THE TEMPLE PRIMERS

OUR WEATHER

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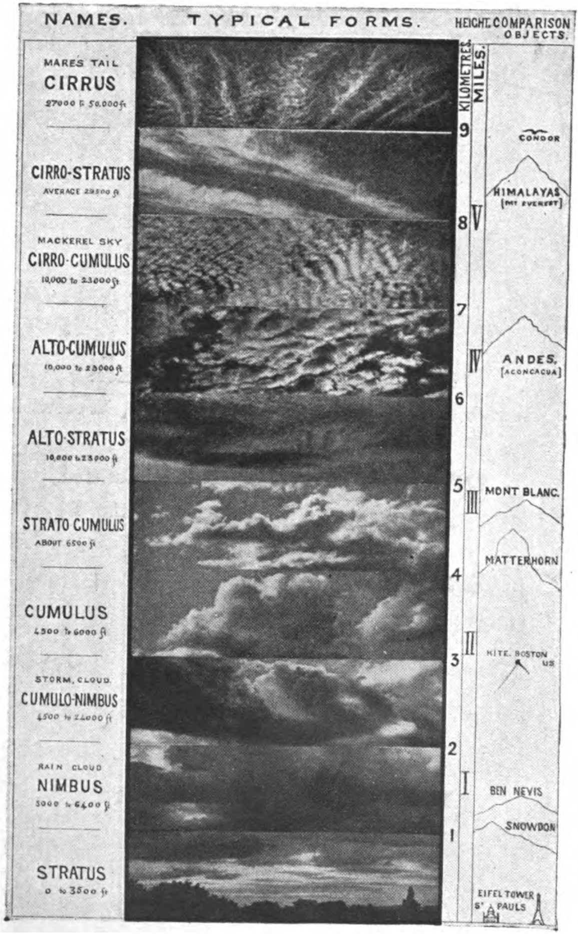

NAMES.
TYPICAL FORMS.
HEIGHT. COMPARISON OBJECTS.
KILOMETRES.
MILES.
MARES TAIL
CIRRUS
27000 to 50,000 ft
CIRRO-STRATUS
AVERAGE 29500 ft
MACKEREL SKY
CIRRO-CUMULUS
10,000 to 23000 ft
ALTO-CUMULUS
10,000 to 23000 ft
ALTO-STRATUS
10,000 to 23000 ft
STRATO-CUMULUS
ABOUT 6500 ft
CUMULUS
4500 to 6000 ft
STORM. CLOUD.
CUMULO-NIMBUS
4500 to 24000 ft
RAIN CLOUD
NIMBUS
5000 to 6400 ft
STRATUS
0 to 3500 ft
9
8
V
7
IV
6
5
III
4
II
3
2
I
1
CONDOR
HIMALAYAS
[MT EVEREST]
ANDES.
[ACONCAGUA]
MONT BLANC.
MATTERHORN
KITE. BOSTON US
BEN NEVIS
SNOWDON
EIFEL TOWER
ST PAULS

CLOUD FORMS

OUR WEATHER

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PREFACE

The authors have felt for some time past that there was a great need for a book presenting the main features of modern meteorology in a popular and simple manner, and which would be of service to teachers and scholars where weather study is included as part of the school curriculum. A similar opinion has also been held by the Council of the Royal Meteorological Society, and as the outcome of a suggestion from them, the authors undertook the preparation of the present volume, which they trust may also be of some interest to the general public.

The authors desire to express their best thanks to the Council of the Royal Meteorological Society for placing at their disposal a large number of the blocks used in the illustration of this book, to Mr. H. Mellish, Past President, and to Mr. F. Druce, Chairman of the Education Committee, for suggestions in the preparation of the book, and to Mr. H. J. Spencer, Woolwich, and Mr. C. R. Darling, City and Guilds Technical College, Finsbury, for reading the proofs. The authors are also indebted to Mr. R. Inwards for permitting them to make the block illustrating the forms of clouds; to Messrs. Macmillan & Co. for permission to reproduce Fig. 55 from *Travels in the Air*; to Mr. A. C. Williams, for drawing some of the illustrations; and to others who have kindly helped in various ways.

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OUR WEATHER

CHAPTER I

Introduction

It needs some amount of reflection to realize what a highly important question this of Our Weather is to all of us.

Our houses must provide us with adequate protection. The roofs should be water-tight not only against ordinary rainfall, but against the heaviest storms that are known to us. It is only during the last century or so that the cheap and durable slate has been found to answer this purpose. The walls must be thick enough to keep the heat in during winter or out during summer. In Egypt and tropical countries generally, houses have walls two feet or more thick, and the interiors are thus much cooler than the air outside. The material of which houses are constructed also makes a difference. Any one who has passed a hot summer day, or a cold winter one, in a galvanized iron building will appreciate that.

The drains of our buildings and of the towns generally are constructed so that they may be able to carry off the greatest rainfalls likely to occur, in order that floods may be avoided.

Apart from the question of the nature of the soil on which it stands, the position of a dwelling-place is of great importance. If we live at the water level, say by a river, we may expect damper weather than the people get who live on the neighbouring hills. If we live on a slope facing the south we shall get more sunshine than if we lived on one facing the north, besides avoiding the north and east winds, which are usually keen and cold. If we live in a large manufacturing district we must not expect so much sunshine as we should get in the open country.

"What will the weather be?" "What shall we wear?" may any day be vital questions to us. If it is cold and the wind keen we should have wool next our skin (in fact, prudent people clothe themselves so all the year round), and we must also see that the thicknesses are sufficient. In the hot weather we wear lighter clothes, lighter in substance and lighter in colour, for the colour makes a difference, and, generally speaking, we use more cotton and linen and less wool. If we have been perspiring and a dry wind causes a chilly feeling, we must not neglect its warning, but hasten to adequately clothe ourselves.

We are all concerned with the productions of the soil. A large part of our diet comes therefrom, and the influence of the weather upon the quantity produced, and therefore the price of grain, vegetables and fruit, directly affects our pockets. If we get a spell of cold, high winds in April, the seedlings must be watered and protected. Those who have greenhouses or garden frames must look out for night frosts till well into May, or many pounds' damage may be done in a few hours. Later they must take care that the greenhouses are properly ventilated and protected from the glare of the midsummer sun, or damage may be caused in another way. The fruit-grower does not care to see his trees in bloom too early. In late April or early May a few degrees of frost may spoil the whole fruit crop of a county or group of counties. Thus there is more risk in growing the earlier varieties than the later ones. Too much rain will spoil the strawberries, and a violent rain, or hailstorm with wind, will bring down the young plums, apples and pears.

The businesses of a large section of the community are intimately connected with the weather. Drapers and clothiers suffer largely when the weather is unseasonable.

People will not buy summer clothing while the weather continues winterly, and *vice versâ*, and the tradesmen say the loss is never made up, as they have to clear their stocks at low prices later. A wet Saturday night causes a considerable difference to the small shopkeeper's takings, and even a dead loss if his goods are perishable. The outings of all, either for business or for pleasure, are largely determined by the weather. If it is not suitable they must be either postponed or abandoned. And how unfortunate it is to have our annual holidays spoilt by cloudy and rainy days.

What a difference, too, the weather makes to our spirits. It is shown when we meet a friend on a dull, wet morning, huddling himself as small as possible under a dripping umbrella, and he greets us with a curt "Mornin'." If it should be a fine, sparkling, sunny morning, we mark his springy steps, and we note the change of tone in his "Glorious morning this!" Who can feel bright and gay in a dense London fog? and who ought not to be so on a glorious morning in the open country or in some beflowered garden?

We grumble and growl at our weather often enough, but we ought to mark this. The continued struggle, necessitating alertness, ingenuity, tenacity and hardihood, has a marked effect on the character of the races inhabiting the temperate regions of the globe, which are those most subject to change in the weather. The result is seen in this, that very few indeed of the men who have done great things and have become famous, have had their origin in the frigid or torrid zone.

Of course, no amount of information will bring us weather that will suit our own particular requirements, but there is considerable pleasure and profit in its study. Some investigation of the heat that warms us, of the sunshine which gladdens us, of the rain which fertilizes our soil, of the air which sustains us, and the wind which continually purifies and freshens, results in interesting information which concerns us all. By it we may learn that the forecasts in the daily papers are not a set of haphazard guesses of the people in the Meteorological Office in London, but are based on definite scientific information, the weather to which they refer frequently follows on in an order which all can learn; and that by using it in conjunction with our own powers of observation we may make very fairly successful local predictions of our own.

There is a certain satisfaction also in being able to explain and account for the weather we may be experiencing. We can learn which of the oft-quoted proverbs to trust, and which to reject. "The further the sight, the nearer the rain" is much more often true than "The new moon will bring a change of weather." The barometric readings will convey a greater amount of information; and we shall no longer pay attention to the words "Fine," "Change," "Rain," etc., which happen to appear on the dial opposite the end of the index at any particular moment, but we shall note the steadiness or rate of movement during a period of investigation. And, generally speaking, many hitherto neglected signs will attain a fresh significance, our walks abroad will have an added interest, which can oftentimes be turned to practical value, as, even with the fickle climate of our isles, to be forewarned is to a certain extent to be forearmed.

CHAPTER II

Pressure of the Atmosphere

THE gaseous covering or envelope of the earth is called the Atmosphere or the Air. Dry air is a mixture of gases, one hundred parts by volume containing about 21 per cent. of oxygen, 78 per cent. of nitrogen, 1 per cent. of argon and other gases, and a slight trace (about 0·03 per cent.) of carbonic acid gas. If the air is moist, it contains aqueous vapour to a limit of about 3 per cent. It is remarkable how little the composition varies wherever the samples are examined, but this is no doubt due to the incessant intermixing caused by the winds. Samples gathered from balloons at great heights, at the sea-level, over the ocean, in country districts, and even in thickly populated districts, show only very slight differences in composition. But these differences, small as they may be, are of considerable importance. It takes the cleverest chemists to discover them, but they have an important effect on the human body, especially in the case of the poisonous carbonic acid gas. These effects are very largely due to the great quantity of air breathed by the individual in the twenty-four hours. A man requires about three pints of water per day, and a very small quantity of poisonous matter in that would be sufficient to make him ill, but in the case of air he requires about 2,200 gallons, or, put it in another way, he uses each day the air that would fill a room 8 feet × 8 feet × 6 feet, (about 10 cubic metres). Absorption goes on without a pause day and night, and in time, if injurious gases are present, his health is affected. In addition to the gases mentioned, in towns gaseous compounds of sulphur and also of nitrogen are to be found, at the seaside salt, and everywhere and at all times dust, tiny seeds and pollen from plants, and bacteria or germs of many sorts.

The height to which the atmosphere extends is not absolutely known. As gases are very compressible and elastic, the lower layers of the atmosphere are much denser than those at some distance from the earth. We generally speak of air as a light body, but if we get vast quantities of even a light substance, the weight becomes considerable. Since the lower layers have to support the weight of the air extending for miles above them, the particles are consequently packed closer together. Astronomers deduce from observations of meteors, or shooting-stars, that there must be air at a distance of over one hundred miles from the earth's surface.

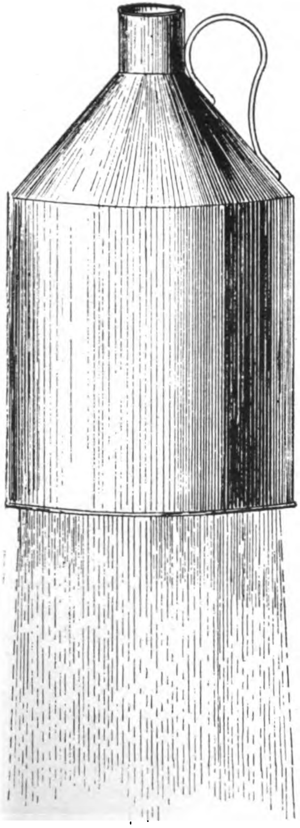


Fig. 1.
Tin vessel with perforated bottom.

When these meteors enter the air they fire by friction with it, and if two astronomers at a considerable distance from each other happen to observe the lighting of a certain meteor, they note at what part of the heavens this occurs and trace its apparent path among the stars. It will not appear to be in the same position to each observer, but from the knowledge of these positions and the distance apart of the observers, the height of the meteor, when it became illuminated, can be determined.

It has already been indicated that the air has weight. At sea-level it would take from seven to eight hundred gallons of air to weigh as much as one gallon of water. If the temperature is increased the air, following the general rule, expands, and consequently a greater number of gallons would be required. Moisture causes it to be lighter also, as the weight of a given quantity of aqueous vapour is about half that of the same bulk of air. In a living room at ordinary temperature, one cubic foot of air weighs 0·4 oz. Thus in a room say 12 feet ×

12 feet × 10 feet, the air would weigh 35 lb. The pressure of the air is not only extended downwards, but, as in the case of liquids, in all directions. Its pressure in an upward direction may be illustrated by an experiment with a tin vessel (Fig. 1) having a perforated bottom. One hand should be placed underneath to cover the holes, and the vessel filled and corked as quickly as possible. On taking the hand from below, it will be found that the water remains in the can, held there by the pressure of the air, until the cork is taken out. The water then descends in a shower.

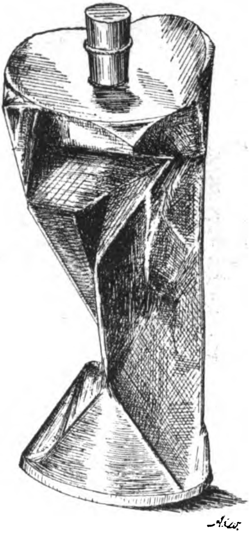


FIG. 2.
Tin vessel crushed by atmospheric pressure.

The effect of atmospheric pressure may also be shown by means of a vessel of thin tin plate (Fig. 2) about 12 inches high and 4 inches in diameter. A good cork will be necessary. Water to a depth of 1 inch should be poured in the vessel and heated till it has boiled vigorously for five minutes. Then the source of heat should be taken away, and at the same time the cork should be forced well in. If the tin be allowed to stand on the table, in a few minutes it begins to collapse. If the joints do not give, and the precautions mentioned have been taken, it very soon presents an appearance such as it might have had it been stamped on. The prolonged boiling drives out nearly all the air, so that when the cork is put in there is nothing inside but the remaining water and aqueous vapour. This latter rapidly condenses as cooling takes place, and the tin has to support the great pressure of the air, which is too much for it.

The so-called Magdeburg hemispheres also furnish a good illustration of the pressure of the air. They consist of two hollow metal hemispheres (Fig. 3), the meeting edges of which are accurately ground so as to ensure a perfect fit. These are placed together, and the air withdrawn as completely as possible by means of an air-pump. The stop-cock is closed and the handle screwed on. It then requires a great amount of force to separate the parts.

Fig. 3.
Magdeburg hemispheres.

Barometers. — Let us now consider how we may obtain some measure of this air pressure. If an open glass tube three feet long be placed in a vertical position with the lower end in a basin of mercury, and the upper end connected with an exhaust-pump (Fig. 4), on pumping out the air the mercury will be seen to rise in the tube, and if the pump is powerful it will rise to a height of about twenty-nine inches above the level of the mercury in the bowl. But even with a good pump there will still be a little air in a rarefied or thin condition above the mercury in the tube. The mercury is not really "sucked up," but the pressure of the air is taken off that part of the surface included in the lower part of the tube, and the pressure on the open surface of the mercury in the bowl " forces " the liquid up to the observed height in the tube. So, however perfect and powerful the pump may be, the mercury in the tube will not rise higher than the atmosphere outside can press it. A balance is established, a column of air having a base equal in area to the base of the tube, and a height extending from the surface of the earth to the atmosphere's uppermost limits, weighs as much as the column of mercury.

There is a simpler way, however, of showing the full effect of the pressure of the air in supporting a column of mercury. We take a glass tube about thirty-three inches long, closed at one end and open at the other, and completely fill it with mercury. The finger is then pressed tightly over the open end and held there while the tube is inverted. The next step is to immerse the finger and the end of the tube in a bowl of mercury. The tube should be held vertically, and on releasing the finger it will be noticed that the mercury in the upper part of the tube has fallen several inches; but it will be seen that a column about thirty inches in height is maintained up the tube by the pressure of the air on the surface of the mercury in the bowl. A barometer of this form is called a cistern barometer. To obtain a satisfactory result from the experiment the bore of the tube must be quite clean, and the mercury pure and free from moisture. Under these conditions the space above the column of

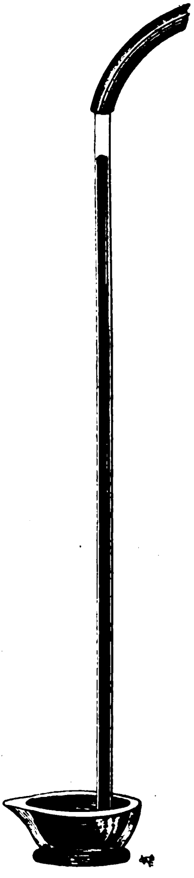


FIG. 4.
Tube filled with mercury.

mercury is perfectly free from air. This space is called the Torricellian vacuum, after the name of the Italian scientist, Torricelli, who first made a similar experiment in 1643. It is found that the size of the bore of the tube has nothing to do with the vertical height of the column, so that if we imagine a tube to have a bore of 1 sq. inch, the air would hold up 30 cubic inches of mercury. A cubic inch of mercury weighs 7·85 oz., and 30 cubic inches 14·7 lb., which is, therefore, the pressure of the air per square inch of surface.

In the making of barometers other liquids than mercury could be used, but they are all open to various objections. In the first place, they would be considerably lighter, and consequently the atmospheric pressure would support a much longer column than 30 inches. Water, for instance, is 13·6 times lighter than mercury, and therefore the column would be 30 inch × 13·6 or 34 feet, which is higher than the top of the chimneys of an ordinary two-storeyed house. Glycerine is 10·8 times lighter than mercury, and in this case the column would be 30 inches × 10·8, or 27 feet. These two liquids have been mentioned, because barometers are in existence in which such liquids have been used. Water barometers may be seen at the Natural History Museum at South Kensington, and at the Crystal Palace, and a glycerine barometer is in use at *The Times'* office, London, the readings of which are given in a diagrammatic form in that newspaper each day. The largest barometer ever made has recently been constructed by Father Alfani at Faenza, the birthplace of Torricelli. Purified oil is used, and so a column of 36·7 feet is maintained up the tube. One obvious objection to the general use of such barometers is their unwieldy size, and another is due to the fact that the space above the liquids becomes filled with the vapour of the substances, which, as the temperature rises, exerts a considerable pressure downwards, and consequently the barometer gives too low a reading.

We may say, then, that the atmosphere exerts as much pressure on the surface of the earth as would be exerted were it covered to a depth of thirty inches with mercury, thirty-four feet with water, or twenty-seven feet with glycerine.

The most accurate form of barometer is that known as the Fortin pattern (Fig. 5), which is constructed on the "cistern" principle, already described. It must be borne in mind that the height of the column is measured from the level of the mercury in this cistern, and if the tube and cistern were both fixed, as the mercury in the former fell that in the latter would rise, and so the scale for measuring the height would need continual adjustment. To avoid this, it is found easier to always adjust the surface of the mercury in the cistern to the end of a fixed ivory point, which is the starting-point of the scale. To enable this to be done, the bottom of the cistern is made of leather, and working against this from below is a screw which is moved up or down as required, until the ivory point and its reflected image on the mercury appear to just touch each other. The top of the column of the mercury in the tube is usually more or less convex, and there is in standard barometers a vernier sliding scale worked by a screw, and the bottom of this scale is brought to such a position that it appears to just touch the topmost point of the convex curve. With the assistance of the vernier, the height of the mercury can be read to a thousandth of an inch.

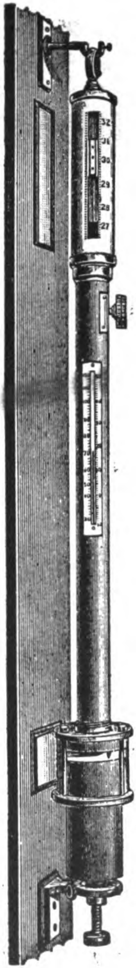


FIG. 5.
Fortin barometer.

The Wheel Barometer, a form in more general use, is constructed on a different plan. The tube in this case is shaped like a U. The long arm is about thirty-six inches in length, and is sealed, while the short arm is about seven or eight inches in length, and is open. Mercury is poured in here and worked to the closed end until the whole tube is filled, with the exception of about four inches of the short arm—an operation entailing some amount of patience and dexterity. On placing the tube as in the sketch (Fig. 6), the mercury falls somewhat in the long arm, leaving the Torricellian vacuum at the top, and the height of the column is measured from the surface of the mercury in the lower arm. This form, called a syphon barometer, is usually fitted into a banjo-shaped frame, and over the circular part an index hand moves as in a clock. This hand is made to move in the following way. A wheel is fixed to the woodwork and a thread is attached to and wound round it. At the two free ends of the thread glass floats are tied, the one shown on the right in the sketch being slightly heavier than the other. As the mercury column in the short tube rises and falls, the glass float on the top follows it, and in so doing turns the wheel to which the index hand is attached. There is usually another hand turned by a screw outside the glass protecting the face of the instrument, which is placed over the index moved by the atmospheric pressure at the time of observation. When the height is next read the extent of the movement can be readily observed. It should be pointed out if the height of the column is measured directly in the syphon barometer,

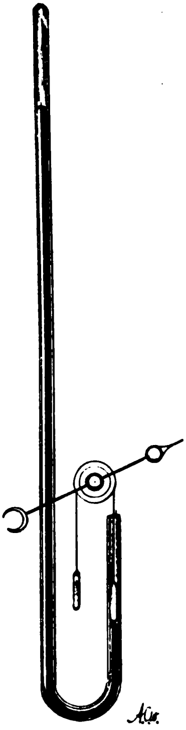


Fig. 6.
Principle of wheel barometer.

a fall, say of half an inch in the long column, means that the mercury in the short column will have risen half an inch, and that consequently the total difference in the heights will be one inch.

When mercurial barometers are used on board ship, means must be taken to maintain them as far as possible in a steady vertical position. If such a barometer deviates from the perpendicular it gives too high a reading; and the rising and falling in response to the movement of the vessel or the gusts of the wind is called "pumping." To obviate this as much as possible, in the first place the instrument is suspended in gimbals, and in the second the tube for some inches is considerably constricted. This constriction checks somewhat the barometer's action and consequently tends to deaden the "pumping."

The chief defect to which mercury barometers are subject is due to air in the space above the mercury. The presence of air may be detected by slightly inclining the tube so as to allow the mercury to flow to the top of it. If a sharp metallic "click" is heard as the mercury strikes against the top of the tube, it may be assumed that no air is present. To prevent the intrusion of air and moisture into the vacuum, a small funnel or "pipette" is sometimes inserted in the tube between the cistern and the top of the mercury column (Fig. 7). With this arrangement the air gets entrapped at the points **A** and does not affect the reading of the barometer.

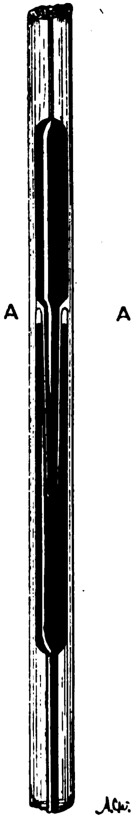


FIG. 7.
Barometer tube.

There is still another form of barometer which merits our attention, inasmuch as specimens of it far outnumber all other patterns. This is called the Aneroid (without liquid) barometer. It consists essentially of an elastic metallic box with a corrugated lid, and exhausted of air. This lid rises and falls as the pressure varies, and the movement is communicated by a system of delicate levers to an index hand which moves over a circular face (Fig. 8). As the movement is much multiplied

FIG. 8.
Aneroid.

by the levers and also by the hand, an instrument is obtained which is extremely sensitive to slight variations of pressure.

