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5

METEOROLOGY

IN ITS

CONNECTION WITH AGRICULTURE.

[FROM THE AGRICULTURAL REPORT OF THE UNITED STATES PATENT OFFICE, 1856.]

ROYAL COLLEGE OF SURGEONS OF ENGLAND

BY PROFESSOR JOSEPH HENRY,

SECRETARY OF THE SMITHSONIAN INSTITUTION.

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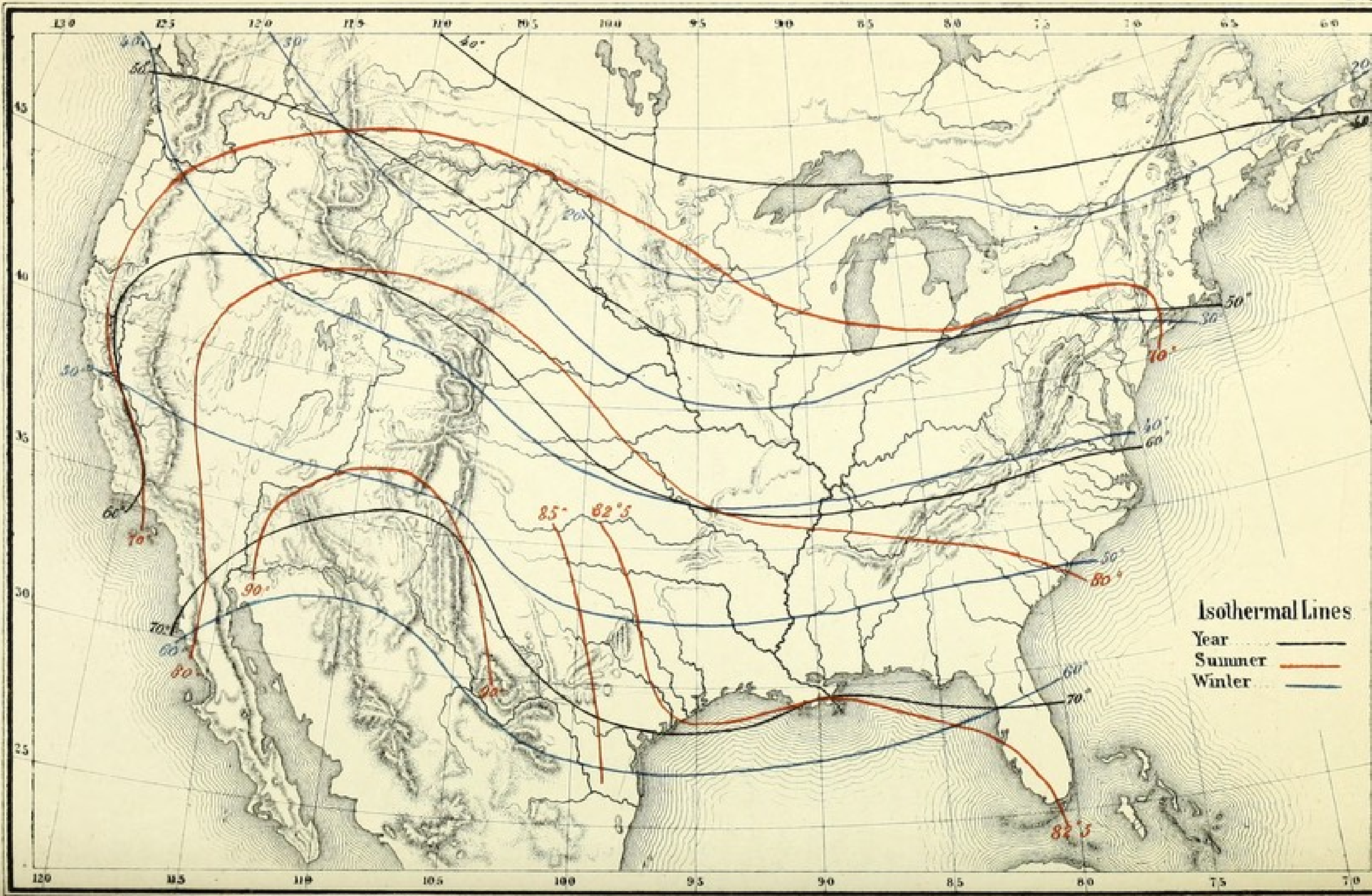
Pl. IV.



METEOROLOGY.

METEOROLOGY IN ITS CONNECTION WITH AGRICULTURE.

BY PROF. JOSEPH HENRY, SECRETARY OF THE SMITHSONIAN INSTITUTION.

The system of meteorology jointly prosecuted by the Smithsonian Institution and the Patent Office has been carried on during the past year with increased efficiency, and with the manifestation of a growing interest in the subject, particularly in its connection with agriculture. A large amount of valuable statistics has been collected, and quite an addition has been made to the number of full sets of standard instruments, as well as to the number of voluntary observers. The work of reduction has been continued, and the results for 1854, '55, and '56, are now ready for the press. The temperature tables for one year have been stereotyped ; but the cost of the publication of the material in detail is found to be so expensive, that it must be delayed for a time, unless Congress shall make a special appropriation for the purpose. The value of the material is, however, constantly increasing with every year which is added to the series of observations. Though their importance would be much enhanced could copies of them be placed in the hands of all who may wish to deduce general principles from them, or to apply the deductions to purposes of immediate utility, yet they are of considerable use in their present condition, since they are open to all who, under proper restrictions, desire to consult them. They have been of importance in preparing the series of articles to which the present publication belongs, and in furnishing the materials for the fourth report of Mr. Espy, which was ordered to be printed at the last session of Congress.

In the last Report of the Patent Office, I gave an account of the several systems of meteorology now coöperating in this country to advance the science, and also endeavored to show the importance of this branch of knowledge in its connection with agriculture. I propose in this Report and the subsequent ones to continue the subject, and to present some of the physical laws on which meteorology depends, the general principles at which it has arrived, and their application to the peculiarities of the climate of the United States. An exposition of this kind presented to the farmer, through the Report of the Patent Office, it is thought, will serve to awaken a more lively interest in the subject, will tend to diffuse a knowledge of the advantages of general principles, and will convey information not readily accessible, and which, in reality, does not exist in the condensed form in which it will be here given.

Perhaps no branch of science has given rise to more speculation or excited a greater amount of angry controversy than that relating to the nature and interpretation of atmospheric phenomena. The former may arise from the dependence of man for health and comfort on the state of the weather, and the latter from the limited sphere of individual observation to which the cultivators of this branch are generally confined. While the astronomer, without quitting his observatory, if situated near the equator, can watch the motions of all the heavenly bodies as they present themselves in succession to his telescope, the meteorologist can only take cognizance of the changes which occur immediately around him, and hence the origin of partial views and imperfect generalizations. Controversies, however, in this science, as in most others, may frequently be referred to the partiality we entertain for the products of our own minds. Truth, as has been properly said, belongs to mankind in general; our hypotheses belong exclusively to ourselves, and we are frequently more interested in supporting or defending these than in patiently and industriously pursuing the great object of science, namely, the discovery of what *is*.

In the account of meteorology which it is proposed to give, the writer has no hypotheses or theories of his own to support, but will endeavor to confine his statements to the exposition of such principles as are generally recognized at the present day ; and if hereafter it shall be found that views have been presented in this paper which cannot be sustained, he will point out in the subsequent Reports the errors which may have been committed. The expounder of science, unlike the politician, is at liberty to change his opinions when they are found to be at variance with the actual condition of things. Indeed, in the investigation of nature, we provisionally adopt hypotheses as antecedent probabilities, which we seek to prove or disprove by subsequent observation and experiment; and it is in this way that science is most rapidly and securely advanced.

