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METEOROLOGY.

BY

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EXCERPT PAPER
FROM HUGHES'S "READING LESSON BOOKS."

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EXCERPT PAPER

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Meteorology.

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LESSON I.

THE BAROMETER.

"And God made the firmament, and divided the waters which were under the firmament from the waters which were above the firmament."

1. METEOROLOGY is that part of Natural Philosophy which treats upon the various phenomena which have their origin in the atmosphere. With the view of connecting cause and effect, and determining the laws by which atmospheric changes are regulated; its pursuit embraces investigations into the degrees of atmospheric pressure, temperature, humidity, purity of air, and it admixture with exhalations more or less salubrious; the course of storms, clouds, clearness of sky, meteors, the fall of rain, hail, snow, and all other phenomena and modifications of the atmosphere, by which our organs are affected.

2. The volume of the atmosphere is composed of permanently elastic fluids, which are retained near the surface of the earth by gravitation. Its main constituents are the gases oxygen and hydrogen. The atmosphere also contains a certain amount of moisture; carbonic acid, and minute portions of vapours of all substances with which it is in contact, some of which are of too subtle a nature or in too small quantities to be detected by our instruments. Some of these unknown substances, when mingled with the atmosphere,

impart to it deleterious qualities. By experiment it has been found that the proportions of oxygen and hydrogen are very uniform at all places on the earth, at all heights above its surface, and at all seasons of the year, and amount to 77 parts nitrogen, 23 oxygen by weight—79 parts nitrogen, 21 oxygen by volume. The component in the atmosphere which is liable to the greatest change in its quantity is the amount of moisture, and including this and carbonic acid at an average temperature and pressure, the ordinary constituents of the atmosphere appear to be in the following proportions:—

Oxygen - - - -	19·7
Nitrogen - - -	78·8
Aqueous vapour - -	1·4
Carbonic acid - - -	0·1
	100·0

3. These several elastic fluids constituting the atmosphere do not separate or arrange themselves according to their relative specific gravities, and therefore form independent atmospheres mixed together, but not in a state of combination. Each of its ingredients exerts its own separate pressure to make up the whole pressure of the atmosphere, and when the reading of the barometer is 30 inches, the part due to each is nearly as follows:—

			in.
The elastic force of	nitrogen	- -	23·4
,, ,,	oxygen	- -	6·2
,, ,,	vapour	- -	0·4
			30·0

The pressure due to the presence of carbonic acid gas amounts to 0·02 inch only; and of ammonia there is only a trace.

4. Weight of the Air.—If a glass tube, three feet in length, and closed at one end, be filled with mercury, and its open end plunged in a basin filled with the same metal, the surface of the mercury in the tube will be, at the level of the sea, nearly 30 inches higher than that in the basin. This column of mercury is

balanced by a column of air, of the same area as that of the tube, and extending to the top of the atmosphere; if that of the tube be one inch, the mercury in the tube weighs nearly 15 pounds, therefore the atmosphere presses on the surface of the earth, with a weight of 15 pounds to the square inch, when the reading of the barometer is 30 inches.

5. The atmosphere is influenced by a multitude of causes, and is ever varying in pressure, temperature, humidity, &c. The barometer is one of the instruments employed to determine these incessant changes, and has rendered very essential service to science. It has determined that the pressure of the atmosphere at the level of the sea supports a column of mercury from 29 to 30 inches in length all over the world, and that as we ascend, the pressure decreases. Approximate laws have been determined connecting the pressure of the higher with that of the lower strata of the air, and these have had an important bearing in relation to physical geography in making known to us the various irregularities of the earth's surface, determining the elevation of the sources of rivers and the sites of ancient cities, the heights of mountains, &c. It is in daily use in determining, in astronomical observations, the amount of atmospheric refraction; on board of ship in indicating the approach of storms; and connected with the changing direction of the wind in storms, points the way to sail out of them.

6. Thus the barometer holds an intimate connexion with the pressure of the air, and its distribution over the varied surface of the earth. Its value, however, is greatly dependent upon the method of its construction. In the making, all air and moisture should be excluded from the tube, and the mercury with which it is intended to be filled should be pure and boiled within it: the diameter of the tube should be such that the correction for capillarity be small, as in such a tube the mercury moves with greater freedom, and the variation follows with more promptness than in one of small diameter. Its readings before use should be compared with those of a standard barometer, for the purpose of determining

its index error. In use corrections should be applied for index error, capillarity of tube, and for the reduction of the observations to what they would have been at a constant temperature.

7. The annexed engraving (fig. 1.) shows the form of instrument in general use among the members of the British Meteorological Society. It consists of a tube from three to four-tenths of an inch in its inner diameter, filled with pure mercury, of 13·5 specific gravity,* and which has been boiled within it throughout its whole length. The open end of the tube is immersed in a cistern of pure mercury, and the whole inclosed in a brass cylinder or tube. A piece of ivory or steel is fixed to the upper part of the cistern, pointing downward: the image of this is reflected from the surface of the mercury in the cistern, which is raised or lowered *at every observation*, till the ivory point and its image are just in contact. This ivory point forms one end of the scale. The upper part of the brass tube is graduated into inches, and parts of inches, reckoning from the ivory point in the cistern, and constitutes the scale. A thermometer is attached to the barometer with its bulb

Standard Barometer.

Fig. 1.

* As the lengths of liquid columns balanced by the atmosphere are inversely as their densities, it is imperatively necessary to employ pure mercury, and of the same specific gravity, or otherwise the length of the column will be longer than that shown by a standard barometer.[1]

[1] Mercury is purified from the presence of lead or iron by washing it with acetic or sulphuric acid.

immersed in the mercury in the cistern, or, if the instrument is intended for travelling, it is affixed to the tube, its bulb being of the same size as the tube of the barometer. The whole is attached to a slab of mahogany, which may be secured at will against a wall or wooden frame.

8. We will now suppose the observer in possession of his barometer; he is desirous to ascertain that it is in good working order: he must, for that purpose, determine whether the space above the mercury be free from air. This is done by inclining the instrument from its vertical position, when, if the mercury, in striking against the upper end of the tube elicit a sharp tap, the perfect condition of the vacuum is fully established. If the tap be dull or not heard at all, the amount of air above the mercury is considerable, and must be driven into the cistern by inverting the instrument, and gently tapping it with the hand. If the confined air cannot be thus expelled, the instrument is useless.

Having satisfactorily determined that there is no air within the tube, it is necessary to fix the barometer in a suitable position. For this purpose a place should be chosen, commanding a good light, but not exposed to sunshine; and the tube adjusted vertically or nearly so, by means of a plumb-line, and fixed by means of the three screws, either situated at the top or at the bottom of the tube.

9. In observing, the eye should be placed, by means of the fore and back part of the lower termination of the vernier, at an exact level, and whilst so placed, the lower part of the vernier should be brought to the apex of the mercurial column,—so that the eye, the fore part of the vernier, the top of the mercurial column, and the back of the vernier, be all in the same horizontal plane.

The reading is to be taken by means of the scale on the limb and the vernier. It is necessary, however, to explain the vernier and its action.

10. *The vernier* is a contrivance (invented by Peter Vernier, who published an account of it, in a work printed at Brussels, in 1631), for measuring small spaces

between the divisions of the graduated limb of an instrument. It consists of a short moveable scale, made to pass along the graduated limb, the divisions of the one being to those of the other in the proportion of two numbers, which differ from each other by unity. The vernier is moved by either a micrometer-screw, or, as applied to the barometer, by a rack and pinion, and slides up and down the principal division on the instrument.

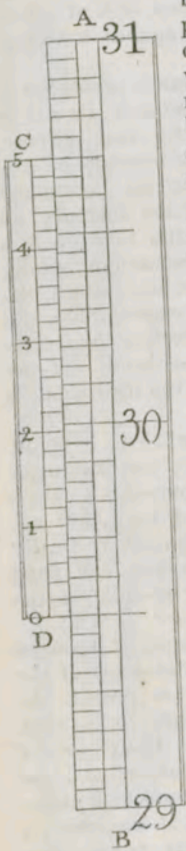


Fig. 2.

When the vernier is so placed that its zero coincides exactly with a division on the limb, the reading is made at once from the limb, and the vernier is not brought further into use; but, if the zero of the vernier does not coincide with any divisions on the limb, but falls between two of them, which is usually the case, then some other division of the vernier will coincide, or very nearly coincide, with one of the divisions on the limb, and the reading on the limb at the zero of the vernier, is to be increased by the reading of the vernier.

11. The scale of the barometer is divided into inches, reckoning from the surface of the mercury in the cistern: each inch is divided into ten parts, or into tenths of inches; and each tenth of an inch is further divided into half-tenths, or five hundredths of an inch. The vernier is made equal in length to twenty-four of these divisions, and divided into twenty-five equal parts; consequently one of the smaller divisions on the barometer-scale is divided into as many parts as there are divisions on the vernier. In this case, each division on the scale

is 0·05 inch, which divided into twenty-five parts gives 0·002 inch, so that a vernier thus arranged reads to two-thousandths of an inch. In practice it will at times happen that no line on the vernier is in coincidence with a line on the scale: in these cases the reading is intermediate, and may be taken to a thousandth of an inch.

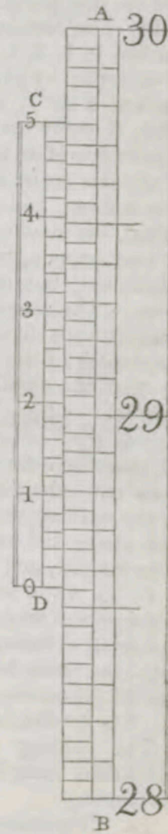


Fig. 3.

12. An example will make this description (necessarily complicated) easy. Let A B (fig. 2.) be the scale of the barometer, divided into inches, tenths, and five hundredths of an inch.

Let C D be the vernier, equal in length to twenty-four of the smallest divisions on the limb, and divided into twenty-five equal parts.

Let the position of the vernier with respect to the scale be as represented in the diagram, where its zero is coincident with the line 29·5 inches on the scale, the reading in this case would be 29·500 inches. If the zero of the vernier coincided with any other division on the scale, the reading of that division would be the one required.

13. Suppose, on the contrary, that the position of the vernier with respect to the scale be such, that its zero does not coincide with any division on the limb, then by passing the eye along the vernier, some other division will be found coincident, or nearly coincident, with a line on the scale.

Let A B (fig. 3.) be the barometer scale as before, and C D the vernier, the zero of which is situated between the readings of 28·5 and 28·6 on the scale, therefore the reading is greater than 28·50, but less than 28·60. The reading

28·5 is at once taken, the zero is above the half-tenth or five hundredth, making therefore 28·55. The reading is 28·55, and the space between the zero of the vernier and the line 28·55 : *this space is measured by the vernier.*

14. The vernier is divided into five great divisions, marked 0, 1, 2, 3, 4, 5, corresponding to the hundredths of an inch: by passing the eye up the vernier, if the line marked 3 on it be found coincident with one on the limb, it shows that the zero line of the vernier is three-hundredths of an inch above the division the next below it on the scale, and the reading would be 28·58. In like manner, had the line marked 1, 2, or 4, been coincident, the reading would be found in the same way. It may happen, however, that not one of these lines is coincident, but one which is situated between two of them. The space between two consecutive numbers on the vernier is divided into five equal parts; that is, one-hundredth of an inch is divided into five equal parts, so that the small division on the vernier corresponds to $\frac{0·01}{5} = 0·002$ inch, (two-thousandths of an inch). If, therefore, the first line on the vernier above 3 had been coincident in the last example instead of the line 3, the reading would have been 28·582; if the second line above had been coincident, the reading would have been 28·584, and so on.

In fig. 3 the second line from the zero of the vernier is coincident with a line on the scale, and as each of the small divisions on the vernier corresponds to 0·002 inch, the space between the zero of the scale and the line 28·55 on the limb is 0·004 inch, and the reading of fig. 3 is 28·554 inch.

The reading of the thermometer attached to the barometer must be taken with every observation of the barometer.

15. *Corrections to be applied to barometer-readings* are three in number—viz., one for the depression of the mercury in the tube, owing to capillarity; the second for index-error: these two corrections are constant for the same instrument, and may be combined by taking their algebraical sum, applied as one correction. The

corrections for capillarity for boiled-tubes of different diameters are as follows :—

Diameter of tube.	Corrections for capillarity.
0·1 inch	0·070 inch
0·2 „	0·029 „
0·3 „	0·014 „
0·4 „	0·007 „
0·5 „	0·003 „
0·6 „	0·002 „

These numbers in all cases are to be applied additively. As the corrections are considerable, and some uncertainty exists when the diameter is small, tubes of less than 0·3 inch should not be used. The index-error is the difference between the true readings and those given by the barometer, and is determined by means of a standard barometer, or by one whose error of graduation is known. If the barometer reads too high, the correction for index-error is subtractive; and if too low, additive.

16. As both the mercury and the tube expand and contract with an increase or decrease of heat, the readings of a barometer will vary with the differences of temperature, although the atmospheric pressure may continue unaltered; it is therefore necessary to apply corrections on this account, and also for the purpose of comparing together observations, taken at distant places, where the temperatures are necessarily different.

17. *Example.*—Suppose the reading of a barometer —whose inner diameter of tube is 0·3 inch, and index-error is +0·005 inch—to be 29·785, and that of the attached thermometer to be 75°, required the correct reading of the barometer at the temperature of 32°.

Reading of the barometer		29·785	attached therm. 75°
Correction for capillarity	+	·014	
		29·799	
Correction for index-error	−	·005	
		29·794	
Correction for temperature	−	·124	
Correct reading at 32°		29·670	

Had the reading of the attached thermometer been 20° instead of 75°, the reduction would have been performed as follows:—

	In.
Barometer reading corrected for index error and capillarity - - - - - - - -	29·794
Corrections for temperature to 32° - - - +	·023
Correct reading at 32° - - - - - - -	29·817

18. The readings of the barometer are almost constantly varying; the daily changes in a year are as follows:—

	in.		in.
On 132 days the change is		less than	0·1
On 123 days it exceeds	0·1	and is less than	0·2
On 61 ,, ,,	0·2	,, ,,	0·3
On 27 ,, ,,	0·3	,, ,,	0·4
On 12 ,, ,,	0·4	,, ,,	0·5
On 6 ,, ,,	0·5	,, ,,	0·6
On 4 ,, ,,	0·6	,, ,,	1·0

and on one day in ten years the variations may amount to $1\frac{1}{4}$ inch.

19. The average daily change of reading in the months of

	in.
March, April, and May, is - - - -	0·165
June, July, and August, is - - - -	0·139
September, October, and November, is -	0·190
December, January, and February, is -	0·213

Upon the whole year the average is 0·175 inch.

The range of reading in each month is shown in the following table:—

Month.	Range of Readings of Barometer.	Month.	Range of Readings of Barometer.
	in.		in.
January -	1·44	July - -	0·79
February -	1·22	August -	0·97
March - -	1·23	September -	0·95
April - -	1·06	October -	1·33
May - -	1·02	November -	1·53
June - -	0·89	December -	1·52

In summer the range may be as small as 0·5 inch, and in winter as large as 2·5 inch.

20. In the torrid zone the daily oscillations of the readings of the barometer are so uniform that the hour of the day may almost be known from them: even in the temperate zones, where the constant variations from heat to cold, from fine weather to bad, changes in the direction of the wind, &c., seem to impress uncertainty over all, yet, from series of observations extended over a sufficient length of time, with good instruments, analogous changes are shown.

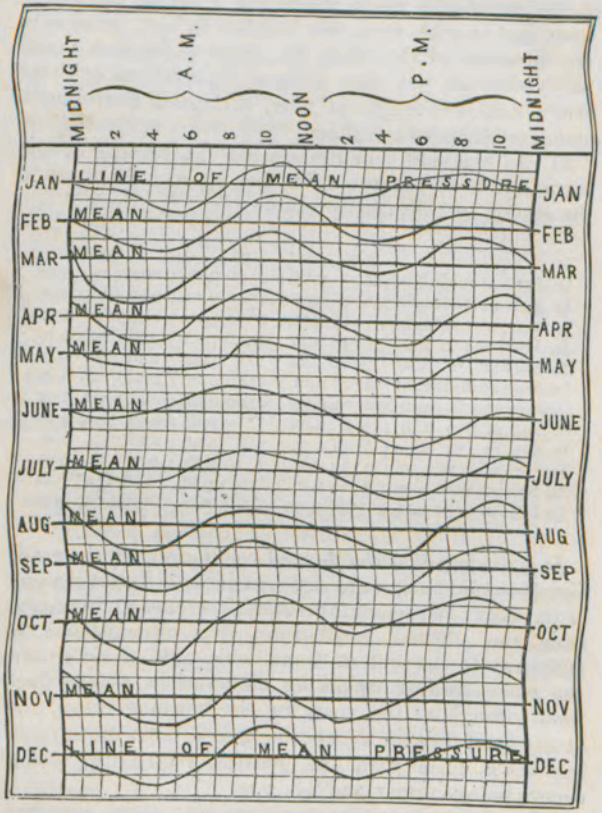
21. In England four times a-day the reading of the barometer is at its mean value (see fig. 4): the times in the several months are as follows:—

	h.m.	h.m.	h.m.
In Jan. at midnight;	8·0 a.m.;	0·40 p.m.;	and 5·0 p.m.
In Feb. at midnight;	8·0 a.m.;	1·40 p.m.;	and 6·20 p.m.
In Mar. at midnight;	7·35 a.m.;	1·50 p.m.;	and 6·0 p.m.
In April at 1·0 a.m.;	6·40 a.m.;	1·40 p.m.;	and 7·20 p.m.
In May at 1·0 a.m.;	8·20 a.m.;	1·0 p.m.;	and 8·0 p.m.
In June at midnight;	4·20 a.m.;	1·40 p.m.;	and 9·20 p.m.
In July at 1·0 a.m.;	6·25 a.m.;	1·40 p.m.;	and 8·45 p.m.
In Aug. at 1·0 a.m.;	7·0 a.m.;	1·10 p.m.;	and 7·35 p.m.
In Sep. at 1·0 a.m.;	7·30 a.m.;	1·0 p.m.;	and 7·0 p.m.
In Oct. at 0·25 a.m.:	7·50 a.m.;	1·10 p.m.;	and 5·0 p.m.
In Nov. at 1·40 a.m.;	8·20 a.m.;	11·40 p.m.;	and 5·45 p.m.
In Dec. at 0·40 a.m.;	7·40 a.m.;	0·45 p.m.;	and 6·5 p.m.