Most people buy barometers in order to get some guidance as to what the weather is likely to be, and their utility in this direction will be dealt with in a later chapter. But there is another use to which they can be successfully applied —viz. the measuring of heights. The aneroid barometer is the form usually employed for this purpose, and its chief recommendation is its portability. If the heights of mountains are under consideration it is no light thing to be embarrassed in an awkward climb with a large barometer, to say nothing of the liability to injury of the instrument itself, and the risk of spilling the mercury. Where mercury barometers are employed for measuring heights, precautions are taken in the manufacture to avoid these mischances as far as possible.

Though in respect to portability the aneroid form of barometer possesses a great advantage over the mercurial form, its use for meteorological work is restricted, and records made from it are not held to be as reliable as those from a mercurial barometer. The instrument being made of metals, its parts are liable to expansion or contraction as the temperature alters. This is likely to cause the readings to be inaccurate, though the best varieties are "compensated" to allow for this variation. In addition, friction between the parts and also the tension of the spring alter with time. Thus, to make the readings comparable with those of mercury barometers, frequent adjustments may be necessary. The adjustment can be made by turning a small screw at the back of the instrument.

It can readily be seen that as we rise in the atmosphere all that which is below us ceases to exert any pressure, and therefore the higher we go the lower will be the reading of the barometer. But the lower layers of the atmosphere are denser than those above, so that the fall for the first 1,000 feet is greater than that for the second, and for the second 1,000 feet greater than the fall for the third, and so on for each successive 1,000 feet. This diminution of pressure has been the subject of very careful investigation, and very exact results have been arrived at. But the question naturally arises, from where is the first 1,000 feet measured? The reply, at any rate as far as Great Britain is concerned, is the mean half-tide level at Liverpool, more generally, though somewhat indefinitely, referred to as the "mean sea-level.'

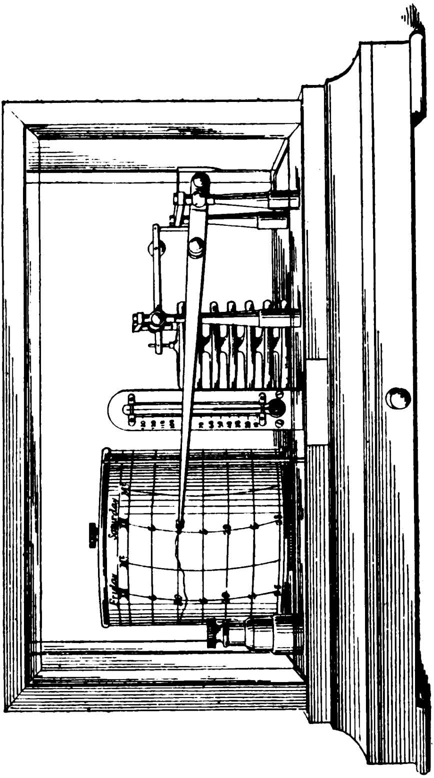


Fig. 9.
Barograph.

When the heights of the barometer recorded by different observers are compared, allowances have to be made for the different altitudes of the points of observation above the sea-level according to the following scale.

Pressure—inches.	Altitude—feet.	Difference in altitude in feet for fall of 1 inch.
30	0	—
29	910	910
28	1850	940
27	2820	970
26	3820	1000
25	4850	1030
24	5910	1060
23	7010	1100
22	8150	1140
21	9330	1180
20	10550	1220

When a considerable time elapses between consecutive readings of a barometer, it is quite possible that temporary fluctuations may escape notice. This is particularly liable to occur in unsettled weather—that is, at just those times when the behaviour of the barometer affords useful indications of the immediate prospects. To get a complete record of all changes in pressure an instrument called a Barograph is used (Fig. 9). In its most usual form the barograph consists of an aneroid box to which a system of levers is attached. These actuate a long arm carrying a pen which records on a chart wound round a cylinder revolving by clockwork once a day or once a week. It is obvious if the record is to be of any scientific value both the barometer and the clock must be of high quality, and consequently the instruments are somewhat costly.

CHAPTER III

Temperature of the Atmosphere

Our weather is so intimately connected with the temperature of the air, that some consideration must be paid to the sources of heat, its methods of transmission, and its manifestation in the rise and fall of temperature. The possible sources may be regarded as the sun, the stars, and the internal heat of the earth. The stars, as the astronomers tell us, are many of them larger than the sun, and probably as hot or hotter; but they are at distances so great as to be beyond the powers of our mind to conceive; and so far as can be ascertained they exert no appreciable effect on the temperature of the earth. We know that there is a vast amount of heat stored in the interior of the earth, evidence of which is furnished by the eruptions of geysers and volcanoes. From observations taken in mines, it has been noticed that there is a steady rise in temperature from the surface of the earth downwards. There are good reasons for believing that the moon is a cold ball, and it seems probable that in the course of ages the earth will also cool down and contract in doing so, as practically all cooling bodies do. This shrinking of the earth may cause heat to be generated by friction, yet the earth must part with a deal of heat to the atmosphere, as every warm object does to a cooler one in contact with it. This heat, however, is given out equally and constantly all over the surface of the globe, and we cannot judge to what extent it affects the air surrounding it. In any case it does not prevent us having arctic and tropical weather, or summer and winter.

Without doubt it is the sun that governs the temperature of the different parts of the earth. It is a vast globe of incandescent gases many times hotter than the greatest heat we know how to produce. This must be so when we consider that it is over ninety million miles from the earth, and that the earth's share of its heat is so small a fraction that it is quite beyond our conception; yet it is amply sufficient for the purpose of sustaining the animal and vegetable life of the earth. The sun's rays are sent out or radiated from it in straight lines in all directions; and the strange part about it is that they do not warm the space through which they pass, and no rise of temperature is experienced till they encounter some form of matter—gas, liquid or solid. Heat received in this way is called "radiant heat," and it is this radiant heat which we feel when we leave the shade and stand in the sunshine. We may reflect the rays by means of a mirror on to a thermometer in the shade, and observe a rise in temperature, or bring them to a focus by a convex lens, and so form a burning-glass. If a body reflects heat well, as for instance a burnished silver reflector, hardly any heat is used in warming it, the reflected rays departing without loss of power. Water in any form, either as snow, liquid or cloud, is a good reflector. When radiant heat encounters bodies they offer varying degrees of resistance to its passage. Some allow nearly all the rays to pass through. This applies strongly to the gases of the atmosphere, which allow nearly all the sun's rays to pass through without rise of temperature. This accounts for the fact that, though we might make an ascent in a balloon on a fine sunshiny day, the air at an altitude of a few thousand feet would be quite cold. On the other hand, some substances reflect little of the sun's rays, absorbing nearly all, with a consequent rise of temperature. The substances which form the earth's surface are of this nature, while the water, as has been said, reflects a goodly proportion and allows nearly all the remainder to pass through it, each successive layer taking a little from the power to a depth of some hundreds of yards. Almost all the heat of the air is obtained by contact with the warmer earth, that is, it is "conducted heat." As soon as the atmospheric layer nearest the soil becomes warmed, it has a tendency to expand, and from the fact of its becoming lighter, to rise through the cold layers, allowing air at a lower temperature to take its place. This ascending warm air and descending cold air form what are called "convection currents." These three method of the transmission of heat, viz. by radiation, conduction and convection, are incessantly at work, and play an all-important part in determining our weather.

It must be noted that heat rays proceeding from an intensely hot body like the sun pass without difficulty through substances like glass, yet if they come from a body say as hot as an ordinary fire, they have considerable difficulty in making their way through. This accounts partly for the general use of glass for windows and greenhouses. Any one who enters a greenhouse some hours after the sun has set, may notice how the heat has been trapped, as it were, though the glass through which the sun's rays have been entering is of no great thickness.

The Thermometer.—The instrument used for observing the temperature is the thermometer. A glass tube with a fine uniform bore is taken, and a bulb blown at one end, and a funnel-shaped cup made at the other (Fig. 10). At a little distance below the cup the tube is heated and drawn, so that the bore there is constricted. Some of the liquid which is to be used—either mercury or alcohol—is placed in the cup, and the bulb is heated. The air inside expands, and forces its way out through the liquid in bubbles. When the bubbling has almost ceased the heating process is carried on less strongly and is finally discontinued for the time being. As the air inside the bulb cools, with consequent contraction, the liquid in the cup makes its way down the tube, to take the place of the air which has been expelled. If this process goes on too rapidly, so that the comparatively cool liquid reaches the bulb while it is still hot, the glass is likely to crack, which accounts for the necessity of gradually discontinuing the heating process. If this preliminary operation has been done thoroughly, after the lapse of a few minutes the bulb will be found almost filled with the liquid. The bulb should be again heated till the liquid boils, and the vapour given off carries with it the remaining air, so that on re-cooling, we get a continuous column of liquid from the bulb to the cup, the vapour having once more returned to its liquid condition. The bulb is now heated to a temperature slightly above that which the thermometer is to finally

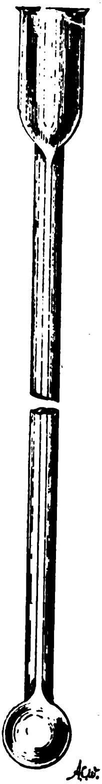


FIG. 10. Method of filling thermometer tube.

register, and while in this condition the constricted part of the tube is heated, softened and closed by means of a small blowpipe flame. This operation, which needs considerable skill, being done while the column of liquid is complete, ensures the total exclusion of air. The next step is the graduation, and the scale is determined by two fixed points called "Freezing" and "Boiling" points. The former of these is obtained by immersing the lower part of the thermometer in a funnel containing finely-divided pure ice, and noting the position of the head of the column of liquid when it becomes stationary. The temperature obtained is not necessarily the "freezing point of water," which circumstances may cause to vary, but that of the "melting point of pure ice," which is invariable.

The Boiling point is obtained by enclosing the thermometer in a vessel so that the steam from boiling water has free access to the greater part of the stem and to the bulb. This latter is not allowed to enter the water, as the temperature at which water boils is not constant. Allowance has to be made for the atmospheric pressure, as water only boils at 212° F. when the atmosphere exerts a pressure of 29·95 inches. The temperature thus obtained is called the "Boiling" point.

Having obtained these two fixed points, the stem of the thermometer is graduated in degrees. In practice, however, the instrument makers do not determine the freezing and boiling points for each thermometer. They use another thermometer which has been compared with a recognized standard, and mark off from it the divisions which they wish to graduate on the tube of the thermometer they are making.

The Fahrenheit scale is that most generally used in Great Britain, and in this the freezing point is numbered 32° and the boiling point 212°. Most of the continental nations use the Centigrade scale, in which the freezing point is 0° and the boiling point 100°. In Russia, however, the Réaumur scale is in use, the freezing point being 0° and the boiling point 80°.

The origin of the Fahrenheit system is of interest. The inventor made a mixture of ice and salt, and by this means he obtained a temperature which he considered the lowest possible. This temperature he called 0° or zero. Also he was aware that the temperature of the blood of normal human beings was practically constant. This gave him his second fixed point, which he called 96°. Having fixed on the value of his degrees, he found out the freezing and boiling points of water, 32° and 212°. It was discovered, however, that a mistake had been made in the blood temperature, which is not 96° F. but 98°·4.

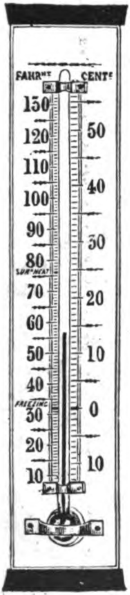


Fig. 11. Thermometer.

Scientists in many parts of the world are in favour of using the Centigrade system. Consequently in the perusal of scientific works it is often an aid to intelligibility if one can readily turn degrees of one system into degrees of the other.

180° Fahr. (212° - 32°) are equal to 100° C.
∴ 9° Fahr. „ 5° C.

If we wish to turn degrees Fahrenheit to degrees Centigrade (Fig. 11) we first subtract 32° and then take $\frac{5}{9}$ of the answer. If we wish to reverse the process we multiply the degrees Centigrade by $\frac{9}{5}$ and add 32° to the result.

$$x^\circ \text{ F.} = \frac{(x - 32^\circ)\, 5^\circ}{9} \text{ C.}$$

$$x^\circ \text{ C.} = \tfrac{9}{5}\, x + 32^\circ \text{ F.}$$

In the Appendix will be found a Table for the conversion of temperatures of the one system into those of the other (p. 123).

For meteorological purposes the tubes or stems of the thermometers are mounted on wood or porcelain, and are so suspended that the bulb is fully exposed.

Of course, the ordinary thermometer shows the temperature at the time at which it is observed. For the purpose of ascertaining how high or how low the temperature may have been during any interval, self-registering thermometers

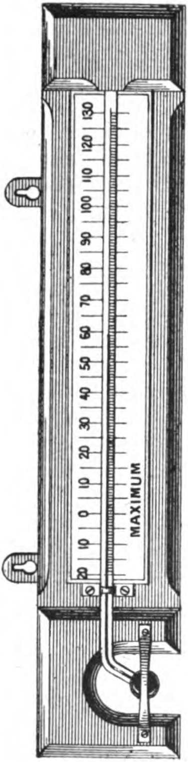


Fig. 12.
Negretti and Zambra's Maximum Thermometer.

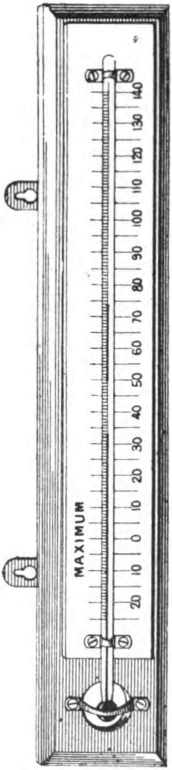


Fig. 13.
Phillips' Maximum Thermometer.

are used, one for the highest or maximum, and one for the lowest or minimum temperature.

The usual maximum thermometer is the Negretti & Zambra pattern (Fig. 12). This is hung so that the stem is in a horizontal position. At the bend of the tube a tiny piece of glass has been inserted in the bore and nearly fills it. When the temperature rises the mercury forces itself past the obstruction, but when the temperature falls the piece of glass acts as a valve and so prevents the mercury from returning. Thus the further end of the mercurial column indicates the maximum temperature. After a reading has been taken the instrument is reset by inclining it bulb downwards and giving it a gentle shake.

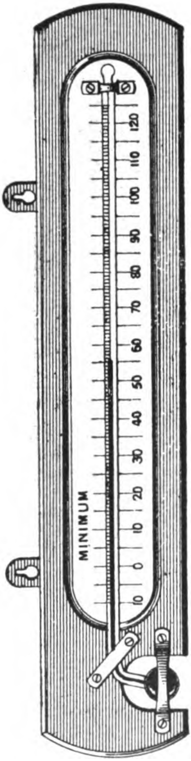


Fig. 14.
Minimum Thermometer.

Phillips' maximum thermometer (Fig. 13) is one in which a portion of the mercurial column is separated from the main body by a bubble of air. When the temperature rises, the whole column moves forward; but when it falls, the detached portion which is beyond the air bubble remains stationary, and so indicates the maximum temperature. It is reset by holding it in a sloping position and gently tapping the bulb end of the frame.

The usual form of minimum thermometer contains alcohol, and in the liquid in the tube is immersed a pin or index (Fig. 14). As the alcohol contracts on cooling, it draws the index down along with it, but on a rise of temperature the liquid passes the index, leaving it at the lowest point to which it has been drawn. The minimum temperature is read from the end of the index furthest from the bulb. The thermometer is hung horizontally, and when it is required to be set, it is taken from its supports and held in a sloping position till the index reaches the end of the column of liquid. If the thermometer is shaken too violently in this operation, the column of spirit may become divided. Sometimes, too, especially after great heat, it may be found that some of the alcohol has evaporated and become condensed in the upper part of the tube. From either of these causes a minimum thermometer may give too low a reading.

There is yet another form of thermometer occasionally met with, viz. Six's Thermometer (Fig. 15). This instrument registers both the maximum and minimum temperatures. It consists of a tube bent as in the sketch, with a bulb at each end. The lower portion of the tube is occupied by mercury, and the upper parts of the two arms by alcohol. Above the mercury on each side is an index which is lightly held in its place by a fine hairspring. The bulb shown on the right in the illustration is not completely filled with alcohol. As the temperature rises the whole column of liquid expands and tends to fill the vacant space referred to. When the mercury in the right-hand column encounters the index it pushes it forward, and the reading at the lower end of this index gives the maximum temperature. The index in the other column is similarly acted upon when the temperature falls, and the lower end gives the minimum temperature. Thus the low

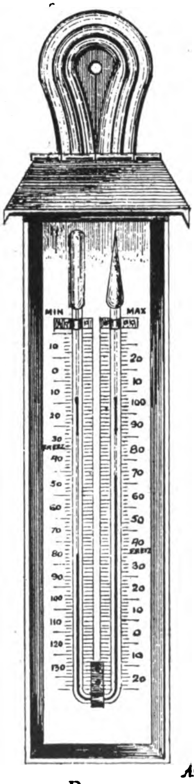
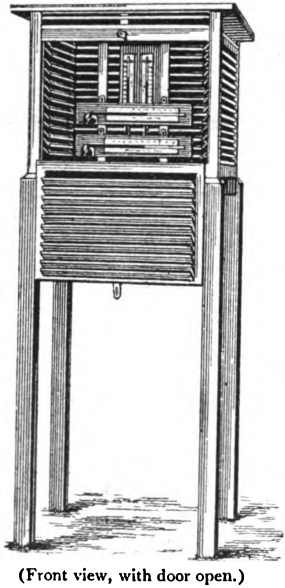


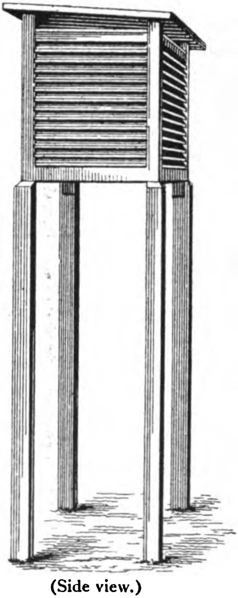
FIG. 15.
Six's Thermometer.

temperatures in the latter case are at the top of the scale. This thermometer need not be taken from its supports for setting, as the steel indexes can be brought to the heads of the mercury columns by means of a magnet. This kind of instrument is largely used in gardens and greenhouses.



(Front view, with door open.)

Fig. 16.



(Side view.)

Fig. 17.

Stevenson Thermometer Screen.

Temperature observations.—When the thermometers are intended to show the temperature of the air, they should be mounted in such a manner that they thoroughly represent the actual conditions of the place. They should therefore be fixed facing the north, so that the sun cannot shine on them, and they should be so placed that they are not affected by radiation or reflected heat from the ground or surrounding objects. It is desirable that they should be about four feet from the ground.

At regular meteorological stations an arrangement called a "Stevenson Thermometer Screen" is employed for exposing the thermometers (Figs. 16 and 17). From the illustrations it will be seen that it is a kind of box with louvred sides, that is, the sides are so made that they somewhat resemble a venetian blind, the laths being so inclined that the sun cannot shine directly into the inside. This ensures free ventilation and protects the thermometers from the effects of radiation. The screen should be placed in the open, over grass, and with the door opening to the north.

For strictly comparable observations it is desirable that the various thermometers and other meteorological instruments should be verified at the National Physical Laboratory, Kew Observatory. This is done by comparing them with the standard instruments, a small fee being charged for the certificate of verification.

The usual hour for reading the instruments is 9 a.m. At so-called "second order stations," where observations are taken twice a day, the hours of reading are 9 a.m. and 9 p.m.

From the readings of the maximum and minimum thermometers we obtain the highest and lowest temperatures which have occurred during the previous twenty-four hours. The average of these gives the "mean temperature" of the day. The difference between these two readings gives the "range of temperature." It is very important that the "range of temperature" should be considered in conjunction with the "mean temperature." A place may have a high maximum and a low minimum temperature which might give the same "mean" as another place where the "range" had been only a few degrees. Verification of this can be obtained from any "Daily Weather Report." Thus on a certain day in June 1908, the maximum and minimum temperatures at Stockholm were 68° and 46°, giving a "mean temperature" of 57°; at the Scilly Isles the corresponding figures were 61° and 53°, which give the same "mean temperature," though the "range" in the first case was 22°, but only 8° in the second. Thus we see the maximum and minimum thermometers, as their names imply, give us the highest and lowest readings for a given period, but they give no inkling of the variations which may have taken place in the interval.

From 1840 to 1847 regular observations at the Royal Observatory, Greenwich, were taken every two hours day and night, in order to find out the diurnal range of temperature,

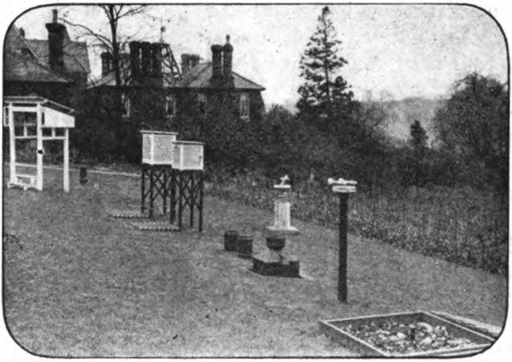


Fig. 18.
Meteorological station at Berkhamsted.

and to note the changes which are continually taking place. Since 1847 continuous records have been obtained there, and also at several other observatories from instruments which record the variations of temperature by means of photography. Such an instrument is called a thermograph.

During recent years another and much cheaper pattern of thermograph, invented by MM. Richard Frères of Paris, has come into general use (Fig. 19). A sheet of paper is fixed to a vertical cylinder which revolves by clockwork, usually one revolution a week. This paper is divided vertically into two-hour intervals, and horizontally into degrees of temperature. The thermometer consists of a metal tube, flattened and somewhat curved. This contains alcohol or ether, which, as it expands with a rise of temperature, tends to straighten out the curve. One end of the tube is rigidly fixed to the body of the instrument, and the other end, which moves, is attached to a system of levers, which in turn cause a pen to trace a line on the chart covering the revolving cylinder. A thermograph is an essential instrument to a well-equipped meteorological station, and the records furnish important information as to the temperature changes and the

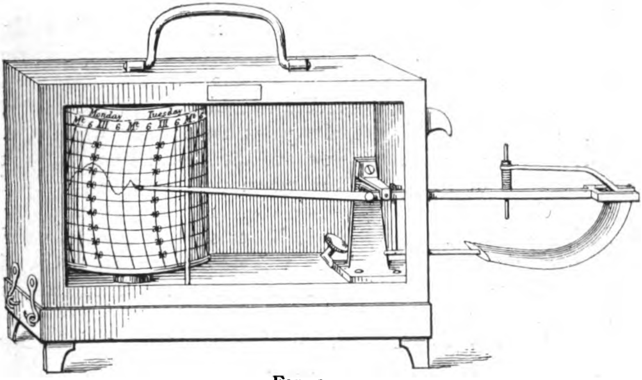


FIG. 19.
Thermograph.

times at which they occur, especially those accompanying storms and changeable weather.

From the data furnished by these records, we find that the minimum or lowest temperature occurs just before sunrise, that the temperature then rises until about one or two o'clock in the afternoon, when the maximum or highest point for the day is reached; after which the temperature falls throughout the afternoon and night until the minimum is again reached about sunrise.

In bright, clear weather the range of temperature is very considerable, but in dull, overcast weather the range is usually much smaller.

The accompanying illustrations (Fig. 20) show the average diurnal range of temperature for the year at the Royal Observatory, and also the range when the sky is either cloudless or overcast.

If the average daily mean temperature for the year be plotted in diagrammatic form, as in Fig. 21, it will be seen that the coldest period occurs about the second week in January, after which the temperature rises with various irregularities until about the middle of July, when the warmest period is reached. The temperature then begins to fall, at first slowly and afterwards more rapidly, until the coldest period is again reached in January. Thus, on the average, January is the coldest month of the year and July the warmest.