Some parts of our subject, as will be seen, are intimately connected with leading questions of the day; and on this account it might be considered prudent to avoid allusion to them. But the great aim of science is the discovery of truth ; and the proverbial veneration entertained for it by the human mind is a sure indication that truth, and the whole truth, will always be conducive to the real progress of nations or individuals, and that to present it simply as a proposition without special application is the best means of supplanting error. We hold in high veneration the plan of government established by the wisdom of our forefathers ; but we cannot be blind to the fact that it required a peculiar theatre for its application, a wide territory of fertile soil and genial climate, well fitted to reward the labors of the husbandman and to promote the health of his body and the vigorous activity of his mind. Next to our political organization, under Providence our prosperity has mainly been promoted by the ample room afforded us for expansion over the most favored regions of this continent. It becomes, therefore, important for us to ascertain the natural limits, if there be any, to the arable portion of our still untenanted possessions, and to determine, if possible, what parts of it are best fitted, by climate and soil, for the future operations of the husbandman. The data do not exist at present for the definite solution of this problem; but it is one object of the systems of meteorology now in operation in this country to collect the facts by which it may be fully resolved. Agriculture as a science, in the United States, has up to this time been of comparatively little importance; refined processes of cultivation are not required where the products of millions of acres of virgin soil can be gathered without skill and with comparatively little labor. It is only when the organic power and material which Nature has thus stored up in the primitive earth have been to a greater or less extent exhausted, that scientific processes must be adopted in order to secure the continued production of ample harvests. The time is at hand when scientific agriculture can no longer be neglected by us; for, however large our domain really is, and however inexhaustible it may have been represented to be, a sober deduction from the facts which have accumulated during the last few years will show that we are nearer the confines of the healthy expansion of our agricultural operations over new ground than those who have not paid definite attention to the subject could readily imagine. We think it will be found a wiser policy to develop more fully the agricultural resources of the States and Territories bordering on the Mississippi, than to attempt the further invasion of the sterile waste that lies beyond.

The laws of nature are all simple and readily comprehended by a mind of ordinary capacity, when separately announced; but when the conditions under which they operate are varied, and a number of forces are called into action, the resulting phenomena frequently become so complex that their investigation transcends not only the ordinary logic of the most gifted mind, but even the more powerful analysis of the mathematician. It has been properly said, by Professor Peirce, of Cambridge, that, had the lot of man been cast upon one of the outer planets of our system, the phenomena of the motions of the heavenly bodies, as viewed from this point, would have been so complex and apparently irregular, that our present state of civilization, resting as it does on the principles of science, beginning with astronomy, the most perfect, would not have existed. Man would never have arrived at the definite idea and the conclusive evidence of the universality of causation, or, in other words, at the fact that, amid all the apparently confused and accidental occurrences that we observe, a few simple laws, which constantly diminish in number as our views become more extended, govern all events, whether they be those which we refer to order and succession, or those which, in our ignorance, we ascribe to chance. Astronomy is the most perfect of all the sciences, not only because it has been longer studied, but more especially because it is the simplest exhibition of the laws of force and motion; and yet, even in this science, where all the data are furnished, the introduction of a few conditions renders a problem too complex for direct solution. For example, to determine the path described and the time of revolution of a single planet round the central body by the application of the laws of motion and gravitation is a simple problem, which was solved at an early period in the history of astronomy. When, however, a third body was introduced, such, for example, as the moon, in addition to the earth and sun, the problem baffled for a long time the skill of the first mathematicians of the age; and even yet a direct *a priori* solution of all the results which will be produced by the mutual action of a series of planets revolving round the sun has not been effected, and recourse is had to indirect methods of approximation. Had man confined his observations to the complex and multiform changes of the weather, the probability of his ever arriving at a definite law would be far less than even in the before mentioned case of astronomy; for, though we are assured that the motion of every atom of air is governed by the same laws which direct the heavenly bodies, yet the amount of perturbation and reciprocal action presented in the case of myriads of atoms renders the probability of a complete solution of the problem of the currents of the atmosphere, even with the greatest possible extension of human science, extremely doubtful. We must, therefore, be content with approximations deduced from general principles combined with the results of extended, precise, and definite observation.

The history of meteorology illustrates the fact, that what may be termed popular observations and experience, without scientific direction, seldom lead to important rules. The uneducated sailor of to-day, after three thousand years of experience, firmly believes that he can invoke the winds and entice them from the caves of Æolus by a whistle. Most of the aphorisms in reference to the changes of the weather, though of venerable antiquity, merely relate to the greater or less degree of moisture in the atmosphere. They declare what has happened, that a change has already taken place in the air, but give no certain indication of what is to occur. In order, therefore, to the successful study of meteorology, the results of *systematic* observations are to be compared with the deductions from well established principles of science, and the converse; or, in other words, deduction and observation should constantly go hand in hand, the former directing the latter, and the latter correcting the conclusions of the former.

In meteorology, as in all other branches of science, the important rule adopted by Newton should never be neglected, namely: "No more causes are to be admitted for the explanation of any phenomenon, or class of phenomena, than are true and sufficient." Though a general principle which is in strict accordance with the established laws of force and motion cannot be immediately applied to the explanation of an isolated class of phenomena, it is not, on that account, to be set aside for some new and unknown agent. We must look to further investigations for the light which shall enable us to perceive the connection. The undulatory theory of light connects so many facts, and has enabled the scientist to predict so many others which were previously unknown, that, though a few outstanding phenomena may still exist, they do not militate against our convictions of the truth of the generalization which this theory so admirably expresses; and we may safely attribute the apparent want of agreement to our ignorance of some essential condition of the phenomena in question, or to some error in the logical deduction from our principles. The history of science abounds in apparent exceptions to general rules, which, when better understood, become additional evidences in support of the general principle. The foregoing remarks will not be thought inapplicable on the present occasion by those who have studied the history of the progress of meteorology.

One of the most important general truths at which science has arrived by a wide and cautious induction, and which is the foundation of meteorology, is that nearly all the changes which now take place at the surface of the earth are due to the action of the sun. The forces which pertain to the earth itself—such as gravity, chemical affinity, cohesion, electricity, magnetism, &c.—are forces of quiescence; they tend to bring matter to a state of rest at the surface of the globe, from which it is only again disturbed by the solar emanation. All the elementary substances which constitute the surface of our planet, with the exception of the organic matter, have long since gone into a state of permanent combination. The rocks and various strata are principally composed of burnt metals. The whole globe is an immense slag, analogous to that drawn from the smelting furnace, surrounded by a liquid and an aerial envelope; the former in a state of ultimate chemical combination, and the active principle of the latter—the oxygen—finding nothing to combine with, except what has been released from a former combination by the action of the sun. If, therefore, the solar impulses were suspended, all motion on the surface of the planet would cease: the wind would gradually die away; the currents of the ocean would slacken their pace, and finally come to rest; and stillness, silence, and death would hold universal reign. We cannot, however, at present, pursue this thought, but must confine our remarks to the effects of those impulses of the sun denominated *heat* in their connection with meteorology.

