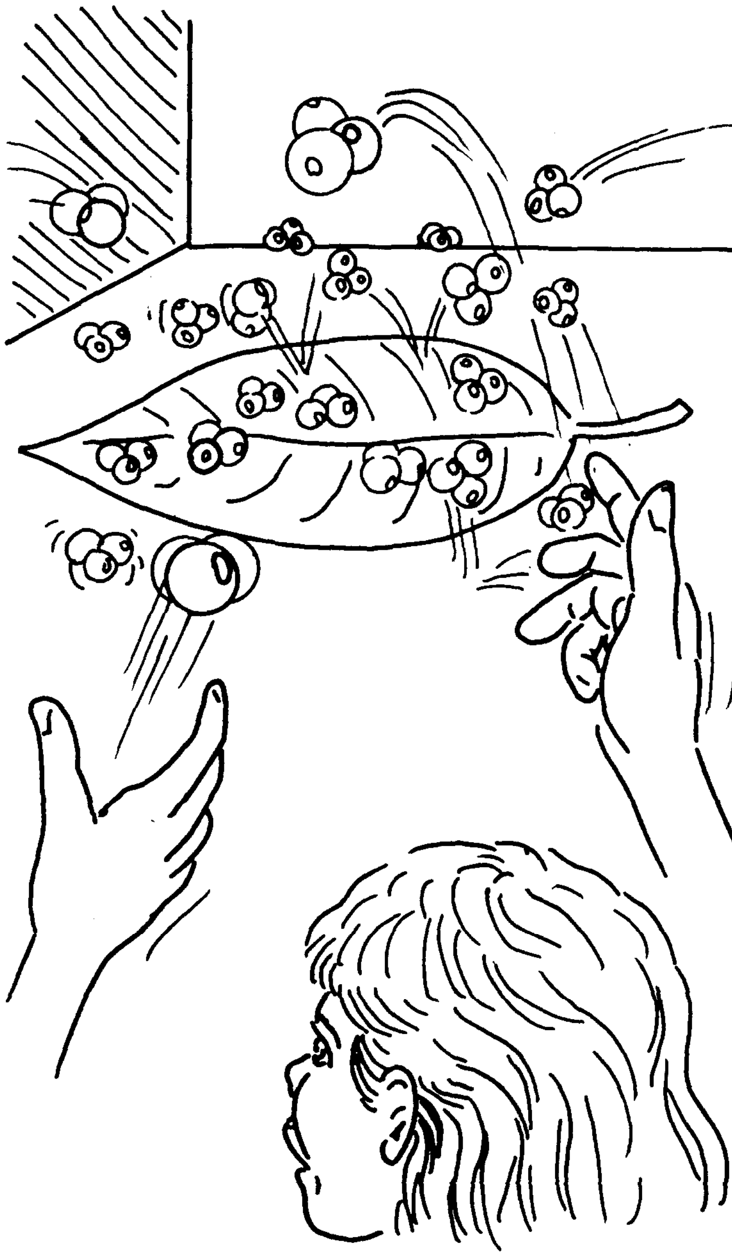
Whilst ozone in the upper atmosphere is a 'good thing' filtering out harmful radiation it can also be formed near the ground when car exhaust fumes react in the presence of sunlight.

Context

The formation of low level ozone and its effects on plants can be illustrated using table tennis balls.

Equipment

Table tennis (ping pong) balls - velcro (or double-sided sticky tape) - indelible markers



Making it

1. Start by making 'exhaust fume' molecules or oxides of nitrogen. Mark one ball with 'N' and two with 'O'. Then attach them together as O-N-O. (Velcro is particularly suitable if available).

2. Make an oxygen molecule by marking two balls with 'O' and velcroing them together.

3. Mark out a leaf shape on the floor and make a score card and a sun symbol.

4. Make enough molecules to ensure each member of the group has at least two.

Using it

1. Place each set of molecules in a separate bucket. Explain that when the sun symbol shines the molecules can react. An 'O' is removed from the 'N' molecules and attaches itself to the oxygen (O-O) molecules forming ozone.

2. Then split the group into two. Each participant has to race to the buckets and take one molecule from each and make ozone. This happens as a relay until both buckets are empty.

3. The teams are now invited, in turn, to throw their ozone molecules onto the leaf. The ozone will look like spots on the leaf. Each team assumes that more ozone molecules on the leaf scores more points, until you tell them it's a minus point as each spot is leaf damage from pollution!

Adapting it

Table tennis balls linked together with velcro can be used for any reaction you wish to explain. Papier maché or polystyrene balls can be used instead and stuck together with cocktail sticks.