There are certain well-marked irregularities in the curve, which so long a period as fifty years has not smoothed out. The most noticeable of these are the "cold days" about the middle of May, and the warm period at the end of November. The cold spell in May is much dreaded by florists and fruit growers, as it is occasionally accompanied by frosts which may destroy in a single night whole crops of young flowering plants in the nursery, or the fruit blooms in the orchard.

Extremes of temperature.—In summer time our temperature may reach 90° F. in the shade, but very seldom exceeds 93°. The only instances in which it has exceeded 94° at Greenwich Observatory since 1841 are the following:—

Degrees.	
94·5	June 16, 1858.
96·6	July 22, 1868.
97·1	July 15, 1881.
94·2	August 11, 1884.
94·2	August 17, 1893.
95·1	August 18, 1893.
94·3	August 31, 1906.
95·6	July 22, 1911.
100·0	August 9, 1911.
94·1	September 8, 1911.

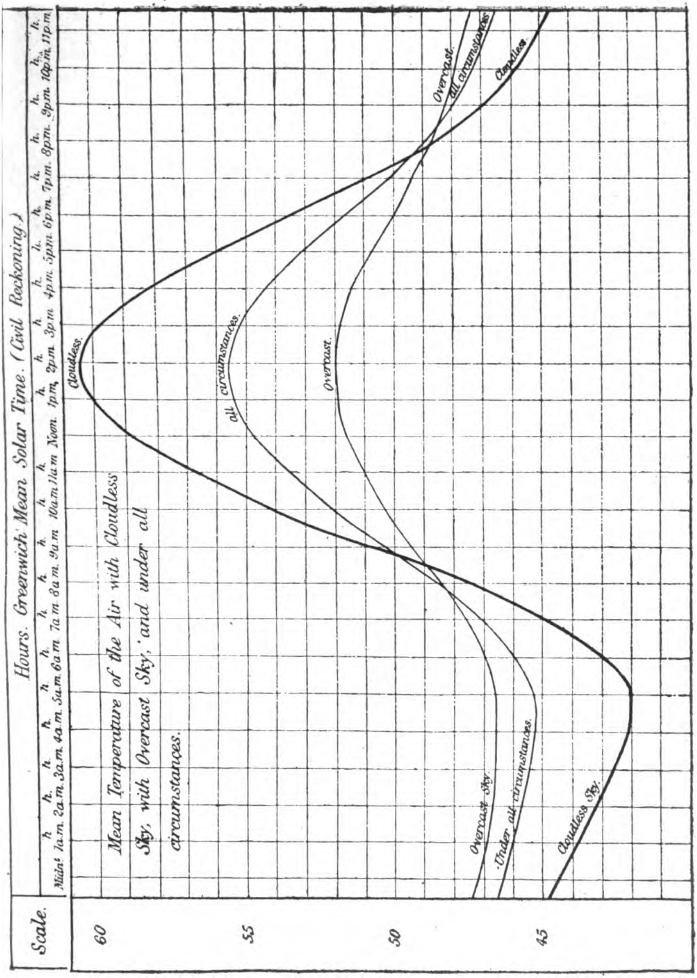


Fig. 20.
Diurnal range of temperature.

In winter the temperature may fall to 10° or lower. This has only happened ten times at Greenwich since 1841, the lowest of which were the following—

Degrees.	
4·0	January 9, 1841.
6·6	January 5, 1867.
6·9	February 8, 1895.

Lower temperatures than these, however, have been recorded in other parts of the British Isles, which are favourably situated for nocturnal radiation, as for instance: − 23° at Blackadder, Berwickshire, on December 4, 1879; and − 17° at Braemar, and − 11° at Buxton, Derbyshire, on February 11, 1895.

Very occasionally we have spells of prolonged frost. The prolonged frosts in London during the last century were as follows—

1813	Dec. 26–1814, Feb. 5	42 days
1838	Jan. 5–Feb. 23	50 „
1855	Jan. 10–Feb. 25	47 „
1860	Dec. 15–1861, Jan. 19	36 „
1879	Nov. 14–Dec. 27	44 „
1881	Jan. 7–26	20 „
1890	Nov. 25–1891, Jan. 22	59 „
1895	Jan. 22–Feb. 20	30 „

Such frosts as these impress themselves on the memory and appeal to the imagination. They are the "good old-fashioned winters" of our grandfathers, and of the Christmas Annuals.

During the severe frost of 1895, thermometers placed in the soil showed that the frost penetrated to a depth of three feet, and as a consequence many water pipes, not laid to that depth, burst.

Isothermal Maps.—It has been mentioned that the air gets cooler as we ascend from the earth. This rate of cooling is about 1° F. for every three hundred feet. If, therefore, we apply such a correction to the temperature made at stations at different altitudes, we can reduce all the readings to the

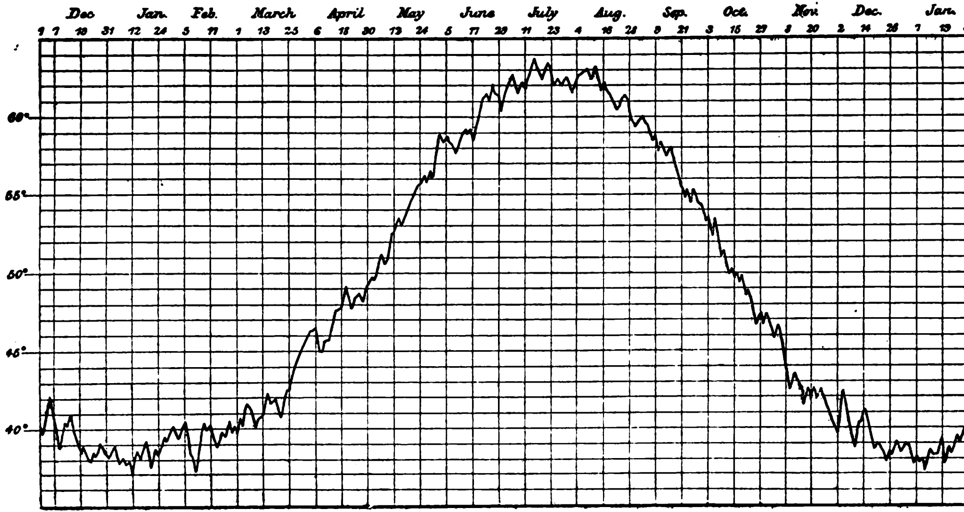


FIG. 21.

Average daily mean temperature at Greenwich.

sea-level temperature. When this has been done we can make a map showing the distribution of temperature.

Such a map may be prepared as follows: Having reduced the temperatures to sea-level, first plot the readings on the map in the positions of the stations. Then draw lines through those places having values of 10°, 20°, 30°, 40°, etc. If stations have intermediate temperatures, estimate where the temperature would accord with these 10° values and continue the lines. Do the same for the 5° values. It will then in all probability be found that there are some continuous lines encircling smaller ones—the innermost of which will represent the area of the highest or of the lowest temperature as the case may be. If we put the temperatures on these lines we can then rub out or dispense with the readings at the individual stations, and so have a clear map, showing the distribution of temperature by means of lines. These lines are called "isotherms," or lines of equal temperature; and such maps are called "isothermal" maps.

Figs. 22 and 23 are isothermal maps of the British Isles for the winter month of January and for the summer month of July. We find that in January (Fig. 22) the mean temperature is highest along the south-west and west coasts, and lowest over the north-eastern inland districts. It ranges from 43° to 45° along the western and southern coasts of Ireland and the south-western coasts of England, to less than 40° over the inland parts of the north of Ireland, and to less than 38° over the inland and eastern parts of Scotland and England.

In July (Fig. 23) the conditions are reversed, for the inland districts are now much warmer than the coasts. The warmest region is the valley of the Thames, where the temperature is over 64°.

We thus see that the range of temperature is much greater inland than on the coast. The land areas are cooler in the winter and warmer in the summer, while the sea has a moderating effect on the temperature of the air round the coasts. The high temperature in the west and south-west during the

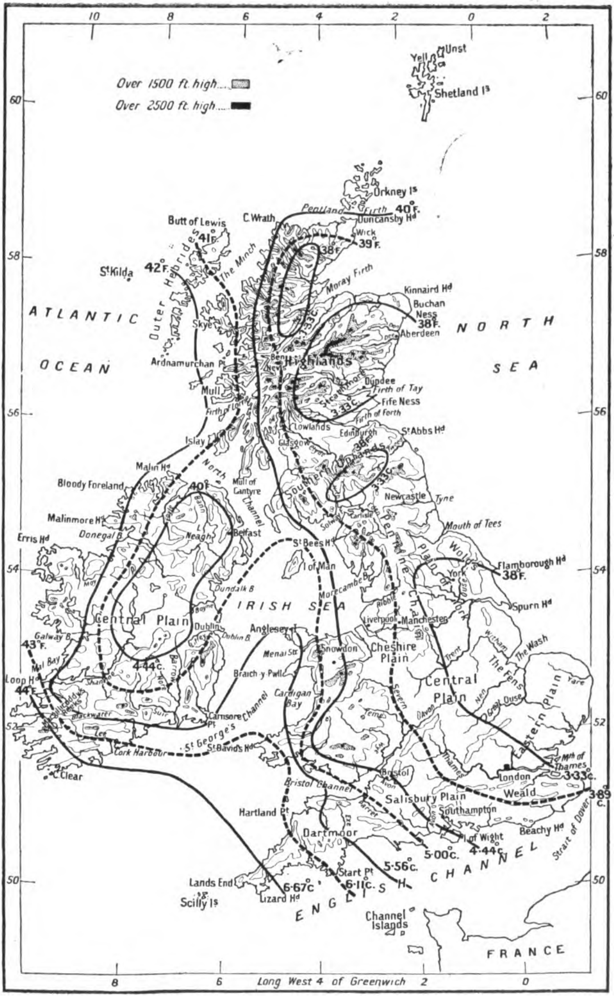


Fig. 22.

Isothermal map of the British Isles for January (Buchan).

Fig. 23.

Isothermal map of the British Isles for July (Buchan).

winter months is due to the influence of the warm water of the Atlantic.

If we refer to an isothermal map of the world for the month of January, which is winter time in the northern hemisphere and summer time in the southern hemisphere, we shall find that the mean temperature is below the freezing point over a large part of the northern hemisphere. The region of greatest cold is in Siberia, where, at a place called Werchoyansk, the mean temperature is $-50°$ F. (that is, 82° below the freezing point). Instead of the isothermal lines decreasing uniformly in value from the equator northwards, there is a most remarkable divergence over the Atlantic and north-west coasts of Europe. This is caused by the warm waters of the Gulf Stream flowing in that direction and considerably raising the air temperature. The warmest districts are in the neighbourhood of the equator, where the temperature is above 80°.

An inspection of the isothermal map of the world for July shows a great change from that of January. Instead of temperatures below freezing point over the greater part of the northern hemisphere, we find that the temperature is well above the freezing point. Also in Siberia, where the temperature had been $-50°$ in January, it is now $+50°$, thus showing a rise of 100° in the mean monthly temperature from January to July. We also find that the hottest region is north of the equator over Africa, Arabia, etc., where the temperature exceeds 90°.

CHAPTER IV

Sunshine

In connection with the question of heat, the amount of bright sunshine received by various places is of considerable importance. Sunshine has a cheering effect upon all; it gives fresh life to the weak and diseased, and it behoves every one to spend as much time in it as he conveniently can. Our dwelling-places are all the better for it; and a house built on a site that receives a full measure of sunshine is much more likely to be healthy than one that is in the shade for most of the hours of daylight. So, if possible, we should live in houses on the slope of the hill that faces the south, and spend most of the indoor hours in the rooms upon which the beneficial sunlight has played. What applies to our bodies applies to many kinds of crops. These require not only a certain temperature, but the bright rays of the sun to bring them to perfection.

Speaking generally, seaside places, especially along the South Coast, enjoy a greater amount of sunshine than inland districts. The following are the average monthly amounts of bright sunshine in hours in various parts of England—

Month.	Brighton.	Oxford.	Llandudno.	Falmouth.	Southport.	Lowestoft.	Durham.
January	53	48	48	57	41	52	44
February	76	66	70	83	65	78	66
March	133	113	111	138	111	141	113
April	171	151	156	179	163	174	133
May	221	195	206	236	213	229	170
June	223	193	204	227	207	224	171
July	235	203	185	228	199	230	168
August	217	185	167	213	171	211	150
September	165	145	129	160	131	169	118
October	120	101	88	117	89	114	89
November	68	57	55	73	47	65	53
December	49	41	37	55	29	45	42
Total for year	1731	1498	1456	1766	1466	1732	1317

The duration of bright sunshine is obtained from what are called "Sunshine Recorders." The instrument in most general use is the Campbell-Stokes recorder (Fig. 24).

The rays of the sun are brought to a focus by the glass ball on to a strip of card, which is of such a nature that the heat is sufficient to burn it. This card is marked in hours and half-hours, and as the sun journeys through the heavens from east to west it burns its own record. The total length of the charred portion on the card on the scale referred to gives the duration of bright sunshine for the day.

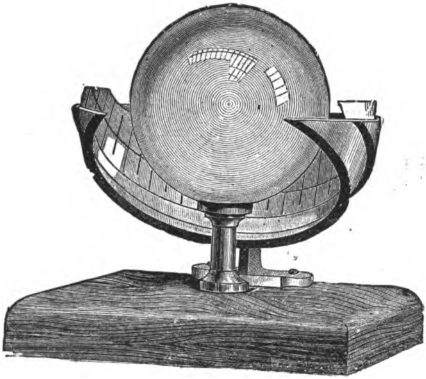


FIG. 24.
Campbell-Stokes sunshine recorder.

Another form of sunshine recorder is the Jordan Photographic Recorder. This consists of a cylindrical box, on the inside of which is placed a sheet of sensitive cyanotype paper. The sunlight, which is admitted into the box by two small apertures, acts on the paper, and so the sun, in his journey from east to west, leaves a distinct trace of chemical action. The record is fixed by the paper being immersed in water for a few minutes.

Both these recorders must be carefully adjusted to the meridian and to the latitude of the place.

CHAPTER V

Moisture of the Atmosphere

THE moisture of the air in its many manifestations in the form of rain, snow, hail, clouds and fog, plays an important part in determining our weather. For the proper understanding of this we must have a clear idea of what the term "*saturated*" air means. Imagine a large glass bell jar closely fitting to some flat surface. The top of the jar should be closed by a rubber cork through which passes the stem of a funnel. This funnel should be fitted with a stop-cock, and in it should be placed some water. Turn the stop-cock so that one drop of water falls through from the funnel. If this experiment is performed on a thoroughly dry day the drop of water will evaporate. Allow another drop to fall, and possibly it will also evaporate after a longer interval. Continue the process, and in time you will find that no more water will evaporate however long you may wait. The air in the jar is said to be saturated for the temperature of the air inside. That is because the volume of air is holding as much water as it can possibly take up at that temperature. If now the air inside the jar be warmed, it will be found that additional water will evaporate, but after a time the air becomes once more saturated. This process can be continued if the temperature is further increased.

It has been found that a given volume of air will hold a definite amount of water as vapour for a given temperature. The air, when it holds this amount, is said to be saturated. If the temperature is lowered slightly, the air will part with some of its moisture, and part of this will be deposited in the form of tiny drops on the sides of the jar. If the air were suddenly cooled several degrees, the jar would be seen to become full of fog, mist or cloud. This is what really happens when we breathe out of doors on a cold winter's day. The air as it leaves our lungs is charged with water vapour, and being suddenly cooled, a miniature cloud consisting of minute globules of water is formed as it issues from the mouth. The cloud in the jar referred to above would not last long. The air in the jar would clear, but it would be seen that there was an increased deposit of drops of water on the sides of the vessel. Air, then, which is kept in contact with the surface of water, will become saturated in time. Both cold air and warm air can be saturated, but the warm air holds a larger amount of moisture per unit volume than does the cold air.

Whether the air is saturated or not makes a great difference to our feelings. This is largely due to its effect upon the evaporation which is continually taking place from our skins. Nature has made provision for a certain quantity of water to leave our bodies in this way. If the air is very moist, this evaporation does not take place; but on the other hand, if the air is very dry, the evaporation may take place too rapidly. A cold winter's day when the air is saturated produces a chilly feeling which seems to penetrate to our bones. This we often experience in the moist climate of the British Isles, with a temperature very little, if at all, below freezing point; while in Canada, with a temperature approximating to 0° F., the air being dry, the sensation of coldness is not nearly so great. A very dry winter's day, however, causes evaporation to take place so rapidly that the delicate skin is often injured, and chapped hands and faces result.

We all feel a hot, moist summer's day to be oppressive and "muggy." The skin is not able to get rid of its proper amount of moisture, and so it feels clammy, and we have a general sense of discomfort, due largely to the unaccustomed effort of other parts of the body to perform the work left undone by the skin. The temperature, however, may not be so very high; in fact, the hottest days of the year sometimes pass without people noticing that they are such, if they should happen to be fairly dry. Travellers find it much easier to sustain high temperatures with a fairly dry atmosphere, than lower ones if the air is humid. The hot air of summer takes a larger quantity of moisture from our bodies than the cold air of winter, and the need of replenishing the supply is greater in the former case; and hence the feeling of thirst, which is much more apparent in the hot than in the cold part of the year.

Humidity.—The consideration of the dampness or humidity of the air is then of very great importance. A cubic foot of air at 32° when saturated holds 2·1 grains of aqueous vapour; at 50° it would hold 4·1 grains. If in the latter instance it were found to hold 2·5 grains, the air would be considered to be rather dry, and the proportion between what there is to what there might be would be expressed by the fraction $\frac{2 \cdot 5}{4 \cdot 1}$, or ·61.

This value is called the "Relative Humidity." If, on the other hand, it were found that there were 3·5 grains, the relative humidity would be ·85—a high value—and the air would be considered very damp. But should the temperature be 77°, 10 grains of aqueous vapour would be necessary to saturate a cubic foot of air, and the presence of 4·1 grains in the same volume, sufficient for saturation at 50°, would cause the air to be considered moderately damp. (Table II, p. 124, gives the weight in grains of a cubic foot of vapour at temperatures from 20° to 99°.) Thus, on what we should call a dry day (low relative humidity) in summer, there may be as much aqueous vapour in the air as on a damp day (high relative humidity) in winter. The aspect that most affects us is whether the air is dry or damp *when the temperature is taken into consideration.* With low relative humidity moisture is continually being absorbed by the air from every available source, the ocean, rivers and ponds, all vegetation, the damp earth, and from the bodies of every living thing. As the relative humidity reaches a higher value evaporation still goes on, but at a slower and slower rate, till it practically ceases when the maximum value of unity is reached.

There are many signs by which we can recognize that the air is damp. A piece of seaweed contains salts that readily absorb moisture, and so it becomes damp before rain. If, however, the seaweed hangs out of doors and is washed many times by the rain, these salts are largely dissolved out, and it does not act so readily. A saucer full of common salt placed in a covered position out of doors answers the same purpose, and for the same reason. The threads of a spider's web hang loosely in moist weather and tighten up in dry. Catgut strings of musical instruments moisten and lengthen, and so cause the instruments to get out of tune. Use is made of catgut to actuate an old-fashioned device for foretelling rain or fine weather, called the Dutch Weather House. This consists of a cardboard representation of a cottage with two doors. Within these doors are the figures of a man and a woman which are so arranged that as the air becomes damp the man comes out of the door and the woman retires, and when the air is dry the woman comes out and the man goes in.

Some substances contract when moisture is absorbed, as for instance ropes. The contraction in the supporting rope of a tennis net, if the air is very damp, is sometimes great enough to break the supporting pillars at the end. The guy ropes of tents, after rain or heavy dew, sometimes pull out the pegs fastening them to the ground, with possible uncomfortable results should there be any sleeping occupants. Wood, especially if not oiled or varnished, absorbs moisture readily. This causes the joints of furniture to swell—with possible creaking. Doors and windows get jammed for the same reason.

Some woods absorb moisture more readily than others, and use of this fact can be made to fashion a piece of apparatus by means of which you can tell at a glance the degree of dampness of the air. Two strips of wood are needed, say one teak and the other soft deal. They should be about eighteen inches long, three-quarters of an inch broad, and one-eighth of an inch thick. Some care is needed in joining them together, but small screws will answer, say ten in five couples at equal intervals. If one end is now firmly fixed into a block of wood so that the double lath is in a vertical position, it will be ready for use. On exposure in the open air, for instance on a window sill, the lath will bend considerably in one direction when the air is very damp, and in the other when it is very dry. A scale can be fixed at the back and graduated by trial. The action of a fir cone under the influence of moisture is doubtless due to a similar action. Here, however, the wood is of one kind, but there is a difference in texture between the upper and lower surfaces of the scales. As a result of this, in dry weather the scales stand out well, while in damp weather they close on one another. A good-sized fir cone hung outside the window furnishes a very good indication as to the moisture of the atmosphere. The sweating of walls and some sorts of cement is looked upon as a sign of rain. It must not be imagined, however, that the moisture really comes from the walls, etc. The dampness is either due to some constituent absorbing the abundant moisture in the air, as in the case of the seaweed, or more frequently because the walls are colder than the air and so condense the moisture, with the result that some is deposited. A similar result is liable to occur in the cabins of iron ships, and to prevent the moisture trickling down the walls they are covered with a special paint containing cork ground in very small pieces.

Hygrometers.—The instruments used by weather observers in this country for measuring the amount of moisture present in the air are the dry- and wet-bulb thermometers (Fig. 25). These are two ordinary and precisely similar thermometers fixed to a wooden frame and placed in a Stevenson screen. The dry-bulb thermometer shows the temperature of the air. The wet-bulb thermometer has the bulb covered with a piece of muslin which is kept wet by a conducting thread passing into a small vessel of water. If the air is dry, the moisture evaporates from the damp muslin, and in doing so lowers the temperature. Consequently the wet-bulb thermometer gives a lower reading than the dry-bulb. If there is a considerable difference between the two readings, it indicates that the air is very dry, but if the readings are alike it shows that the air is saturated with moisture. By using the readings in conjunction with hygrometrical tables the amount of moisture actually present in unit volume of the air can be ascertained, or alternatively

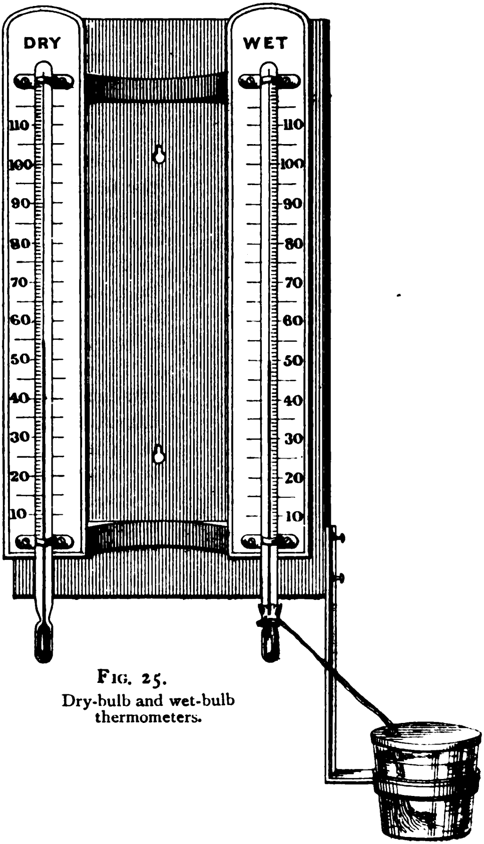


FIG. 25.
Dry-bulb and wet-bulb thermometers.

the relative humidity can be found—that is, the ratio between the actual amount of moisture present in the air to what there would be if it were saturated at the temperature of the dry-bulb thermometer.

Table III (p. 125) gives the relative humidity for each 10° of temperature from 30° to 90°, and for every degree of difference between the dry-bulb and wet-bulb readings from 0° to 16°.