All the phenomena referable to the rays of heat from the sun acting under varying conditions will now be considered, so far as they affect the climate of the United States, under two heads:

1. The effects of varying astronomical conditions, irrespective of atmospheric and other influences.

2. The effect of all conditions, other than astronomical, such as the influence of the air, the ocean, the land, &c.

Results of Astronomical Conditions.—The earth, in its annual revolution in its orbit round the sun, does not describe a perfect circle, but an ellipse, of which the sun occupies one of the foci; and hence, we are nearer at one season of the year to this central luminary, than at another. It is well established, by mathematical investigation, from astronomical data, that, at the present historical period, the earth, as a whole, receives the greatest amount of heat, during any one day in the year, on the 1st of January, and the least amount on the 4th of July. The coincidence of the latter date with that of the anniversary of American Independence might by some be considered as an inauspicious omen. It should be recollected, however, that this statement refers to the whole earth, and not to the maximum of heat received on the surface of the United States. The variation in the distance of the sun produces no effect on the different seasons; since the rapidity of motion, or the less duration of proximity to the sun, just compensates for the greater intensity of the rays due to the nearer approach. Were it not for this, the eccentricity of the orbit would materially influence the heat of the seasons, since the fluctuation in the heating power of the sun's rays on this account amounts to one-fifteenth of the whole; and it does, in reality, increase the diurnal intensity for a few days in January, as is shown from the ardor of the sun's rays under a clear sky at noon in the southern hemisphere. One-fifteenth, says Sir John Herschel, is too considerable a fraction of the whole intensity of sunshine, not to aggravate, in a serious degree, the sufferings of those who are exposed to it, without shelter, in the thirsty deserts of the South. The accounts of what is endured in the interior of Australia, for instance, at this season, are of the most frightful kind, and seem far to excel what have ever been experienced by travellers in any part of the northern hemisphere..

Another astronomical deduction is, that the point of the earth's orbit which approaches nearest the sun is constantly changing its place, and in time the order will be reversed; the greatest amount of heat from this cause will be on some day in July, and the least in January. But this change is so slow, that no appreciable effect has been produced during the historic period. A slight variation also takes place in the distance of the earth and sun when nearest to each other; but this, also, is confined to such narrow limits, that it is entirely insufficient to account for the changes undergone in the earth's temperature, as indicated by fossil plants and animals, and cannot, on account of its slowness, have had any appreciable effect upon the temperature of any part of the earth since the first records of civilized man. If, therefore, it be true, as some suppose, that the seasons have changed in different parts of the earth within the memory of man, the effect must be due to other than to astronomical causes.

The earth is approximately a sphere, and, consequently, the sun's rays strike it obliquely at all places, except those over which it is precisely vertical. The amount of variation on this account can readily be calculated; the sun's beam may be considered as a force, and resolved into two parts, one of which is parallel to the surface of the earth, and the other perpendicular to it, the latter alone producing the result. The intensity of the sun's beam will be the greatest at the equator, and will gradually diminish to the poles. It is true, the sun does not continually remain vertical at the equator, but the average result, in the course of the year, is nearly the same as if this were the case; since the greater amount of heat received while he is at the north just compensates for the less while at the south. The average temperature of any given place, in consideration of the obliquity of the rays which the earth would receive if uninfluenced by other conditions, can be obtained by multiplying its equatorial temperature into the radius of its parallel of latitude.

From this formula, which we owe to the celebrated savant, Sir David Brewster, we have calculated the following table, which exhibits the astronomical and observed temperatures of the valley of the Mississippi, along a line passing through the city of New Orleans:

Lat.	Astron. mean temp.	Observed temp. reduced.	Difference.
25°	74.32	74.50	+ 0.18
30°	71.01	69.00	— 2.01
35°	67.17	62.00	— 5.17
40°	62.81	53.00	— 9.81
45°	57.98	44.50	—13.48
50°	52.70	37.00	—15.70

The temperature of the equator is assumed to be 82°. The first column gives the latitude, the second the astronomical mean temperature, the third the observed temperature reduced to the level of the sea, as taken from the isothermal chart accompanying this Report, (see Plate IV,)and the fourth column the difference between the two last. It will be seen that the difference between the calculated and the observed temperature in the lower latitudes is quite small; but as the latitude increases, the deviation becomes very great. This difference is due to other than astronomical causes, and by eliminating the latter we narrow the field of research.

Empirical formulas of much nearer approximation to the truth in high latitudes have been proposed, which will be noticed hereafter, our object at present being only to exhibit the difference between the astronomical results and those derived from actual observation.

Let us next consider the changes of temperature, in different parts of the day and in different seasons of the year, produced by the varying obliquity of the sun's rays. If we assume a given length of sunbeam as the representative of the force, then resolve this into two,—one perpendicular, the other parallel to the horizon,—the sum of all the perpendicular lines, from the rising to the setting of the sun, on any day, will represent the whole intensity of the heat on a given place during that day ; and in this way may be calculated the relative amount of heat received on different latitudes at different seasons of the year. From this estimate we shall find that the amount of heat received during a given day in summer, say the 16th day of June, from the sun, at different northern latitudes, is greater than that which falls upon the equator during the same time. This is exhibited in the following table, from the paper of L. W. Meech on the sun's intensity, in the 9th volume of the Smithsonian Contributions:

The sun's diurnal intensity at every ten degrees of latitude in the northern hemisphere.

A. D. 1853.	Latitude 0°.	Latitude 10°.	Latitude 20°.	Latitude 30°.	Latitude 40°.	Latitude 50°.	Latitude 60°.	Latitude 70°.	Latitude 80°.	Latitude 90°.
Jan. 1	77.1	67.2	55.8	42.8	30.1	16.5	5.1	......	......	......
Jan. 16	78 1	68.9	58.2	45.8	32.7	19.3	7.2	......	......	......
Jan. 31	79.6	71.7	61.9	49 7	38.6	25.0	11.9	1.4	......	......
Feb. 15	81.0	74.7	66.6	55.6	45.1	31.9	19.0	6.4	......	......
Mar. 2	81.6	78.0	71.3	62.9	52.7	41.1	27.9	14.5	2.1	......
Mar. 17	82.0	80.2	76.0	69.6	61.1	50.2	37.1	25.5	11.6	......
April 1	80.8	81.4	79.5	75.6	68.9	60.2	49.9	38.0	25.6	20.5
April 16	79.0	81.7	82.0	79.5	75.1	68.6	61.1	51.4	44.0	44.6
May 1	76.9	81.5	83.7	83.6	80.8	77.1	70.9	64.6	64.3	65.3
May 16	74.7	80.8	84.7	86.7	85.7	83.3	79.7	76.8	80.3	81.5
May 31	73.0	80.1	85.1	87.8	88.9	87.8	85.7	86.8	91.0	92.4
June 15	72.0	79.6	85.2	88.4	90.1	89.9	88.8	91.7	96.1	97.6
July 1	72.0	79.5	85.0	88.5	90.4	89.5	88.4	90.8	95.1	96.6
July 16	73.0	79.8	84.7	87.5	87.6	86.5	84.1	84.3	88.3	89.7
July 31	74.7	80.4	83 9	85.1	84.5	81.6	77 3	73.4	76.2	77.4
Aug. 15	76.7	80.8	82.7	82.4	79.8	74.7	68.2	60.9	59.2	60.1
Aug. 30	78.5	80.7	80.6	77.7	72.1	65.5	57.3	47.7	38.8	38.9
Sept. 14	79.8	79.8	77.5	72.8	65.9	58.8	46.9	34.5	21.9	14.7
Sept. 29	80.5	78.4	73.8	67.0	57.8	47.0	36.2	22.5	9.0	......
Oct. 14	80.7	76.4	69.7	61.0	50.2	38.2	25.7	12.6	1.0	......
Oct. 29	79.9	73.5	65.0	54.6	42.5	30 1	17.5	5.2	......	......
Nov. 13	78.8	70.7	60.8	49.8	37.1	23.8	11.0	0.9	......	......
Nov. 28	77.5	68.3	57 3	45.3	31.8	18.9	6.8	......	......	......
Dec. 13	76.9	66.9	55.4	43.0	30.3	16.3	4.9	......	......	......