It is evident that the diurnal oscillations of the readings of the barometer are different at the different seasons of the year; the season, therefore, exercises an influence over the diurnal oscillation: this circumstance is sufficient to prevent us from being able to determine the mean reading by taking observations at any fixed time throughout the year, for the morning mean, and at any fixed time for the evening mean. That mean reading takes place with the greatest regularity, which occurs between noon and 2 h. P.M.

The diagram in fig. 4 shows that there are two maxima and two minima daily in the readings of the barometer; and throughout the world there are two daily atmospheric tides, the pressure of the atmosphere being *greatest about 10 h., both* A.M. *and* P.M., and least in the early morning and afternoon hours.

FIG. 4.—DIURNAL CURVES OF THE READING OF THE BAROMETER IN EVERY MONTH AT GREENWICH.



Scale 0·1 inch to an inch.

22. As we can deduce the mean temperature of the air from a few daily observations, to be spoken of presently,

so also can we deduce the mean reading of the barometer from a few readings taken daily; and if this be the only element of investigation, that time or times most convenient to the observer may be chosen; but if, in addition, such observations be needed as will serve for *studying the irregular oscillations of the readings of the barometer, then several observations must be taken.*

When the barometer is to be taken down for removal, the first thing to be done is to remove the thermometer, if its bulb be immersed in the mercury, and to insert the plug; next, by means of the finger-screw at the bottom, *to drive the mercury up the barometer tube till it nearly reaches the top: the instrument is then to be taken* down, and turned gently over, and carried with the cistern uppermost.

LESSON II.

TEMPERATURE OF THE AIR.

"In the day the drought consumed me and the frost by night."

1. THE thermometer is an instrument employed to *determine the temperature of the air,* and is familiar *to every one. The principle of its construction is* founded upon the expansion of bodies under the influence of heat, and mercury, as expanding more uniformly under equal increments of heat than any other fluid within the range of atmospheric temperature, is mostly employed in its construction. The qualities necessary for a *good thermometer are, that the bore be even, that the zero points on the tube be accurately determined,* and the graduations performed with exactitude. Before use, every instrument should be compared with a standard, to see whether these conditions are fulfilled, and if not the amount of error should be ascertained.

2. The graduation in use in England, is that of Fahrenheit, the scale of which is determined by dividing the space between the point 32° (freezing point of water) and 212° (boiling point of water) into 180 parts, called degrees. By continuing the divisions both above and below these points, the scale may

be continued at pleasure, for the requirements of extreme temperatures.

3. The graduation in use by the Germans is that of Reaumur; by the French, that of Celsius, called the Centigrade. The freezing point of water on both these scales is numbered 0°, and the boiling points are 80° by Reaumur, and 100° by the Centigrade. The number of degrees included between the freezing and boiling points of water, therefore, are in Fahrenheit's scale 180°; in Reaumur's 80°; and the Centigrade 100°. So that 9° of Fahrenheit, are equal to 4° of Reaumur, and 5° of Centigrade.

4. The following are the rules for the conversion of any reading on one of these scales into its equivalent reading on another:—

To reduce Fahrenheit's scale to Reaumur's, when the reading is above 32°.—Take 32° from the reading, multiply the difference by 4, and divide the product by 9.

To reduce Fahrenheit's scale to Reaumur's, when the reading is below 32°.—Take the reading from 32°, multiply the difference by 4, divide the product by 9, and affix the minus sign (−).

To reduce Reaumur's scale to that of Fahrenheit, when the reading is above the freezing point..—Multiply the reading by 9, divide the product by 4, and add 32° to the quotient.

To reduce Reaumur's scale to that of Fahrenheit, when the reading is below the freezing point.—Multiply the reading by 9, divide the product by 4, and take the quotient from 32°.

To reduce Fahrenheit's reading to Centigrade, when the reading is above freezing point.— Take 32° from the reading, multiply the difference by 5, and divide the product by 9.

To reduce Fahrenheit's reading to Centigrade, when the reading is below the freezing point.—Take the reading from 32°, multiply the difference by 5, divide the product by 9, and affix the minus sign (−).

To convert the readings of the Centigrade scale into those of Fahrenheit.—Proceed exactly as in the case of Reaumur into Fahrenheit, except using 5 instead of 4.

To reduce Reaumur's scale to that of the Centigrade.—Multiply by 5, and divide the product by 4.

To reduce the Centigrade scale to that of Reaumur.—Multiply the reading by 4, and divide the product by 5.

As the French tables and observations of temperature are those which most frequently come under our notice, it is desirable that a simple mental calculation should suffice. The following rule is one to convert, in a moment, all readings of the Centigrade scale into their equivalent values in Fahrenheit's scale; viz. double the Centigrade degrees, and deduct one-tenth of the product, adding 32° if the temperature is above the freezing point, or subtracting the product from 32° if below.

5. The thermometers in use in a series of meteorological observations, consist of the following:—

A maximum thermometer, for determining the highest temperature of the air.

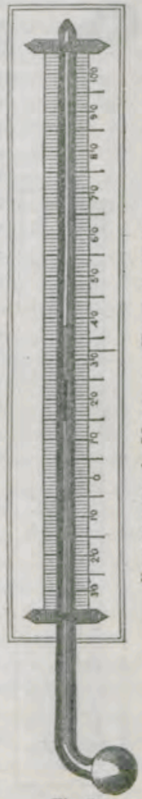
A minimum thermometer, for determining the lowest temperature of the air.

A maximum thermometer, for solar radiation.

A minimum thermometer, for terrestrial radiation.

A dry- and wet-bulb thermometer, for hygrometrical results.

A maximum and a minimum thermometer with moistened bulb, for determining the maxima and minima temperatures of evaporation.



RUTHERFORD'S MAXIMUM THERMOMETER.

Fig. 5.

I will speak of these instruments successively.

6. *The self-registering maximum thermometer* is used, as its name implies, to determine the maximum or highest temperature of the air. That of Rutherford,

(fig. 5.) till lately, was in general use; it differs from the ordinary thermometer, chiefly in the introduction of a steel index within the tube, which, being adjusted to the end of the mercurial column, slides along, as the increasing temperature of the air causes an expansion of the mercury within. It follows, then, that the index so propelled remains at the highest point of expansion, and thus records the maximum temperature of the day. On the decline of temperature, the mercury is withdrawn from contact, the index remains, and that end nearest the bulb which was in contact with the mercury, being read upon the division of the scale, gives the required maximum temperature. In use, the instrument is suspended nearly horizontally, its bulb being a little raised. One end of the instrument should be moveable, so as to be readily detached for the purpose of setting the index after reading; which is done by inclining the instrument with its bulb downward, so as to allow the index to pass at once from its last reading, to the end of the mercurial column; having done this, the thermometer is again replaced, and is in order for the next day's observation.

Negretti and Zambra's Maximum Thermometer.

Fig. 6.

In practice, this instrument is subject to frequent derangement, by the tendency of the steel index to become fixed in the tube, either by its plunging into the mercury, or by its oxidation, and allowing the mercury to pass, instead of being carried forward by it, thus rendering the instrument useless. For the upper part of the tube of this thermometer is required to be full of air, to prevent the mercury moving about in the tube; and as the mercury passes the index, on one side small particles of air insinuate themselves

into the column and cause separations, which require an instrument-maker to correct.

7. A maximum thermometer, invented by Professor Phillips, is better in its action than Rutherford's: a part of the mercurial column is separated by the introduction of a small portion of air; this portion acts as an index, and remains in the tube at the highest temperature, thus marking the maximum temperature; but, in practice, as I have found many times in the last 20 years, the air soon escapes, and the instrument is reduced to a simple thermometer; and again, whilst in use, the portion of air assumes a different length, at different temperatures, and the index-error is variable. Instruments of this construction have been tried, both by myself and the Members of the Council of the British Meteorological Society, and although they have acted with tolerable accuracy for a time, they have all ultimately failed.

8. A necessity therefore continued to exist for another form of instrument free from these inconveniences. This has lately been produced by Messrs. Negretti and Zambra. The annexed engraving (fig. 6.) shows the form of the instrument invented by them. In its construction, whilst the tube is straight, a small piece of glass, which nearly fills the bore, is inserted, and dropped to a place situated near the bulb, and the tube bent at this part, so that the piece of glass cannot move. On an increase of heat, the mercury is forced, in its expansion, past this obstruction, but cannot repass on a decrease of temperature: the contraction of the mercury takes place within the space below the bend of tube. The end of the column of mercury, therefore, gives the required reading. The instrument, after observation, is set by raising the end the farthest from the bulb, and shaking it a little; it is easily set, and scarcely liable to derangement, either in travelling or in use. The tube is free from air.

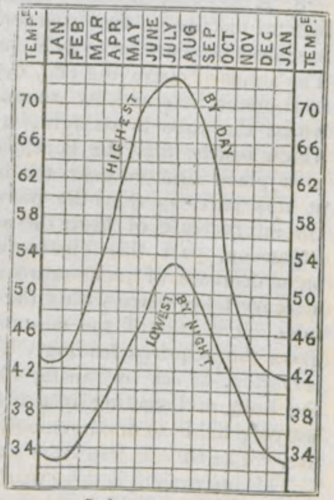
This instrument is to be read daily, either in the morning, or evening; if at the latter time, the reading will be that of the day; but if in the morning, the reading is that of the day before, and must be so entered.

9. The following table shows the most probable highest temperature in each month in the suburbs of London :—

Month.	Highest Temperature.	Month.	Highest Temperature.
	°		°
January -	50	July - -	85
February -	54	August -	83
March -	62	September -	78
April - -	70	October -	67
May - -	77	November -	60
June - -	84	December -	54

In extreme cases the temperature in January may rise to 55° ; in February to 60° ; in March to 67° ; in April to 77° ; in May to 86° ; in June, July, and August exceeding 90° ; in September 86° ; October 73° ; November 66°, and December 60°.

Fig. 7.—Yearly Curves of Average Highest Temperature by Day and Lowest by Night.

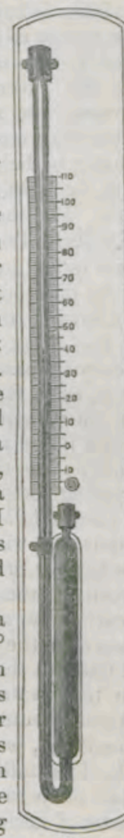


Scale 20° to one inch.

The Table 2 in the Appendix shows the monthly mean of the highest daily temperature of each day, for a series of years, and in fig. 7, the average highest temperature of the air by day is shown.

10. *The minimum thermometer* for recording the lowest temperature of the air is constructed up to the present time, with alcohol, within which floats a glass index. Alcohol, however,

does not expand equally with equal increments of heat, and tubes of instruments so filled are for this reason not of even bore. The instrument in use is suspended with its bulb a little depressed and its index set to the end of the spirit column, when on a decrease of temperature, the fluid contracts, and carries the index in its descent towards the bulb: this remains at the lowest point of temperature, thus registering the minimum temperature as required. The observer should take care to read on the scale, the position of *that end of the index the farthest removed from the bulb*, and in re-setting to either raise the bulb, or depress the other end till the index is at the extremity of the spirit column. On an increase of temperature the index remains fixed as the alcohol expands. The instrument is not fitted for delicate thermometric purposes, and a mercurial minimum thermometer has long been a desideratum. Within the last few weeks, however, Messrs. Negretti and Zambra have invented one, which, so far as I have examined and tried, answers well ; its form is shown in the annexed engraving. It is made as follows :—



Negretti and Zambra's Mercurial Minimum Thermometer.

Fig. 8.

Having blown, filled, and regulated a thermometer-tube in the usual way, 60° of temperature being about half-way in the tube, a small cylindrical bulb is blown about two inches from the upper end of the thermometer, into which is introduced a steel needle pointed at both ends, rather abruptly at that nearest the mercury, and terminating in a long conical point at the upper end. The portion of the thermometer-tube above the smaller bulb is now drawn into a fine capillary-tube, and the bulb of the instrument warmed sufficiently to raise the mercury into the smaller bulb completely covering the needle; this bulb being full, the warming is continued until the mercury passes the capillary-tube; at this moment, and before the mercury has time to return, the flame of a blow-pipe lamp is applied, which melts the glass, and enables the operator to draw off a small portion of it containing mercury, thus effectually cutting off all communication with the external atmosphere. As the temperature decreases, the mercury will descend and indicate the surrounding temperature. If, whilst cooling, the thermometer be held upright, as the last portion of mercury leaves the bulb, the steel index will, of its own gravity follow. The thermometer, in appearance, is very similar to Rutherford's maximum, viz.: a tube of mercury with a steel index floating on its surface, but with these important differences: the new thermometer is free from air, allowing the mercury to move freely in the tube; and the index is pointed at both ends to allow the mercury to pass, instead of being ground flat to prevent it, as in Rutherford's. Unlike the ordinary minimum thermometer in use, it is suspended vertically, with its index resting on the surface of the column of mercury; as the mercury in the bulb contracts from decreasing temperature, that in the tube descends, and the needle follows. On the contrary, as the mercury expands and rises in the tube, having only a point to press against, it passes the index without moving it from its position, thus leaving the upper point of the needle indicating the minimum temperature. This instrument is shown in the annexed engraving (fig. 8); it is to be read daily as the maximum thermometer, but, the minimum temperature occurring for the most part at about the time of sunrise, the reading of this thermometer in the morning, is usually the lowest in the day.

11. The following table shows the most probable lowest temperature of the air in each month, in the suburbs of London:—

Month.	Lowest Temperature.	Month.	Lowest Temperature.
	°		°
January -	21	July - -	44
February -	18	August -	44
March -	24	September -	36
April - -	32	October -	32
May - -	37	November -	26
June - -	43	December -	24

In extreme cases the temperature in January may descend below 0°; in February to 5°; in March to 13°; in April to 27°; in May to 32°; in June, July and August to 40°; in September to 32°; in October to 28°; in November to 22°; and in December to 18°.

12. The means of the lowest daily temperature of the air in every month, are shown in Table 3 in Appendix; and in fig. 7, the average lowest temperature of the air by night is shown.

13. *Range of temperature* during the day is simply the difference between the highest and lowest temperatures within 24 hours, as determined by the maximum and minimum thermometers respectively. The range is variable from day to day; within the year upon an average in the suburbs of London—

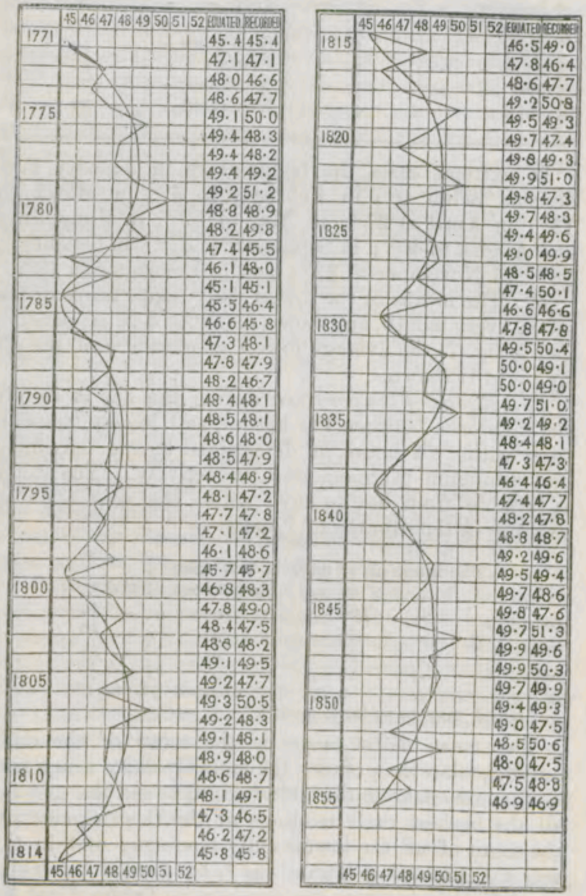
The range on	27 days	is less than	° 5	°
”	93 ”	is between	5 and	10
”	108 ”	”	10 ”	15
”	74 ”	”	15 ”	20
”	35 ”	”	20 ”	25
”	16 ”	”	25 ”	30
”	2 ”	exceeds	30, one of	

which may be as large as 40°.

The mean daily range is the mean of the daily ranges within the period; the monthly daily range may be found by taking the difference between the mean of all the highest daily readings of the thermometer and the mean of all the lowest daily readings; and in this way the preceding Table has been formed by taking the difference between the numbers in Tables 2 and 3.

14. *Temperature of the air* is understood to be that

Fig. 9.—Observed Mean Annual Temperature of the Air at the Royal Observatory, Greenwich, for every Year from 1771 to 1855, and Equated Elliptic Curve of the several Yearly Temperatures for the same Period.