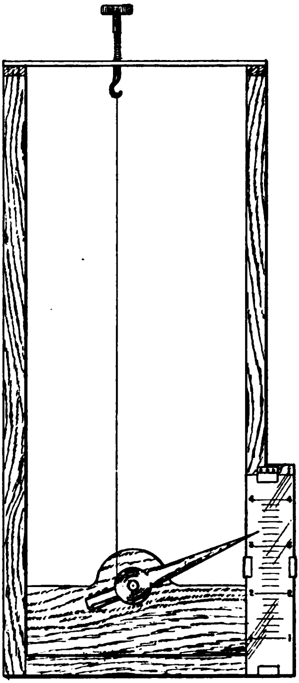


FIG. 26.
Principle of Saussure's Hair Hygrometer.

In cold countries, where the temperature in winter is persistently below the freezing point, the hair hygrometer is mostly used. In this instrument a human hair is fitted vertically into a frame. The upper end is fixed and the lower is attached to a small drum or barrel, on the face of which is an index. When the air is moist the hair lengthens, and *vice versâ*, and the degree of moisture is indicated by the movement of the index over a graduated scale (Fig. 26).

Dew and hoar frost. —Any mass of air containing water vapour will, if cooled sufficiently, be reduced to a temperature at which condensation will take place and moisture be deposited. This temperature is called the "dew point."

Any one desirous of finding the dew point at any time can do so in the following manner. A small vessel with a highly polished exterior is partially filled with water. A metal vessel or a glass beaker will serve, and the latter is made very efficient if the inside is coated with Brunswick black. The bulb of the thermometer is placed in the water, and can be used as a stirrer. On the addition of a small piece of ice, the temperature of the water falls, and if a careful watch is kept it will soon be noticed that the outside of the vessel becomes dimmed owing to the deposition of dew. The temperature at which this deposition commences is called the dew point. Ice may not always be available, but a very good substitute is ammonium chloride (sal ammoniac), which is cheap and more readily stored than ice. This salt as it dissolves absorbs heat and soon lowers the temperature of the water below the dew point. The photographers' hypo and many other salts will answer equally well. To get an accurate result the air near the vessel should be kept quite still, and the observer should take care not to let his moist breath or the heat of his body influence the result.

A similar process goes on in the atmosphere, and if condensation occurs above 32° F. the product will be water; if below 32° it will be ice in the form of frost, snow or hail. This condensation from still air or cold surfaces frequently accompanies the diurnal changes of temperature in the atmosphere. As the temperature rises in the morning any moist surface rapidly yields vapour to the warming air. As a rule the increase of temperature goes on so rapidly that the supply of vapour does not cause saturation. During the morning hours, even though the actual amount of vapour in unit volume, viz. the absolute humidity, increases, the proportion between the amount of moisture held by the air to what could be held, viz. the relative humidity, quickly falls. During the first hours of the afternoon, if evaporation continue from the warmed ground into the warm air, the absolute humidity still increases slowly, but now the temperature is falling and the capacity for vapour is thereby decreasing; as the afternoon advances, the relative humidity rapidly increases. About sunset in well-watered regions, the air close to the ground becomes nearly saturated, as we know from the growing dampness of the grass, and from this time onwards the further cooling of the ground by radiation and conduction, and the consequent cooling of the air next to it, causes the continuous deposition of vapour in the form of dew, or hoar frost (Fig. 27). The whole of the dew or hoar frost, however, does not come from the air, some part being formed from the moisture from the soil, and from the

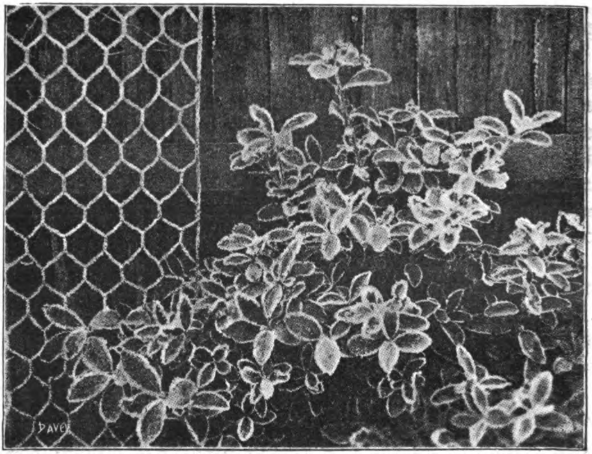


FIG. 27
Hoar frost.

leaves of plants. If the ground is covered with vegetation the leaves become colder than the ground beneath them. The vapour rising from the ground will then be in good part condensed on the cold leaves before any appreciable moisture is noticed on the bare earth. For a similar reason dew will be found sooner on the metal part of a spade than on the wooden part, the iron parting with its heat much quicker than the wood.

Dew does not form on windy nights, as the air in contact with the earth does not remain long enough to become saturated, but is whisked away, fresh air taking its place. On cloudy nights the heat that is radiated from the earth is checked or reflected back by the clouds, thus keeping the temperature of the air warmer than it otherwise would be and enabling it to hold the moisture it happens to carry. At first sight it might appear that hills would receive more dew than valleys. As a matter of fact, though the summits of hills cool quicker than the valleys, there is more air movement there, which, as has been explained, hinders the deposit of vapour.

If any considerable thickness of the air is cooled to the dew point, the tiny globules of water vapour become visible in the form of mist or fog. Should this process occur in the higher regions of the atmosphere, clouds are formed.

CHAPTER VI

Clouds

Clouds formed at temperatures above 32° consist of very minute spherical drops of water. If formed at temperatures below 32° they consist of minute spicules of ice which may cohere, and become snowflakes. Clouds formed of such particles prevail in the upper regions of the atmosphere in all parts of the world. The constituents of clouds, whether ice crystals or water globules, are ordinarily so minute that they fall very slowly through even so light a medium as air, and a slight upward current is sufficient to cause them to ascend. As they increase in size they fall at a faster rate. Were it not for the resistance of the air, a drop of water, though it is a liquid, falling from the height of half a mile, would be as dangerous as a bullet.

A Quaker gentleman named Luke Howard, in 1803 devised a nomenclature for the various forms of cloud. This was generally in use until about fifteen years ago, when an

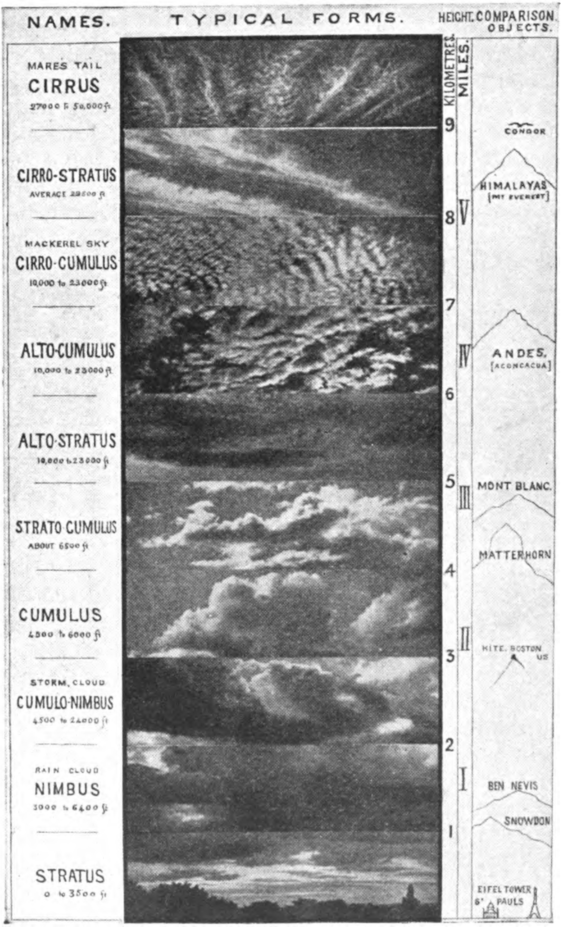


Fig. 28
Clouds.

International Conference of Meteorologists agreed to the following classification of the clouds (Fig. 28), which is now universally employed—

Name.	Abbreviation.	Approximate altitude.
Cirrus	Ci.	5–10 miles.
Cirro-stratus	Ci.-st.	Average 5 miles.
Cirro-cumulus	Ci.-cu.	2 to 4 miles.
Alto-stratus	A.-st.	2 to 4 miles.
Strato-cumulus	St.-cu.	About 1¼ miles.
Cumulus	Cu.	About 1 mile.
Cumulus-nimbus	Cu.-nb.	1 to 4 miles.
Nimbus	Nb.	½ to 1¼ miles.
Stratus	St.	0 to ¾ mile.

Some of these forms deserve special attention.

The *Cirrus* [Latin *cirrus*, a curl or lock of hair] or Mare's tail clouds generally present the appearance of a lock of hair streaming out, but occasionally they may be noticed in light tangled feathery masses. They are very delicate and fibrous looking, and from their great height must consist of ice particles. Their height, also, prevents us from forming a true idea of their rate of movement, which observers have calculated to be sometimes from fifty to a hundred miles per hour. Cirrus clouds are often the first indication of a coming change of weather, especially if they develop into the denser forms.

The *Cirro-cumulus* [Latin *cumulus*, a heap] type of cloud forms what is called the "mackerel sky." These clouds consist of small globular masses or white flakes arranged in groups. Some people consider them to look like a flock of sheep lying down.

The *Strato-cumulus* [Latin *stratum*, a layer] type consists of large globular masses of dark clouds frequently covering the whole sky, especially in winter. Patches of blue sky are often visible through the intervening spaces, and the cloud may be distinguished from the Nimbus variety by its globular or rolled appearance, and also because it does not bring rain.

The *Cumulus* [Latin *cumulus*, a heap] clouds resemble large dome-shaped heaps of wool, and are usually seen in fine weather during the daytime. When these clouds are opposite to the sun the main body is brighter and whiter than the edges; but when they are on the same side as the sun, the edges appear bright and the main body dark. The true Cumulus cloud has clear upper and lower limits. When the sun shines through these clouds, or through gaps in them, we have the phenomenon popularly described as the "sun drawing water."

The *Nimbus* [Latin *nimbus*, rain] clouds are thick layers of dark clouds without definite shape and with ragged edge, and from which continued rain or snow generally falls. The Cumulo-nimbus, the thunder-cloud or shower-cloud, is a heavy mass of cloud rising in the form of mountains or towers from a base of a cloud similar to the nimbus. From the base there usually fall local showers of rain, snow or hail.

The *Stratus* [Latin *stratum*, a layer] type of cloud may be described as a horizontal sheet of lifted fog. This, if it remain for any length of time over a large manufacturing town, gradually becomes impregnated with smoke and dust, giving rise to the gloomy appearance one associates with such places, especially in winter.

Meteorologists usually observe the proportion of the sky covered with cloud. This is done by estimation, the scale adopted being 0 to 10. The 0 indicates a cloudless sky, and the 10 a sky completely covered with clouds or overcast.

When any one is asked "What is the weather likely to be?" he naturally looks at the clouds; and a long study of them in a particular district will generally enable him to make a fairly accurate forecast. But it should be borne in mind that in another district, with a different arrangement of the hills or other physical features, the various types of weather may be accompanied by very different cloud characteristics. The observant native, be he fisherman or farm hand, will always have the advantage over the casual meteorologist.

CHAPTER VII

Precipitation

Rainfall.—When the tiny particles of water constituting a cloud have grouped themselves in drops of such a size that the air is no longer capable of supporting them, they fall as rain, snow or hail.

Rain for the purpose of measuring is collected in an instrument called a "rain-gauge" (Fig. 29). This is best made of copper, and consists of a cylinder made in two parts, the upper of which fits on to the lower. About six inches below the upper rim a funnel is fitted, the pipe of which conducts the water into a bottle or can placed in the lower part of the cylinder. The water from this receptacle is poured into a glass jar, which is graduated into hundredths of an inch. The rain-gauge should be placed in an open situation, well away from trees and buildings, at the very least as many feet from their base as they are in height. The gauge should be so fixed that the top of the rim shall be one foot above the ground and quite level.

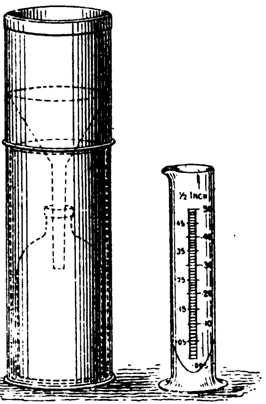


FIG. 29.
Snowdon Rain-gauge and Measuring-glass.

A rough substitute for this official instrument can be made by the local tinsmith for a small sum, and instead of the jar graduated in hundredths of an inch, one graduated in cubic centimetres will serve, if the number of cubic centimetres that go to make one inch of rainfall over an area equal to that of the mouth of the instrument are calculated, intermediate values being found by calculation or preferably by means of squared paper.

The rain-gauge should be examined every day at 9 a.m., and the amount of rain, if any, should be measured and entered in hundredths of an inch in the journal to the *previous* day. This is the practice adopted by all British observers. When no rain has fallen a dash should be inserted, not the figures ·00. A fall recorded as 0·01 inch, or above, is held to constitute a "rain day."

On only a very few days in the year in England do we get one inch of rain even if it continues all day. An inch of rain over an acre of surface would weigh 101 tons.

The average monthly rainfall at the Royal Observatory, Greenwich, for the ninety years 1815–1904 is as follows—

	Inches.		Inches.
January	1·81	July	2·45
February	1·54	August	2·32
March	1·52	September	2·24
April	1·60	October	2·71
May	1·95	November	2·28
June	1·95	December	1·95

Average for the year 24·32 inches.

Some points in this table are worthy of attention. Considerably more rain falls in the second half of the year than in the first, January to June contributing 10·37 inches and July to December 13·95 inches. February is sometimes called "February Fill-dyke," but the Greenwich records do not warrant the title, as this month and March are, on the average, the driest of the twelve, while October is the wettest. Those who take their holiday in July are often aggrieved at the amount of rain that falls, yet July is, on the average, the second wettest month of the year. It is true, however, that the total of 2·45 inches is often made up of considerable amounts which fall in a short space of time in thunderstorms.

In the British Isles The Stye, in Cumberland, about a mile from Seathwaite in Borrowdale, has been considered to have the heaviest rainfall, its yearly average being 170 inches

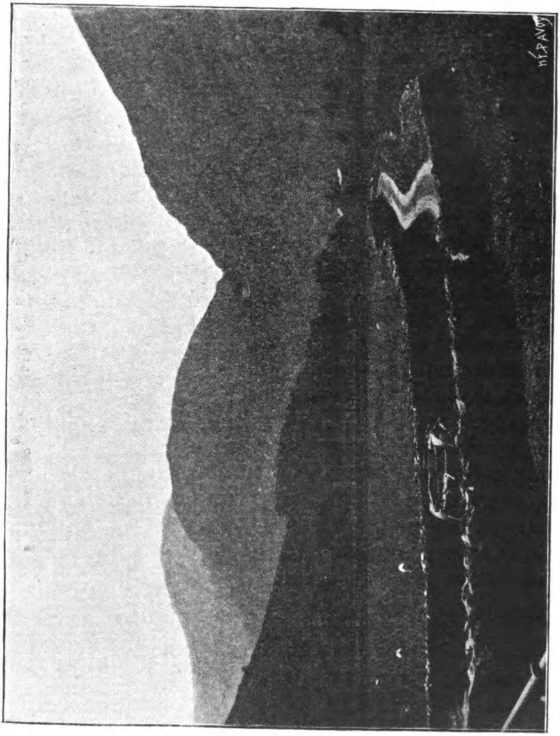


FIG. 30.
Seathwaite and The Stye, looking S.W.

(Fig. 30). Just recently a number of rain-gauges have been placed in the Snowdon district, and from the records already obtained it appears that a much heavier rainfall occurs there than at The Stye. In 1908 a total rainfall of 237 inches was recorded by a gauge near the copper-crushing mill on the Snowdon side of Llydaw.

The prevailing wind in this country is from the south-west. The air then has passed over some part of the Atlantic Ocean, and in its passage has absorbed a large amount of moisture. On reaching our western shores it comes in contact with the more or less high ground of that part of the country. The air is then forced to ascend, and in doing so is reduced in temperature; its capacity for holding moisture is consequently diminished to such an extent that rain falls. On descending on the leeward or eastern side the air becomes warmer, and, having parted with a considerable amount of its moisture, it is much drier. This accounts for two facts, viz. the western side of our islands gets a great deal more rain than the eastern, and that places of greater altitude get more rain than those at a lower level.

These facts are seen very clearly in the following figures, which are the results of the grouping of a large number of stations in England and Wales for each 100 feet of altitude during the period 1881–90, and separating them into western and eastern divisions. A western station was considered to be one at which the watershed drained to the west, and an eastern station one that drained to the east.

Altitude.	Rainfall.	
	West.	East.
Feet.	Inches.	Inches.
100	33·15	24·82
200	35·87	25·94
300	35·72	26·89
400	39·56	28·45
500	46·08	29·87
600	38·08	35·84
700	41·25	35·27

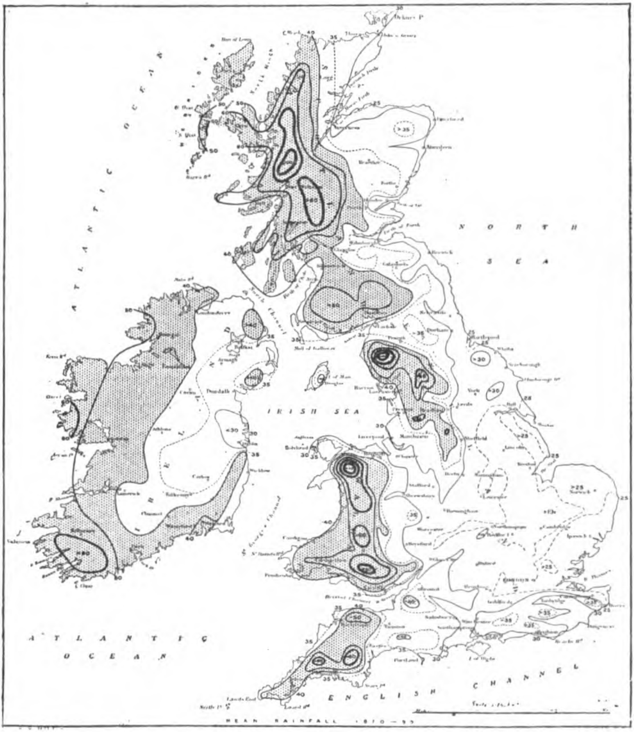


FIG. 31.
Annual rainfall of the British Isles (Dr. H. R. Mill).

These features are also brought out very prominently in the accompanying rainfall map of the British Isles (Fig. 31).

From this we learn that the average annual rainfall exceeds 40 inches along our western coasts, and that in several districts it exceeds 80 inches, chiefly in the west Highlands of Scotland, the English Lake District, and the Snowdonian District of North Wales. Over the eastern part of Ireland and of Scotland, and the south of England, the rainfall is mostly between 30 and 40 inches, while over the eastern counties of England it is less than 25 inches.

England, taken as a whole, has an average rainfall of about 32 inches, Wales 49 inches, Scotland 47 inches, and Ireland 42 inches. The average number of "rain days" (·01 inch or more) is about 150 per annum in the south-east of England, and over 250 in the north-west of Ireland and Scotland.

The rainfall is subject to great variations. The wettest year may have a rainfall nearly half as much again as the average, while the driest year may have one-third less than the average. The average rainfall of the three driest consecutive years at any place is about one-fifth less than the mean.

At times excessively heavy falls of rain occur in all parts of the country. For instance, on July 14, 1875, 5 inches fell in 24 hours over the whole of Monmouthshire. The heaviest rainfall recorded in one hour in any part of the British Isles was 3·63 inches at Maidenhead on July 12, 1901. When such heavy falls take place, serious floods ensue.

At times droughts occur, when the supply of water that a community requires falls very low or becomes exhausted. A "drought" in a meteorological sense is a period of fifteen days or more without measurable rain.

Mr. G. J. Symons, F.R.S., started the British Rainfall Organization in 1860, and through his instrumentality a large amount of data has been collected. This work is now being continued by Dr. H. R. Mill, who receives records from nearly 5,000 observers. The information so obtained is of the greatest value to those concerned with questions relating to water supply, drainage, and agriculture. Much valuable information as to the rate at which rain falls is now obtained from self-recording rain-gauges.

Snow.—Snowflakes consist of minute ice crystals built up on a hexagonal design (Fig. 32). Many liquids can be

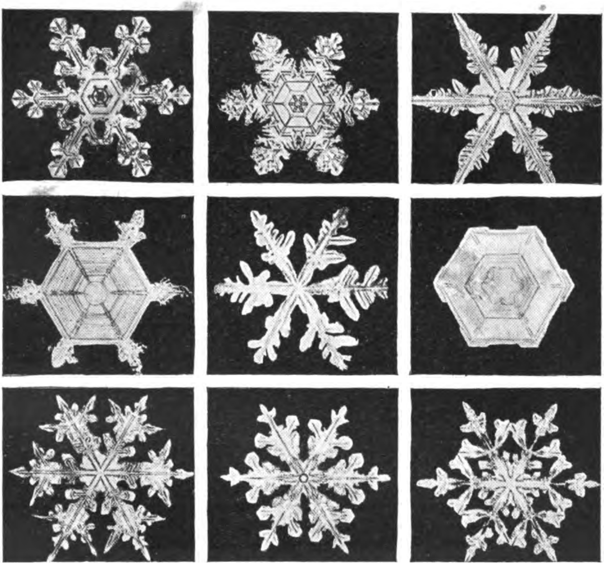


FIG. 32.
Snow crystals (W. A. Bentley).

crystallized, but usually the crystals have few or only one shape, but with snow crystals it is different. Hundreds of forms have been observed, all of which have been of wonderful beauty. They can be readily examined by the aid of a magnifying glass, if they are allowed to fall on the sleeve of the coat or on a dark cloth. Although snowflakes are so small and light, when they accumulate their weight is often sufficient to break off large branches from trees, snap telegraph wires, and impede traffic, and if blown by the wind, drifts are formed through which even very powerful locomotives cannot force their way. A foot of snow is roughly

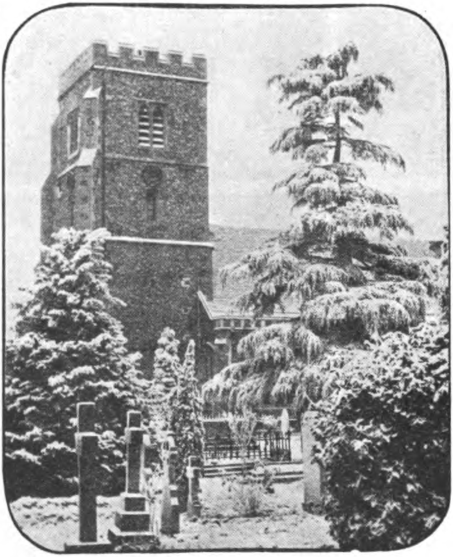


FIG. 33.
Snow scene.

equal to an inch of rain, but snow is lighter when it first falls than after it has been on the ground some time. It is also lighter in the woods than in the open plain, and lighter in a gentle than in a strong wind. Naturally also the lower layers having to support the upper become more dense. Indeed, if enough snow accumulates, the lower layers soon approach the consistency of ordinary ice.

Though most people consider snow rather a nuisance after its first beauty has disappeared, yet it is often welcomed by the farmers. Snow is a non-conductor of heat, a fact which the dwellers in Arctic regions utilize when they build houses of it. When the earth is coated with snow, it prevents frost from penetrating into the ground and injuring the plants. Moreover, if the snow melts slowly, the greater

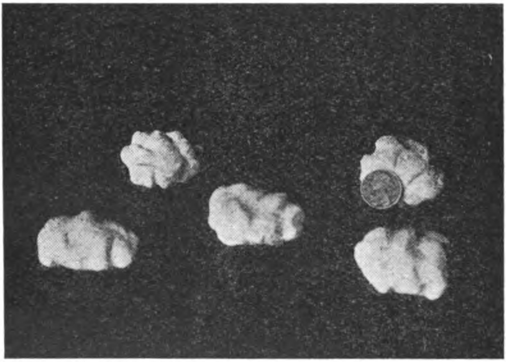


FIG. 34.
Models of hailstones seven inches in circumference.

part of the water soaks into the soil and replenishes the underground springs, so making provision for dry weather, whereas when rain falls a considerable portion of the water often runs off into the drains and ditches.