On the fifteenth of June the sun is more than 23 degrees north of the equator, and therefore it might be readily inferred that the intensity of heat should be greater at this latitude than at the equator; but that it should continue to increase beyond this, even to the pole, as indicated by the table, may not, at first sight, seem so clear It will, however, be understood, when it is recollected that the table indicates the amount of heat received during the whole day; and though in a more northern latitude the obliquity of the ray is greater, and on this account the intensity should be less, yet the longer duration of the day is more than sufficient to compensate this effect, and to produce the result exhibited. This is an important fact, in comparing the agricultural capacity of different latitudes; for though there is absolutely more heat at the latitude of New Orleans during the year than at Madison, in Wisconsin, yet there is more heat received at the latter place during the three months of midsummer than in the same time at the former place. An analogous but contrary result is exhibited in regard to the cold of winters, as will be seen by the table. It is from this principle that, as we advance toward the equator, the extreme variations of the season become less and less. It is important to remark in this place that the foregoing tables exhibit the amount of heat actually falling upon the earth during the day as unmodified by any extraneous causes. They do not, however, exhibit the hottest portion of the season. This will depend upon another condition, which may be properly explained in this connection, though it is not classed under the astronomical causes. It is a well established principle that all bodies are radiating heat even while they are receiving it. If the amount received in a definite time is greater than that given off, the temperature will increase; on the contrary, if the amount given off is greater than that received, the temperature will diminish. The earth is constantly radiating heat into space, but only receiving it from the sun during the day. As the sun is declining towards the south, the daily amount received at length becomes less than that given off in the night, and hence the temperature begins to fall; and this diminution will continue until the two quantities again become equal, which will not be at the point where the greatest amount of heat is given off. On the twenty-first of June, in northern latitudes, the earth is receiving the greatest amount of heat, and hence it is becoming heated up most rapidly at this time. On the twenty-second, it receives a less amount of heat, but the heating continues, since the gain is still greater than the loss; and this goes on until about the 25th of July, or later, after which the radiation during the day and night together exceeds the amount received from the sun during the day, when the temperature begins to decline. The action is a little complicated, on account of the fact that the radiation increases with the temperature. A similar result is produced in the heating of the day, as will be seen from the following table of observations taken at every hour of the twenty-four, at Girard College, under the direction of Professor Bache:

MEAN DIURNAL VARIATION OF THE TEMPERATURE OF THE AIR AT PHILADELPHIA.

Computed from the observations made in 1842, *and from the* 1st *July*, 1843, *to the* 1st *July*, 1845.

1 A.M.	2 A.M.	3 A.M.	4 A.M.	5 A.M.	6 A.M.	7 A.M.	8 A.M.	9 A.M.	10 A.M.	11 A.M.	NOON.
48.2	47.8	47.3	46.8	46.6	47.0	48.1	50.1	52.1	54.1	55.7	56.8
				— Minimum.							

1 P.M.	2 P.M.	3 P.M.	4 P.M.	5 P.M.	6 P.M.	7 P.M.	8 P.M.	9 P.M.	10 P.M.	11 P.M.	12 NIGHT.
57.9	58.6	58.9	58.7	57.7	56.0	54.1	52.5	51.0	50.2	49.4	48.7
		+ Maximum.									

The result in the above table is somewhat affected by the greater humidity of the atmosphere towards morning, which prevents a greater radiation and fall of temperature, even after the rising of the sun.

RESULTS OF OTHER THAN ASTRONOMICAL CONDITIONS.—The deductions that have thus far been given are from established astronomical data; and, unless some error has been committed in the statement, their correctness cannot be doubted by any person properly educated in the line of physical science. The effects produced by the air, the water, and the land, are, however, of a much more complicated character, and, like the problem of the mutual action of all the planets on each other, have never yet been submitted to a successful mathematical analysis. In the investigation of a phenomenon, it is not enough that we explain how it is produced; besides this, positive science requires that the explanation be true in measure as well as in mode, and, indeed, it is only when we can predict the exact amount of an effect, the principles being known, and certain data given, that a phenomenon can be said to be perfectly analyzed. We have seen in the preceding paragraphs that the meteorological phenomena produced by astronomical causes admit of relative numerical expression; but in what follows we are obliged to content ourselves with the explanation in mode, and to refer to direct experiment and observation for the amount of the effect in measure. It is in this part of meteorology that so much uncertainty prevails, and in reference to which so much discussion, even of an excited character, has arisen. As was said before, the writer has no hypothesis of his own to advance, and will therefore confine himself to a statement, and in some cases a brief examination, of such hypotheses relative to the effects of the atmosphere, the ocean, &c., in modifying climate as have been suggested, and which appear to be in accordance with well established principles.

Effects of the atmosphere in a statical condition.—Were it not for the aerial envelope which surrounds our earth, all parts of its surface would probably become as cold at night, by radiation into space, as the polar regions are during the six months' absence of the sun. The mode in which the atmosphere retains the heat and increases the temperature of the earth's surface may be illustrated by an experiment originally made by Saussure. This physicist lined a cubical wooden box with blackened cork, and, after placing within it a thermometer, closely covered it with a top of two panes of glass, separated from each other by a thin stratum of air. When this box was exposed to the perpendicular rays of the sun, the thermometer indicated a temperature within the box above that of boiling water. The same experiment was repeated at the Cape of Good Hope, by Sir John Herschel, with a similar result, which was rendered, however, more impressive by employing the heat thus accumulated in cooking the viands of a festive dinner. The explanation of the result thus produced is not difficult, when we understand the fact that a body heated to different degrees of intensity gives off rays of different quality. Thus, if an iron ball be suspended in free space, and heated to the temperature of boiling water, it emits rays of dark heat, of little penetrating power, which are entirely intercepted by glass. As the body is heated to a higher degree, the penetrating power of the rays increases; and, finally, when the temperature of the ball reaches that of a glowing or white heat, it emits rays which readily penetrate glass and other transparent substances. The heat which comes from the sun consists principally of rays of high intensity and great penetrating power. They readily pass through glass, are absorbed by the blackened surface of the cork, and, as this substance is a bad conductor of heat, its temperature is soon elevated, and it in turn radiates heat; but the rays which it gives off are of a different character from those which it receives. They are non-luminous, and have little penetrating power; they cannot pass through the glass, are retained within the box, and thus give rise to the accumulation of the heat. The limit of the increase of temperature will be attained when the radiation from the cork is of such an intensity that it can pass through the glass, and the cooling from this source becomes just equal to the heating from the sun. The atmosphere which surrounds the earth produces a similar effect. It transmits the rays from the sun, and heats the earth beneath, which in turn emits rays that do not readily penetrate the air, but give rise to an accumulation of heat at the surface. The resistance of the transmission of heat of low intensity depends upon the quantity of vapor contained in the atmosphere, and perhaps also on the density of the air. The radiation of the earth, therefore, differs very much on different nights and in different localities. In very dry places, as, for example, in the African deserts and our own western plains, the heat of the day is excessive, and the night commensurably cool. Colonel Emory states, in his Report of the Mexican Boundary Survey, that, in some cases, on the arid plains, there was a difference of 60° between the temperature of the day and that of the night. Indeed, the air is so permeable to heat, even of low intensities, in this region, that a very remarkable difference was observed on some occasions when the camp-ground was chosen in a gorge between two steep hills. The inter-radiation between the hills prevented in a measure the usual diminution of temperature, and the thermometer in such a position stood several degrees higher than on the open plain.