	Equated	Recorded
1771	45·4	45·4
	47·1	47·1
	48·0	46·6
	48·6	47·7
1775	49·1	50·0
	49·4	48·3
	49·4	48·2
	49·4	49·2
	49·2	51·2
1780	48·8	48·9
	48·2	49·8
	47·4	45·5
	46·1	48·0
	45·1	45·1
1785	45·5	46·4
	46·6	45·8
	47·3	48·1
	47·8	47·9
	48·2	46·7
1790	48·4	48·1
	48·5	48·1
	48·6	48·0
	48·5	47·9
	48·4	48·9
1795	48·1	47·2
	47·7	47·8
	47·1	47·2
	46·1	48·6
	45·7	45·7
1800	46·8	48·3
	47·8	49·0
	48·4	47·5
	48·6	48·2
	49·1	49·5
1805	49·2	47·7
	49·3	50·5
	49·2	48·3
	49·1	48·1
	48·9	48·0
1810	48·6	48·7
	48·1	49·1
	47·3	46·5
	46·2	47·2
1814	45·8	45·8

	Equated	Recorded
1815	46·5	49·0
	47·8	46·4
	48·6	47·7
	49·2	50·8
	49·5	49·3
1820	49·7	47·4
	49·8	49·3
	49·9	51·0
	49·8	47·3
	49·7	48·3
1825	49·4	49·6
	49·0	49·9
	48·5	48·5
	47·4	50·1
	46·6	46·6
1830	47·8	47·8
	49·5	50·4
	50·0	49·1
	50·0	49·0
	49·7	51·0
1835	49·2	49·2
	48·4	48·1
	47·3	47·3
	46·4	46·4
	47·4	47·7
1840	48·2	47·8
	48·8	48·7
	49·2	49·6
	49·5	49·4
	49·7	48·6
1845	49·8	47·6
	49·7	51·3
	49·9	49·6
	49·9	50·3
	49·7	49·9
1850	49·4	49·3
	49·0	47·5
	48·5	50·6
	48·0	47·5
	47·5	48·8
1855	46·9	46·9

indicated by a correct thermometer properly placed,

being effectually protected from the effects of radiation; reflection of heat; and all foreign influence; if an instrument thus placed be read at short and equidistant intervals throughout the day, as, for instance, at the commencement of every one of the twenty-four hours, or every two hours, we find that at each hour the temperature is different, (see fig. 10); by adding all the readings together, and dividing the sum by the number of observations, we obtain the *mean temperature of the day*. In like manner, by taking the sums of the mean daily temperatures for a week or a month, we obtain the *mean*

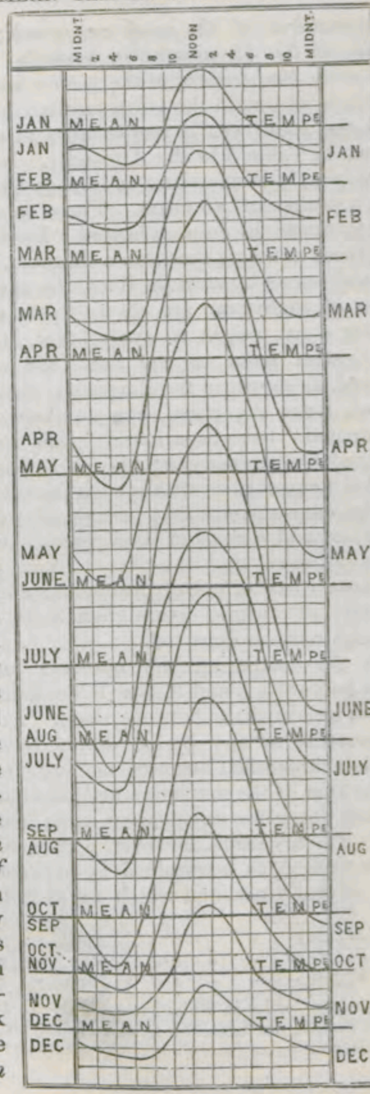


Fig. 10.—Diurnal Curves of Temperature of Air in every Month. [*Scale* 10° *to* 1 *inch.*]

temperatures of the week or month; by taking the mean of the 12 months in a similar way, we obtain the *mean temperature of the year*; and from a number of years we obtain the *mean* temperature of each month and the mean yearly temperature at a given place, as shown in Table 5 in the Appendix. In this manner the mean yearly temperature at Greenwich has been found for a period of 85 years. These results are shown in fig. 9, under the column headed "Recorded." By laying these numbers down on a diagram, and joining the several points by straight lines, the successive temperatures of each year are shown to the eye; from them, giving equal weight to every point, and starting from one lowest point to the next, the elliptic curve is formed, as shown in the diagram; then, by reading the values from the curve, the numbers under the head "Equated" have been found. The summation of the equated temperatures equals the summation of the recorded temperatures within each period. An inspection of the curves shows that periods of warm years come together, and periods of cold years come together; and it would seem, that the present year (1856) is about the lowest part of one of the cycles; and, therefore, that a series of warmer years than those recently passed through may be expected.

15. By comparing the numbers in Table 5 with those in Tables 2 and 3, it will be found that they are almost intermediate between them. In fact the mean temperature of any period differs but little from the simple arithmetical mean of the extremes, and the half of the sum of the maximum and minimum temperatures of each day gives an apparent mean temperature of the day. To this value, however, a correction is necessary to be applied, as determined by experiments extending over several years, and which are as follows:—*

January - -	0·2°	April - - -	1·5°
February - -	0·4	May - - -	1·7
March - - -	1·0	June - - -	1·8

* See my Tables in Phil. Trans., Part I., 1848, and Diurnal Range Tables, published by R. and H. Taylor, Red Lion Court, Fleet Street.

July - - -	1·9°	October - -	1·0°
August - -	1·7	November - -	0·4
September - -	1·3	December - -	0·0

and these numbers are always to be applied subtractively to the simple arithmetical mean of the maximum and minimum thermometers.

16. *Range of temperature* is simply the difference between the highest and lowest temperatures in the period, as determined by the maximum and minimum thermometers respectively. The monthly mean daily range of temperature is the mean of the range of temperature each day in the month, or it is found by taking the difference between the monthly mean of the highest temperature by day and the lowest temperature by night. In fig. 7, the mean daily range of temperature is shown in each month, by the space between the two curves there laid down.

17. The best plan is to take observations of the dry-bulb thermometer, at those hours which are the least liable to interruption by the avocations of the observer, and to apply to their mean results the necessary corrections. Of the hours which are equally convenient, those are preferable about which the least changes are taking place, as then a small error in the time of observation will entail little or no error on the readings. Twice during the day the temperature of the air is at its mean value, and these times are as follows in the several months:—

		H.		H.
In January	at	10·0 a.m.	and again at	8·0 p.m.
„ February	at	9·30 a.m.	„	6·40 p.m.
„ March	at	9·10 a.m.	„	7·20 p.m.
„ April	at	8·40 a.m.	„	7·0 p.m.
„ May	at	8·25 a.m.	„	7·30 p.m.
„ June	at	8·0 a.m.	„	8·0 p.m.
„ July	at	8·0 a.m.	„	8·5 p.m.
„ August	at	8·20 a.m.	„	7·20 p.m.
„ September	at	8·55 a.m.	„	7·20 p.m.
„ October	at	9·0 a.m.	„	7·0 p.m.
„ November	at	9·25 a.m.	„	6·45 p.m.
„ December	at	10·0 a.m.	„	7·20 p.m.

18. To determine the mean temperature of the air, it would therefore seem that it would be sufficient to

take an observation at one of these two periods; but it must be borne in mind that at these times the changes of temperature are rapid, and consequently if the observations be made a little too soon, or a little too late, very considerable errors may be committed; therefore observations at these times, unless they are made very accurately with respect to time, are not worthy of implicit confidence.

19. If we compare the mean temperatures of places that differ considerably from each other in latitude, we shall find that the mean values are lower as we proceed north. If we compare the mean temperatures of places having the same latitude, we shall find that the mean value of those situated at the higher level will be less than those at the lower level; if we compare places having the same latitude, we shall find that the mean temperatures of those places situated inland will be higher in the summer months, and lower in the winter months than those situated in the vicinity of the sea. If we compare places differing only in their geological formations, we shall find that those places situated upon an arid, dry soil, will have a greater range of temperature than those situated upon a clayey, wet soil.

20. At all places the form of the diurnal variation is a simple progression, having one ascending branch and one descending branch (see fig. 10), the maximum occurring early in the afternoon, and the minimum at about the time of sunrise; but the amount of the difference of the extremes at different places is very different, depending upon latitude, elevation, local exposure, the configuration and extent of the country; the nature of its soil as more or less favourable to radiation and evaporation; proximity to the sea; direction of chains of mountains, &c.

LESSON III.

HYGROMETRY.

"And some seed fell upon a rock; and as soon as it was sprung up, it withered away because it lacked moisture."

1. After pressure and temperature the next condition of the atmosphere to be investigated is its humidity.

Water exposed to the air evaporates and mixes with it, in the invisible form of vapour. How much water will the air contain, and how is it supplied?

2. At different temperatures air is saturated with different amounts of vapour, for instance, at 0° Fahrenheit it is saturated by 55 grains in 100 cubic feet; but is capable of containing twice this amount by raising its temperature to 16°; its capacity is doubled again by a further elevation of 17°, and again by an increase of 19°. At the temperature of 27°, when air is saturated with moisture, it is capable of containing $\frac{1}{200}$ of its weight of water in the invisible shape of vapour; at 45°, when saturated, it contains $\frac{1}{100}$ of its weight; at 64°, $\frac{1}{50}$; and at 85°, $\frac{1}{25}$.

3. The great source of supply of moisture is the ocean, and all exposed water, but evaporation also proceedsfrom the surface of land, differing in amount according to peculiarities of surface, and over every variety of country, according to its soil, temperature, and humidity.

4. The most simple contrivance for measuring the amount of evaporation from a surface of water is that of an evaporating-dish of the same form and area as the rain-gauge, its receiving surface having been turned in a lathe. It should be rather more than an inch in depth, and furnished with a measuring-vessel, so that the amount of water evaporated within a given time, as 12 or 24 hours, may be estimated. In use, the evaporating-dish should be filled till the water is an inch in depth, and the amount less than an inch when measured will indicate the amount carried of by vapour. As the water of the great body of the ocean, of rivers, and deep water generally does not vary much in temperature although exposed to the sun, while water in an evaporating-dish exposed to the sun will often rise to a temperature much beyond that of the air; evaporation from the observing pan will proceed too rapidly, if it be not situated in a shaded place, but fully exposed to the breeze.

5. When the amount of evaporation from damp earth is to be determined, it must be done by weighing a certain mass of earth before and after exposure.

The water in the invisible shape of vapour in the atmosphere, like air, is an elastic body, and its weight at the earth's surface is its elastic force; it is necessary therefore that this should be determined in order that we may ascertain how much the reading of the barometer is affected by the water mixed with the air.

6. *Tension or elastic force of vapour.*—Water boils at 212° Fahrenheit under a pressure of 30 inches of mercury; it boils at a higher or lower temperature as the pressure is greater or less respectively. When the action of boiling begins, it shows that the elastic force of the vapour is equal to the pressure of the atmosphere; but though ebullition and very rapid formation of vapour take place, only when the elastic force of the vapour is equal to this pressure, vapour as before stated, will rise from the surface of water or ice at all temperatures, and with different elastic force at different temperatures. Dr. Dalton, of Manchester, was the first who ascertained by experiment the force at different temperatures below the boiling point, but the most recent and best determinations are those by Regnault ("Annales de Chimie"). These values, for every degree from 0 to 100, are given in my Hygrometrical Tables. The numbers in the Table show the length of a column of mercury corresponding to the tension of aqueous vapour at different temperatures, and to find the elastic force of the vapour present at any time in air, it is simply necessary to determine the temperature of the dew-point; to seek for that temperature in the Tables, and the corresponding quantity will be seen by inspection.

7. Dry and Wet Bulb Thermometers.—The dry and wet bulb (fig. 11) thermometers consist of two thermometers, as nearly as possibly alike. The bulb of the wet thermometer is covered with thin muslin, and around its neck is twisted a conducting thread of lamp-wick—common darning-cotton, or floss silk; this passes into an adjacent vessel of water, placed at such a distance as to require about 3 inches of conducting thread. The water-vessel should be placed on one side and a little beneath, so that the water within

may not affect the reading of the dry bulb by its too near vicinity. The water-vessel should always be supplied with rain or distilled water.

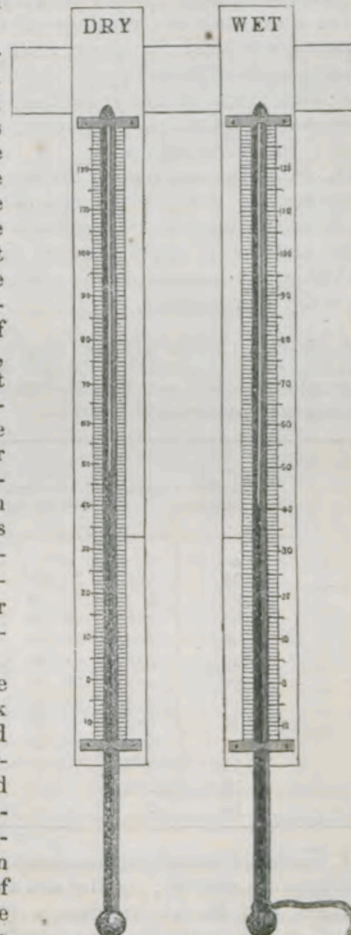


Fig. 11.—Dry and Wet Bulb Thermometers.

8. In frosty weather the water in the reservoir will be frozen, but this is no reason for the suspension of the observations; if the water upon the muslin is frozen at the same time, the readings are perfectly available. If the muslin be dry, it is necessary that it be wetted a sufficient time before the observation for the water to become frozen. When the weather is frosty, the muslin should be immersed in water after every observation.

Before use, the cotton lamp-wick should be washed in a solution of carbonate of soda, and pressed whilst under water throughout its length. In use it should be of such extent that the water conveyed be sufficient in quantity to keep the muslin moist, without having a drop attached to it. The amount of water supplied can be increased or diminished by increasing or diminishing the extent of the conducting thread.

The mean monthly readings of the dry-bulb thermometer, corrected for diurnal range, are inserted in Table 5 in the Appendix.

9. The mean monthly readings of the wet-bulb thermometer, similarly corrected, are contained in Table 6 in the Appendix.

10. From the readings of the dry and wet bulb thermometers, the dew-point is calculated by multiplying the difference between the readings of the dry thermometer and that of the wet by my factors in the following Table, and subtracting the product from the reading of the dry thermometer.

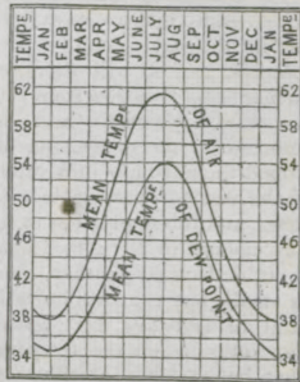
Table, showing Glaisher's factors, by which the differences of readings of the dry-bulb and wet-bulb thermometers are to be multiplied, in order to deduce the difference between the temperatures of the air and dew-point.

Reading of Dry-bulb Thermometer.	Factor.	Reading of Dry-bulb Thermometer.	Factor.
°	°	° °	°
25	6·5	37 and 38	2·4
26	6·1	39 to 41	2·3
27	5·6	42 to 45	2·2
28	5·1	46 to 50	2·1
29	4·6	51 to 55	2·0
30	4·2	56 to 63	1·9
31	3·7	64 to 72	1·8
32	3·3	73 to 86	1·7
33	3·0	87 to 100	1·6
34	2·8		
35	2·6		
36	2·5		

11. Temperature of the dew-point in summer is lowest a little before sunrise; as the sun ascends, evaporation increases, and the air receives a greater quantity of vapour, consequently the temperature of the dew-point increases till about noon, when it attains its maximum,

and remains at this value till after the temperature of the air begins to decline, and then gradually decreases till the following morning.

Fig. 12.—Yearly Curves of Mean Temperature of the Air and Dew-point.



[Scale 20° to 1 inch.]

In winter its minimum occurs some hours before sunrise, and its maximum occurs at about the time of the maximum temperature of the air, and then gradually declines to the following morning.

12. The use of this Table is very simple. Example.—In Table 5, June 1841 the mean temperature of the air was 56·4, and in Table 6, that of evaporation for the same month was 52·6. Required the temperature of the dew-point?

Reading of dry bulb - - - - - -	56°·4
Reading of wet bulb - - - - - -	52·6
Difference - - - - - - -	3·8
Factor for 56° - - - - - - -	1·9
Product - - - - - - - -	7·2
Reading of dry bulb - - - - - -	56·4
Difference or temperature of dew-point - -	49·2

In Table 7, the dew-point observed was 49°·1.

13. Whenever the air of the atmosphere is saturated with moisture, the temperature of the air, evaporation, and dew-point is the same.

Whenever the temperature of the air is above the temperature at which it is saturated by the moisture which it contains, a portion of all exposed water undergoes a gradual diminution of bulk, and ice imperceptibly wastes away by rising in the atmosphere.

Whenever air is cooled below the temperature at which it is saturated, a portion of moisture is separated, in proportion to its newly-acquired temperature.