Hail.—When rain is frozen, hail is formed. This frequently happens in thunderstorms. The hailstones are usually about the size of a pea, but there are many authentic records of hailstones as large as eggs having fallen in this country. At Richmond in Yorkshire, on July 8, 1893, hailstones six to seven inches in circumference fell. If these large hailstones are cut in halves, it is usually found that they consist of alternate layers or coatings of clear and opaque ice.

Fig 34 shows models of five hailstones, seven inches in circumference, which fell at Montereau, France, on August 15, 1888. A penny (1·2 inch diameter) is placed by the side of the upper right-hand model.

When large hailstones fall, they are often accompanied by sudden squalls of wind, and so destroy large quantities of glass, and cut down the crops of fruit and vegetables.

CHAPTER VIII

Thunderstorms

FROM our earliest childhood we have been frequently awed and alarmed at the flashing of the lightning and the crash of the thunder, especially if the storm has occurred during the night. The pictures of lightning which have been drawn by artists show acute angular and zigzag flashes, but during recent years photographs of flashes of lightning have been obtained, and these have shown that the lightning does not take this angular path, but that it usually follows a course more or less sinuous. Its branches and ramifications may, however, be very erratic and extensive (Figs. 35, 36, 38 and 39). This is no doubt due to the fact that lightning takes "the path of least resistance."

Lightning is really the discharge which takes place between two electrically charged clouds or between a cloud and the earth. The thunder is the noise which accompanies the electrical discharge.

When a thunderstorm occurs, it is probable that the parts of the thunder cloud are oppositely charged with electricity, and that the lightning flashes depend upon the relative movement of these sections within the disturbed area. The cloud masses are whirled about till they come within striking distance of one another, or of the earth, the former of these conditions prevailing much more frequently than the latter.

During the summer displays of what is called sheet or summer lightning are sometimes visible in the evening. There is probably no difference between this and ordinary lightning, except that the storm centre is at such a distance

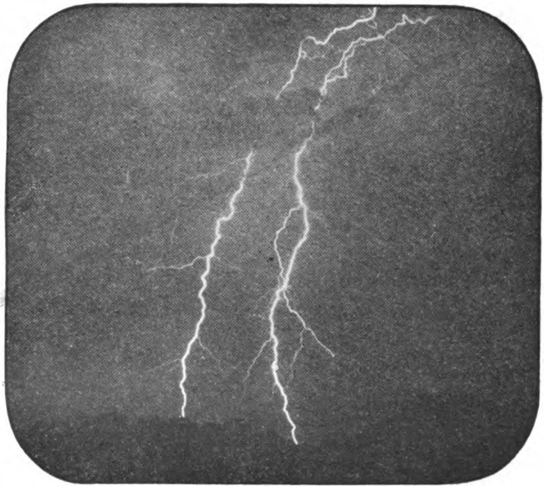


FIG. 35.
Lightning.

away that while the light waves reach us the sound waves do not. Instances are on record in which lightning has been seen at night for a distance of more than a hundred miles from the actual thunderstorm with which it was associated.

When an electrical discharge occurs between the clouds and the earth, buildings and trees, which are isolated or project above others, are liable to receive the full force of the current. If the electricity cannot pass through them freely, injury is likely to result, and they may be set on fire. To avoid this, exposed buildings should be provided with an efficient lightning conductor. The word "efficient" is used advisedly, as a badly adjusted conductor is considerably worse than none at all, for in the first place it invites the passage of the electric current, and secondly it furnishes no

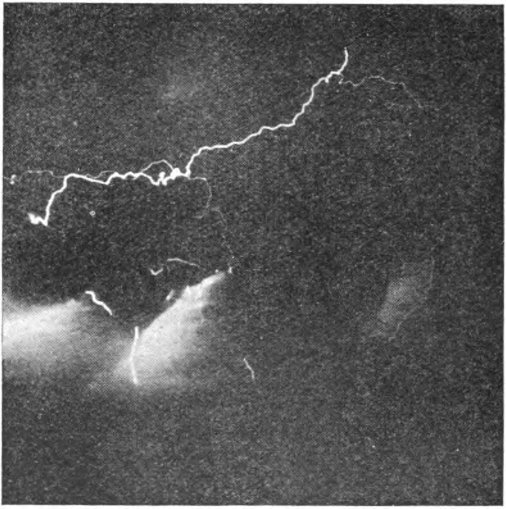


Fig. 36.
Lightning.

means of conducting it readily to the earth where it will do no harm. The usual form of lightning conductor is a broad band or strip of copper or iron, fixed to the outer side of a building, terminating upwards in one or more sharp points some feet above the highest part of the building. The lower end should be connected to a metal plate buried in the ground at such a depth that the soil is always moist.

With the same object the conductor is sometimes connected directly with a drain, the moisture increasing the conducting power. Many failures of conductors have been traced to the fact that the lower end was not embedded in permanently wet soil. Lightning conductors should only be put up under the supervision of a competent authority, and they should also be periodically inspected to see that they are in good

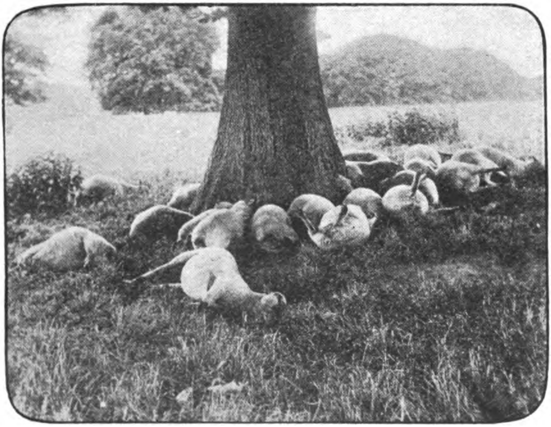


FIG. 37.
Sheep killed by lightning.

order, otherwise they may become sources of danger rather than a protection from lightning.

All kinds of trees are liable to be struck by lightning, but the poplar, oak, ash, and elm appear to be most exposed to this danger. When a tree is struck the trunk may be shattered, the bark stripped off, or a charred path may be seen from top to bottom. Living creatures sheltering under it at the time may participate in the shock, death often resulting (Fig. 37). It is therefore preferable to run the risk of a wetting rather than to seek shelter under an exposed building or isolated tree during a thunderstorm.

Many persons have stated that during a thunderstorm they have seen a ball or globe of fire fall to the earth or run along the ground. This may possibly be due to the flash of lightning being seen " end on," as it were, and so being

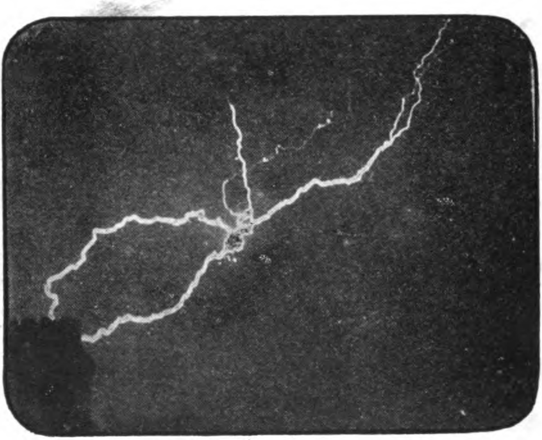


Fig. 38.
Lightning.

visible and brighter for a longer time than would otherwise be the case.

Reports are often circulated that a " thunderbolt " has fallen. When these reports are investigated it is usually found that the so-called thunderbolt is merely some wire or metal which has been melted by the lightning. When lightning strikes soil of a sandy character it may fuse the particles of sand, and form a kind of vitrified tube called a " fulgurite."

The deep rumbling sound which we call thunder is caused by the violent vibration set up in the air when a discharge occurs. Should a storm be very near sharp crackling reports may first be heard. These proceed from the branches of the flash which are nearest to the observer, and the heavy crash which follows comes from the near part of the main flash, and the continuous rumbling from the parts farther

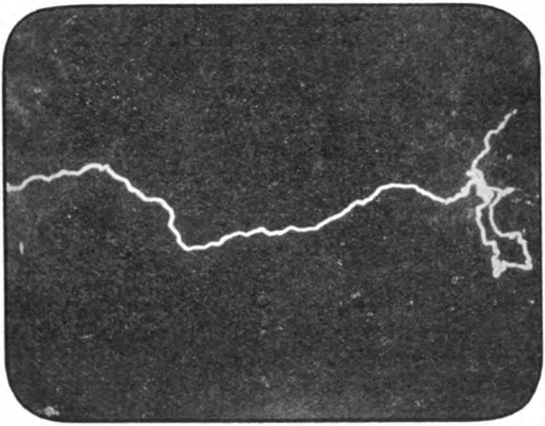


Fig. 39.
Lightning.

off (Figs. 38 and 39). The sounds may be prolonged for many seconds, especially in mountainous regions.

Light travels so quickly that when a flash of lightning is formed it is seen to be practically instantaneous, while the sound of the thunder travels at the rate of 1,100 feet in a second. If we therefore count the number of seconds between the time of seeing the flash and of hearing the thunder, we can approximately calculate in miles the distance of the storm by allowing five seconds to a mile. By determining the interval between the lightning and the thunder for successive flashes, and noting whether it is increasing or decreasing, we can judge whether a storm is approaching or receding.

Lightning may sometimes appear to vibrate or flicker. This is caused by several flashes following one another along the same path. These are often seen on photographs which have been taken by a camera which has been moved during the exposure, the other objects on the photograph showing the same amount of displacement as the lightning flashes.

By far the greater number of thunderstorms occur in the summer and in the latter half of the day. The atmosphere previous to their arrival is often oppressive and sultry. They may be preceded by cirro-stratus clouds, which give way to dense clouds of the cumulus type. These develop in turn into the livid blue-grey clouds characteristic of thunderstorms. When the rain or hail falls there is often a marked fall in temperature, and after the passage of a storm the sense of physical discomfort and tension which previously existed disappears.

Thunderstorm formations are usually small atmospheric whirls. As the wind nearly always falls light or calm during their occurrence, while there is considerable and often violent motion in the clouds above, and as the thunderclouds are of no great altitude, it is most probable that the whirl is confined to a stratum of air at only a little distance above the earth's surface. Sometimes, however, violent gusts of wind occur during a thunderstorm; this probably takes place when the storm is of low altitude.

Thunderstorms seem to travel at an average rate of about twenty miles per hour in ill-defined low barometric systems, but at a higher rate in squally conditions, such as subsidiary barometric depressions or secondaries. Thunderstorms appear to take the path of least resistance, and so are most frequent over low and flat ground.

The areas affected by the passage of thunderstorms are usually narrow and irregular in form as traced by the amount of rainfall, and it is not uncommon to find a number of storm areas in a straight line separated by nearly dry patches.

Several thunderstorms have been tracked across the country for a distance of more than four hundred miles, the rate of progression being about fifty miles per hour.

There is also another type of thunderstorm in which the region of simultaneous thunder disturbance extends along a line which may be a hundred miles long. This storm line advances as a whole usually in a direction from north-west to south-east, and its rate of progress may amount to fifty miles per hour. Such storms have been called "line thunderstorms."

CHAPTER IX

Evaporation

The amount of water passing into the atmosphere by evaporation varies according to the temperature and humidity of the air, the strength of the wind, and the character of the water surface. Evaporation takes place not only from water surfaces but also from ice and snow, from the ground, trees, plants, etc. Occasionally it is to be noticed after a shower that the pavement on one side of the road gets dry sooner than that on the other side. This is sometimes due not to the air being drier on one side of the road than on the other, but to a stronger current of air which is able to lick up more moisture in a given space of time than the lighter current on the other side of the road.

Comparatively very little attention has been given to the subject of evaporation, although it is an important one, especially to engineers and others who have to provide for an efficient water supply.

The early forms of evaporation gauges were merely small cylinders or shallow dishes, which were usually mounted on a stand or placed on the ground. During the day the water became very considerably heated, and consequently these gauges gave the evaporation much in excess of the true amount. The best form of evaporation gauge is a galvanized iron tank about four or six feet square and two feet deep. This is sunk in the ground with the top about level with the blades of the grass, and is kept filled with water to within two or three inches of the rim. The height of the water is carefully measured every day, and the difference gives the amount of evaporation. When rain has fallen, the amount, as shown by the rain-gauge, should be deducted from the height of the water in the tank.

The evaporation in this country is from about fifteen to twenty inches in the year. From the records kept at Camden Square, London, during a period of twenty-three years, it appears that the average monthly evaporation is as follows—

	Inches.		Inches.
January	·10	July	3·16
February	·26	August	2·38
March	·68	September	1·37
April	1·51	October	·62
May	2·33	November	·23
June	2·92	December	·09

Average for the year, 15·65 inches.

The greatest amount of evaporation on any one day does not exceed a quarter of an inch. The comparison between the average monthly evaporation and the average monthly rainfall (see p. 54) is of interest.

CHAPTER X

Wind

When the air is in motion, what is called "wind" is the result. This is caused by the inequalities of pressure exerted by the atmosphere. These inequalities are brought about by the heating action of the sun's rays. The sun's power is greater at the middle than it is at the beginning and end of the day. It varies also with the season: the higher the sun is at midday, the greater is its warming power. It has, as already mentioned, more effect upon the land than upon the water. All these causes produce an increasing circulation in the atmosphere—as the warm air expands it rises, and colder air takes its place. Were the sun's warming influence to be withdrawn, it seems probable that this circulation would cease, and the pressure would be equalized over the globe. In addition, the temperature would fall so low that all water would be frozen and all forms of animal and vegetable life would become extinct. Many of the poisonous gases being heavier than air, would remain where they were generated, and populous countries like England would soon be enveloped in a deadly atmosphere, for most forms of life require abundance of fresh air.

Winds may be of a local character, or they may form part of great atmospheric movements, extending over large portions of the globe. In fine summer weather we get types of the former kind on our coasts in the form of land and sea breezes. As the day progresses and the sun's power increases the earth rapidly gets warmer than the sea, causing the air above it to become warmer in turn. This air rises on expansion, and the cool breeze from the sea flows landwards. During the night the reverse process takes place, the earth losing its heat more rapidly than the water, and so a breeze off the land arises. These movements may be confined to a comparatively narrow strip of land along the coast, and they are frequently not observable at all, being overwhelmed by more extensive and powerful air movements.

The main movement of the atmosphere is brought about as follows. The sun is always overhead at midday at some latitude between the Tropics of Cancer and Capricorn, and speaking generally, this is the hottest part of the globe, the heat equator occurring in an average position rather to the north of the geographical equator. At the heat equator there will always be an ascending current of hot air, which of course cannot accumulate, but flows polewards. This ascending current is not felt as wind, so in this district there is a belt of equatorial calm. A current of cooler air flows in to take the place vacated by the warmer air, but the direction of both these currents is very much affected by the rotation of the earth on its axis. Considering only this movement of the earth, a person on the equator would be whirled round in a circle roughly 25,000 miles in circumference daily, but as he approached the poles the circles would become less and less, till at the poles themselves he would merely be turned

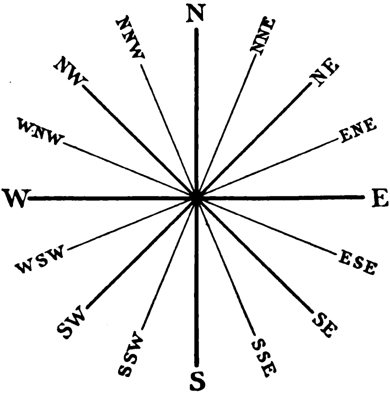


FIG. 40.
Points of the compass.

N	North.
NNE	North-north-east.
NE	North-east.
ENE	East-north-east.
E	East.
ESE	East-south-east.
SE	South-east.
SSE	South-south-east.
S	South.
SSW	South-south-west.
SW	South-west.
WSW	West-south-west.
W	West.
WNW	West-north-west.
NW	North-west.
NNW	North-north-west.

round on the same spot. The air in the equatorial regions at the moment of rising has the same rate of movement as the land under it. As the air flows polewards it is continually coming to places moving at a slower rate, and as it were the air shoots ahead. For a similar reason the air from the poles appears to lag behind, as it travels towards the quicker moving equatorial regions. The earth rotating from west to east causes the surface currents towards the equator to come from the north-east and south-east respectively, in the northern and southern hemisphere; and the upper currents towards the poles in a south-west and north-west direction. Within the tropics these north-east and south-east winds blow regularly for the greater part of the year and are known as the "Trade Winds," owing to the great influence they exert on the duration of the voyages of sailing ships. These trade winds extend in a belt roughly 20° N. and 20° S.

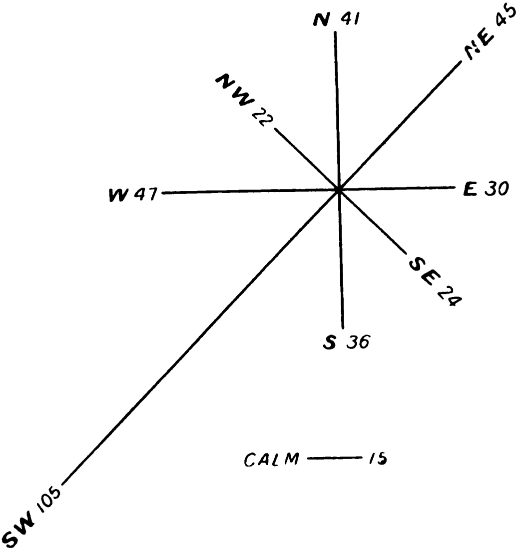


FIG. 41.
Number of days in the year of winds from different points of the compass at Greenwich.

of the equator. They do not blow with the same regularity upon the land within this region, the physical features and other local conditions modifying them considerably.

The warm air from the equator, in its passage north and south, after a time becomes denser than the air below and descends towards the earth once more. Here it somewhat interferes with the currents going in the opposite directions, and hence it is that in the temperate zones we get variable winds.

Direction.—We must not imagine that all the air immediately above us is moving in one direction, viz. that indicated by the weather-vane. It is within the experience of every aeronaut that at varying altitudes currents are often met which differ considerably in direction. Occasionally

FIG. 42.
Wind-swept tree.

this fact can be noticed by careful observation of the movement of clouds, and as many as three diverse currents are sometimes noticed at the same time. A word of caution, however, should be given on this point, as owing to the different altitudes of the various cloud forms their apparent movements relative to each other are often deceptive.

The direction of the wind may be ascertained from the indication of a freely moving vane or weather-cock, or else by observing the drift of smoke. By the direction of the wind, we always mean that point of the compass from which it is blowing (Fig. 40). In adjusting a wind-vane care should be taken to determine the North point by means of the Pole Star, or the South point by means of the sun. The compass needle points to the magnetic North, and not to the true North. The magnetic North varies in the British Isles from

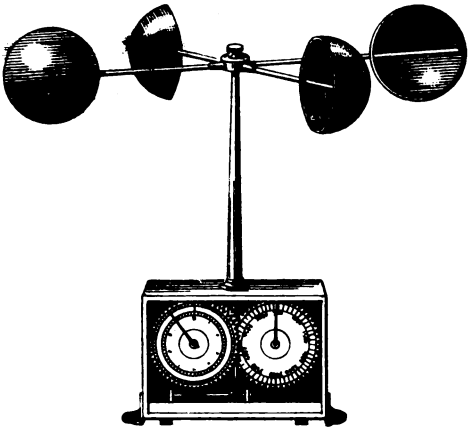


FIG. 43.
Robinson anemometer.

about 15° west of true North in the east of England to about 21° in the west of Ireland.

Though in this country we seldom get the wind blowing in the same direction for more than a few days at a time, yet on almost one-third of the days throughout the year it has a south-westerly direction. The average numbers of days in the year on which the wind blew from the different points of the compass at the Royal Observatory, Greenwich, during the last fifty years is shown on the accompanying diagram, or "wind-rose" (Fig. 41).

In spring there is usually a considerable prevalence of north-easterly winds. In exposed parts of the country the trees often give an indication of the direction of the prevalent winds by the way in which the trunks and branches are inclined, and the more extensive growth of foliage on the leeward or protected side (Fig. 42).

Velocity.—The velocity of the wind, speaking generally, has a daily variation; it is greatest about midday and least during the night. The velocity of the wind is registered by an instrument called an Anemometer. In the Robinson or cup Anemometer four arms are fixed at right angles, each with a hemispherical cup at the end. The junction of the arms is attached to a vertical axis connected with a train of cog-wheels so arranged as to count the rotation of the arms and translate them into miles per hour (Fig. 43). It has been found by experiment that the wind moves with about two and a third to two and a half times the velocity of the cups.

An approximate estimate of the force of the wind can be made by Beaufort' scale. This, revised according to the latest comparisons by the Meteorological Office, is as follows—

Beaufort scale.	Equivalent velocity. Miles per hour.
0. Calm	0
1. Light air	1–3
2. Light breeze	4–7
3. Gentle breeze	8–12
4. Moderate breeze	13–18
5. Fresh breeze	19–24
6. Strong breeze	25–31
7. High wind	32–38
8. Gale	39–46
9. Strong gale	47–54
10. Whole gale	55–63
11. Storm	64–75
12. Hurricane	Above 75

During great gales and storms much damage is wrought by the wind owing to the tremendous pressure which it exerts. The greatest velocity of the wind recorded in one hour has been between seventy-seven and eighty miles at Fleetwood. In gusts, however, the velocity of the wind may momentarily exceed the rate of a hundred miles an hour.

CHAPTER XI

Weather Maps and Storm Warnings

Weather Map.—The average condition of a district as to temperature, moisture (vapour, clouds, rain, snow) and wind, forms what is commonly called its "climate." The state of the atmosphere as regards the presence of these elements, however, at a particular moment of time is called "weather."

At the present time, practically every civilized country collects by telegraph systematic information as to its daily weather. It was not, however, till 1848 that the first steps in this direction were taken in the British Isles. The pioneers in the matter were the proprietors of the *Daily News*, acting in co-operation with Mr. James Glaisher of the Royal Observatory, Greenwich. The first table of simultaneous meteorological observations was published in the above-mentioned paper on August 31, 1848. The way in which it was prepared may perhaps be best described in the words of Mr. Glaisher, taken from a letter to the Secretary of the Smithsonian Institution, Washington, where similar work was started about the same time—

"Among the forms sent, you will find one very simple, and which is used daily at about fifty railway stations at the hour of 9 a.m., Greenwich time. The different railway companies have agreed that the stationmasters shall take these observations, and that they shall be brought to London the same day, free of expense. The proprietors of a London newspaper, the *Daily News*, incur the expense of sending a messenger to the several railway termini at about 2 a.m., and all the returns then collected are immediately printed, so that the weather of the day previous, at one time, all over the country and parts of Scotland are publicly known. On receiving the paper, I lay all these returns on a map, using a long narrow-headed arrow to indicate the direction of the wind, and other symbols for the other information, and then daily I know the weather, direction of the wind, etc.—the whole being exhibited to the eye. . . .

"It is believed by these arrangements very important information, with respect to the passage of storms in particular, will thus be collected."

The first printed Daily Weather Map was issued at the Great Exhibition, Hyde Park, August 8, 1851.

It was not until 1854 that the Government took the work in hand and established the Meteorological Office, the first chief of which was Captain (afterwards Admiral) FitzRoy. At first the collection of marine observations went on as practically the sole object of the Office, until Admiral FitzRoy turned his attention to the development of telegraphic weather intelligence. He believed strongly in the possibility of predicting storms, though public opinion was against him, preferring to believe that "the wind bloweth where it listeth, and no man knoweth whence it cometh and whither it goeth."