We shall next briefly consider the mechanical constitution of the atmosphere. The aerial ocean which surrounds the earth consists of atoms of matter self-repellent, which, in proportion as the interior pressure is lessened, constantly tend to separate from each other, and produce an enlargement or expansion of the whole mass. When the pressure is increased, the mass sinks into a less volume, the atoms are brought nearer together, the force of repulsion is increased with the diminution of distance between the atoms, and a new equilibrium is attained. From this constitution of the air, it immediately follows that the density of the atmosphere near the surface of the earth is greater than that at a higher altitude, since the lower stratum bears the weight of all those which are above it. The diminution in weight of equal bulks of air as we ascend is in a greater ratio than the height, since it diminishes on two accounts: first, because as we ascend in the air the number of strata pressing on us is less; and secondly, each succeeding stratum is lighter. From the law of this diminution of density a table may be formed of the pressure of the atmosphere at various heights, of which the following is an example:

Density of the air at increasing altitudes

Miles above the sea.	Bulk of equal weight of air.	Density.	Height of barometer.
0	1	1	30.00
3.4	2	$\frac{1}{2}$	15.00
6.8	4	$\frac{1}{4}$	7.50
10.2	8	$\frac{1}{8}$	3.75
13.6	16	$\frac{1}{16}$	1.87
17.0	32	$\frac{1}{32}$	0.93

From this table it appears that one-half of the whole atmosphere is found within the limit of height of $3\frac{2}{5}$ miles, and one-third of the whole quantity beneath the level of the Rocky Mountains; and this fact has an important bearing on the influence of mountain ranges in modifying the direction of the winds.

The question occurs at this place, Why does the air grow colder as we ascend? The answer is, that a pound of air, at all distances above the earth, contains at least an equal amount of heat with the same weight taken at the surface, and that, as the pressure is removed, this air is expanded in bulk, and consequently the heat is diffused through a greater amount of space; and hence the reduction of its intensity, or temperature. To illustrate this, take a large ball of sponge and squeeze it into one-quarter of the space which it naturally occupies. In this condition dip it into water, it will imbibe a certain quantity of the liquid, and when drawn out will be dripping wet; now let it expand to its natural dimensions, the water will be distributed through a large amount of space, and the sponge itself will appear comparatively dry. Squeeze it again into its former condensed state, and it will appear wet; suffer it again to expand, and the apparent dryness will be resumed. In a like manner we suppose that, while the quantity of heat is the same, its intensity is increased by condensation into a smaller space, and diminished by the converse process. In the foregoing illustration the amount of water contained in the sponge represents the amount of heat in the air, and the degree of wetness produced by condensation the intensity of the temperature exhibited in diminishing the bulk of air.

It follows from this that the blowing of a current of air over a high mountain, provided it descends again into the plain, does not necessarily diminish its temperature. When it arrives at the top of the mountain, it will become as cold as the circumambient air, not because it has lost any of its heat, but because that which it contained is now distributed through a greater space; when it descends again to the plain, it will suffer a corresponding diminution of bulk, on account of the increased pressure, and with this the original temperature will be restored.

This principle, as we shall see hereafter, is of great importance in the study of the peculiarity of the temperature of the western portion of the territory of the United States. We have said that every pound of air, from the bottom of the aerial ocean to its surface above, contains at least an equal quantity of heat; and this was the inference of Dalton. From the investigations of Poisson and others it appears that the absolute quantity of heat, pound for pound, slightly increases rather than diminishes as we ascend; and this seems necessary to the stability of the equilibrium of the atmosphere as a whole. If the amount of heat were greater in the lower strata than in the upper, the equilibrium would be unstable, and an inversion would tend constantly to take place. An equal quantity of heat, pound for pound, as we ascend, would produce an indifferent equilibrium, while an increased amount, in the order of ascent, would produce a stable condition of the atmosphere, such as that which really exists. The question, however, has not yet been fully settled, although it is an important one, having a bearing on the explanation of many meteorological phenomena.

Another question of much interest is the exact law of diminution of temperature as we ascend into the air. Were this actually known, we could reduce to the same level all the observations which are made in a country; and thus, in addition to the astronomical effects, we could eliminate those due to altitude, and present the remainder as results which are due to the other conditions producing the peculiarities of climate. In order, however, to apply the law with precision in this way, it is desirable that it should be determined from observations made by ascents in balloons or at points of different heights on isolated mountain peaks. Relative observations made for this purpose on the top and at the base of mountain systems of considerable width and extent will probably give results involving the influence of the mountain surface itself, which, in turn, would be somewhat affected by the direction of the prevailing wind and other causes. The progress of meteorology will call for an increased number of observations of the proper character, and for the repetition of the experiments with balloons, in different parts of the earth.

Celestial space, in which our sun and the earth and other planets of our system are placed, is known, from different considerations, to have a temperature of its own, which is supposed to be the result of the interradiation of all the suns and planets which exist in every part of the visible universe. The temperature of this space is estimated to be about —60°. This fact being allowed, it will follow that, since the heat at the top of the air remains constant, the rate of decrease of temperature as we ascend will be diminished with the decrease of temperature at the surface of the earth, and also that the rate of decrease will follow a slightly diminishing ratio. At all accessible elevations in the atmosphere, however, it may be considered as almost constant. In some cases the rate of diminution is interfered with by abnormal variations of temperature ; for example, as we ascend into the region of the clouds, the latent heat evolved in the condensation of the vapor produces a local heat in the atmosphere beyond the natural temperature. In temperate latitudes it is usual to allow 300 feet of elevation for the reduction of temperature one degree of Fahrenheit's scale. This quantity was deduced from thirty-eight observations collected by Ramond. Boussingault found, from observation in the tropics, a diminution of 335 feet. Col. Sykes, from mountain observations in India, a diminution of 332 feet. Saussure ascertained the mean value in the Alps to be 271 feet. Gay Lussac's celebrated voyage gave 335 feet. And the result of several series of observations with the balloon by Mr. Welch, under the direction of the British Association, omitting the points unduly heated by the condensation of vapor, was about 320 feet. In the construction of the isothermal chart which accompanies this Report, we have adopted 333 feet, or three degrees to one thousand feet, as the rate of diminution, and find, in comparing the temperature of different places of varying heights which have been reduced by it, that they afford very satisfactory corresponding results. We propose to give a fuller discussion of this part of the subject in another Report.

Motions of the Atmosphere.—The repulsion of the atoms of the air is not only increased by a diminution of distance from being pressed closer together, but also by an addition of heat. From the latest and most reliable experiments on this point it is found that, the pressure being the same, air expands $\frac{1}{491}$ part of its bulk at the freezing point for each degree of Fahrenheit's scale. Heated air, therefore, becomes specifically lighter, and tends constantly to ascend, being pressed upwards by the heavier circumambient fluid. The effect thus produced upon the air by the impulses from the sun is the great motive power which gives rise to all the currents of the atmosphere, from the gentle zephyr which slightly ripples the surface of the tranquil lake to the raging hurricane which overwhelms whole fleets, or destroys in a moment the hopes of the husbandman for an entire season. This fact is so well established by science, that it is unnecessary to seek for any other *primum mobile* for the great system of constant agitation to which the aerial ocean is subjected.