14. The air of the atmosphere is, however, generally in that state, that a depression of some degrees is necessary for the deposition of a portion of the water which it contains, and it will therefore take up water. The further it be removed from saturation, the more rapidly evaporation proceeds, and as it proceeds, the heat absorbed in the conversion of the thin film of water around the wet-bulb into vapour will cause the reading of the wet to decrease below that of the dry thermometer, and this depression in hot weather in this country may amount to 20° ; in India and Australia at times to 30°. In cold weather, the difference will in general be small, but evaporation will proceed when the temperature is below 32° ; great care is required in the observation when the temperature of the air is somewhat below 32°: at times it will happen, when the temperature has descended below this point, that the water on the bulb *has not begun* to freeze, and the reading of the wet bulb will be the higher of the two: these readings must not be recorded; when water has begun to freeze, the lower readings are taken. When the temperature is below 32°, the reservoir of water is useless, and the bulb must be moistened some time before the observation, by a sponge or brush. When the temperature of the air has risen above 32°, the bulb of the wet thermometer, with its conducting thread, should be immersed in warm water, for the purpose of removing any ice that may still remain on the bulb.

15. Having determined the temperature of the dew-point, the elastic force of vapour is at once extracted from a properly-constructed Table. Table 8 at page 63, has been thus formed.

16. *Position of the Thermometers.*—They should be placed in a position sheltered from the direct rays of the sun; at such a distance from walls as not to be influenced by reflected heat; protected from rain, and from the effects of radiation, with the bulbs freely

exposed to unimpeded circulation of air from all sides.

17. *Stand for carrying the Thermometers.*—In fig. 13, is an accurate representation of such a stand: it consists of a frame of deal boards, through all parts of which the air passes freely, for the purpose of carrying away any heat which may be conducted through them. It can be constructed by any carpenter. The whole revolves; its inclined side is always turned towards the sun. On its face, the dry and wet bulb, the maximum and the minimum thermometers are attached in such way that their bulbs project two or three inches below the frame, and about four feet above the ground.

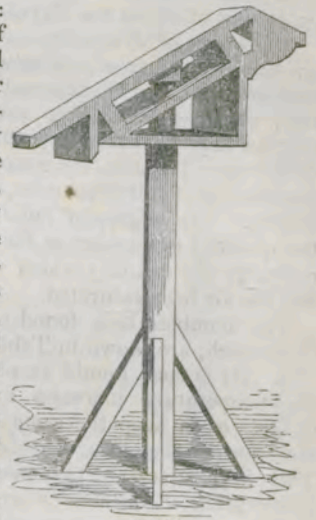


Fig. 13.

LESSON IV.

VAPOURS.

"For what is your life? It is even a vapour, that appeareth for a little time, and then vanisheth away."

1. *Weight of Vapour in a Cubic Foot of Air.*—A cubic foot of vapour at 212° and under a pressure of 30 inches, weighs 258·4 grains; and air expands $\frac{1}{491\cdot13}$, or 0·0020361 for every increase of 1° of heat; it therefore expands 0·3665 of its bulk from 32° to 212°, and its expansion is uniform between these points. A cubic foot of vapour at any other temperature may be calculated from the following formula:—

$$\frac{1\cdot3665 \times 258\cdot4 \text{ gr.} \times \text{elastic force of vapour at temperature}}{30\left(1 + 0\cdot0020361 \times \overline{t - 32^\circ}\right)}$$

2. Table 9 in the Appendix contains the weight of a cubic foot of air, at the Royal Observatory, Greenwich.

3. *Degree of Humidity.*—With a knowledge of the amount of vapour which saturates the air at different temperatures, and the amount existing in the air at the time of observation, we are enabled to determine another important element, viz., the degree of humidity of the air. In calculating the numbers, saturation may be assumed as 100 or as unity, and air, without moisture, as zero. The degree of humidity is found by dividing the quantity of vapour at the temperature of the dew-point, by the quantity which would have been present had the air been saturated.

The numbers thus found at the Royal Observatory, Greenwich, are shown in Table 10 in the Appendix.

4. Air is most humid at night: as the sun ascends the temperature increases more rapidly than water evaporates to keep the same degree of humidity; the atmosphere, therefore, becomes less and less humid. This is particularly the case in summer, when the temperature of the dew-point is for some hours nearly stationary, whilst the temperature of the air is increasing.

When evaporation commences in the morning with the increase of temperature, vapour accumulates near the surface of the soil, till the air becomes heated and the daily ascending current of air sets in. It then ascends and spreads as long as the ascending current continues. Towards evening, when the temperature of the air is decreasing rapidly, the ascending current is checked, then ceases, and gives place to the descending current of night. Therefore there is a rapid increase of evaporation and decrease of humidity during the day, and a rapid increase of humidity during the evening and night hours.

5. *Weight of a Cubic Foot of Air.*—A cubic foot of dry air at 32°, and under the pressure of 30 inches of mercury, weighs 566·86 grains. As the weight of air

varies inversely as the volume, a cubic foot of air at any other temperature, under the same pressure, will be found by dividing 566·86 by the number expressing the volume of dry air after expansion from heat. Reckoning the volume of dry air at 32° as unity, for instance, required the weight of a cubic foot at 60°?

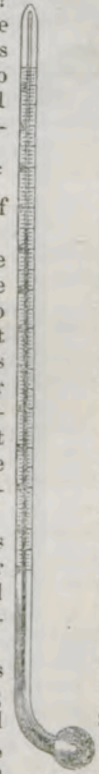


Fig. 14.

Negretti and Zambra's Maximum Thermometer for Solar Radiation with Blackened Bulb.

We have seen that the expansion of volume is 0·0020361 for every degree of heat; this multiplied by (60° − 32) 28 = 0·05701, so that a cubic foot of air increases from 1 at 32° to 1·05701 for an increase of temperature from 32° to 60° and $\frac{566\cdot86}{1\cdot05701} =$ 536·3 grains, the weight of a cubic foot of air at 60°.

6. A cubic foot of vapour at the same temperature and under the same pressure weighs 5·8 grains; the sum of these two weights is 542·1 grains, and a cubic foot of saturated air is 532·8 grains, and this would be the weight of a cubic foot of air under a pressure of 30 inches, and saturated with moisture: in all other cases it is to be calculated from the degree of humidity and pressure of the atmosphere.

7. Table 11 in the Appendix contains the mean weight of a cubic foot of air under its mean pressure, temperature, and humidity at the Royal Observatory, Greenwich.

8. *Solar Radiation.*—The sun's rays pass through the atmosphere, exercising but little influence on its temperature till they reach the earth, accumulate there, and cause the earth to become much more heated than the air. Its amount is an important element in meteorology, and is determined by the excess of reading of a thermometer, placed near the surface of the earth, fully exposed to the direct rays of the sun, above that of the thermometer, placed to deter-

mine the temperature of the air in the shade. The solar-radiation thermometer (fig. 14), consists of a maximum thermometer, with blackened bulb, graduated on its own stem. In use it may rest on the forks of two Y's, precaution being taken to prevent lateral wind striking the bulb. In this situation its reading may be 150°, whilst that in the shade is 60°.

Minimum Thermometer for Terrestrial Radiation with Transparent Bulb.

Fig. 15.

The average daily amount of solar radiation from November to February is 5° or 6°; in March 13°; in April 17°; from May to August 20°; September 18°; and October 10°.

In fine summer months the mean reading of the solar-radiation thermometer may exceed 100°, whilst in others it will not exceed 85°.

9. *Terrestrial Radiation.*—The amount of terrestrial radiation is of equal importance with that of solar radiation. From the surface of the earth heat is constantly escaping, and on cloudless nights the earth throws off heat by radiation more rapidly than the air, and its surface is reduced to a lower temperature than the surrounding air. Its amount is determined by the defect of the readings of a thermometer, with its bulb fully exposed to the sky, and placed on grass, or on a non-conductor of heat, as wool or flax, below those of the thermometer to determine the temperature of the air in the shade. The terrestrial-radiation thermometer consists of a minimum thermometer with transparent bulb, and graduated on its own stem: in use it should rest on the fork of two Y's, so that the bulb is on the top of the grass, and not covered by a single blade.

A thermometer thus placed, when the sky is covered with low dense clouds, will read the same as that placed some feet above it; but on the clouds rising or the sky becoming less cloudy, will read from 3° to 5° lower;

and when the sky is cloudless and bright, and the air calm, the reading may be from 3° to 20° lower than the air. I once observed a difference of 28°·5 between the readings of two thermometers, the one placed on raw wool, and the other in air at the height of 8 feet. On calm and clear nights a terrestrial-radiation thermometer may read less than 32° in every month of the year.

10. The daily amount of terrestrial radiation is dependent on the amount of cloud. During any period when the nights are generally cloudy, there will be but little difference between the readings of the two thermometers: the mean difference monthly varies from 5° to 10°.

The greater coldness of grass than that of air in clear and calm weather, in places sheltered from the sun, but open to a considerable portion of the sky, may continue all day as well as night.

The formation of dew depends solely on the temperature of the bodies on which it is deposited, and never appears till their temperature decreases below that of the dew-point in their locality.

The amount of water deposited in the shape of dew is the largest on those substances which radiate heat freely, and on which the reading of a thermometer is lowest.

11. The great difference in temperature of the surface of the earth between day and night affords an explanation of the current of air denominated land and sea breezes. During the day the air in contact with the heated earth becomes heated, expands in bulk, and is specifically lighter, and rises in consequence, when the cooler air from the sea rushes in to supply its place, and thus causes the current called the sea breeze. During the night, on the contrary, the earth is cooled by radiation; the air in contact with it is cooled, becomes smaller in bulk, and specifically heavier than the air over the water, which parts with its heat much more slowly than the land, and a current from the land takes place.

12. *Condensation of Vapour.*—Whenever the temperature of the air is below that of the dew-point, a

portion of vapour is deposited; and the forms of water so condensed are various, depending on circumstances. When this depression of temperature is small, as when saturated air is mixed with a stratum of a little lower temperature, the separation takes place in the air in very minute globules, which diffused over a large space, assume the form of clouds, mist, or, if near the earth, of fog. When the depression is large, the quantity of water separated from the air is great: and it falls in the form of rain, hail, or snow.

13. Clouds, are visible collections of minute globules of water suspended in the atmosphere: they differ very greatly in respect of form and magnitude, depending on the quantity of vapour of which they are composed, the direction and force of the wind, &c. They have been classified by Luke Howard, F.R.S., into three primary formations, the cirrus, the cumulus, and the stratus, which are represented in the accompanying plate, fig. 16; and into four secondary, the cirro-cumulus, cirro-stratus, cumulo-stratus, and the nimbus.

Cirrus is composed of fibres or wisps or curling streaks, in appearance like a lock of hair, or a feather, sometimes resembling a brush. It occupies the greatest elevation, and is vulgarly known as "mares' tails."

Cumulus denotes a cloud in dense, convex heaps, with rounded, and frequently white, rocky surfaces, upon a horizontal base, definitely terminated above. It is the cloud of day, and is most characteristic in fine summer weather. It is formed when ascending currents draw the vapour from the lower into the upper strata of the atmosphere.

Stratus is an extended, continuous, level sheet, and is the lowest of clouds: it forms at sunset and disappears at sunrise. It is the cloud of night.

Cirro-cumulus is intermediate between the cirrus and cumulus, and is composed of small, rounded masses, apple-shaped, and forming a net-like appearance.

Cirro-stratus is composed of bands of filaments, resulting from the subsidence of the fibres of the cirrus, to a horizontal position as they approach each other laterally. These clouds form horizontal strata, and

1.1 Cirrus.—2.2. Cumulus.—3.3 Nimbus.—4. Stratus.

exhibit the phenomena of the solar and lunar halos, as well as parhelia (mock suns) and paraselenæ (mock moons).

Cumulo-stratus is composed of cumulus clouds heaped together, frequently into a pyramidal shape, increasing in density. When this cloud assumes a bluish or black tint, near the horizon, it is ready to pass into nimbus.

Nimbus is the rain cloud : it is dense, and of a uniform black or gray tint, in a horizontal sheet with fringed edges.

14. *The amount of sky covered by clouds* is represented numerically in tenths, of which 0 indicates a cloudless sky, and 10 one entirely covered by cloud. In estimating the proportion when the sky is partially covered, it must be borne in mind that in the zenith only the forms and outlines of clouds are exhibited, and the space they cover and the intervals between them distinctly seen. In estimating, therefore, the amount of cloud, regard must be had to this circumstance, and the observer's judgment formed rather from the appearance of the sky within 60° of the zenith, than from the appearance of the clouds near the horizon. The average amount of sky covered by cloud in the suburbs of London is as follows:—

January	7·7	July	6·9
February	7·4	August	6·5
March	6·6	September	5·9
April	6·1	October	6·9
May	6·1	November	7·2
June	6·1	December	7·4

15. *Mists* differ from clouds only in occupying a lower elevation: their origin is the same, viz., vapours which rise from water and the surface of the earth.

16. *Fog* is vapour resting on the surface of the land or water, and at times is so dense that objects cannot be distinguished at the distance of a few yards. During calm weather the surface of rivers, lakes, &c., are frequently in the morning covered with fog, owing to the water during the night being at a higher temperature than the air; the stratum of air, therefore, in immediate contact with the water is heated, and rises, in con-

sequence, till it meets with the cold air above—is cooled, and its moisture precipitated. Such fogs are soon dislodged by the heat of the sun, because the air increases in temperature, and becomes capable of supporting the vapour.

LESSON V.

RAIN, SNOW, &c.

"Fire, and hail; snow, and vapours; stormy wind fulfilling His word."

1. When the water separated from the air is large, and the temperature is above 32°: it falls in drops varying from the thirtieth to one-third of an inch in diameter.

2. When two currents of saturated air of different temperatures meet and mix together, the resulting temperature will be the mean of the two, but the resulting tension of vapour will always be higher than that belonging to the mean temperature; consequently there will be an excess of vapour which will be precipitated in the form of water. Let us suppose two currents of air, the one having a temperature of 50°, and the other a temperature of 70°, and that these two currents are mixed together,—

The elastic force of vapour at 50° is	-	0·361
" " 70° is	-	0·733
Sum	- -	1·094
Mean	- -	0·547

3. The mean temperature of the two currents is 60°, and the mean of their elasticities is 0·547. The elastic force of vapour at 60° is 0·518 inches; therefore, after the intermixture of the two currents, a quantity of vapour corresponding to the elastic force of 0·029 inch will remain; and as this excess cannot be held in solution by air of the temperature 60°, it will be separated in the form of clouds, or of rain, according to circumstances, as before stated.

4. The drops of rain when they begin to fall are of the temperature of the stratum of air in which they are situated, and if this be of less temperature than that of the dew-point of the strata through which they pass, they increase as they descend; but if otherwise, and the air be dry, they decrease, and it may happen that none reach the ground.

5. To determine the fall of rain, that is, to determine the depth of water in inches that would be found on a perfectly level surface, if the fall remained there after a shower, a day, a month, or a year is important. The form of gauge should be simple, and such that the water collected should not be subjected to loss by evaporation. Its receiving surface should not be rectangular, a figure difficult to obtain correct in all its angles, and very liable to have its shape distorted by careless treatment. We can, however, always insure a perfect circle, by the use of the turning-lathe: the receiving surface, therefore, should be circular; and its area calculated, multiplied by 252·525 grains (the weight of one cubic inch of water), for the purpose of determining the weight of a cylinder of water, an inch in height, and of a base equal to that of the receiving surface of the gauge.

6. The engraving fig. 17, shows the form of gauge in general use by the members of the British Meteorological Society; the diameter of the receiving surface is about 8 inches, attached to an inverted funnel, terminating in a tube of small diameter, bent upwards; this funnel is connected with a cylinder or reservoir about 12 or 13 inches in height, by a water-joint. In use, the cylinder is sunk about two-thirds of its height below the surface of the soil, so that the receiving surface is about 5 inches above the ground.

7. If the gauge be read once a-month only, the quantity may be ascertained by simply measuring the depth of water in the reservoir; if it be read daily, or after a shower, it is necessary to have a measuring vessel of small diameter; a glass vessel graduated into inches in accordance with the calculated weight of water for the area of the mouth of the gauge is requisite for this purpose.

8. The gauge should be placed in a locality free from trees, buildings, or walls—in fact, in as open a space as possible.

If a second gauge be placed at a higher level, as on the roof of a building, it should be read frequently, to prevent the loss by evaporation; and if so placed, the quantity of rain will generally be very much less than at the lower level, as shown in the following table.

TABLE showing the Amount of Rain collected in each Month of the Year 1855, at the Royal Observatory, Greenwich, in Gauges placed at different distances from the soil.

1855. Month.	Monthly amount of Rain collected in each Gauge. Osler's Anemometer Gauge.	On the Roof of the Library.	Cylinder partly sunk in the Ground.
	In.	In.	In.
January .	0·2	1·0	1·5
February .	0·2	1·4	1·0
March . .	0·5	1·3	2·0
April . .	0·1	0·1	0·1
May. . .	0·5	1·5	1·8
June . .	0·5	0·7	0·9
July. . .	3·1	4·8	5·3
August . .	0·6	0·8	1·4
September .	0·8	1·1	2·0
October . .	2·6	4·5	5·2
November .	0·5	1·1	1·5
December .	0·4	0·9	1·1
Sums	10·0	19·2	23·8

The heights of the receiving surfaces of the gauge are as follows:—

	Above the level of the sea. Ft.	Above the ground. Ft.	In.
Osler's Anemometer Gauge - -	205 - -	50	8
Gauge on the Roof of the Library -	177 - -	22	4
Cylinder Gauge - - - - -	155 - -	-	5

One observation daily is generally enough; but at times it is desirable to observe at short intervals, as when, in engineering operations, it is of importance to know the greatest fall in the shortest interval of time.

9. The fall of rain is different in different places; and is larger on mountains than on plains; greater in the neighbourhood of the sea than at sea; greater on the west than on the east coast of our country.

GLAISHER'S RAIN GAUGE.