Storm warnings.—In 1861 arrangements were made for hoisting cautionary or "Warning" signals at one hundred and thirty stations, and in August of that year Daily Forecasts of the Weather were also made, and communicated to the newspapers. Naturally great value was set on these storm warnings, at a time when by far the greater number of vessels on the sea were sailing craft. To the gigantic liners of the present day a storm, unless it is very violent indeed, matters little; but one has only to see the large number of small steamers and sailing vessels laying to during a storm in roadsteads, such as at Yarmouth, or Deal, to appreciate that the weather still plays a very important part in their movements and safety. On receipt of notices of threatening atmospherical disturbances on or near the coasts of the British Islands, the fact was made known at ports and fishing stations by hoisting a black canvas cone, three feet high and three feet wide at base. When a cone was hoisted with the apex downward (Fig. 44), it was understood to imply that a gale might be expected from a southerly direction; if with the apex upward (Fig. 45), a gale from a northerly direction.

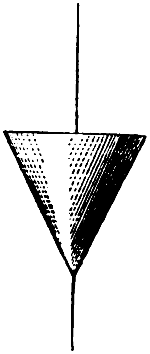


FIG. 44.
South cone.

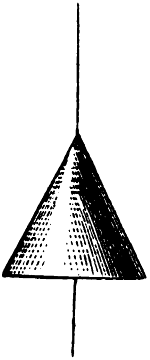


FIG. 45.
North cone.

At dusk, whenever a signal would have been exhibited if it had been daylight, a night signal consisting of three red lamps hung on a triangular frame was hoisted in the place of the cone. This system of warning is still maintained at numerous stations on our coasts, especially at those which have fishing fleets.

In 1866 the storm Warnings and Forecasts were discontinued on the ground that those who made them could not explain the underlying principles. This was true enough then, and it is true, though to a smaller extent, to-day, previous experience being the chief guide. The warnings, however, were very popular among those chiefly concerned, viz. the shipowners and mariners; and several memorials were presented to Parliament praying for their restitution.

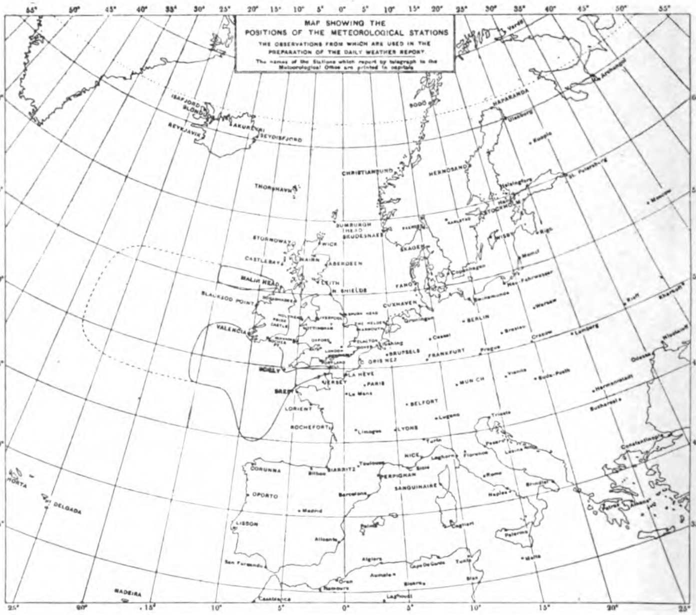


FIG. 45.

"Daily Weather Report" stations.

Reproduced from the Annual Report of the Meteorological Office by permission of the Controller of H.M. Stationery Office.

The agitation was successful, for in 1867 the warnings were again issued.

Synoptic Charts.—This period marks a new era in meteorological study. We find an indication of the general introduction of the isobaric method of dealing with the weather, with its cyclones, anticyclones and secondaries, etc.

The introduction of these ideas, the application of Buys Ballot's Law (see p. 88), and the idea of barometer gradients were the characteristic advances of this epoch.

In 1879 it was considered that the knowledge of the sequence of the weather had been so much extended by the study of synoptic charts that the issue of forecasts, which had been discontinued in 1866, might be again commenced. Henceforward forecasts were prepared, and in 1881 the Daily Weather Report was issued in much the same form as it is in the present day. The recent extension of the telegraph cable to Iceland and the Azores has greatly widened the area from which observations are received (Fig. 46).

The stations now sending in by telegram daily information to the Meteorological Office in London are distributed as follows: Scandinavia 11, Iceland and the Faroe Isles 4, British Islands 30, Germany, etc., 6, France 12, Spanish Peninsula, etc., 6. In 1909 arrangements were made with the companies owning the liners that cross the Atlantic that information should be sent by wireless telegraphy as long as the ships were within range of the receiving stations on our coasts.

The observations were formerly made at 8 a.m., but since July 1, 1908, they have been made at 7 a.m. in the British Isles in order to be synchronous with those made on the Continent. The particulars sent give the reading of the barometer, the direction and force of the wind, the readings of the dry- and wet-bulb thermometers and the maximum and minimum temperatures, and the rainfall during the preceding twenty-four hours; also the amount of bright sunshine for the previous day. In addition to the full information received from these official stations, many towns in the British Islands send details as to the maximum and minimum temperature, sunshine, rainfall, and the state of the weather generally. The information sent from the ships on the Atlantic Ocean by wireless telegraphy is much the same as that sent from the land stations with the addition of the latitude and longitude at the time of observation.

Weather forecasts.—The particulars received are tabulated and charted by about 10 a.m. and a forecast for the twenty-four hours following noon is formulated. Most of the stations send in observations taken at 6 p.m., and forecasts are prepared from them for the twenty-four hours from the following midnight. These are the forecasts which appear in the morning newspapers, and are apportioned to the districts shown in the accompanying map (Fig. 47). *The Times* newspaper prints each morning a copy of the Weather Chart for 6 p.m. of the previous day.

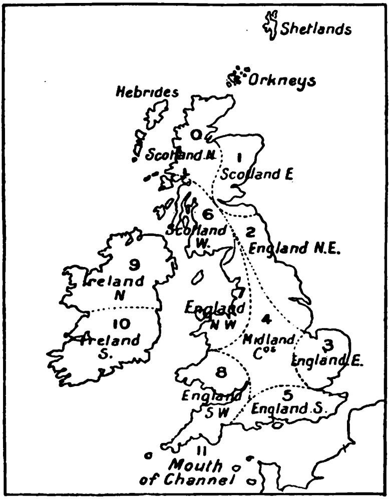


FIG. 47.
Forecast districts.

Any person particularly interested in the weather of the ensuing twenty-four hours can have a forecast sent to him from the Meteorological Office on payment of sixpence in addition to the cost of a prepaid telegram. If forecasts are required daily for longer intervals they can be obtained at proportional rates. A special service of afternoon forecasts, prepared at 3.30 p.m., are issued during the season of the hay and corn harvests, June 1 to September 30. This provision should be very useful to farmers who have haymaking or reaping in contemplation and also for organizers of outdoor excursions.

As weather study develops the proportion of accurate forecasts will probably advance still more. The position of the British Islands is a very difficult one in this respect; they are comparatively small and on the borders of a vast ocean to the westward; in addition, they are at such a distance from the equator and pole that they are the battle-ground of warm and cold winds, causing a climate justly called "fickle and uncertain." Notwithstanding this, it is found that seventy to eighty per cent. of the forecasts for the year are correct, and only about ten per cent. are wrong, the remaining portion being partially correct. This must be considered very satisfactory progress for so young a science as meteorology.

The production of the forecast proceeds on the following lines. The items of information received are recorded on two blank maps. These have the stations marked on them, and on one the barometric height, direction of the wind, and state of the sea are inserted, and on the other the temperature and general condition of the weather. Lines are drawn through places recording the same barometrical height, and through those having the same temperature. The former lines are called "isobars" and the latter "isotherms." The isobar through places recording the average barometrical height (29·9 inches) is drawn thicker than the others.

At this stage the maps are ready for the expert in forecasts, to whom every item of information is of moment. He applies all the knowledge that reason and experience has taught about the weather, and the wonder is how a few curved lines and wind arrows can guide him to conclusions which, speaking generally, are so accurate. It is the purpose of the following chapter to show how in the simpler and more straightforward cases he arrives at these conclusions. Even an advanced course of study in meteorology will not enable us to forecast authoritatively, for the conditions of temperature, pressure, wind, etc., vary so rapidly in the region of our Islands that one needs information red hot, as it were, from the telegraph wires to enable him to attain any considerable measure of success. For all that, some progress can be made in that very desirable direction.

To this end we will first direct our attention to the maps on which are drawn the isobars and wind arrows. It will be noticed that the isobars show a tendency to form closed curves or ellipses, and very often these are actually formed. Taking cases of the latter type, as shown in the accompanying map (Fig. 48), we notice that in one instance the isobars indicate a fall in pressure as we get towards the smallest ellipse, and in the other the reverse is the case.

CHAPTER XII

Types of Weather

Cyclones.—The first of these types is called a cyclone, or an area of low pressure, and the second an anticyclone, or an area of high pressure. Alternative names to these terms " cyclone " and " anticyclone " are " low " and " high." The term " cyclone " was perhaps not happily chosen for use in this connection. To the popular mind it conjures up visions of a terrible storm in the tropical regions associated with wrecked ships, falling trees and damaged buildings, while in a general meteorological sense it may refer to quite a gentle weather condition. As the pressure shown by the isobars may be regarded as the measure of the amount of the atmosphere, looked at from above, the cyclone would form the valleys and the anticyclone the hills or mountains, and the steeper the sides of the valley, or cyclone, the closer will be the lines representing the alternation of pressure, viz. the isobars (Fig. 48).

It will be observed that the direction of the wind runs nearly parallel to the isobars, and that it is inclined slightly inwards. One would naturally expect this, as the force of gravity has a tendency to level out the inequalities in the thickness of the atmosphere, thus causing all hollows to be filled up. An effect somewhat similar can be seen on swishing water round in a basin. Here we should get the depression in the centre, and the continual effort of the water on the edges to fill it up. The quicker we move the water the deeper the depression; and the closer the isobars, the quicker will the wind blow. Working outward from the centre of a cyclone, it will be noticed that each successive isobar on the map represents a rise of two-tenths of an inch pressure. When the isobars are close together, therefore, we say that the gradient is steep; and when the isobars are far apart, that it is moderate or gentle. Thus, if we know the gradient of an approaching cyclone we can, in a measure, estimate the probable force of the wind. A steep gradient would be represented by a change of a tenth of an inch or more in pressure for eighty-five miles measured on a radial line from the centre of the depression. In such a case we might expect strong winds or a gale travelling at the rate of thirty miles or more per hour.

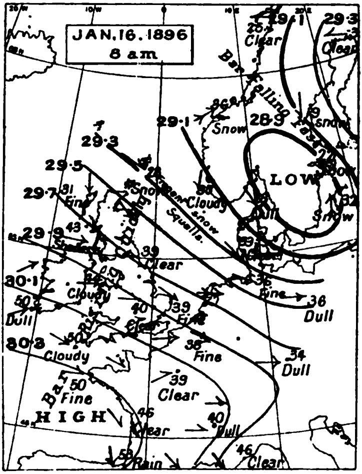


FIG. 48.
Cyclone.

As a rule the cyclone does not remain stationary, but travels along much in the same way as the miniature whirlwinds along the dusty roads in summer. A rapidly moving cyclone may travel as fast as thirty miles per hour, and some idea of its speed is necessary if correct forecasts are to be made concerning it. It is to be noted also that in their passages across the surface of the earth the depressions have a tendency to follow certain paths, which have been traced out in certain districts, as in the United States, and the western mainland of Europe. As far as our Isles are concerned the cyclones most frequently pass over in a direction approximating east-north-east. Thus they must, as a rule, have passed over the

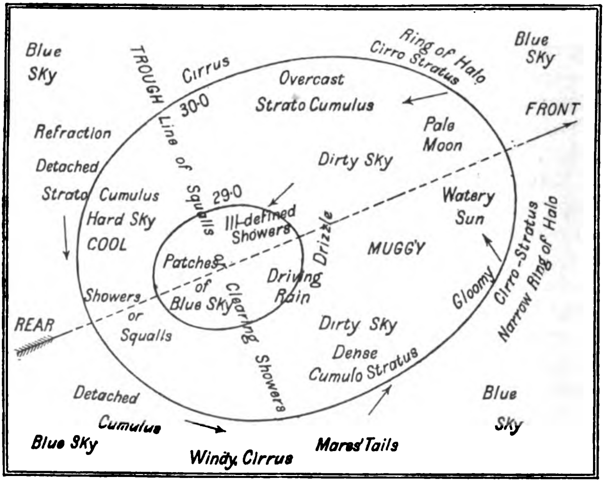


Fig. 49.
Weather in a cyclone (Abercromby and Marriott).

Atlantic Ocean, and when the transmission of meteorological information by wireless telegraphy becomes part of the daily routine of every steamship between Europe and the United States, much valuable aid will be given to the Meteorological Office. The diameter of a large cyclonic system may be as great as a thousand miles, and it has been estimated that the vertical thickness of the atmosphere concerned is not much more than two miles.

The importance of the study of these depressions is due to the fact that certain distinct types of weather are associated with them as they travel over an observer, and a well-defined cyclone may affect our weather for four or five days. If we are immediately on the path of its centre the sequence of the weather would be something like the following: The first indications are a fall in the barometer and the presence of cirro-stratus clouds, the latter gradually making their way to the zenith. The barometer falls slowly at first and more rapidly later. The sun, if in evidence, has a watery appearance, and the moon, if shining, is most likely surrounded by a halo. The temperature then rises, and the increasing amount of moisture causes the atmosphere to become muggy and close. As the centre of the depression approaches, the sky becomes thoroughly overcast, the rain commences and continues till the barometer has turned to rise, the wind dropping meanwhile. When the barometer is at its lowest, that is at the passage of the trough of the storm, there is often an extra heavy downpour of rain. This, as it heralds the early cessation of the rain, is often called the "clearing shower." After which the air becomes fresher and cooler, and patches of blue sky appear as the barometer rises.

The diagram (Fig. 49) prepared some years ago by the Hon. R. Abercromby and Mr. W. Marriott, epitomizes these changes.

It will readily be seen that if the centre of the depression passes to the north or to the south of an observer, the weather experienced will be a modification of the above. The changes in the direction of the wind in each case are of interest. A knowledge of these, used in conjunction with the information conveyed in the Daily Weather Chart, gives a good idea of the progress of a depression and the probable weather of the immediate future.

If the centre passes to the north of the observer, the wind first "backs" to south or south-east and then "veers" to south-west and west, with increasing force. A wind is said to "back" when it goes against the sun, and to "veer" when it goes with it.

If the centre passes to the south of the observer, the wind "backs" first from south to south-east and then on to east, north-east and north.

It will thus be noted that a veering wind indicates the passage of a depression to the north, and a backing wind to the south of the observer. This information can to some extent be gained by the application of a law enunciated by a Dutch meteorologist, Buys Ballot, viz. "Stand with your back to the wind and the barometer will be lower on your left hand than on your right." This applies to the northern hemisphere only. Here, as has been shown, the wind circulates around a depression in an anti-clockwise direction, while in the southern hemisphere the motion is clockwise.

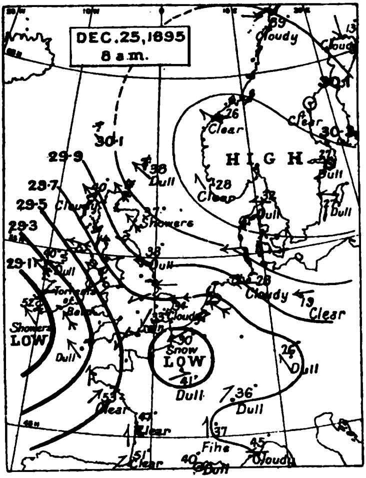


FIG. 50.
Secondary depression.

Sometimes a secondary depression occurs within the boundaries of the larger or primary cyclone (Fig. 50). This most frequently occurs to the south or south-east of the centre of the main depression. On the charts they appear as bulges on the isobars, and the height of the barometer varies little during their progress. As far as the British Isles are concerned, these secondaries frequently take a course up the English Channel to the North Sea. There is, as a rule, no great force in the wind, though there may be squalls, but the cloudiness increases, and there is often a considerable fall of rain. The unexpected development of these secondaries is liable to throw the forecast out, especially on our coasts. Some indication of their formation, however, may be noticed if the wind does not change in the manner indicated above, as normal to the passage of a primary cyclone.

Anticyclones.—Anticyclones are areas of high barometric pressure (Fig. 51). As shown by the isobars, they have not so regular a shape as the cyclones. The wind circulates round them in a clockwise direction, and slightly inclined outwards. In these two particulars the anticyclones present features the opposite of what occur in the case of the cyclones. As the air is continually flowing outwards from the centre and the supply must be kept up, fresh instalments must be received from the upper layers; thus the air in an anticyclone has a downward tendency towards the centre. This movement would not be felt as wind; and, as a matter of fact, associated with anticyclones the winds are as a rule gentle. Anticyclones differ from cyclones in another important particular. A cyclonic movement almost invariably has a forward motion as a whole, while an anticyclone may remain in the district over which it is developed for days or even weeks.

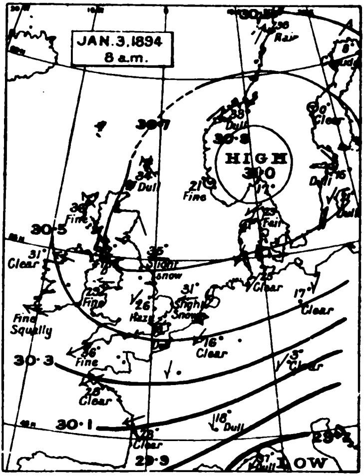


FIG. 51.
Anticyclone.

This is an important feature, as fine weather is generally associated with this condition of barometric distribution. Cloudless skies allow the full force of the sun to act on the surface of the earth during the day, and also for the rapid radiation of heat during the night, and so we get warm sunny days and cold starlight nights. In winter such conditions tend to produce severe frost, or should the cold descending currents fall on air containing a considerable proportion of moisture, fog may become prevalent. The May frosts, so dreaded by the fruit-growers and horticulturists, are usually anticyclonic in character. Speaking generally, we all wish for fine weather, yet it is a peculiar fact that after about a fortnight of pronounced anticyclonic weather, with its high atmospheric pressure, dry air, and calms or gentle winds, there is a general desire for a change, especially in summer. This is not entirely due to our innate love of variety, but partially to the physical effect of such weather on our bodies. The animal world appears to suffer as much as the vegetable world in such circumstances. The spring of our life appears to dry up and become foul, in like manner to the water springs, and all living things seem gasping for a welcome shower.

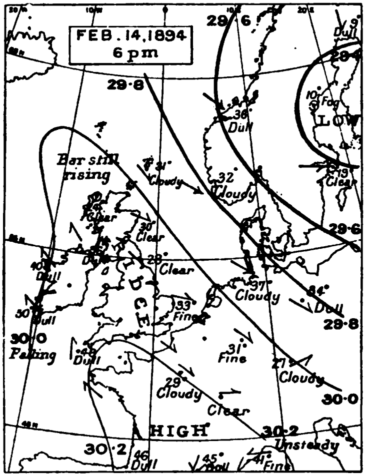


FIG. 52.
Wedge or ridge of high pressure.

Other types.—There are other types of the distribution of barometric pressure, all of which have their distinctive weather characteristics. When one cyclone follows closely on the course of another, between the two we get what is called a "Wedge" or ridge of high pressure (Fig. 52). This projecting area of high pressure usually points northwards.

This is frequently associated with brilliantly fine weather, bright sunshine and blue sky with a north-west wind or calm. So fine is the weather, indeed, that people are suspicious and say "It is too fine to last." The crest or dividing line having passed, the wind soon changes to the south-west, the moon or sun may be seen with a halo, bands of fleecy cirrus clouds appear, to be followed shortly by rain, as the falling barometer indicates the oncoming of the fresh depression.

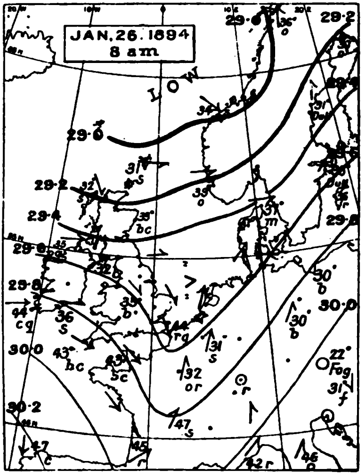


Fig. 53.
V-shaped depression or line squall.

As opposed to the wedge or ridge of high pressure, which occurs between two cyclonic movements, we get a "V-shaped" depression between two anticyclonic movements (Fig. 53). This area of low pressure usually is a projection from a cyclone. The front part of this has the usual characteristics of an advancing cyclone, falling barometer, cloudy sky, increase of moisture, etc. After these warnings the rain falls till the axis or line of minimum pressure is reached. This past, the wind changes from south-west to north-west often very suddenly, and squalls and showers give place to finer weather as the barometer rises.

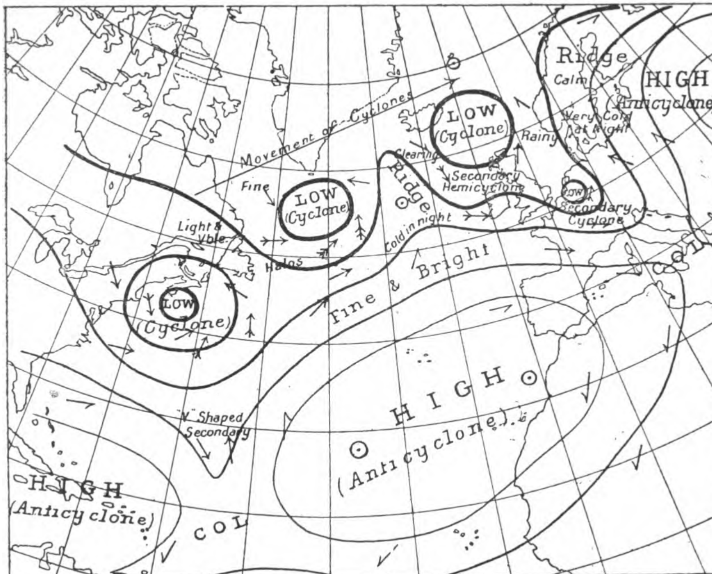


Fig. 54.
Typical shapes of Isobars.

CHAPTER XIII

The Upper Air

As our weather is very largely dependent upon what takes place in the atmosphere, there is a very natural desire to ascertain the meteorological conditions of its upper layers. From time to time attempts have been made to investigate these by means of balloons and kites.

Observations by Balloonists.—There are limitations to the use of manned balloons owing to the rapid diminution of the air pressure as the altitude increases, and to the low temperatures encountered. No particular physical discomfort is felt until a height of about four miles is reached. Then the heart and lungs have difficulty in performing their office, and sensations of palpitation, shortness of breath and drowsiness are experienced. At this height the temperature also is usually at zero (Fahr.) or lower, so that there is considerable risk of frostbite, and altogether the conditions impose such a strain on the system that insensibility is likely to result if the ascent is continued. The temperature records obtained from instruments carried in the cars of balloons are not always satisfactory. The balloon is carried along in the general current of air, and those in the car as a rule experience no sensation of wind. Clinging about it, however, there is a considerable body of air brought from other levels, while the temperature of its own mass, which will alter comparatively slowly, will be liable to affect any thermometer in the immediate neighbourhood. There is also another factor of importance to be considered. It has already been pointed out that the radiant heat from the sun passes through the air without appreciably warming it, but if the rays encounter a solid body they produce a rise of temperature. If, then, the direct rays of the sun fall upon an exposed thermometer, the temperature it records is not the temperature of the air. But as it is this temperature of the air that we require to know, some method has to be adopted to protect the thermometer from this insolation effect. This is in some measure attained by enclosing them in metal tubes with polished exteriors, which reflect the heat, and to prevent stagnation of the air bellows are used to blow air through the tubes. In Germany and some other countries, Assmann's apparatus for aspirating the thermometer is used, which on being wound up causes a small fan to rotate, and so a current of air is sucked up round the bulbs of the thermometers.