Allowing the temperature of the equator, on an average, to be 82°, that of the pole zero, and of the top of the air, or, in other words, of celestial space, to be —60°, and estimating the height of the atmosphere at 50 miles, it will follow, from the law of expansion by heat, that the excess of elevation of the air at the equator will be upwards of four miles above that of the pole. Although this is not intended to present the exact amount of the aerostatic pressure, yet it will serve to show the great motive power constantly maintained by the influence of the solar radiation. In order to simplify the conception of the motions which result from this disturbing power, let us, in the first place, suppose the earth to be at rest, and its whole surface of a uniform character, consisting, for example, of water. It is obvious, from well established hydrostatic principles, that the air, expanded, as we have stated, at the equator, would flow over at the top, and descend, as it were, along an inclined plane towards the poles, would sink to the earth, flow back to the equator below, and would again be elevated in an ascending current; and thus a perpetual circulation from either pole to the equator, and from the equator back towards the poles, along the several meridians of the globe, would be the continuous result. It is further evident that, since the meridians of the earth converge, and the space between them constantly becomes less, all the air that rose at the equator would not flow along the upper surface entirely to the poles, but the greater portion would proceed north and south no further than the 30° of latitude; for the surface of the earth contained between the parallel of this degree and the equator is equal to that of half of the whole hemisphere. Portions, however, in the northern hemisphere, for example, would flow on, to descend at different points further north; and of these some would probably reach the pole, there sink to the surface of the earth, and from that point diverge in all directions in the form of a northerly wind. Between the two ascending currents near the equator would be a region of calms or variable winds, influenced by local causes. The currents which flow over towards the poles would descend with the greatest velocity at the coldest point; because there the air would be most dense, or, in other words, have the greatest specific gravity.

According to the view here presented, a section of the atmosphere made by cutting through a meridian from pole to pole, perpendicular to the horizon, would exhibit two great systems of circulation: one from the north and another from the south to the equator below, rising at the latter place, and pouring over on either side to return again by longer or shorter circuits to the place whence they started. Such would be the simple circulation of the aerial ocean if no perturbing influences existed, and the whole science of meteorology would be one of comparatively great simplicity. But this is far from being the case. A number of modifying conditions must be introduced, which tend greatly to perplex the anticipation of results. First, the earth is not at rest, but in rapid motion on its axis from west to east. Every atom therefore of the current of air as it flows towards the equator in the northern hemisphere would partake of the motion of the place at which it started, and in its progress southward it would reach in succession latitudes moving more rapidly than itself. It would, therefore, as it were, fall behind continually, and appear to describe on the surface of the earth a slightly curvilinear course towards the west. A similar result would be produced on the south side of the equator; and hence we have the first conception of the cause of the great systems of currents denominated the "trade winds," blowing constantly within the parallel of 30° from the northeast in the northern hemisphere, and from the southeast in the southern, towards the belt of greatest rarefaction.

The motion, however, will require further consideration. The particles of air approaching the equator will not ascend in a perpendicular direction, as was first supposed, but will rise continually as they advance towards the west along an ascending plane, and will continue for a time their westerly motion in the northern hemisphere after they have commenced their return towards the north.

They will, however, as they advance northward, arrive at parts of the earth moving so much less rapidly than themselves, that they will gradually curve round towards the east, and finally descend to the earth, to become again a part of the surface trade wind from the northeast. The atoms will tend to move westward as they ascend: first, on account of their momentum in that direction; and secondly, because, as they reach a higher elevation, they will have less easterly velocity than the earth beneath. They will also be affected by another force, as has lately been shown by Mr. Ferrell, due to the increase of gravity which a particle of matter experiences in travelling in a direction opposite to that of the rotation of the earth. The last mentioned cause of deflection will operate also in a contrary direction on the atoms when they assume an easterly course.

The result of the complex conditions under which the motive power acts in such a case would be to produce a system of circuits inclined to the west; the eastern portion of which would be at the surface, and the western at different elevations even to the top of the atmosphere. To give definiteness to the conception, let us suppose a series of books to be placed side by side on edge, pointing to the north: these books would represent the planes in which the currents of the air would circulate in the northern hemisphere, were the earth at rest; but if the earth is supposed to be in motion, then the books must be inclined to the west, so as to make an acute angle with the horizon, and overlap each other like the inclined strata in a geological model. If on each leaf of each book a circuit of arrows be drawn, then will the assemblage of these represent the paths of the different atoms of the atmosphere. The currents of air, however, would not be in perfect planes, but in surfaces which could be represented by bending the leaves to suit the curvature of the earth. In this manner would be exhibited the general motion of the wind, which has been determined by actual observation.

The greater portion of the circulation would descend to the earth within 30 degrees of the equator, giving rise to the trade winds; a portion would flow further north, and produce the southwest winds; another portion would extend still further northward, descend towards the earth as a northwest wind, and so on. The air which descends in the region of the pole would not flow directly southward, but, on account of the rotation of the earth, would turn towards the west and become a northeasterly current. At first sight it might appear that the north wind which descends from the polar regions would continue its course along the surface until it joined the trade winds within the tropics; but this could not be the case, on account of the much greater western velocity this wind would acquire from the rapidly increasing rotary motion as we leave the pole. There would, therefore, be three distinct belts in each hemisphere, namely: the belt of easterly winds within the tropics, the belt of westerly in the temperate zone, and the belt of northwesterly at the north. The existence of these belts has been clearly made out by Professor Coffin in calculating the resultant of all the winds of the northern hemisphere, or, in other words, by eliminating the effects of extraneous action, and exhibiting the residual as the result produced by the general circulation.

Another condition, however, must be introduced. These belts would not be stationary, but would move laterally towards the south or the north, according to the varying positions of the sun at different seasons of the year. Their breadth would also vary; because they would be crowded into a smaller space towards the pole in the winter, and expanded into a wider space in the summer.

To trace with precision, while under these varying perturbing influences, the path which would be described by a particle of air in its circuit, transcends the power of unaided logic, and can only be accomplished, if at all, by means of the most refined mathematical artifices. This problem has lately, it is believed, been presented as one of the prize questions of the French Academy of Sciences. Were it, however, solved, with all the conditions that have been assigned, this would not be sufficient; since there is another cause of disturbance, perhaps more active than any yet enumerated, namely: the condensation of the vapor which arises from the surface of the ocean and is carried to different parts of the earth by the currents described. We owe to Mr. Espy, of this country, the principal development of the action of this agent in modifying and controlling atmospheric phenomena. The heated air which ascends at the equator is saturated with moisture, which it has absorbed in its passage over the northern and southern oceans. As it ascends above the surface of the earth it meets continually with a diminished temperature; and a considerable portion of it daily, as the sun declines into the west, is converted into water, which returns to the surface in the form of rain. The greatest effect of this action is immediately beneath the sun; and hence the belt of intertropical rains oscillates to the north and south with the course of the sun in its annual changes of declination. A portion, however, of the same vapor is probably carried by the upper current far beyond the tropics, and deposited in fertilizing rains even at the extremities of the polar circles.