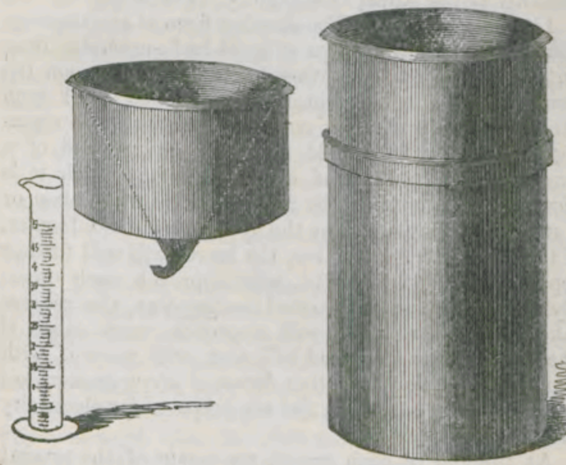


Fig. 17.

Thus, in the valleys, in the lake districts of Cumberland and Westmorland, the usual fall of rain varies from 50 to 100 inches in depth in a year; and these large quantities increase with the elevation till the greatest annual depth of rain is obtained at an elevation of about 2000 feet: at higher elevations, it then decreases in amount. Dr. Miller, F.R.S., of Whitehaven, to whom we are indebted for this information, has recorded the very large fall of 38·9 inches in a single month, a quantity exceeding the average annual fall of the whole country. The quantity that falls annually in Jersey and Guernsey, is about 31 inches; in Cornwall and Devonshire, from 30 to 40 inches—exceeding the latter in some places: it is about 30 inches in the Isle of

Wight, and over the South of England; 25 inches about London; 24 inches about Bedford, York, and Durham; 27 inches near the east coast; 30 inches near the west coast; about 27 or 28 inches elsewhere. In winter the rain-drops may become frozen and fall in this shape.

10. Table 12 in the Appendix shows the fall of rain monthly at the Royal Observatory, Greenwich.

11. *Electrometer.*—The simplest form of electrometer consists of two thin slips of gold-leaf suspended from an insulated conductor; this instrument acts upon the principle that bodies similarly electrified repel each other. The electricity is collected by a flame—a cigar-lighter, for instance, held by a clip at the end of a brass rod. The kind of electricity with which it is charged is determined by the use of excited glass or a stick of sealing-wax: by the application of the former, if the electricity be positive, the leaves will still further separate; and if negative, will approach each other. By the application of excited sealing-wax, the reverse takes place, and they will approach each other if charged with positive, and will open still more if with negative electricity. Other forms of electrometers act upon the same principle, and are prepared for electricity of various intensities.

At the end of each month the means of the several subjects of numerical research should be taken. At the end of each year these should be arranged in one table, and the mean values of every element for the year determined: an example of such a table for the year 1855, at the Royal Observatory, Greenwich, is shown in Table 13 in the Appendix.

12. Minor Phenomena dependent upon Reflection of Light.—The *Rainbow* is a frequent phenomenon, appearing in the region of the sky opposite to the sun, when rain is falling at the same time that the sun is shining. Under these circumstances, if the observer turns his back to the sun, he sees a brilliant-coloured arch projected on the opposite cloud, exhibiting all the colours of the solar spectrum. When perfect, there are two bows, the inner being called the primary, and the outer the secondary rainbow; their common centre is in the prolongation of the line joining the centre of the sun, and the eye of the observer.

13. *Electrical state of the atmosphere.*—The atmosphere affords almost daily indications of electricity; in fine weather, and generally at times when no rain, hail, or snow is falling, the electricity of the atmosphere will be positive, and is negative generally when rain, hail, or snow is falling. During storms accompanied by thunder, lightning, and rain, the electricity varies in amount and kind, not unfrequently changing several times in quick succession, and at such times usually settles into negative electricity. During the passage of a cloud across the zenith, it often happens that the electricity changes to negative, on the edge of the cloud reaching the zenith—remains negative whilst the cloud is passing, and again becomes positive on the cloud leaving the zenith.

14. Lightning and thunder exhibit the phenomena of electricity on a large scale; the former is caused by the passage of electricity between one cloud and another, or between a cloud and the earth, and the latter is the noise produced by such passage.

15. The Aurora-borealis is supposed to be in some way connected with the electrical state of the atmosphere; certain it is that there is an intimate connexion existing between the magnetism of the earth and the Aurora-borealis. In every case that I have heard of, the Aurora being present at that time, the magnets have been in a state of disturbance. Its precise nature is, however, still obscure.

16. *Ozone.*—Among meteorological phenomena, attention has recently been drawn to certain effects produced on chemical test-papers when exposed to atmospheric influence, which it is inferred are produced by the presence in the air of a chemical element or compound, Ozone (ὀζω, I smell), varying in the intensity of its reaction or amount under different circumstances. The term was applied, in 1848, by Dr. Schönbein, of Bâle, to the peculiar odour perceptible during the action of a powerful electric machine, and in the decomposition of water by the galvanic battery. It was afterwards as-

certained that a similar smell is developed by the influence of phosphorus on moist air, and in many instances by slow combustion. For some time the existence of ozone, as its name indicated, was recognised by the odour alone, that being its sole known character; but another fact was soon established, that some element of the atmosphere endowed with this peculiar smell possessed likewise an oxidising power. The evidence, then, of the existence of ozone depends entirely on these two characters. In experimenting in close vessels on a limited scale, it is possible to demonstrate both of these properties. When, however, we direct our attention to the atmosphere, it will be impossible to detect ozone by more than one character, viz. its oxidising property.

The directions for noting the presence and measuring the amount of ozone in the atmosphere are very simple, being the free exposure to the atmosphere (protected from rain and the direct rays of the sun) of a small strip of dry paper, previously saturated with a solution of starch and iodide of potassium. There are two preparations of test-papers, the one by Dr. Schönbein and the other by Dr. Moffat of Hawarden: by the former the amount of discoloration is determined by a momentary immersion of the test-paper in water, and comparison with a scale of purple tints numbered from 1 to 10; and by the latter by comparison at once with a scale of brown tints numbered also from 1 to 10. The same purple tints will be shown by Moffat's paper on immersion in water, but by the use of the purple tints the paper is valueless afterwards; but when the intensity is determined by the brown tints, if kept in the dark, or between the leaves of a book, the colour may be retained for several years.

The amount of ozone at stations of low elevation is small: at stations of high elevation it is almost always present; and at other and intermediate stations it is generally so. The presence and amount of ozone would seem to be graduated by the elevation, and to increase from the lowest to the highest ground.

The amount of ozone is less in towns than in the open country, at the same elevation; and less at inland

than at sea-side stations. During the presence of the epidemic of cholera, in London, in the year 1854, scarcely any ozone was recorded at any station near the river Thames, but at stations of high elevation it was of general occurrence. This may be accounted for by the presence of large quantities of organic matter, decomposed by ozone, itself being simultaneously destroyed.

17. The next class of phenomena are those produced by the passage of light through crystals of ice floating in the atmosphere. The angular form of snow crystals is such as to determine the rays of light in directions giving rise to halos (coloured circles or rings surrounding the sun or moon), and where they cross each other of parhelia (mock suns), and paraselenæ (mock moons). In looking for these phenomena, particularly those connected with the sun, it is imperatively necessary to know where to look for them, and this will be known by the following particulars:—

18.—Solar halos are circles round the sun, of different diameters, some coloured and some not.

1st. A coloured circle may appear at the distance of 7° to 10° from the sun.

2nd. A coloured circle may appear at the distance of 22° 30′ from the sun.

3rd. A coloured circle may appear at the distance of 46° from the sun.

And these may all appear at the same time. The *red* colour is at the *innermost* part of the ring.

4th. A colourless circle may appear at the distance of 90° from the sun. [This is of rare occurrence. I have never seen one.]

5th. A horizontal white circle passing through the sun may appear.

6th. Inverted arcs of circles, touching the halos of 22½°, and 46° at their highest and lowest points may appear.

19. Mock Suns (*Parhelia*) are images of the true sun appearing simultaneously with him.

7th. The parhelia, or mock suns, are coloured, the red part being nearest the sun. They appear as follows:—

8th. With halos—They usually occur a little beyond the points where the halos intersect the horizontal circle passing through the sun (5); if, therefore, the horizontal circle be visible, the place is immediately determined; but if not, by considering where such a circle would cut the visible halos, the place is indicated.

9th. Parhelia sometimes appear in the halos vertically above the true sun, and also in the inverted arcs, vertically above the true sun.

10th. A mock sun sometimes occurs in the part of the sky exactly opposite to the true sun, and in this case it is called anthelion.

11th. Mock suns frequently occur at the distance of 22½° from the sun, in a horizontal plane passing through the sun, at the time when no halos are visible.

12th. Vertical lines passing through the sun, and circles containing the sun in their circumference, are to be looked for. Their several phenomena may continue visible for several hours.

20. Lunar Halos and *Paraselenæ*, or images of the moon,

13th. Are much more easily seen than solar halos. The same remarks apply to them as to solar halos, and also to mock moons.

21. Glories, Coronæ, &c.—The coloured rings seen round the sun and moon, when thin, white clouds, generally of a cirro-cumuli kind, pass over their discs, are carefully to be distinguished from the true halos.

14th. They are much smaller, being immediately round the sun or moon, and their whole diameters vary from 1½° to 12°. When large, their colours are beautiful, and several series of colours appear at once.

15th. The diameter of any ring is not constant for any length of time.

16th. The *red* occupies the *outermost* ring, instead of the innermost, as in the true halo.

22. Of minor phenomena not dependent upon instru-

mental aid for observation, are those relating to the congelation of water. It is well known that water freezes at a temperature of 32°, but the first processes of its change from a fluid to a solid state is not so well known. As seen on the surface of ponds, or wayside water during periods of frost in winter, the method of its change may be described as follows:—The first commencement of congelation is attended with the almost simultaneous appearance of long needles, radiating for the most part from the sides of the bank, within the margin of the water: these increase in length, sometimes appearing divergent and sometimes parallel. Those at the sides are generally the first to make their appearance, but, by degrees, others similar in form, and the thinnest possible, gradually form at intervals on the surface, transversely, and in all directions, until the very smallest interstices are filled. The needles are laminated, as may be distinctly seen on the surface of thin and newly-formed ice. But the freezing of water is not always so accomplished: it frequently happens that the needles on the surface, generally those towards the centre of the pond, group themselves into stars of three or six radii, feathered on either side with fine spiculæ, which quickly form a crystalline encrustation of serrated outline, giving to each radial arm or pinna the appearance of a frond of fern. Fig. 18 is a representation of this the most elementary form of water crystal, as commonly seen on water just below the freezing point, and may be seen extending to a length of upwards of 18 inches radius, and again small and beautifully defined, not exceeding an inch in diameter. The interstices between these crystals are frequently filled in here and there with single pinna of the same, and everywhere besides with needles crossing and recrossing in all directions. If the frost continue, in the course of a few hours as the ice thickens these beautiful markings become obliterated. They are best witnessed on the cold

Fig 18.

morning of a fine clear winter day, when the process of congelation is proceeding slowly; at such times the water by the road side, or the surface of a pond, affords matter of the highest interest and infinite study.

23. These processes in part may be repeated within doors and during severe weather, by exposing in shallow vessels of wood, porcelain, &c., about an inch depth of water, under an open window, in a room of about 32° temperature. By this means the process may be seen in miniature, but the observer should be prepared to watch repeatedly before he can hope to see it displayed in full perfection. The annexed engraving (fig. 19) is copied from the surface of a bath of water so exposed: the entire surface was covered with groups equally interesting and graceful.

24. The forms of hoar frost, as deposited on various out-door substances, are infinitely varied: hoar frost or white frost is simply frozen dew, and may be seen to great perfection before sunrise on mornings following cold and cloudless nights, during which the radiation of heat from the earth is large, the cooling effect of which on the passing air is to cause an abundant deposition of dew, which on becoming frozen gives rise to innumerable combinations of spiculæ, varying in arrangements and grouping according to the nature of the substances on which the dew is deposited. It varies very greatly on the leaves of different plants, which of itself may be said to constitute a study. During the years 1841 to 1845, whilst carrying on a course of experiments on the radiation of heat, I paid considerable attention to the subject; the results of these


Fig. 19.

experiments are published in the Philosophical Transactions for the year 1847.

25. Every one is familiar with the beautiful encrustations on the surface of window-panes in frosty weather, another of this class of phenomena, and produced by the same process of congelation; and which the observer may perceive for himself by effacing with his hand a portion of that already crystallized, and breathing upon it anew. After a short interval there will simultaneously appear along the inner margin of the part an almost imperceptible fringe of spikes or needles, which speedily lengthen — a few generally exceeding very greatly the remainder in length. They are most frequently curved, and soon assume the arborescent form: sometimes the lines of crystallization will run parallel to each other, in undulations, so as to give rise to beautiful semblances of the most varied objects.

The graceful and flowing curves occasionally exhibited about the freezing point on various substances may be illustrated in the following engraving (fig. 20), the

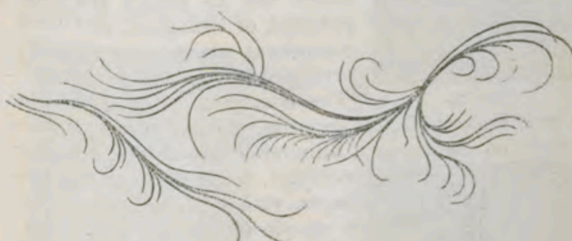


Fig. 20.

original of which was observed upon a wooden handrail in the open air, and was continued on for a length of seven feet.

26. The crystallization of water or vapour in the upper regions of the air is a still more interesting field of inquiry, and leads us to the consideration of snow. Very little is as yet known respecting the formation of snow, excepting that it is water congealed in the higher

regions, and can therefore only be formed at or below a temperature of 32°. It falls for the most part in flakes of such density, that from 10 to 12 inches in depth of fresh-fallen snow produces water to the depth of an inch; but it is not always that snow assumes the form of flakes, it occasionally falls in clusters of small needles or spiculæ, sometimes broken in their descent into the finest possible fragments, while at other times it descends in minute and highly-crystallized stellar particles, designated by ancient writers as Polar snow, and generally supposed to be confined to the more northern latitudes: its density in this form is somewhat greater than in flakes, 8 inches of snow producing about an inch of water. The simple or elementary crystals of snow, formed at or near the freezing-point, bear considerable analogy to those on the surface of water already referred to, but, unlike them, are in these latitudes invariably minute and rarely exceed 0·5 inch in diameter. Water crystallizes at an angle of 60 degrees: in accordance with which law its figures are compounded of hexagons, and their component parts respectively arranged at an angle of 60°. The combinations so given rise to may be considered, according to our present information on the subject, illimitable, but always, however complex, referable to one of two bases, viz., a plane hexagon, or a simple elementary star. Fig. 21, drawn as seen through a high-power Coddington lens, and compounded of solid hexagons, is selected as illustrative of the former class; and fig. 22, made up entirely of spiculæ, as illustrative of the latter. The great variety observable in the conformation of these bodies is remarkable, and adds not a little to the complexity of the problem, respecting the conditions and circum-

Fig. 21.

Fig. 22.

stances attending their crystallization. They descend simultaneously in differently progressive stages of development, and distinct classes, or rather distinct orders of crystals. Fig. 23 is illustrative of a crystal in an intermediate stage of formation. Fig. 24 is of a very high order, and fell on a day when the temperature differed very greatly from the average for the time

Fig. 23.

Fig. 24.

of year. Unlike those of which I have been speaking, it was an almost imperceptible speck, and it was difficult to conceive how it could contain such an aggregation of solid figures. Some crystals are double, that

Fig. 25.

Fig. 26.

is, two similar crystals are united by an axis at right angles to the plane of each. Such is fig. 25, which is one of the most simple types I have been able to select. The manner of the subsidence of these bodies on first melting, is a very important point of observation; if it proceed gradually, every line becomes relaxed, and bent inwards, and every angle blunted. Thus a figure laden with prisms upon the main arm will assume the appearance of fig. 26, which was drawn while melting, and to the eye of a casual observer, presents a very anomalous appearance. In the Report of the British Meteorological Society for 1855, I have treated at length on these interesting bodies,* and have appended illustrations of more than 150 varieties; but the plan of the present work will not here permit me to enlarge on the subject further than to call attention to the manner of the crystallization of water, which as occurring on the surface of the earth, as falling in the familiar form of snow, or as deposited in the form of hoar frost—call into operation the same code of laws. In the case of snow, its crystallization is, I am convinced, intimately connected with the electrical and chemical condition of the air generally; and in this opinion I am confirmed both by Dr. Smallwood of Isle Jesus, Canada, and Sir Edward Belcher: the latter gentleman, in his work on the Arctic Seas, recently published, has devoted some pages to the subject, having, he observes, for many years regarded them with great interest, both in a mineralogical and chemical point of view, independently of their belonging to the ordinary range of meteorological inquiry. Sir Edward Belcher says, "three classes were made by me, and termed:—

1. "Stars and garters—from their resemblance to the order of knighthood and perfection of crystal, or such as might result from temporary currents of electricity suddenly forming and condensing vapour, as compared to fine, light, passing showers between bright gleams of sun. It will be understood that such light rain, which in other climes would not obscure the sun, would in the state of snow be more opaque.

2 "Rain—heavy flocculent snow, cohering, and into which the travellers and sledge sank deeply, warning the intelligent officer that he had better pitch his tent, and reserve the strength of his crew for a period when search would be rational.

* In the 'Art Journal' for the months of March and April 1857, is an article on the Application of Snow Crystals for the purpose of Design.

3. "Bad-omened—fine, spicular snow, the result of No. 1 broken by the wind into fine particles: this induced us to expect the sharp rain attended by wind of other climates, but did not hinder travel,—it was not so opaque as to impede vision.