Another consideration has to be borne in mind. Balloons often rise and fall at a rapid rate, and if a just idea of the temperature of the air layers at different altitudes is to be obtained, the thermometers used must take up the temperature rapidly—that is, they must be very sensitive. It is thus probable that many temperature records are too high for the ascent and too low for the descent.

In the years 1862–6, Mr. James Glaisher, F.R.S., made a number of balloon ascents with Mr. Coxwell, the aeronaut, on behalf of the British Association, and much valuable information was obtained. Their experiences on their first voyage are instructive. In six minutes from the start the first cloud was passed at 5,800 feet and a further cloud encountered 2,000 feet higher. Four minutes later, the ascent proceeding, the sun shone out, brightly expanding the balloon into a perfect globe, and a magnificent view of the clouds was obtained. A height of 12,700 feet was attained twenty minutes from the start. A minute later the earth was sighted through a break in the clouds, and at 16,900 feet the clouds were far below, the sky above being perfectly cloudless and of an intense Prussian blue.

The temperature records are of considerable interest. At starting the temperature of the air was at 59°. Then at 4,000 feet this was reduced to 45°, and further to 26° at 10,000 feet, when it remained stationary for an ascent of 3,000 feet more. However, at 15,500 feet the temperature had actually risen to 31°, increasing to no less than 42° at 19,500 feet. "At this height," says Mr. Glaisher, "my pulse had accelerated, and it was with increasing difficulty

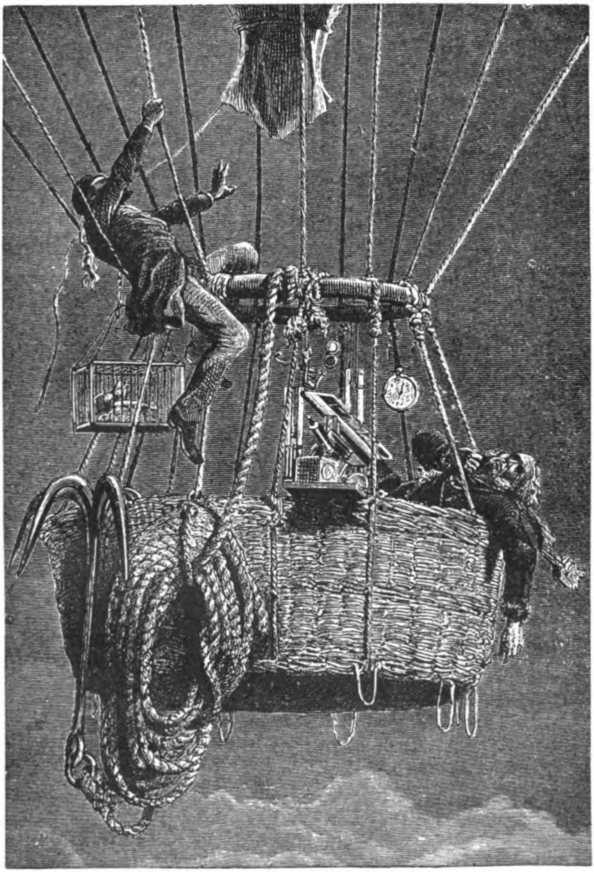


Fig. 55.
Glaisher and Coxwell seven miles above the earth.

that I could read the instruments; the palpitation of the heart was very perceptible. The hands and lips assumed a dark bluish colour, but not the face."

In these days, aeronauts if they intend to reach high altitudes provide themselves with a cyclinder of oxygen, and inhale the gas when the attenuated air causes symptoms similar to those experienced by Mr. Glaisher.

The most remarkable ascent of the series was that from Wolverhampton on September 5, 1862, when an estimated altitude of seven miles was reached. At this great height the barometer pressure was seven inches, and the thermometer indicated a temperature of — 11·9° F. Mr. Glaisher became insensible before reaching this altitude, and Mr. Coxwell's hands were frozen so that he was only able to open the valve by tugging at the cord with his teeth (Fig. 55).

In 1901 Messrs. Berson and Süring in Germany ascended in a balloon to within about 300 feet of the height supposed to have been reached by Messrs. Glaisher and Coxwell, but they had a plentiful supply of oxygen gas to inhale. The lowest temperature which they recorded was — 65° F.

A height of seven miles above the earth's surface seems tc be the limit of human endurance.

In a later ascent Mr. Glaisher found that at two mile from the earth the wind was from the east; between two an three miles it was from the north-east, while higher still i was again directly opposite, viz. south-west. On anoth occasion the temperature was 45° at the commencement o the ascent, andgradually decreased till 4,000 feet was reached Here, in a layer of warm fog it commenced to rise again, til at 7,500 feet it was identical with the reading at 1,500 feet; but what was more remarkable still was the fact that at 10,000 feet the air was actually warmer than when the ascent began.

Mountain observatories.—A good many meteorologists maintain that natural progress in the science depends largely on the systematic investigation of the upper air; and the instances given above, though possibly somewhat extreme cases, give some idea of the complexity of the problem. A

A few years after Glaisher's balloon ascents it was thought that much valuable and regular information of the upper air might be obtained from the summits of mountains, and accordingly a number of high-level observatories were established in various countries.

In 1883 the observatory on Ben Nevis in the west of Scotland was started, and the work there was continued for a period of twenty-one years (Fig. 56). This frequently

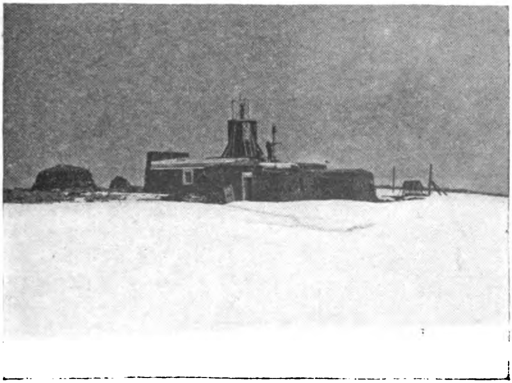


FIG. 56.
Ben Nevis Observatory.

had to be carried on under very difficult conditions. During the months of February and March it was not uncommon for south-easterly gales to blow for three or four days continuously at the rate of eighty to one hundred miles an hour. On these occasions the observers had to go out roped together or to crawl along the surface, otherwise they would have been blown away by the wind. At other times the rain would freeze as it fell, and so everything became coated with ice, which continued to increase in thickness almost indefinitely. During summer, or when the temperature was above the freezing point, the fog soaked everything exposed to it, and so all the instruments outside the observatory streamed with moisture even though no rain was actually falling; while in winter, or when the temperature was below the freezing point, the effect of the fog was to cover everything with long feathery masses of rime or crystalline specks of snow. These continued to grow to great lengths on the windward side until

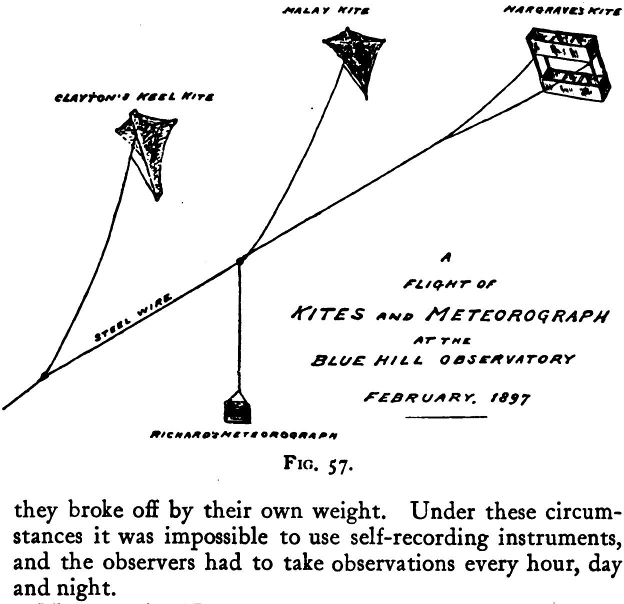


FIG. 57.

they broke off by their own weight. Under these circumstances it was impossible to use self-recording instruments, and the observers had to take observations every hour, day and night.

The summit of Ben Nevis is 4,400 feet high above sea-level, and is the highest point in the British Isles. As temperature decreases approximately at the rate of 1° F. every 300 feet, the temperature at the summit is usually about 15° lower than at Fort William, consequently the snow on the top of the mountain remains unmelted for the greater part of the year. A very complete and valuable record of mountain weather was obtained, but it was found that the results were rather different from what would have been recorded at the same altitude in the free air, as the mountain itself influences the temperature and deflects the air currents.

Records from Kites and Small Balloons.—During recent years great success has attended the efforts to obtain information as to the meteorological conditions in the upper atmosphere by means of kites and balloons. The pattern of kite used for this purpose is the box kite (Fig. 57), and as these kites sometimes ascend to a height of two or three miles above the surface of the earth it is necessary to use a steel wire, and also to have an engine for winding it in or out. Inside the kite is fixed a meteorograph, which is a combination of automatic instruments for recording the pressure, temperature and humidity of the air. The kite being directly under the control of the operator, accurate records of the conditions prevailing above the earth's surface can be obtained. Kites, however, cannot be sent up when the wind is very light or calm.

For obtaining information in regions of the atmosphere at high altitudes, so-called *ballons-sondes* are used (Fig. 58). These are india-rubber balloons about two yards in diameter, usually inflated with hydrogen. When one is about to be used, a very light meteorograph for recording the temperature and pressure is attached to the balloon by a cord about ten feet long. The total lifting power of the balloon is about eight ounces. The ascent continues until the pressure of the imprisoned gas is sufficient to burst the envelope, when the balloon falls. A small parachute then opens and ensures a gentle descent, in order that the meteorograph may not be injured in its fall. A notice is affixed to this, inviting the finder to send it, untampered with, to an address given, and a reward is offered for compliance with the request.

The extremely ingenious form of meteorograph now generally used for these balloons in this country was designed by Mr. W. H. Dines, F.R.S. (Fig. 59). It only weighs about an ounce, and consists essentially of a thin strip of polished metal which bends with the alteration of temperature, and of a metallic box, exhausted of air, which acts as an aneroid barometer. To the strip of metal and to the barometer are attached levers, which cause two hard steel

FIG. 58.
Ballon-Sonde with meteorograph.

points to scratch a record on a small piece of sheet metal about the size of a postage stamp, which is electroplated with copper and silver. The marks consist of two lines, roughly parallel, about half an inch long, about $\frac{1}{30}$ inch apart at the bottom, diverging to about $\frac{1}{10}$ inch at the top. These lines are measured with great accuracy under a microscope, and the results compared with traces obtained by testing the instrument under known conditions of temperature and pressure previous to the ascent. The fact that the meteorograph is suspended at some distance below the balloon and that it is enclosed in an aluminium case like a canister, but

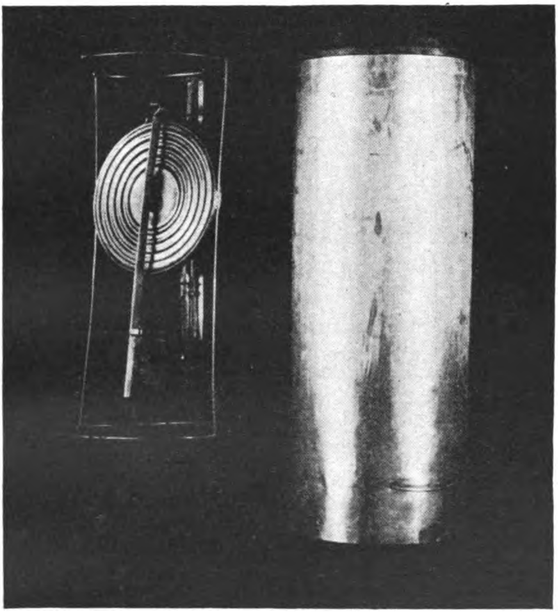


Fig. 59.

Dines' meteorograph for balloons, with aluminium case.

open at the top and bottom, tends to diminish an undue rise of temperature owing to insolation. This is still further eliminated if the ascent is made in the evening after sunset.

In some cases the course taken by the balloon is followed by two observers at the ends of a measured base line. Observations are taken by means of special theodolites, and the successive positions afterwards obtained by trigonometrical

INVESTIGATION OF THE UPPER AIR
VARIATION OF TEMPERATURE WITH HEIGHT

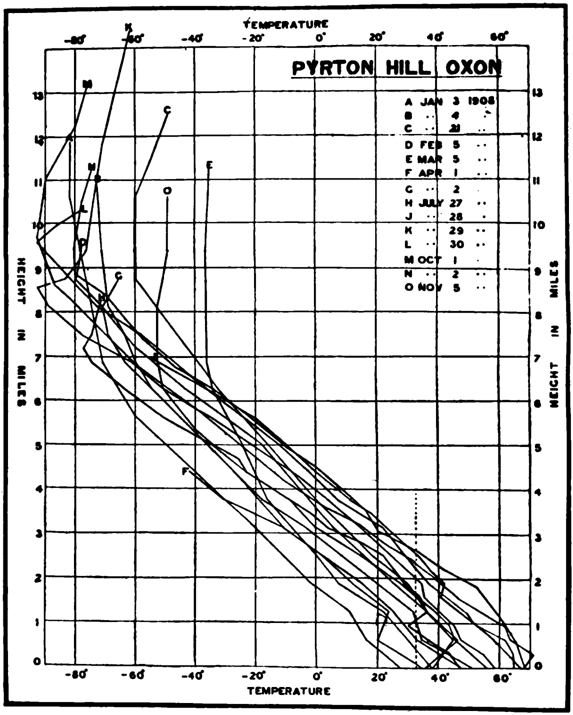


Fig. 60.

calculations. From these the change in the direction and velocity of the wind at various altitudes can be ascertained.

It has been found that owing to friction and the inequalities of the surface the wind is more fitful in the first few hundred feet than it is higher up. Its velocity increases rather rapidly for the first 600 yards of ascent, then remains fairly steady for another 600 yards, after which there is again a considerable increase. The direction of the wind may vary considerably as the ascent continues; but speaking generally, in the temperate regions at a height of two or three miles it has a marked tendency to a westerly direction due to the rotation of the earth. Ascents have been made in the region of the north-east trade winds, and at a height of about three and a half miles the south-west anti-trade winds were encountered. Aeronauts take advantage of the variability, for, aided by skilful observations of the clouds, by ascending or descending they can travel in the air current most suitable for their projects.

A synopsis of the results as regards temperature is given in the accompanying figure (Fig. 60). From these it may be noticed that the temperature decreases with fair uniformity up to about six or seven miles above the earth, but beyond that height there is little or no change, and in fact there is often an increase of temperature.

CHAPTER XIV

Phenological Observations

As soon as we get into the new year those interested in Nature begin to look out for the signs of spring. The appearance of leaves on the trees, the flowering of plants, the advent of some birds and the commencement of the songs of others, the appearance of butterflies and other insects, awaken the interest, and questions often arise as to whether they are early or late in the season. Methodical observations of these facts from typical stations in the British Isles have for many years been collected by the Royal Meteorological Society.

Plants.—The following plants and trees are recommended for observation—

1. Hazel
2. Coltsfoot
3. Wood Anemone
4. Blackthorn
5. Garlic Hedge Mustard
6. Horse Chestnut
7. Hawthorn
8. White Ox Eye
9. Dog Rose
10. Black Knapweed
11. Harebell
12. Greater Bindweed
13. Ivy

A few words of description may enable the lesser known of these to be more readily recognized.

The Coltsfoot is one of the earliest of spring flowers. The bloom appears before the leaves at the end of an upright woolly stalk. It is bright yellow and consists of a great many tubes and somewhat resembles the flower of the Dandelion. It resembles the latter plant, too, in the fact that when the seeds are fully developed a downy ball is formed. When the leaves are small they are covered with down, but later this disappears. The leaves differ from those of the Dandelion, as in the case of the Coltsfoot they are nearly round.

The name Wood Anemone indicates where the dainty little plant so named is to be found. The buds of the flower are pink, but the flowers themselves are white. Each bloom has six sepals, and grows on a short stalk which rises from three dark green leaves, each leaf having three deeply indented divisions.

The unattractive yellow flowers of the Hedge Mustard grow in small clusters at the end of a long stalk. This stalk is covered with thin heavy green pods which hold the seeds. The leaves are very much indented and are rough and hairy. Those at the lower part of the plant have no stalks.

The Black Knapweed is not unlike the Thistle in appearance, but it has no prickles. The flower consists of a multitude of tiny purple tubes fitted into a hard ball. This hard ball is covered with green scales, and it protects the flower before it blooms, and remains on its stiff stalk after the flower has withered. The leaves have little or no stalk, lying rather close to the stem.

The Harebell blooms in late summer or autumn. It has a blue flower, the five petals of which are joined together into a beautiful bell. The flowers grow singly on very slender stalks.

If observations are taken for purposes of comparison, the same individual trees and shrubs should be observed each year, and as regards the plants, those growing in the same spots, under as near as possible the same conditions. The species of tree selected should be common in the locality, and it should not be in a situation either especially favourable or unfavourable to its development. A plant is said to be in flower when the stamens of the first blossom on it first become visible.

The following are the average dates of the flowering of the thirteen selected plants in the various districts of England and Wales based on twenty years' observations—

Plants.	S.W.	S.	Mid-lands.	E.	N.W.
Hazel . . .	Feb. 9	Feb. 4	Feb. 12	Feb. 5	Feb. 13
Coltsfoot . . .	Feb. 25	Mar. 3	Mar. 7	Mar. 5	Mar. 7
Wood Anemone	Mar. 27	Mar. 24	Mar. 30	Mar. 29	Apr. 2
Blackthorn . .	Apr. 2	Apr. 7	Apr. 10	Apr. 9	Apr. 14
Garlic Hedge Mustard .	Apr. 18	Apr. 21	Apr. 24	Apr. 21	May 4
Horse Chestnut	May 2	May 7	May 11	May 7	May 12
Hawthorn . .	May 11	May 12	May 15	May 12	May 19
White Ox Eye .	May 26	May 22	May 29	May 26	June 3
Dog Rose . .	June 6	June 7	June 9	June 7	June 12
Black Knapweed	June 24	June 21	June 27	June 28	July 8
Harebell . . .	July 15	July 4	July 9	July 8	July 8
Greater Bind-weed . .	July 6	July 8	July 11	July 12	July 15
Ivy	Sept. 21	Sept. 28	Sept. 26	Sept. 22	Oct. 10

Birds.—The birds recommended for observation are the

Song Thrush	Nightingale
Swallow	Flycatcher
Cuckoo	

Soon after January 1 the Song Thrush may be heard. It must not be mistaken for the Missel Thrush, a larger bird, which sings with a harsher note. As a rule the Song Thrush lives near the gardens, while the Missel Thrush prefers the plantations and woods, but severe frost brings both sorts to our doors.

The appearance of the Swallow is generally looked upon as a precursor of the coming summer. This bird must be distinguished from the House and Sand Martins, and also from the Swift. The Swallow is bluish black on the back and head, and has a dark bar across the breast. The under parts are white, and the throat and the front part of the beak reddish in hue. The Swift is sooty black all over except a whitish spot on the throat. The House Martin resembles a Swallow, though it is smaller. In addition no part is red, the whole of the underneath part being white, and there is a white patch at the lower part of the back. The Sand Martin is smaller than either of the others, and brown rather than black. The under parts are white, with a band of brown across the breast. In addition to the date of the first appearance of the Swallow, that of its last appearance is also noted.

There is no mistaking the note of the Cuckoo, but to distinguish the note of the Nightingale from those of other evening songsters is not such an easy matter. The song of the Thrush in particular is often taken for that of the Nightingale, and on the other hand the Nightingale sings freely during the day without attracting notice. His song is clear and ringing, every note full and musical.

The Flycatcher reaches us about May. His back and head are brown and his breast greyish with brown spots. He is usually to be seen sitting on a post, rail or perch, in the open, whence he can readily dart off and seize a fly or bee and then return to his perch again.

The average dates of the song and migration of birds for the British Isles are—

Song Thrush	first heard January 23
Swallow	first seen April 18
Cuckoo	first heard April 23
Nightingale	first heard April 22
Flycatcher	first seen May 15
Swallow	last seen October 12

Insects.—The dates when the following insects appear are also noted—

Honey Bee	Orange Tip Butterfly
Wasp	Meadow Brown Butterfly
Small White Butterfly	

The average dates of their first appearance for the British Isles are—

Honey Bee	February 26
Wasp	April 13
Small White Butterfly	April 19
Orange Tip Butterfly	May 11
Meadow Brown Butterfly	June 14

It is a very remarkable fact that the dates should be so close year after year, and it furnishes abundant food for thought.

In addition, detailed information is obtained of the yields in farm crops and fruits. As our weather is more extensively studied, especially in its relation to agriculture, this accumulation of information will be of first rate value as a testing ground for any new theories or reputed discoveries.

CHAPTER XV

Weather and Agriculture

If each month of the year had its proper weather, what a host of difficulties would disappear for the farmer and gardener. Those engaged on the soil may apply all their knowledge and adopt all the means that science dictates, but in the end the last word remains with the weather. Apparently this will always be so in the British Isles, where no dependence whatever can be placed on the climatic conditions for any considerable period. If every farmer equipped a meteorological station and records were kept for years, there would always be the chance of the establishment of a fresh record. Still, an intelligent study of the data obtained, and the application of available knowledge in the same direction, somewhat lessen the agriculturists' risks, and that is a point gained. The reason of a failure may become apparent and its repetition avoided; and an experiment which would be foredoomed to failure from the start may never be commenced. Though previous experience has been in the past, as it is now, the chief guide, no agriculturist can afford to neglect the information placed at his disposal by modern science.

All the weather elements exert an influence on our crops, but the predominating factors are heat and moisture. As regards the temperature, each kind of plant, at every stage of its growth, has its own particular requirements, both for the day and the night. If these are exceeded the plant becomes over-developed and weak, and if they are not reached growth is checked. These requirements, too, must be maintained for a sufficiently long period to enable the plant to reach maturity. For some years in this country maize has been grown as a fodder crop, but our summers are not long enough for the grain to ripen.

It is common knowledge that if the summer is hot the grain crops are ready for harvest sooner than when lower temperatures are the rule. Investigations on an elaborate scale apparently lead to the conclusion that each species requires a constant and definite amount of heat to ripen it. If the average temperature is low it will take a longer time, and *vice versâ*, provided always that a certain minimum temperature is reached. For instance, it has been found that wheat will not mature unless a mean summer temperature of 56° F. is attained. Observations show that our cereals begin to germinate at 42° F., and temperatures above this are effective for growth. From this base temperature, what have been called "accumulated temperatures" are calculated. If the mean temperature of the day was 43° the accumulated temperature for that period would be called one "day-degree." Ten day-degrees for a day would mean that the mean temperature was 10° above the base, viz. 52°, and 70 day-degrees for a week would mean that the mean temperature was 10° above the base. If during part of the twenty-four hours the temperature falls below 42°, the value of the accumulated temperature for the day is obtained by special calculation. Much attention has been paid to wheat, and it has been found by various observers in the British Isles and on the Continent that approximately 1900 day-degrees are necessary from the time the grain germinates till it is ripe for harvest. The finer kinds of barley require about the same amount.

The amount of sunshine plays an important part in the growth of most of the plants we cultivate. Many species will grow freely and mature under the rays of the electric light, if a screen of clear glass intervenes, but no light is so suitable for vegetation as sunlight. Almost every crop is more dependent upon sunshine at some particular period of the year than any other. For instance, corn needs it most at the time of ripening, the grass crops in the spring, the roots in the autumn, and the fruit crops when they are ripening. On the other hand, lack of sunshine appears to affect the fertility of seeds to some extent. Thus it seems desirable to obtain seed that has been ripened under favourable circumstances as regards sunshine.