The condensation of the vapor which ascends in the equatorial regions evolves an astonishing power, in the form of heat, which accelerates the upward motion of the air, and modifies, in a greater degree than almost any of the causes we have heretofore mentioned, the primary motion, due simply to the difference of heat between the poles and the equator. To understand this, it is sufficient to refer to the great amount of heat contained in a given amount of steam; and for illustration let us suppose the following simple experiment: A quantity of water at the temperature of melting ice is placed in a vessel over a lamp, which is so adjusted as to impart one degree of heat to the water in each minute of time. If the process is properly conducted, the heat will continue to increase, and, in accordance with the supposition we have made, the water at the end of about twelve hundred minutes will be all converted into vapor. If the process has been so conducted that a degree of heat has been given to the liquid in each minute of time, the steam will evidently contain about twelve hundred degrees of heat above the zero of Fahrenheit's scale. The greater portion of this will be in what is called a "latent" state; but it will all reappear, as is well known from abundant experiments, when the vapor is reconverted into water. From these data it is easy to prove mathematically that every cubic foot of water which falls on the surface of the earth in the form of rain leaves in the air whence it descended sufficient heat to produce at least 6,000 cubic feet of expansion of the surrounding atmosphere beyond the space which the vapor itself occupied. The ascensional force evolved by this process must evidently be immense, when we consider the great amount of rain which falls within the tropics. A similar power is evolved whenever rain falls; and this principle, which has been so ably developed by Mr. Espy, is undoubtedly a true and sufficient cause of most of the violent and fitful agitations of the atmosphere which have so long puzzled the scientific world. It, however, in its turn, will probably require the consideration of modifying conditions in its applications; and while at present the data are known with sufficient precision to warrant the assumption of the evolution of the immense force we have mentioned, they are not in all cases sufficiently well determined to enable us to predict, with numerical accuracy, the results which have been shown to proceed from them. The same principle of condensation of vapor and evolution of heat is fertile in the explanation of the approximate cause of rain: for example, so long as the wind blows over a surface of uniform height and temperature, there is no cause to induce it to precipitate its vapor; but if in its course it should meet a mountain, the slope of which it is obliged to ascend, the vapor will be condensed on the windward side by the cold due to the increased vertical height. The latent heat will be evolved, the circumambient air will be abnormally heated, and an upward motion will ensue, towards which air will flow with increasing velocity to restore the equilibrium of the ascending column. In this way Mr. Espy explains very satisfactorily the fact that the wind blows over the desert of Zahara to supply the diminished pressure occasioned by the rains over the windward side of the Himalayah mountains. The same principle is immediately applicable to the explanation of the rainless districts in South America, Mexico, and other portions of the earth. The air, as it ascends the windward side of the mountains, deposits its moisture; and if the elevation is sufficiently high, it will pass over in a desiccated condition.

The idea that mountains attract vapor, is not founded on any well established principle of science. Molecular attraction extends only to imperceptible distances, and the attraction of gravitation is too feeble a force to produce results of this kind. The evaporation of water, and the transfer and subsequent condensation of the vapor in other parts of the earth, is undoubtedly the most active cause which produces the continual and apparently fitful changes of the weather.

We have stated that within the torrid zone there exists a belt of rain, produced by the partial condensation of the vapor which ascends with the air of this region; and since the sun between the 21st of March and the 21st of June passes from the equator to 23½ degrees north, and then makes a similar excursion as far south, the rainy belt follows his course, and hence all countries within the tropics must have periodically a rainy season.

The air, also, which flows over to the north, and which, as we have seen, descends to the earth in the westerly belts of wind, carries with it a portion of vapor, and deposits it in the form of rain; and hence, there is a tendency to a rainy and dry season beyond the tropics, which oscillates north and south with the varying motion of the sun. This tendency to regularity of rain is in many places masked or neutralized by the configuration of the country. It is, however, distinctly marked on the western coast of the United States and of Europe, as well as in various other places in the north temperate zone. Oregon and California have their rainy belt, which descends to the south in the winter, and again returns in the spring. In Lisbon, the number of rainy days in December is 55, to 2 in July; in Palermo, 37, to 2½ in

July. In Algiers, which is also north of the tropic, but further south, from the average of ten years, there are 88 rainy days in January, and, on the other hand, only a single one in July. Another fact of interest with regard to the extra-tropical belt of rain is, that it commences sooner at greater elevations above the surface: for instance, at the peak of Teneriffe, the rainy season commences at the top a fortnight earlier than at the bottom; so that, while rain is falling in abundance on the summit, the country in the vicinity of the mountain, at the level of the sea, is enjoying sunshine and a balmy atmosphere. The latter results, according to Mr. Espy's views, from the radiant heat given off by the condensing vapor above. The sun, however, descending still further to the south, brings down the rain belt to the level of the earth in this latitude, and the rainy season then commences. Similar phenomena have been observed on the higher parts of the coast range of mountains of California; and indications of a like action are witnessed on the higher peaks of the Appalachian chain. Besides the causes of the general perturbations of the atmosphere which we have thus given in considerable detail, some authors have added magnetism and electricity, and others have indeed attributed some of the principal effects we have mentioned to these agencies; but the present state of science does not warrant us in considering these as true or sufficient causes, except in the case of thunder storms, and perhaps tornadoes, in which the electricity evolved by the action of the storm itself may modify some of the results. Electricity, however, probably plays a subordinate part; since it is itself a consequence, and not a cause.

Terrestrial magnetism has not been shown in any case to affect meteorological phenomena; it is a force which never produces translation, but merely direction of the needle. The air in its natural condition is not magnetic, in the proper sense of the term, any more than a piece of steel wire is so before the power has been developed in it by a magnet.

We are not allowed, in strict scientific investigations, to explain a phenomenon by referring it to any agent, unless we show, in accordance with the laws of that agent, that it is capable of producing the result; and consequently magnetism is here not admissible.

Currents of the Ocean.—We have seen the effect of the unequal heating of different parts of the earth by the sun in giving rise to great gyrations of air; and it must be evident that there is a tendency to produce a similar result in the aqueous envelope of the globe. Let us first suppose the ocean to cover the whole earth, of a uniform depth, and uninterrupted by continents. If the earth were at rest and the heat of the surface at the equator could extend down sufficiently into the depths of the water, the latter would be expanded and would stand higher in the equatorial regions than in those of the poles; a current, therefore, as in the case of the air, would be established in both directions, towards the north and south, from the equator, which would be cooled in its passage, would sink to the bottom, and return again to its starting point, to commence the same course anew. If we now suppose the earth, as in the case of the atmosphere, to be put in motion around its axis towards the east, the bottom currents, or those flowing towards the equator, coming from a part of the earth moving slower to a part going faster, would fall behind, and thus assume a westerly direction. They would, therefore, ascend obliquely in a westerly direction towards the surface, flow back towards the pole, (in their course curving constantly towards the east,) and as they cooled would sink down towards the bottom, to return again to the equator. Different portions of the upper surface of the current, as in the case of air, would continue their northerly course obliquely, and descend at intervals, some reaching nearly to the poles.

The result of the whole of this action would be a series of gyrations to the north and south, with the upper portion turned towards the west, forming a continuous circuit at the equator round the whole earth in a westerly direction, and a circuit in each temperate zone from the west. This would be the result, if the water could be heated to a sufficient depth; and, accordingly, it is considered by some that heating the water is the principal cause of the currents of the ocean (on which account we have so described it). Yet, though doubtless a true, I do not consider it a sufficient cause, but would mainly ascribe the currents of the ocean to the action of the winds in the belts of the equator and in the two temperate zones.