"These remarks apply simply to the question of utility in such pursuits; and, as regards the terms selected by me, were adapted to the minds of those by whom I was surrounded, and who fully understood, in their own way, the full intent of the freemasonry which most leaders maintain with their followers."

JAMES GLAISHER.

LIST OF METEOROLOGICAL WORKS OF REFERENCE.

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TABLE 1, showing the Monthly Mean Reading of the Barometer, corrected and reduced to the temperature of 32° Fahrenheit, at the Royal Observatory, Greenwich. Height above the level of the sea, 159 feet.

Years.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
1841	29·702	29·697	29·784	29·731	29·731	29·801	29·716	29·768	29·624	29·436	29·672	29·574
1842	29·901	29·876	29·747	29·914	29·782	29·901	29·820	29·869	29·715	29·849	29·599	30·007
1843	29·674	29·473	29·758	29·678	29·664	29·700	29·826	29·819	30·017	29·604	29·718	30·245
1844	29·819	29·498	29.710	30·000	29·945	29·814	29·753	29·677	29·881	29·562	29·690	29·885
1845	29·704	29·840	29·795	29·696	29·712	29·775	29·769	29·729	29·801	29·847	29·575	29·658
1846	29·761	29·849	29·655	29·589	29·779	29·866	29·757	29·777	29·824	29·516	29·821	29·697
1847	29·768	29·782	29·882	29·653	29·764	29·805	29·924	29·876	29·825	29·803	29·905	29·778
1848	29·816	29·517	29·505	29·589	29·926	29·642	29·836	29·732	29·832	29·646	29·785	29·807
1849	29·717	30·106	29·915	29·517	29·766	29·868	29·789	29·841	29·767	29·744	29·743	29·795
1850	29·854	29·828	30·039	29·594	29·714	29·886	29·789	29·787	29·930	29·681	29·728	29·914
1851	29·642	29·891	29·600	29·726	29·891	29·895	29·708	29.890	30·025	29·726	29·781	30·135
1852	29·589	29·857	30·007	29·945	29·786	29·560	29·857	29.649	29·739	29·687	29·465	29·581
1853	29·570	29·525	29·780	29.710	29·754	29·729	29·728	29·793	29·833	29·558	29·941	29·804
1854	29·618	30·041	30·186	29·985	29·667	29·735	29·807	29·889	30·031	29·724	29·728	29·768
1855	29·998	29·593	29·535	29·933	29·697	29·863	29·769	29·874	29·966	29·527	29·864	29·761
Means	29·745	29·758	29·793	29·751	29·771	29·789	29·790	29·798	29·854	29·661	29·734	29·827

The excess or defect of pressure in any Month is shown by comparing the Number in that Month with the Numbers in the bottom line, which show the average pressure of the atmosphere in each Month, as found from 15 years' observations.

TABLE 2, showing the Monthly Mean of the highest Daily Readings of a Thermometer in Air, at the height of 4 feet above the soil at the Royal Observatory, Greenwich.

Years.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.
	°	°	°	°	°	°	°	°	°	°	°	°
1841	39·5	40·7	56·2	56·4	69·7	67·0	67·1	70·6	67·2	55·6	48·7	44·8
1842	36·6	46·6	51·8	54·7	64·5	75·2	71·2	78·1	64·3	53·4	48·1	49·4
1843	44·7	40·2	50·5	57·9	63·3	67·0	71·8	72·5	70·4	55·5	50·0	48.2
1844	43·9	41.6	48·9	63·6	65·9	74·1	72.8	67·9	67·5	56·7	48·1	36·8
1845	43·3	38·4	42·4	57·5	59·6	72·5	71·2	67·7	63·9	59·0	51·8	47·6
1846	48·1	49·0	51·6	56·4	66·7	80·4	77·9	74·4	71·9	58·7	50·3	37·2
1847	40·1	41·5	50·1	55·4	68·0	69·4	78·1	74·4	64·9	61·5	52·7	46·7
1848	38·1	48·7	50·7	56·2	74·4	68·0	73·7	68·9	66·8	59·6	51·1	48·9
1849	45·4	49.4	50·1	52·5	63·8	69·1	74·2	74·2	68·7	59·2	49·8	43·2
1850	38·0	50·7	48·6	58·5	62·1	74·1	72·9	70·6	65·3	54·8	52·4	44·8
1851	48·1	47·4	49·5	54·2	61·4	70·8	71·1	73·4	67·9	59·7	44·3	44·4
1852	47·9	47·5	50·7	58·2	61·8	66·5	80·6	72·6	66·6	55·7	54·5	52·1
1853	47·6	39·1	47·1	54·0	63·1	68·9	70·5	70·9	65·2	59·1	47·8	38·8
1854	44·7	47·2	54·6	61·9	63·7	67·5	73·1	73·1	72·2	59·6	47·7	47·1
1855	39·1	35·7	46·2	57·6	59·9	68·1	73·3	72·9	68·5	59·6	47·7	47·1
Sums	645·1	663·7	749·0	855·0	967·9	1058·6	1099·5	1082·2	1011·3	867·7	745·0	677·1
Means	43·0	44·2	49·9	57·0	64·5	70·6	73·3	72·2	67·4	57·8	49·7	45·1

The numbers in the lowest line show the mean highest daily temperature, as found from these observations, and by comparison with those in the body of the Table, the excess or defect of high daily temperature is immediately seen in every month.

TABLE 3, showing the Monthly Mean of the lowest Readings daily of a Thermometer in Air, at the height of 4 feet above the soil, at the Royal Observatory, Greenwich.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	°	°	°	°	°	°	°	°	°	°	°	°	
1841	28·4	31·6	38·7	39·9	48·4	48·2	51·5	54·3	51·2	43·9	38·0	35·4	1841
1842	29·3	36·0	39·2	37·3	45·0	52·2	52·1	56·3	49·8	39·3	39·0	40·2	1842
1843	35·4	31·9	37·5	40·7	45·5	49·0	53·5	55·2	52·3	42·0	38·5	40·3	1843
1844	34·1	30·9	35·7	41·8	45·1	51·6	54·1	50·3	50·2	44·4	39·6	30·6	1844
1845	34·3	27·9	30·8	39·3	42·7	52·2	53·5	50·5	46·9	44·0	40·3	35·8	1845
1846	39·4	39·3	38·1	41·8	47·4	55·1	56·5	56·6	51·4	44·5	40·0	27·9	1846
1847	31·5	30·5	34·3	36·8	47·5	49·7	54·8	52·8	46·1	46·4	40·8	37·2	1847
1848	29·8	38·0	36·4	39·5	43·9	50·5	51·2	50·4	45·9	43·1	35·4	36·2	1848
1849	34·7	36·5	36·3	36·5	46·7	48·5	51·6	54·0	51·2	44·1	38·1	34·1	1849
1850	29·5	39·1	32·1	42·5	43·2	48·1	52·9	52·0	48·2	40·6	41·0	36·1	1850
1851	38·1	34·2	37·4	38·0	41·8	48·7	51·0	53·4	47·3	46·7	32·4	36·4	1851
1852	36·5	35·3	32·1	34·2	43·2	49·4	55·7	54·7	49·2	41·1	44·1	42·4	1852
1853	37·5	29·0	30·9	39·8	41·9	50·2	53·4	51·8	47·2	43·9	36·3	29·5	1853
1854	33·9	33·6	35·4	38·2	42·4	48·3	51·5	52·4	46·5	42·1	35·0	36·1	1854
1855	31·3	24·2	31·9	36·7	40·5	45·7	54·1	53·7	47·7	42·1	35·0	36·1	1855
Sums	53·7	48·0	76·8	133·0	65·2	147·4	47·4	48·4	131·1	48·2	123·5	84·7	Sums
Means	33·6	33·2	35·1	38·9	44·3	49·8	53·2	53·2	48·7	43·2	38·3	35·6	Means

The numbers in the lowest line show the mean lowest daily temperature as formed from this series of observations, and by comparing those in the body of the Table with them, the excesses or defects of low night temperature are immediately seen.

TABLE 4, *showing the Mean Daily Range of Temperature in every Month.*

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	°	°	°	°	°	°	°	°	°	°	°	°	
1841	11·1	9·1	17·5	16·5	21·3	18·8	15·6	16·3	16·0	11·7	10·7	9·4	1841
1842	7·3	10·6	12·6	17·4	19·5	23·0	19·1	22·8	14·5	14·1	9·1	9·2	1842
1843	9·3	8·3	13·0	17·2	17·8	18·0	18·3	17·3	18·1	13·5	11·5	7·9	1843
1844	9·8	10·7	13·2	21·8	20·8	22·5	18·7	17·6	17·3	12·3	8·5	6·2	1844
1845	9·0	10·5	11·6	18·2	16·9	20·3	17·7	17·2	17·0	15·0	11·5	11·8	1845
1846	8·7	9·7	13·5	14·6	19·3	25·3	21·4	17·8	20·5	14·2	10·3	9·3	1846
1847	8·6	11·0	15·8	18·6	20·5	19·7	23·3	21·6	18·8	15·1	11·9	9·5	1847
1848	8·3	10·7	14·3	16·7	30·5	17·5	22·5	18·5	20·9	16·5	15·7	12·7	1848
1849	10·7	12·9	13·8	16·0	17·1	20·6	22·6	20·4	17·5	15·1	11·7	9·1	1849
1850	8·5	11·6	16·5	16·0	18·9	26·0	20 0	18·6	17·1	14·2	11·4	8·7	1850
1851	10·0	13·2	12·1	16·2	19·6	22·1	20·1	20·0	20·6	13·0	11·9	8·0	1851
1852	11·4	12·2	18·6	24·0	18·6	17·1	24·9	17·9	17·4	14·6	10·4	9·7	1852
1853	10·1	10·1	16·1	14·2	21·2	18·7	17·1	19·1	18·0	15·2	11·5	9·3	1853
1854	10·8	13·6	19·2	23·7	21·3	19·2	21·6	20·7	25·7	17·5	12·7	11·0	1854
1855	7·8	11·5	14·3	20·9	19·4	22·8	19·2	19·2	20·8	17·5	12·7	11·0	1855
Sums	141·4	163·7	222·1	272·0	302·7	301·6	302·1	285·0	280·2	219·5	171·5	142·8	Sums
Means	9·4	11·0	14·8	18·1	20·2	20·8	20·1	19·0	18·7	14·6	11·4	9·5	Means

The average daily ranges of temperature in each month are shown in the lower line. In like manner the usual range of temperature in each month may be found by taking the difference between the numbers in Tables 3 and 5; and the large ranges which at times takes place may be found by taking the difference between the numbers in the same months in the notes following these Tables.

TABLE 5, showing the Monthly Mean Temperature of the Air, at the Royal Observatory, Greenwich.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean for Year.
1841	33·6	35·3	46·2	47·0	56·8	56·4	57·8	60·5	58·1	48·8	42·7	40·5	48·7
1842	32·9	40·8	44·9	45·2	53·2	62·9	60·2	65·4	56·4	45·4	42·8	45·0	49·6
1843	39·9	36·0	42·9	47·1	52·2	56·3	60·9	62·1	59·5	48·0	43·8	43·9	49·4
1844	39·1	35·2	41·5	51·7	52·9	60·7	61·4	57·7	56·9	49·5	44·0	33·0	48·6
1845	38·3	32·7	35·2	46·3	49·4	60·7	59·8	57·3	53·6	50·2	45·8	41·7	47·6
1846	43·7	43·9	43·3	47·1	54·6	65·3	64·5	63·2	60·1	50·5	46·0	32·9	51·3
1847	35·1	35·4	41·0	45·3	56·4	58·0	65·4	62·1	54·3	52·9	46·9	42·8	49·7
1848	34·6	43·4	43·8	47·6	59·7	58·5	61·5	58·5	55·8	51·6	43·8	44·0	50·2
1849	40·1	43·2	42·5	43·2	54·0	57·9	62·1	62·9	58·8	51·1	44·1	39·1	49·9
1850	33·7	44·7	39·9	48·5	51·3	60·8	62·2	60·2	56·4	47·0	46·5	40·6	49·3
1851	42·9	40·1	42·6	44·7	50·9	58·9	60·1	62·3	56·9	52·6	37·9	40·4	47·5
1852	42·0	40·8	41·3	45·9	51·5	56·1	66·6	62·1	56·8	47·9	48·9	47·6	50·6
1853	42·4	33·3	38·5	45·2	52·0	58·2	60·3	60·0	55·3	50·9	42·1	34·0	47·5
1854	39·0	39·5	43·8	48·4	50·9	55·7	60·3	60·9	58·1	49·4	40·5	41·3	48·8
1855	34·9	29·4	37·9	45·8	48·8	56·9	62·1	62·1	57·1	51·2	41·3	35·6	46·9
Means	38·1	38·2	41·7	46·6	53·0	58·9	61·7	61·2	56·9	49·8	43·8	40·2	48·4

The numbers in the last column show the mean temperature of each year, and those in the lowest line the mean temperature of each month. The defect of temperature in cold months, and of excess in hot months, will be found by comparing the number in the body of the Table with those in the lower line. Cold and hot years will also be similarly indicated.

TABLE 6, containing the Mean Monthly Reading of the Wet-Bulb Thermometer, at the Royal Observatory, Greenwich.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1841	–	–	44·1	44·2	53·6	52·6	54·5	57·4	55·8	47·1	41·5	38·3	1841
1842	31·9	38·7	42·9	41·9	49·5	57·4	55·9	61·2	54·8	43·9	41·9	44·2	1842
1843	38·8	35·0	41·2	45·0	50·4	53·5	58·2	59·5	56·9	46·4	42·4	43·0	1843
1844	38·7	33·9	40·2	47·6	49·1	55·0	57·3	54·6	54·7	49·3	43·1	32·2	1844
1845	37·4	31·4	33·4	43·5	47·0	57·5	56·7	54·7	51·5	48·4	44·4	40·0	1845
1846	42·5	42·2	41·1	44·8	51·0	59·7	59·8	59·8	57·1	48·8	44·7	31·9	1846
1847	34·5	33·9	37·9	41·4	52·1	53·4	60·0	59·5	51·8	50·9	45·6	41·6	1847
1848	32·6	41·6	41·6	44·5	53·0	54·4	57·6	55·2	53·2	49·3	41·7	42·3	1848
1849	38·6	41·4	39·8	41·5	49·0	48·7	56·2	57·3	54·6	48·2	42·2	37·9	1849
1850	32·5	42·3	37·0	45·4	47·5	54·8	58·4	56·6	52·9	44·4	44·5	39·6	1850
1851	40·9	38·3	40·3	42·2	47·1	54·0	55·7	57·4	52·3	49·5	35·6	38·5	1851
1852	39·2	38·3	38·2	42·3	47·8	52·0	60·7	56·6	52·7	45·0	46·3	44·5	1852
1853	39·8	31·0	35·8	42·0	47·8	52·6	55·8	55·8	52·7	49·4	41·3	33·0	1853
1854	38·0	37·5	40·9	45·0	48·6	52·7	56·2	56·5	53·9	47·1	39·4	39·6	1854
1855	33·8	28·8	36·2	42·6	45·7	52·1	58·2	57·3	53·6	49·4	39·9	33·9	1835
Sums	519·2	514·3	590·6	53·6	739·2	810·4	861·2	99·4	58·5	695·1	604·5	580·5	Sums
Means	37·1	36·7	39·3	43·5	49·3	54·9	57·4	56·6	53·9	46·3	40·3	38·7	Means

TABLE 7, showing the Monthly Temperature of the Dew-Point, at the Royal Observatory, Greenwich.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	°	°	°	°	°	°	°	°	°	°	°	°	
1841	–	–	41·7	40·7	50·6	49·1	51·5	54·7	53·7	45·2	40·1	35·5	1841
1842	30·1	36·1	40·5	38·1	45·8	52·8	52·1	57·8	53·3	42·2	40·8	43·1	1842
1843	37·3	33·6	39·0	42·9	48·6	50·8	55·9	57·4	54·4	44·5	40 8	42·0	1843
1844	38·2	33·6	38·6	43·5	45·3	50·2	53·8	51·8	52·7	48·5	41·9	30·6	1844
1845	35·7	29·0	30·7	40·3	44·6	54·7	54·1	52·4	49·5	46·5	42·9	38·1	1845
1846	41·1	40·1	38·6	42·0	47·8	55·2	56·0	57·0	54·5	47·0	43·1	30·1	1846
1847	34·6	31·9	33·9	36·9	48·1	49·2	55·8	57·2	48·0	48·9	44·1	40·1	1847
1848	29·7	39·5	39·0	41·1	47·3	51·7	54·2	52·3	50·8	47·0	39·3	40·2	1848
1849	36·7	39·3	36·5	39·5	44·2	40·3	51·1	52·6	50·9	44·2	39·9	36·3	1849
1850	31·5	39·5	33·5	42·0	43·5	49·6	55·1	53·4	49·7	41·3	42·3	38·3	1850
1851	38·6	36·0	37·6	39·5	43·1	49·8	51·8	53·3	48·1	43·2	32·5	36·7	1851
1852	36·1	35·1	34·4	38·2	44.0	48·3	56·0	51·8	49·0	42·1	43·4	41·1	1852
1853	36·8	26·7	32·3	38·5	43·3	47·5	51·9	52·1	50·2	47·8	40·3	31·1	1853
1854	36·8	34·9	37·4	41·5	46·2	49·7	52·7	52·7	50·1	44·6	38·0	37·5	1854
1855	32·5	25·9	34·0	39·2	42·3	47·7	54·9	53·2	50·2	47·5	38·1	32·4	1855
Sums	495·7	481·2	547·7	603·9	684·7	748·6	806·9	809·7	765·1	680·5	607·5	553·4	Sums
Means	35·4	34·4	36·5	40·2	45·6	49·9	53·8	53·9	51·0	45·4	40·5	36·9	Means

The numbers in the lowest line show the mean temperature of the dew-point in every month, and by comparison with those in the body of the Table, those months are immediately shown in which the amount of water, mixed with the air, in the invisible shape of vapour was in excess or defect.