An important consideration in the growth of some crops, and especially fruit, is the effect of situation upon the liability to injury from frosts.

Reference has been made in the chapter on temperature to inversions of temperature and their causes, and an explanation has been given of the fact that the lowest temperatures recorded in calm weather generally come from stations on low grounds or situated at the bottom of slopes. It has frequently been observed that frost may injure the lower branches of a tree while the upper branches escape its effects. In many parts of the world plants are grown on the hillside in preference to the valleys, where they run greater risk of destruction by frost. The fruit farmers in the hilly districts of Kent do not plant their early-flowering and more delicate trees in the valleys, nor on the summit of the hills; but they prefer a belt varying from 50 to 200 feet on a hill say 300 feet above the sea-level, obtaining, if possible, a southern aspect in order to catch the maximum amount of sunshine.

In some of the mountainous parts of America in winter the frost line can be distinctly traced along the sides of the hills, the vegetation below being blackened, while that above retains its green hue. In the Alps many of the dwellings are found on the hillsides, preferably on terraces; and here during the autumn and winter flowers may sometimes be seen in bloom, while all the vegetation in the valley is in the grip of the frost.

Frosts in the winter, if not too severe, do more good than harm to vegetable life. They give a wholesome check to growth during a dangerous period of the year, while they greatly benefit the soil by their disintegrating effect. Alpine plants have been introduced into England, but as our coldest winters are not sufficient to check their growth they exhaust themselves. They, in common with many of our native plants, are all the better for a complete cessation of activity.

Spring frosts, which sometimes occur as late as May, are the bugbear of the horticulturist and fruit-grower, as most plants are then in active growth and covered with young tender foliage. It is these frosts which, by destroying the blossoms and fruit-buds, so often destroy what would otherwise have been an abundant fruit crop. The destructive action of frost on vegetation is thus explained by Dr. Vines in his *Students' Text Book of Botany*:—

"When a part of a plant which contains a large proportion of water is exposed to a low temperature, a portion of the water contained in the cells escapes from them, and becomes frozen on their surface, the whole tissue at the same time contracting. The ice formed is very pure (the substances remaining behind in a more concentrated form). It has been ascertained that the formation of ice is, in itself, not necessarily fatal in all cases. If the frozen part be slowly thawed, the cells may gradually reabsorb the water and so return to their previous normal condition. If, however, the frozen part be quickly thawed, the cells cannot absorb the water sufficiently rapidly; it therefore either collects in the intercellular spaces, causing discoloration and decay, or it runs off and evaporates, so that the part dries up."

Many attempts have been made to mitigate the effects of night frosts, especially in those districts in the United States where fruit-growing is an important industry. In some cases actual warming of the air has been tried by lighting a number of small fires in wire baskets. A more common method, known as "smudging," consists in burning various smoky substances, so as to check radiation by the formation of a cloud of smoke over the orchard. The effectiveness of this depends a good deal on so arranging the fires that the smoke drifts over the right spot. In the case of low-growing plants or seedlings, straw, or any similar light litter may with advantage be distributed lightly over them when an unusually keen spring frost threatens, and in the garden single sheets of newspaper are usually quite sufficient to afford the necessary protection.

During germination and the earliest stages of growth of a plant, the temperature of the soil is important. A dark-coloured soil absorbs heat more readily than a light-coloured one. If the soil is damp evaporation from it causes a decrease in temperature, and it takes longer both to warm and to cool than a dry one. Tillage of the surface retards the escape of water by evaporation, and also retards the transmission of heat.

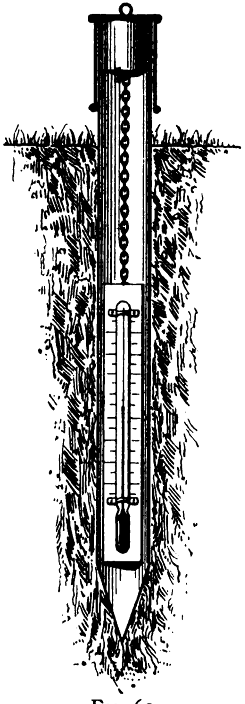


FIG. 61.
Symons's earth thermometer (section).

The most convenient instrument for obtaining the temperature of the soil is Symons's Earth Thermometer (Fig. 61). This consists of a thermometer mounted in a short stick of wood attached to a chain, and of a stout iron tube or gas-pipe with the lower end drawn out to a point and driven into the earth to any required depth. The chain is fastened to a copper cap which covers the top of the pipe.

From the records in various parts of England published by the Royal Meteorological Society we learn that the temperature at a depth of one foot is rather higher than the mean temperature of the air throughout the year, except in the early spring. At greater depths the soil is a little warmer than at one foot on the mean of the year. The range of temperature in the soil between the warmest and coldest month gradually gets less and less the lower we descend, until at a depth of about fifty feet the temperature becomes practically uniform throughout the year. Down to a depth of one foot the ground is liable to be frozen occasionally in most parts of England, but it is only in a few places that readings below 30° have been recorded. In the great frost of February 1895 many water pipes, however, burst, although laid at a depth of three feet.

Indirectly the temperature of the soil must have a considerable influence on the chemical changes and preparation of plant food which take place there. At first sight it would appear that the freezing of the soil would be destructive to insect life, but their winter retreats are generally at such a depth as to render them secure. If they are lured from their quarters by premature warmth, and this is followed by severe frost, doubtless many are destroyed.

The influence of rainfall on vegetation stands second only in importance to temperature, for each kind of plant not only requires a certain degree of warmth, but also a certain amount of moisture in order to attain its full development. In this latter respect the two main divisions of farm crops, cereals and root crops, differ considerably in their requirements. As a general rule in the British Isles, with their comparatively moist climate, there is a sufficiency of rain for the cereals, while the root crops seldom get too much and frequently get too little moisture. Should the rainfall be short, the cereals, with their deeper roots, suffer less than the shallower rooted grasses and root crops. In connection with this question of rainfall, it must be borne in mind that only part of the rain is effective for plant growth. This amount depends upon the following considerations: (1) the natural and artificial drainage; (2) the nature of the soil; (3) the extent and nature of vegetation covering it; and (4) the exposure to action of sun and drying winds.

The agriculturist usually endeavours to get a thoroughly porous surface soil on the dry side, and a permanent supply of moisture within reach of the plants' roots in the subsoil. The broken surface aids in the collection of rain, and allows air to penetrate to the roots. Too severe drainage, whether natural or artificial, impoverishes the land. In the first place it prevents the storage of moisture for the drier parts of the year, and in the second place it tends to wash away the soluble plant food, consisting largely of nitrates. Experiments prove that the soil is richest in nitrates after the driest part of the year, from July to September, and poorest after the drainage has been greatest from April to June. The greatest loss of the valuable plant food consequently occurs during unusually wet autumns and winters, whereas during a dry and sunny spring and summer the soil increases most in fertility. This loss in autumn and winter is accentuated owing to the land at these periods being usually bare of crops. Investigations have been carried on in recent years, notably by Dr. Shaw, with the object of ascertaining if there was any relation between the yield of wheat and the rainfall of the British Isles. From the statistics discussed he found that, with the exception of two years, the yield of wheat was above the average when the rainfall of the previous autumn was below the average, and *vice versâ* (Fig. 62).

It appears that less land is sown with wheat in a wet autumn than in a dry one. This may be possibly because the farmer is aware that a wet seed bed is unfavourable, or more probably because of the increased difficulty in working the soil when it is in a sodden condition. Whatever motive prompts the farmer, his practice in the matter accords with what theory teaches would be most advantageous.

Another point to be considered in connection with the rainfall is the relation between the amount which sinks into the soil and the amount which is evaporated. Naturally this varies according to the season of the year. Thus in experiments conducted at Rothamsted it was found that in November three-quarters of the rain which fell sank into the soil, the other quarter was evaporated. In July and August about one-third sank into the soil and the remainder evaporated. Should the ground be covered with a close crop, the amount accounted for by evaporation is increased, and in the case of land permanently under pasture, very little of the summer rain ever gets below the roots. Thus if a

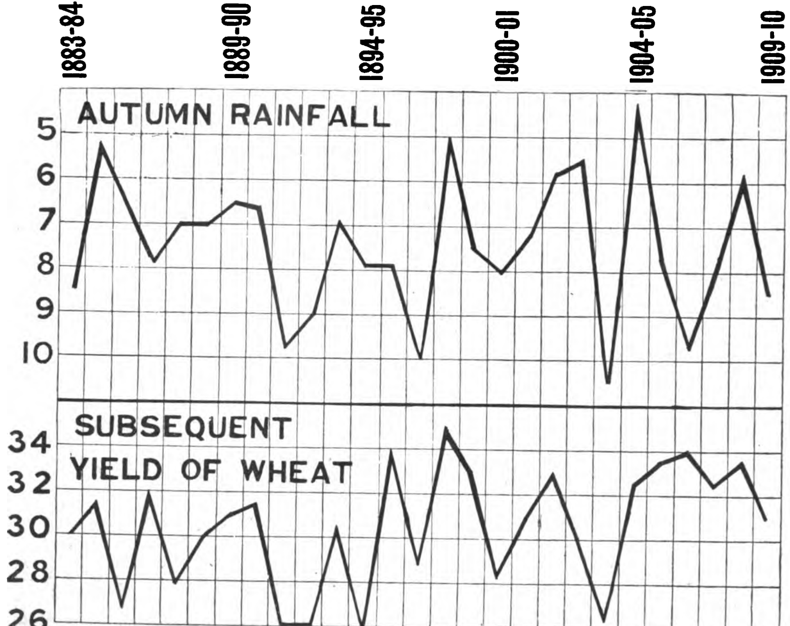


FIG. 62.
Autumn rainfall and subsequent wheat crop.

drought occurs grass, garden plants and root crops suffer more than the deeper rooted cereals and fruit trees. Generally speaking the farmer considers it advisable not to place too many eggs in one basket, but rather to grow a variety of crops, thus diminishing the chances of complete failure for the season. So little dependence can be placed on our weather, that should a period set in favourable to any contemplated work on farm or garden, the operation should be commenced at once. There is always the considerable risk that the opportunity may speedily pass and that a prolonged spell of unfavourable weather may ensue.

CHAPTER XVI

Weather Lore

Ever since men have written at all they have generalized about the weather. In addition, those who lead an outdoor life, be it on land or sea, have accumulated stores of sayings and proverbs, on which they base their prognostications of the weather. Whole volumes have been filled with these short cuts to weather forecasting, and interesting reading they make. These prognostications are associated with the months of the year, or even certain days of the year; the moon and the sun, the appearance of the sky, the winds, the behaviour of animals, birds and insects, and the time of appearance of flowers. Many are true, and reasonable explanations can be given; some are true, but the "reason why" is still obscure; while others may be true, but await scientific investigation. A large number have purely a local application, being only of value in particular districts, but the largest number of all must be disregarded entirely. They have been founded on an entirely inadequate number of facts, the "hits" have been counted, and the "misses" conveniently and quietly ignored. Moreover, some in the latter class are entirely contradictory in their purport.

Predictions associated with certain months or days are very unreliable. In connection with every month of the calendar there are proverbs which claim to foretell the weather at some future date, but none are worthy of general acceptation. Still less worthy are those associated with particular days. There is a general truth in—

"As the day lengthens
So the cold strengthens,"

for it is a well-known fact that, taking a long period, the end of January and the beginning of February are the coldest parts of the year.

Many are the proverbs against a fine February, of which the following is a type—

"If in February there be no rain,
'Tis neither good for hay nor grain."

And there are almost as many in favour of a dry March—

"A dry and cold March never begs its bread."

"A wet March makes a sad harvest."

The second month of the year is often referred to as "February Fill-dyke." As we have said, however, statistics show, in a most unmistakable manner, that on the average February is one of the driest months of the year.

No reliance can be placed on the following—

"March, black ram
Comes in like a lion and goes out like a lamb."

Of the sayings connected with certain days, that associated with St. Swithin's Day, July 15, dies very hard.

"If St. Swithin greets, the proverb says
The weather will be foul for forty days."

Similar predictions are to be found in various other European countries, but there are differences as to the dates. In

France it is the day of St. Medard (June 8); in Belgium, St. Godelieve (July 6), and in Germany the day of the Seven Sleepers (June 27). No reliance whatever can be placed on this prediction.

When we come to sayings based on the appearance of the sky, and of the sun and moon, we are on surer ground. If anticyclonic conditions prevail, mist or fog may be formed in the valleys at night, while the active radiation of the earth's heat is going on, and this is soon dissipated in the morning by the sun's rays, unweakened by filtering through overhanging clouds. If this fine weather mist is not present the sun rises red, and—

> "If red the sun begin his race,
> Be sure the rain will fall apace."

On the other hand, during fine weather the cumulus clouds on the western horizon become thin towards sunset, and give way to the less dense alto-cumulus variety, and the setting sun shines red through these, but—

> "If the sun goes pale to bed,
> 'Twill rain to-morrow, it is said."

> "Evening red, and morning grey,
> Two sure signs of one fine day."

> "A rainbow in the morning
> Is the shepherd's warning;
> A rainbow at night
> Is the shepherd's delight."

The explanation of this well-known weather saw is of interest. The rainbow is caused by the splitting up of the white light of the sun into the prismatic colours, and this occurs in the raindrops. It is always to be observed in that part of the heavens opposite to the sun. If a rainbow is seen, then, in the morning, there is rain towards the west of the observer, and from what has been said about the eastward movement of cyclonic depressions it is likely that the sunshine prevailing will soon give place to rain. If, on the contrary, the rainbow is seen in the eastern sky in the evening, the presumption is that the rain area has passed and that the finer weather usually experienced in the rear of a depression may be expected.

There are still a large number of people who believe that the moon exerts some controlling influence over the weather, and that this influence is greatest at the times of the moon's changes. This theory has been examined by many meteorologists, and has been found to rest on no foundation of fact.

The appearance of the moon or sun, as apart from its phases, does, however, give some indication of the probable future weather. Occasionally it is seen surrounded by a ring or halo which subtends an angle at the eye of the observer of 22°. Still less frequently the ring is larger, the angle being 45°. If these rings are very clear, they appear reddish on the inside edge, and bluish on the outer. They occur when the moon's or sun's rays pass through clouds of the cirro-stratus type. Clouds of this nature are composed of minute ice crystals, and it is the passage of the light through these that produces the halo. As cirrus clouds are often the first indications we get of an on-coming cyclone, the appearance of a lunar or solar halo is often followed by rain.

"If the moon shows a silver shield,
Be not afraid to reap your field,
But if she rises halo'd round,
Soon we'll tread on deluged ground."

A pale, watery moon indicates the presence of much moisture in the atmosphere and probable rain.

We all regard the appearance of the clouds as of first importance in foretelling the weather. But the exact interpretation of the clouds in a particular district is often better understood by the intelligent native than by the more or less theoretical meteorologist, the different types of weather producing their own local characteristics. This is particularly noticeable in hilly districts. Wherever there are hills of any considerable height, we usually find sayings connecting their appearance with the weather. The following are instances—

> "When Cheviot ye see put on his cap,
> Of rain ye'll have a wee bit drap."

> "When Skiddaw hath a cap,
> Criffel wots fu' well o' that."

There are many sayings connected with the winds and the weather associated with them. Usually the explanation of this weather can be readily seen on studying the paths of the cyclonic disturbances as they cross our isles.

> "A Northern air
> Brings weather fair."

> "When the wind is in the East,
> 'Tis neither good for man nor beast."

This wind probably has had much of its moisture wrung out of it in its passage across northern Europe, and when it reaches this country it is cold and very dry. It is the rapid rate at which it extracts moisture wherever possible that causes its withering effects on plant life and the physical discomfort to mankind.

If a succession of depressions rapidly follow one another, as not infrequently happens, we get a justification of—

> "A Nor-wester is not long in debt to a Sou-wester."

The following very general weather saying is often correct—

> "Rain before seven,
> Fine before eleven."

It is usually associated with a small secondary depression, which only lasts a few hours and then passes away.

> "Early morning rain will not last the day."

It is a well-known fact that the atmosphere is frequently exceptionally transparent both before and after rain. Thus we find such sayings as that of the Brighton boatmen, who foretell rain in the next twenty-four hours if they can see Worthing clearly. Both visibility and audibility are most pronounced features of the ridge or wedge-shaped distribution of barometric pressure.

When the air is moist and the sky covered with clouds, which may be thin, the light from towns, factories, furnaces, etc., is partially reflected, and a glow is seen in the sky. On occasion this may be very marked and visible at a distance of many miles.

There is a large amount of weather lore connected with the behaviour of animals, wild and domestic, birds and insects. Many of these creatures seem particularly susceptible to the moisture in the atmosphere, and just before rain they become restless and disturbed, showing signs of this in various characteristic ways. Most of these proverbial sayings are interesting, and many might be quoted if space permitted. A considerable number, however, are included in the following collection of rain prognostics attributed to Dr. Jenner—

"The hollow winds begin to blow,
The clouds look black, the glass is low,
The soot falls down, the spaniels sleep,
And spiders from their cobwebs peep.
Last night the sun went pale to bed,
The moon in halos hid her head.
The boding shepherd heaves a sigh,
For, see! a rainbow spans the sky.
The walls are damp, the ditches smell,
Closed is the pink-eyed pimpernel.
Hark! how the chairs and tables crack,
Old Betty's joints are on the rack;
Her corns with shooting pains torment her
And to her bed untimely send her.
Loud quack the ducks, the peacocks cry,
The distant hills are looking nigh.
How restless are the snorting swine!
The busy flies disturb the kine.
Low o'er the grass the swallow wings,
The cricket, too, how sharp he sings!

Puss on the hearth, with velvet paws
Sits wiping o'er her whiskered jaws.
Through the clear stream the fishes rise
And nimbly catch th' incautious flies.
The glowworms, numerous and bright,
Illumed the dewy dell last night.
At dusk the squalid toad was seen
Hopping and crawling o'er the green.
The whirling dust the wind obeys,
And in the rapid eddy plays.
The frog has changed his yellow vest,
And in a russet coat is dressed.
Though June, the air is cold and still,
The mellow blackbird's voice is shrill.
My dog, so altered in his taste,
Quits mutton bones on grass to feast.
And, see yon rooks, how odd their flight,
They imitate the gliding kite,
And seem precipitate to fall,
As if they felt the piercing ball—
'Twill surely rain—I see with sorrow
Our jaunt must be put off to-morrow."

APPENDIX I

English Climate

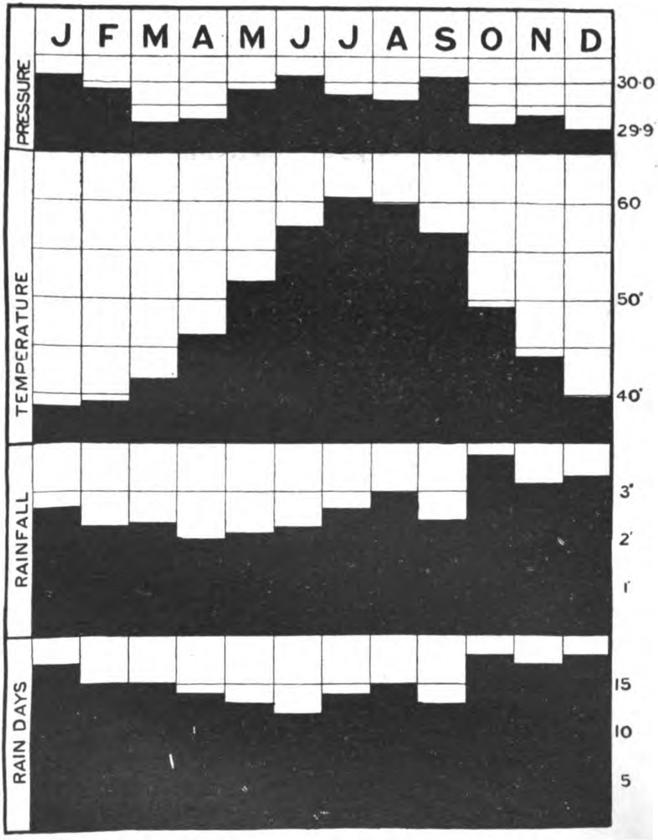


Fig. 63.

Average monthly barometric pressure, temperature, rainfall, and number of rain days for England and Wales, 1881–1910.

APPENDIX II

Table I

Comparison of the Fahrenheit and Centigrade Thermometer Scales

Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.
Degrees.	Degrees.	Degrees.	Degrees.	Degrees.	Degrees.	Degrees.	Degrees.
20	−6·7	40	+4·4	60	+15·6	80	+26·7
21	−6·1	41	5·0	61	16·1	81	27·2
22	−5·6	42	5·6	62	16·7	82	27·8
23	−5·0	43	6·1	63	17·2	83	28·3
24	−4·4	44	6·7	64	17·8	84	28·9
25	−3·9	45	7·2	65	18·3	85	29·4
26	−3·3	46	7·8	66	18·9	86	30·0
27	−2·8	47	8·3	67	19·4	87	30·6
28	−2·2	48	8·9	68	20·0	88	31·1
29	−1·7	49	9·4	69	20·6	89	31·7
30	−1·1	50	10·0	70	21·1	90	32·2
31	−0·5	51	10·6	71	21·7	91	32·8
32	0·0	52	11·1	72	22·2	92	33·3
33	+0·6	53	11·7	73	22·8	93	33·9
34	1·1	54	12·2	74	23·3	94	34·4
35	1·7	55	12·8	75	23·9	95	35·0
36	2·2	56	13·3	76	24·4	96	35·6
37	2·8	57	13·9	77	25·0	97	36·1
38	3·3	58	14·4	78	25·6	98	36·7
39	+3·9	59	+15·0	79	+26·1	99	+37·2

Table II

Weight in Grains of a Cubic Foot of Vapour, at the pressure of 30 inches of Mercury

Temp.	Grains.	Temp.	Grains.	Temp.	Grains.	Temp.	Grains.
Degrees.		Degrees.		Degrees		Degrees.	
20	1·3	40	2·9	60	5·8	80	11·0
21	1·4	41	3·0	61	6·0	81	11·3
22	1·4	42	3·1	62	6·2	82	11·7
23	1·5	43	3·2	63	6·4	83	12·0
24	1·5	44	3·3	64	6·6	84	12·4
25	1·6	45	3·4	65	6·8	85	12·8
26	1·7	46	3·6	66	7·0	86	13·2
27	1·7	47	3·7	67	7·3	87	13·6
28	1·8	48	3·8	68	7·5	88	14·0
29	1·9	49	4·0	69	7·8	89	14·4
30	2·0	50	4·1	70	8·0	90	14·8
31	2·1	51	4·2	71	8·3	91	15·3
32	2·1	52	4·4	72	8·5	92	15·7
33	2·2	53	4·5	73	8·8	93	16·2
34	2·3	54	4·7	74	9·1	94	16·7
35	2·4	55	4·9	75	9·4	95	17·2
36	2·5	56	5·0	76	9·7	96	17·7
37	2·6	57	5·2	77	10·0	97	18·2
38	2·7	58	5·4	78	10·3	98	18·7
39	2·8	59	5·6	79	10·6	99	19·3

TABLE III

For Calculating the Relative Humidity

Difference between Dry and Wet readings.	Temperature of the Air.						
	30°.	40°.	50°.	60°.	70°.	80°.	90°.
Degrees.	Per cent.	Per cent	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
0	100	100	100	100	100	100	100
1	84	92	93	93	94	95	95
2	70	84	86	88	89	90	90
3	58	76	79	82	83	85	85
4	47	70	73	76	78	80	81
5	39	63	68	71	74	76	77
6	32	58	62	66	69	72	73
7	28	52	58	62	65	67	69
8	23	47	53	58	61	64	65
9	18	43	49	54	57	60	62
10	14	38	45	50	54	57	59
11	12	34	41	46	50	53	56
12	10	31	38	43	47	50	53
13	8	28	34	40	44	47	50
14	6	25	32	37	41	45	47
15	5	23	29	35	38	42	44
16	4	21	26	32	36	39	42

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