TABLE 8, showing the Monthly Mean of the Elastic Force of Vapour, at the Royal Observatory, Greenwich.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
1841	–	–	0·264	0·271	0·369	0·349	0·381	0·482	0·413	0·302	0·248	0·208
1842	0·168	0·213	0·252	0·230	0·308	0·400	0·389	0·479	0·407	0·269	0·225	0·278
1843	0·223	0·193	0·238	0·276	0·343	0·371	0·447	0·472	0·424	0·294	0·297	0·267
1843	0·231	0·193	0·234	0·283	0·303	0·364	0·415	0·365	0·399	0·342	0·266	0·171
1845	0·209	0·160	0·172	0·250	0·295	0·428	0·419	0·394	0·355	0·317	0·276	0·251
1846	0·258	0·247	0·234	0·269	0·333	0·436	0·449	0·465	0·425	0·323	0·278	0·168
1847	0·200	0·180	0·195	0·219	0·336	0·351	0·446	0·469	0·335	0·346	0·289	0·248
1848	0·165	0·242	0·238	0·248	0·327	0·384	0·421	0 393	0·371	0·323	0·240	0·290
1849	0·218	0·240	0·216	0·242	0·290	0·250	0·375	0·397	0·373	0·290	0·246	0·214
1850	0·117	0·242	0·192	0·267	0·283	0·356	0·434	0·409	0·357	0·260	0·269	0·231
1851	0·234	0·212	0·225	0·242	0·278	0·358	0·385	0·407	0·336	0·279	0·184	0·218
1852	0·213	0·204	0·199	0·231	0·288	0·339	0·449	0·385	0·348	0·268	0·281	0·258
1853	0·218	0·145	0·183	0·233	0·280	0·329	0·386	0·389	0·391	0·333	0·250	0·174
1854	0·218	0·203	0·224	0·262	0·313	0·357	0·399	0·399	0·389	0·295	0·229	0·225
1855	0·184	0·140	0·196	0·234	0·270	0·331	0·431	0·406	0·391	0·329	0·230	0·184
Sums	·56	·14	·262	3·757	4·616	5·403	6·224	6·313	5·734	4·570	908	3·395
Means	0·204	0·201	0·218	0·258	0·308	0·360	0·415	0·421	0·395	0·300	0·260	0·226

The numbers in this Table show the length of a column of mercury, balanced by the water mixed with the air; and if taken from those in the Table showing the mean pressures of the atmosphere, the difference will show the lengths of the column of mercury supported by air only.

TABLE 9, showing the Weight of Vapour in a Cubic Foot of Air, at the Royal Observatory, Greenwich.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	
1841	-	-	3·1	2·9	4·1	3·9	4·3	4·8	4·6	3·4	2·9	2·4	1841
1842	1·9	2·5	2·9	2·9	3·5	4·4	4·4	5·3	4·5	2·8	2·9	3·1	1842
1843	2·6	2·2	2·8	3·2	3·8	4·2	5·0	5·3	4·8	3·4	2·9	3·1	1843
1844	2·7	2·1	2·7	3·2	3·3	4·1	4·6	4·3	4·4	3·9	3·0	2·2	1844
1845	2·5	1·9	2·0	2·9	3·4	4·9	4·6	4·4	4·0	3·6	3·1	2·7	1845
1846	3·0	2·9	2·7	3·0	3·5	4·8	4·9	5·1	4·7	3·7	3·2	1·9	1846
1847	2·3	2·1	2·3	2·6	3·8	3·9	5·1	5·2	4·0	3·9	3·3	2·8	1847
1848	1·9	2·8	2·8	3·0	3·7	4·2	4·7	4·4	4·2	3·6	2·8	2·8	1848
1849	2·5	2·7	2·5	2·8	3·3	2·8	4·1	4·4	4·2	3·4	2·8	2·5	1849
1850	2·0	2·8	2·2	3·1	3·2	3·9	4·8	4·6	4·1	3·0	3·1	2·7	1850
1851	2·7	2·4	2·6	2·8	3·2	4·0	4·3	4·5	3·8	3·6	2·2	2·5	1851
1852	2·4	2·4	2·3	2·7	3·2	3·8	5·0	4·3	3·9	3·0	3·2	3·0	1852
1853	2·5	1·7	2·1	2·7	3·2	3·7	4·3	4·3	4·1	3·7	2·9	2·3	1853
1854	2·4	2·4	2·6	3·0	3·6	4·0	4·4	4·5	4·0	3·4	2·7	2·6	1854
1855	2·1	1·8	2·3	2·8	3·1	3·7	4·8	4·5	4·1	3·7	2·7	2·1	1855
Sums	33·5	32·7	37·9	43·6	6·9	60·3	9·3	9·9	3·4	7·1	13·7	8·7	Sums
Means	2·4	2·3	2·7	3.1	3·5	4·0	4·6	4·7	4·2	3·5	2·9	2·6	Means

TABLE 10, showing the Degree of Humidity of the Atmosphere, at the Royal Observatory, Greenwich

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1841	-	-	85	80	80	77	88	82	85	88	90	83	1841
1842	90	84	84	76	76	70	76	79	89	89	93	93	1842
1843	91	91	87	86	88	82	84	85	85	88	91	93	1843
1844	96	88	90	74	76	68	76	81	86	96	92	92	1844
1845	93	86	83	80	84	82	82	84	86	88	90	88	1845
1846	91	87	83	83	77	70	74	80	82	88	90	90	1846
1847	96	89	76	73	73	73	71	86	83	87	91	91	1847
1848	82	86	83	79	65	76	78	80	84	85	84	86	1848
1849	88	86	80	87	69	53	68	69	75	81	85	90	1849
1850	89	83	78	79	76	67	78	78	78	82	86	92	1850
1851	85	85	83	82	75	70	74	73	72	80	82	87	1851
1852	79	81	79	75	76	75	70	70	75	81	82	80	1852
1853	81	76	76	77	73	68	74	75	82	90	93	89	1853
1854	92	84	78	77	85	82	76	75	75	83	91	86	1854
1855	95	99	86	78	79	71	78	73	78	88	85	84	1855
Sums	1248	1205	1231	136	102	1184	97	120	15	94	125	124	Sums
Means	89	86	82	79	77	79	76	78	81	86	88	88	Means

TABLE 11, showing the Weight of a Cubic Foot of Air, at the Royal Observatory, Greenwich.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.
	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.
1841	–	–	545·2	543·5	532·3	534·3	531·8	529·1	529·0	535·9	547·0	545·9
1842	562·7	553·3	546·1	549·1	537·5	528·9	531·4	525·3	532·4	547·3	543·5	550·6
1843	550·2	550·8	547·4	542·2	536·2	532·9	529·1	527·9	534·4	539·7	546·8	556·1
1844	553·9	553·4	549·2	543·2	540·8	529·7	527·7	530·3	534·8	537·0	545·8	562·4
1845	553·1	562·0	558·3	543·7	540·7	528·9	529·6	531·8	537·1	541·7	541·8	547·9
1846	548·4	549·1	546·3	540·6	535·7	523·9	524·6	526·1	530·2	535·3	546·0	558·9
1847	557·9	557·5	553·3	544·1	533·6	532·6	526·4	528·9	536·8	537·9	546·7	548·9
1848	559·3	543·6	543·0	540·1	533·1	529·0	529·1	530·4	535·1	536·6	548·2	548·1
1849	551·0	554·5	552·1	543·8	536·4	534·5	527·9	527·9	530·9	538·9	546·8	553·6
1850	563·1	547·8	557·3	540·3	538·3	531·1	527·4	529·7	536·5	542·5	543·9	552·0
1851	546·5	553·3	546·1	546·0	542·1	533·1	528·4	529·4	537·5	536·1	543·8	557·3
1852	546·3	552·9	555·1	548·8	539·6	530·3	524·2	525·4	532·7	541·6	536·4	540·0
1853	545·8	555·6	549·6	545·2	540·3	531·3	523·1	530·1	535·8	535·5	552·6	559·4
1854	549·7	557·7	555·7	547·6	537·7	533·7	525·4	530·7	536·5	540·4	550·7	551·6
1855	562·0	561·1	550·2	548·2	541·9	534·9	526·6	529·2	536·2	534·7	552·4	557·2
Sums	749·9	7742·6	8254·9	8186·4	8066·2	7969·1	7912·7	7932·2	8015·9	8081·1	8192·4	8289·9
Means	556·0	553·8	550·3	545·7	537·7	531·2	527·4	528·8	534·4	538·7	546·1	552·6

The numbers in the lowest line show the average weight of a cubic foot of air in every month.

In my Hygrometrical Tables, all the hygrometric results, when the readings of the dry and wet bulb thermometers are whole degrees, are given by inspection, and when the readings are affected by parts of a degree, the results are obtained with very little trouble.

TABLE 12, showing the Monthly Fall of Rain, at the Royal Observatory, Greenwich.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	
1841	2·1	1·3	1·4	1·9	2·1	2·7	3·6	2·3	3·9	5·9	3·7	2·4	1841
1842	1·0	1·1	1·9	0·4	2·1	0·9	3·0	1·8	4·0	1·4	4·2	0·7	1842
1843	1·4	2·4	0·5	1·7	2·8	1·3	2·4	3·6	0·5	4·2	2·3	0·4	1843
1844	2·4	2·3	2·9	0·4	0·4	1·8	2·8	2·0	1·2	4·0	4·3	0·4	1844
1845	2·4	0·9	1·5	0·6	2·2	1 9	1·9	3·1	2·1	1·4	2·4	2·0	1845
1846	2·8	1·5	0·9	3·1	1·5	0·5	1·5	4·0	1·8	5·1	1·5	1·1	1846
1847	1·4	1·4	0·8	1·0	1·4	1·5	0·7	1·9	1·6	2·0	2·0	2·0	1847
1848	1·2	2·6	3·1	3·4	0·4	3·5	2·0	4·3	2·4	3·5	1·2	2·6	1848
1849	1·6	2·2	0·5	2·2	3·9	0·2	2·9	0·5	3·2	2·7	1·5	3·4	1849
1850	1·2	1·3	0·3	2·3	2·4	0·9	2·9	1·9	1·3	1·4	2·5	1·3	1850
1851	2·7	1·2	4·1	2·3	0·8	1·3	2·8	1·5	0·8	1·8	0·6	0·6	1851
1852	3·6	0·9	0·2	0·5	1·9	4·6	2·3	4·4	3·8	3·0	6·0	2·2	1852
1853	2·0	0·9	1·5	3·1	1·6	2·8	6·0	2·2	2·4	4·3	1·5	0·7	1853
1854	1·7	1·0	0·4	0·6	3·3	1·0	1·7	2·9	0·7	2·6	1·4	1·4	1854
1855	1·0	1·4	1·5	0·1	1·8	0·7	5·1	1·1	5·4	2·6	1·4	1·4	1855
Sums	28·5	22·4	21·5	23·6	28·6	25·6	41·6	37·5	35·1	45·9	36·5	22·6	Sums
Means	1·9	1·5	1·4	1·6	1·9	1·7	2·7	2·5	2·3	3·0	2·4	1·5	Means

TABLE 13, showing the Mean Monthly Results for Meteorological Elements, at the Royal Observatory, Greenwich, in the Year 1855.

1855. Month.	Mean Reading of the Barometer.	TEMPERATURE OF THE AIR. Highest.	Lowest.	Range in the Month.	Mean, of all the Highest.	Mean, of all the Lowest.	Mean Daily Range.	Mean.	Mean Temperature of Dew-point.	Mean Elastic Force of Vapour.	Mean Weight of Vapour in a Cubic Foot of Air.	Mean Additional Weight of Vapour required to saturate a Cubic Foot of Air.	Mean Degree of Humidity, complete saturation = 100.	Mean Weight of a Cubic Foot of Air.	WIND. Prevailing Direction.	Mean Daily Pressure in lbs. on Square Foot.	Mean Daily Horizontal Movement of Wind.	Mean Amount of Cloud.	RAIN. Number of Days it fell.	Amount Collected on the Ground in inches.
	In.	°	°	°	°	°	°	°			Grs.	Gr.		Grs.		lbs.	Miles.			
January .	29 998	52·4	16·2	36·2	39·1	31·3	7·8	34·8	31·7	·200	2·4	0·3	91	558	N.E. & S.W.	0·22	47	8·7	20	1 5
February .	29·593	48·4	11·1	37·3	35·7	24·2	11·5	29·1	26·7	·165	2·0	0·2	91	557	E. & N.E.	0·18	64	7·6	11	1·0
March . .	29 535	57·8	24 5	33·3	46·2	31·9	14·3	37·9	33·6	·212	2·5	0·4	86	546	N.E. & S.E.	0·25	64	7·8	12	2·0
April . .	29·933	72·8	25·9	46·9	57·6	36·7	20·9	45·9	38·8	·251	2·9	0·8	78	544	S.W. & N.E.	0·24	96	5·8	4	0·1
May . . .	29 679	81·5	28·3	53·2	59·9	40·5	19·4	49·0	42·3	·284	3·3	0·8	80	536	N.E. & S.	0·21	118	7·7	12	1·8
June. .	29·863	83·5	39·3	44·2	68·5	45 7	22·8	58·0	47·8	·348	3·9	1·5	74	530	S.W. & N.E.	0·01	87	6·4	9	0·9
July . . .	29·769	79·0	43·7	35·3	73·3	54·1	19·2	62·2	55·5	·444	5·0	1·3	80	523	S.W.	0 03	67	7·0	10	5 3
August. .	29 874	79·0	47·3	31·7	72·9	53·7	19·2	62·4	53·9	·423	4·7	1·5	86	525	S.W.	0·05	107	5·9	10	1·4
September	29·966	78·2	34 1	44·1	68·5	47·7	20·8	57·2	50·5	·378	4·3	1·1	80	532	N.E. & S.W.	0·04	75	5·4	6	2·0
October .	29·527	66·8	35·0	31·8	58·7	45·2	13·5	51·2	47·8	·346	4·0	1·5	89	531	S.W. & N.W.	0·29	106	7·6	22	5·2
November	29·864	58·0	25·7	32·3	46·5	36·8	9·7	41·3	38·5	·250	2·9	0·3	92	548	N.E.	0·04	63	8·1	17	1·5
December	29 761	52·4	16·9	35·5	40·2	30·9	9·3	35·6	31·3	·178	2·1	0·6	79	553	S.W. & N.W.	0·21	114	6·9	11	1·1
																			Sum	Sum
Means	29·780	67·5	29 0	38 5	55·6	39·9	15·7	47·1	42·6	·290	5·7	0·8	83	540				7·1	144	23·8

The articles will be written by the following gentlemen; and those to whose names an asterisk (*) is prefixed are contributors to the first three volumes, which have been practically tested in the school under the Editor's care.

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READING LESSON BOOKS,

BY

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Opinions of the Press.

EXTRACTS FROM A REVIEW OF THE "FIRST BOOK" IN THE LONDON, EDINBURGH, AND DUBLIN PHILOSOPHICAL MAGAZINE.

Those who are practically engaged in the education of youth will be best able to appreciate the value of such reading lessons as Mr. Hughes intends his to be, as well as the difficulties which have to be surmounted in realizing his ideal. This is not the place to speak much of the departments of literature and art. We shall merely remark, that the lessons on Mental Culture, by Mr. Edward Purcell, contain many sound thoughts and much good practical advice. The Biographies, which form an admirable feature in a boy's reading book, are on the whole well-written. We know nothing more calculated to rouse a boy's faculties into activity, and induce him to be diligent and persevering, than well-written lives of men who have demonstrated by their works what diligence and perseverance can accomplish. The chapters on English Literature by Mr. George L. Craik are well-written, and will find many readers. Everybody knows the attractions which Natural History possesses for young people, and we doubt not that Mr. Patterson will be fully appreciated by them. Want of space will not allow us to do more than notice, that the departments of Ethnology and of Animal and Vegetable Physiology are in the hands of the well-known writers, Latham, Mann, and Lankester. Mr. Hughes himself is the writer of the lessons on Physical Geography, and, as might be expected from the originator of the whole scheme, has performed his task well. Mr. Purcell's lessons on Mechanics are also well and clearly written. Professor Tyndall's on Natural Philosophy are in every respect admirable. The style is attractive, lucid and vigorous. The collision of bodies, and the laws of falling bodies, are generally somewhat difficult questions for boys, but they are here made so remarkably clear and simple that no boy of ordinary intelligence can fail to understand them. The last lessons we shall notice are those by the Rev. Robert Main, on Astronomy, which may also be pronounced successful. In conclusion, we wish Mr. Hughes every success; his First Book is a good one, and we hope his future books will be better. We have given unusual space to our review because we deem his project an important one, and because it is almost the first of its kind in which the principle has been recognized, that only the ablest men can expound the elements of a science successfully, and that the task is in every respect worthy of their valuable time.—*December* 1855.

EXTRACTS FROM AN ARTICLE ON "EDUCATIONAL REFORM" IN THE DUBLIN UNIVERSITY MAGAZINE.

The schools in which instruction in natural and physical science is considered an essential part of education are as yet very limited in number, from the operation of causes not difficult to assign. Of these causes we believe the most powerful are, the want of text-books, and the want of teachers. There is no lack of desire to learn physical science, both on the part of teachers and scholars, but the want of accurate and scientific text-books, and of teachers competent to instruct in these branches, is keenly felt. We therefore hail with pleasure the attempt made by Mr. Edward Hughes, Head-master of the Royal Naval Lower School at Greenwich Hospital, to supply the first of these deficiencies. Mr. Hughes proposes, in a series of "Reading Lessons" on a variety of scientific and literary subjects, to direct the school-boy's taste, and form his mind for the profitable study and perusal of scientific works of a less elementary character.

To this movement we heartily wish success, and we congratulate Mr. Hughes on the competent manner in which, on the whole, his task has been executed.

Where so many excellent articles are found, it is difficult to select for approval; but it would be unjust not to record our opinion of the peculiar excellence of that on Natural Philosophy, by Professor Tyndall, who has treated his difficult subject with uncommon skill, and with a rare felicity of illustration.—*October*, 1855.

Mr. Hughes, the accomplished Head-master of the Lower Naval School at Greenwich, has issued a first and a second book of his advanced *Reading Lessons*. They well deserve the attention of parents and teachers.—*The Critic, January* 15*th*, 1856.

We have received the "Third Book" of the above series: it forms a sequence to the two volumes of "Reading Lessons" which we noticed not long since, and which, as we stated, constituted a very important and extremely elegant addition to our School Literature.

We have perused this third volume with no small degree of interest and pleasure, and we must admit that it falls in no way short of its two predecessors, in either excellence of plan, judiciousness in selection of matter, or in elegance of artistic execution.—*The Galway Mercury, March* 1*st*, 1856.

The design of the Series, which is intended to consist of five books, is to supply thoroughly good and practical aids to the development of knowledge in the minds of youthful students, and to put into their hands efficient and well written text-books on the various subjects of which they treat in the different branches of Literature, Science, and Manufactures. To ensure accuracy, and render the work more practically useful and valuable, the various divisions of the volumes have been written by the most eminent men of the day in their particular lines of study. The volumes are profusely illustrated throughout with explanatory diagrams and engravings, so carefully executed as to render them valuable adjuncts to the papers which they accompany. Altogether, we cannot but strongly approve and recommend *Hughes' Reading Lessons* as one of the best books of its kind ever published, and we are glad to see that although only very recently issued, a fresh edition of the first book is already called for.—*The Derby Telegraph, November* 24*th*, 1855.

The series, when completed, will consist of five reading lesson books profusely illustrated, and admirably suited for the more advanced classes. The series will be carefully graduated, the editor, as stated in the preface, "making each book a complete platform of knowledge upon which the mind may, as it were, rest, and take a general view before ascending to a higher stage." How fully this idea has been carried out will be at once apparent by an enumeration of the subjects forming the educational course here presented. They include Mental Culture, Physical Geography, Scientific Biography, Geology, Vegetable and Animal Physiology, Ethnology, Food, Language, Natural History, Political and Domestic Economy, Chemistry, Mechanics, Arts and Manufactures, Natural Philosophy, Astronomy, Fine Arts, Outlines of Musical Study, English Literature, and Poetry. The vast information contained in this comprehensive list has been specially prepared for the series by writers eminent in their particular departments of Literature, Science, and Art.—*The Ipswich Express, November* 20*th*, 1855.

The work now under consideration may justly be denominated one of the greatest educational efforts of the day; and in due keeping with its importance and magnitude, it is gratifying to observe that the most celebrated writers are engaged to contribute the articles, each devoting his pen to the subject on which he has most distinguished himself. The books are

beautifully got up, and judiciously illustrated. We are quite charmed with the mode in which the knowledge of things is conveyed, and with the excellent way in which the subjects are graduated. We fully anticipate and are convinced that the work will become highly popular. From its variety and extent it fairly and completely eclipses current educational courses, and we hesitate not to say that the intellectual calibre will also be found fully as great as that of any existing work. The principal peculiarity of the work, and one which will go far to recommend it, is its being specially written for the purpose to which it is devoted.—*The Berwick and Kelso Warder, November* 30*th*, 1855.

When we mention as contributors the distinguished names of Dr. Lyon Playfair, Hugo Reid, Dr. Sutherland, John Bell (sculptor), James Glaisher (Greenwich Observatory), Digby Wyatt, Owen Jones, and Mrs. Jameson, with a host of others, equally celebrated in their respective walks of literature, science, and art, we have said enough to draw the attention of those engaged in education to the work, which, once done, its high degree of excellence will speedily ensure its popularity.—*The Durham County Advertiser, November* 23*rd*, 1855.

The Essays are interspersed with pieces of poetry, and each subject requiring pictorial aid is profusely illustrated with well-executed wood engravings. We have never seen a work of the kind that we could so thoroughly and conscientiously recommend, and we cordially wish Mr. Hughes success in the profession of which he is so bright an ornament.—*Wilts and Gloucester Standard, November* 17*th*, 1855.

Mr. Hughes seems fully aware that there is no royal road to knowledge, and in so thinking does not profess by these "Lessons" to make youths into scientific men. He has simply brought together a number of brief yet well-arranged treatises on various useful subjects, written by men of experience, and these are intended as the stepping-stones upon which the student may rise to a clearer view of the theories he will have to contend with in a more advanced sphere. The first volume commences with a clearly written chapter on the important questions "How to get Knowledge?" and "How to Observe?" and it is followed by agreeable essays on Physical Geography, Scientific Biography, Geology, Animal Physiology, Political and Domestic Economy, Chemistry, &c. There is also a chapter on the Fine Arts, in which we find useful hints by R. N. Wornum upon the contemplation of a picture; and on the Means of Enjoying a Picture Gallery without necessarily being an Artist, by Mr. Muirhead Mitchell. Both of these articles exhibit good taste in the writers, as well as the power of conveying their ideas in a ready manner to others.—*The Manchester Examiner and Times, December* 15*th*, 1855.

So far as we are able to judge from the first and second volumes, and the comprehensive and methodical prospectus now before us, the work will be valuable. It is cheap, beautifully got up, and we anticipate for it an extensive circulation, of which it seems every way worthy.—*The Edinburg News, December* 15*th*, 1855.

The subjects are written by various eminent men, whose names are guarantees for their value and utility, Mr. Hughes himself contributing largely to the general information, and at the same time displaying great discrimination in the selection and arrangement of the whole. Mental culture, the sciences, natural history, arts and manufactures, English literature, biography, poetry, &c., &c., are each skillfully and pleasingly handled, affording a rich fund of knowledge to be acquired in the most agreeable manner, free from the appearance of "tasks," and leading the reader to a full understanding of the information sought to be imparted. The volumes are illustrated with a large number of sketches and diagrams neatly engraved, which, while they add to the interest, contribute much to elucidate the various treatises or lessons. We hail the appearance of these volumes with much satisfaction, and cordially recommend them to parents or others having the care and instruction of the young. Mr. Hughes has, indeed, contributed greatly to the educational works of the day, and well deserves the thanks of the public. Several of the geographical works of the author we have had the pleasure to notice on former occasions.—*Hereford Journal, November* 21*st*, 1855.

To no person are we more deeply indebted for these improvements than to the able and indefatigable editor of these works, which are, we rejoice to find, extensively patronized. As text books for schools, these works are invaluable, and truly may it be said, that each article they contain takes the student a step forward in the science of which it treats, making, as it were, "each book of the series a complete platform of knowledge upon which the mind may rest, and take a general view before ascending to a higher stage."—*The Cambridge Independent Press, December 29th*, 1855.

The two volumes before us are an evidence of the advanced character of the education he gives, and is desirous of having imparted. Unlike ordinary "reading lessons," these volumes are not mere extracts, but are a well-arranged, well-written, series of lessons on physical science and moral philosophy, written specially for this work by men foremost in their several vocations. In fact the books form a compendium of information on literature, science, and art, the work of the best men of the age in their several specialities.—*Supplement to the Birmingham Journal, January 5th*, 1856.

Mr. Hughes, Head-master of the Lower Naval School at Greenwich, is one of our most celebrated public teachers, and has given to his profession many valuable school-books. He is now issuing a series of Reading Lessons for parents and teachers, to aid them in the "intellectual training" of the young—in the promotion of "the higher object of education, that of informing the mind and disciplining its powers." His fellow-labourers are Craik, De Morgan, Owen Jones, Hugo Reid, Warrington Smyth, Lyon Playfair, Digby Wyatt, &c., &c.—*The Gateshead Observer, November 17th*, 1855.

It is with unfeigned pleasure we perceive the name of Mr. Edward Hughes again before the public, connected, as it always is, with works full of pleasant knowledge for the rising generation. The present publication is a series of five Reading Lesson Books (the two first of which are before us), containing papers on a great variety of subjects, and illustrated by numerous engravings. The writers upon each subject are men selected not only for their eminence in science and literature, but also as well know educators. At the close of the first volume is a copious Etymological and Explanatory Appendix, which will be found a valuable assistance to an intelligent teacher.—*Leicester Journal, January 11th*, 1856.

Mr. Hughes' educational works are well known, and the present series is well calculated to add to his already extensive reputation. It communicates that knowledge which is best adapted to the wants of the day, in the form which is most suited to the prevailing taste. This is the secret of successful authorship, and this Mr. Hughes has shown himself to be completely master of. In the present undertaking he has secured the assistance of some of the most eminent authors in the various departments of popular science of which it treats, and which include Physical Geography, Scientific Biography, Natural History, Political and Domestic Economy, Natural Philosophy, Animal and Vegetable Physiology, and others of kindred nature.—*The Liverpool Courier, November 21st*, 1855.

In the neat and compact volumes before us, the compiler seems to have aimed at combining, with the literary and moral elements of the old-fashioned "collections," the useful knowledge, scientific and economic, which perhaps too exclusively occupies many of our more modern school-books. His own experience, and the abilities of his assistants, are of themselves guarantees of his success. We find Dr. Lyon Playfair, Mr. George Craik, Mr. Robert Patterson, and other names of repute in their special departments, contributing to these well-filled and well-arranged school-books, which are also, at the same time, profusely illustrated with diagrams and other woodcuts.—*The Daily Scotsman, February 19th*, 1856.

These are two of the most admirable books of instruction we have ever seen, and may be used with great advantage, not only in schools, but by the private student. The matter is nearly all original, and the editor has been assisted in his task by many writers of eminence; amongst whom we may mention George L. Craik, R. N. Wornum, Edwin Lankester, R. G. Latham, Digby Wyatt, and Hugo Reid. The contents of each volume are varied, and contain admirably written exercises on mental culture, physical geography, scientific biography, geology, physiology, language, natural history, &c. We have perused them with attention and profit, and we can most confidently recommend them as books replete with instruction and usefulness in the various branches of human knowledge.—*The Blackburn Weekly Times, January 26th*, 1856.

The first and second books of this series, intended for the use of schools, comprise a great variety of useful elementary knowledge. They are intended for exercises for pupils in reading, but at the same time the subjects are so selected as that every lesson will leave ideas imprinted on

the mind. Many of the original articles have been written by men whose names have attained high distinction in connexion with the subjects they treat of.—*Cork Examiner, February 29th*, 1856.

These books are intended to provide, for the use of schools, series of reading lessons that shall be at once models of style and diction, and popular elementary treatises upon subjects in the various departments of literature, science, and art. They have the advantage over a mere miscellaneous collection, however judiciously selected, of a uniformity of design and completeness of execution; and as a means of at once affording good exercise as class-books, and as serving as introductions, more than elementary, to the study of the great departments of human knowledge, these Reading Lessons of Mr. Hughes are well deserving prominent place in those of our seminaries where the scheme of instruction embraces something beyond the dusty curriculum of the traditional classics and mathematics.—*Eddowes' Shrewsbury Journal, November 21st*, 1856.

These reading-lessons are directed to the explanation of various sciences, manufactures, and pursuits mechanical or artistic, of which a concise and clear outline is given. Physiology, animal and vegetable; geography, biography, chemistry, astronomy, philosophy, natural history, political and domestic economy, the study of languages, the fine arts, are all presented to the young mind in simple and attractive forms by authors of acknowledged eminence in their respective walks. Consequently the lessons, while full of instruction on the particular subjects treated of, will constitute by their different styles a good exercise in the vocabulary and forms of language. They will form a valuable addition to school literature, and the rising generation will have great cause to be thankful to Mr. Hughes for providing them with a course of reading, interesting enough to keep attention on the stretch, and so full of instruction that in the time devoted to this branch of education a double measure of improvement will be gleaned.—*Worcester Chronicle, February 20th*, 1856.

Written by men who are recognised by the scientific and literary world as amongst the lights of the age, they have treated of common things in such a manner that they not only impart a large body of most interesting and valuable facts, but they have laid down in easy and progressive lessons the principles of human knowledge in language so suggestive that the pupil, after having mastered them, is prepared to pursue his studies into the highest realms of investigation, without the necessity of being forced to acquire a new nomenclature and forget all he has learned before. Every lesson, and they are all exceedingly short and interesting, is a lecture containing some important principle which leads insensibly to further inquiry, and makes every future step more easy and agreeable. As we have said, these works are illustrated by carefully and beautifully executed woodcuts, so that both the eye and the judgment are educated. The form and structure of plants and animals are all explained to the eye, and their constituents, organization, and uses are described in fitting sentences to the reason, so that when the series, which is to contain five books, is concluded, it will form a complete encyclopædia of elementary lessons in physical and mental science, and the arts. We cannot conclude our remarks without most earnestly recommending these volumes to the careful attention of our readers and all teachers of public and private schools, for while they are calculated to impart a large and valuable store of knowledge to the young, they will form an excellent and compendious library of reference to adults.—*The Glasgow Herald, December 19th*, 1855.

The great complaint against most school books a few years ago was that they were exuberant in words, and great in ambiguity. Now, however, brevity and simplicity are the main points sought for, and the want has not been more efficiently supplied than in the works of Mr. Hughes. This is especially the case with the books before us, which, while addressed particularly to youthful minds, are well deserving the attention of persons of mature years. They embrace short and pithy articles on Mental Culture, Physical Geography, Scientific Biography, Geology, Vegetable Physiology, Animal Physiology, Ethnology, Natural History, Political and Domestic Economy, Chemistry, Mechanics, Manufactures, Natural Philosophy, Astronomy, the Fine Arts, and English Literature; and among the contributors we find the names of such men as Edwin Lankester, Lyon Playfair, Edward Purcell, and Robert Gordon Latham, the Editor taking the precaution to have the various articles written by different authors, in order that they may "afford sufficient diversity in style and diction to form a sound exercise in the vocabulary and forms of our language." The "lessons" are so arranged that in the second book the reader is enabled to advance a stage, the articles in one volume being initiatory to those which appear in the other.—*The Cheltenham Journal, November 24th*, 1855.

The object has been to furnish a series of reading lessons on the various departments of the physical sciences, biography, literature and arts, for the double purpose of supplying to parents and teachers an aid in developing the intelligence and enlarging the knowledge of young minds, and at the same time affording a course of essentially English reading-books. The plan adopted is that of making each book of the series a complete platform of knowledge, "upon which the mind may, as it were, rest, and take a general view before ascending to a higher stage." These lessons carry the reader by the most interesting paths up to the second stage, where the next volume commences, and the same subjects are considered from a higher point of view, and so on until the fifth volume, which will complete the series, when the highest view that the present advanced state of knowledge enables the writers to afford will be given. That this work will speedily become a class-book in all our best schools we can entertain no doubt—and some idea of its value, and of the measure of approbation which it has commanded may be gathered from the fact that within a short period of the publication of the first volume, and before the second was issued, another edition of the former was demanded. But we believe it will become more than a school-book, and that it will be adopted as a general book of reference in our young men's Christian and literary institutes, and by that numerous but deserving class of young men who are endeavouring to compensate for the disadvantages of their early social position and want of education by earnest self-culture. To them and to all, we could not commend a more able, intelligent, or attractive guide.—*The Devonport and Plymouth Journal, November 22nd*, 1855.

Nor is the plan here set forth more excellent, as too often happens, than the execution of the work: it is an admirable production, in spirit, thoughtfulness, and practical utility. We ought also to add that there is the additional charm of pictorial illustration to enliven and enrich the text, along with choice poetical quotations at the close of each chapter, from standard authors—while the size of the volumes is convenient, their typography beautiful, and their price exceedingly moderate.

Any young man who feels a deficiency on the subjects which they embrace could not spend his winter evenings more profitably than by procuring Mr. Hughes' books, and studying them with care and diligence. They contain more sound, practical knowledge, suited for the every-day experience of life, than would be obtained by a year or two's attendance upon lecturers and institutions whose performances are so often and so sadly disproportionate to their pretensions.—*The Newcastle Guardian, November 24th*, 1855.

Many of the subjects treated in them have hitherto been almost incomprehensible to youthful minds, because of the heavy, lumbering, uninteresting way in which authors have written about them, and in some instances the frequent use of technical terms has put them entirely beyond the intellectual power of the young, even though the avowed aim of the writers has been to render themselves intelligible to the "meanest capacity." The learned editor of the books before us steers clear of all rocks and shoals that such "capacities" are likely to founder upon or knock against. He discourses upon even the grandest subjects in language perfectly suited to the class of readers for whom his books are especially intended, and the whole of the writers whom he has enlisted in the work have adopted the same simple intelligible mode of conveying information. These writers are Edward Purcell, on mental culture, and mechanics; Lyon Playfair, on food; Warrington Smyth, on geology; R. G. Latham, on language; Robert Patterson, on natural history; John Tyndall, on natural philosophy; H. F. Chorley, on musical study; Mr. Hughes himself, on physical geography; Digby Wyatt and Owen Jones, on the fine arts; and several others of equal celebrity, on various topics which the mind should be made acquainted with in early life, since information respecting them is calculated, more than instruction upon any other subjects with the exception of those of a strictly religious character, to make wise both as regards the things of this world, of the myriads of worlds that co-exist with it, and also of the worlds to which, sooner or later, all must repair.—*The Somerset County Gazette, December 1st*, 1855.

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