The constant westerly winds on either side of the equator would tend to produce a westerly current around the earth, provided no obstructions existed to its free course; but if, instead of considering the earth as entirely covered with water, we suppose the existence of two continents, extending from north to south, forming barriers across the current we have described, and establishing two separate oceans, similar to the Atlantic and Pacific, then the continuous current to the west would be deflected right and left, or north and south, at the western shore of each ocean, and would form four immense circuits, namely: two in the Atlantic, one north and the other south of the equator, and two in the Pacific, similar in situation and analogous in direction of motion. For a like reason, there will be a tendency to produce a similar whirl in the Indian ocean, the current from the east being deflected down the coast of Africa, and returning again into itself along a southern latitude on the western side of Australia. Besides these great circulating streams, the water supplied by all the rivers emptying into the Arctic basin, as well as that from all the precipitation in this region, returns to the south, and by the motion of the earth must tend westwardly in a current along the eastern shore of each continent between it and the stream flowing to the north. Similar currents, but more diffuse and less in amount, must constantly flow from the Antarctic regions.

We do not mean to assert that these whirls can be continuously traced on the surface of the ocean, though by attentively examining the maps their general outline can be marked out. We wish to convey an idea of the general tendency of the motions of the aqueous covering of the globe,—the central thought, as it were, on which they depend. The regularity of their outline will be disturbed by the configuration of the deflecting coasts and the form of the bottom of the sea, as well as by islands, irregular winds, difference of temperature, and, above all, by the annual motion of the sun as it changes its declination. The effect of these currents in modifying the climate of different parts of the world has long been recognized, though the detail of the mode in which this is produced has not until recently been pointed out. The Gulf stream of the North Atlantic carries the warm water of the equator beyond Iceland and the northern extremity of Europe, and it may even be traced to the shores of Nova Zembla. Without its influence the climate of Norway, Great Britain, and the western coast of Europe, would be as

cold as that of the corresponding parallels of latitude on the North American continent. In like manner, the great circuit of the waters of the Pacific conveys the warmth of the equator along the eastern coast of Asia to Kamtchatka, and, gradually cooling in its course, descends along the northwest coast of the North American continent, to receive a new accession of heat and be again conveyed to the north. The total result of this circulation, in the northern hemisphere, together with those of lesser influence, is shown in the annexed polar projection, in which the series of irregular lines, marked 50°, 32°, 16°, and 0°, indicate the mean annual temperature of the points through which they pass, and are called the yearly isothermal lines, or, in other words, lines of equal heat.

The darker line, marked 32°, indicates the boundary of the region within which the average temperature is below the freezing point. It will be seen at a glance that, instead of being circular in its outline, it has the form of an irregular elongated ellipse, the greater diameter of which is across the pole, from the southern extremity of Hudson's Bay to the south of Lake Baikal, in Siberia. It extends some degrees lower to the south in Asia than in America. The shorter diameter of the ellipse is at right angles to the longer, and passes from near Behring's Straits, through the pole, to the open ocean west of Norway. Its longer diameter is nearly twice that of its shorter, and is in the direction of the greatest amount of land in the polar regions. This form of the curve, and the peculiarities of the other curves, are due principally to the currents of the Atlantic and Pacific oceans transporting the water from the equator to the north, and carrying with it the higher temperature. An elliptical dotted line will be perceived in the polar regions, the centre of which does not coincide with the geometrical axis of the earth, but is nearer the continent of North America than that of Asia, thus indicating that the coldest point on the earth's surface is a number of degrees south of the pole. It is true, this region has never been visited by man; yet knowing the law of the diminution of heat, and the form of the other lines, the smaller one can be drawn with considerable accuracy. It may be interesting to remark in this place that the mean temperature of the coldest part of the northern hemisphere has almost exactly the temperature of the Zero of Fahrenheit's scale—a remarkable although entirely accidental coincidence.

We have thus far almost exclusively confined our remarks to the general principles of science on which the phenomena of meteorology depend; we shall now give special attention to the application of these principles to the peculiarities of the climate of the continent of North America, and more particularly to that part of it which includes the territory of the United States. For this purpose it will be necessary to give a brief sketch of the topography and surface of the country.

Physical geography of the United States.—The climate of a district is materially affected by the position and physical geography of the country to which it belongs. Indeed, when the latitude, longitude, and height of a place above the sea are given, and its position relative to mountain ranges and the ocean is known, an approximate estimate may be formed as to its climate. The North American continent extends across nearly the whole breadth of the nominal temperate zone, and has an average width of more than fifty degrees of longitude. The general direction of the eastern coast of the United States lies in a circle passing through Great Britain. Hence, a ship, while sailing along this coast, is on its direct route to the British isles. This fact—which is not clearly exhibited on the flat surface of a map, but is shown on the convex surface of a globe—has a bearing, not only on commerce, but also on the direction of the Gulf Stream, which conforms to the general direction and sinuosities of the coast. It will be seen by the map, Plate IV, which accompanies this Report, and to which constant reference should be made in reading the brief descriptions here given, that the eastern coast of the United States exhibits three great indentations, or large bays: the first commencing at the extremity of Florida, and extending to Cape Hatteras; the second, from Cape Hatteras to Cape Cod; and the third, from Cape Cod to Cape Sable. These bays, or great concave indentations, have a marked influence on the cold polar current which descends along the coast, and also, as has been shown by Professor Bache, on the great tide-wave of the Atlantic ocean, as it approaches our shore. At the southern extremity of the United States is the great elliptical basin containing the perpetually heated waters of the Gulf of Mexico, an enormous steaming cauldron continually giving off an immense amount of vapor, which, borne northward by the wind of the southwest, gives geniality of climate and abundant fertility to the eastern portion of our domain. On the western side of the continent the coast presents, as a whole, an outline of double curvature, principally convex to the west in that part which is occupied by the United States, and concave further north. These bends of the coast-line and of the adjacent parallel mountain ridges affect the direction of the winds in this quarter, and consequently of the ocean currents. The Gulf of California at the south, between the high mountains of the peninsula of that name and those of the main land, must also modify materially the direction of the wind in that region.

The continent of North America is traversed in a northerly and southerly direction by two extensive ranges of mountains—the Alleghany system on the east and the Rocky Mountain system on the west. We give the latter name to the whole upheaved plateau and all the ridges which are based upon it. These two systems separate from each other more widely as we pass northward, and between them is the broad interval which, within the territory of the United States, is denominated the valley of the Mississippi; but in reality the depression continues northward to Hudson's Bay, and even to the Arctic ocean, giving free scope to the winds which may descend from that inhospitable region. It, however, may be divided into two great basins, one sloping towards the south, comprising the basin of the Mississippi, and the other sloping to the north, including the basins of Mackenzie's river and of Hudson's Bay, the dividing swell which may be traced along the heads of the streams having an elevation of about 1,200 feet. Our remarks must be principally confined to the portion of the continent south of the 49th degree of latitude, and delineated on the map to which we have before referred. (Plate IV.)

The swell of land, or watershed, on which the Alleghanies are situated, has an elevation, on an average, of at least 3,000 feet, although the ridges and mountains based upon it rise to a much higher elevation. The loftiest point is Clingman's Peak, of the Black Mountains, in North Carolina. It has lately been measured by Prof. Guyot, and is found to have a height of 6,702 feet. The next greatest elevation is Mount Washington, the highest peak of the White Mountains, in New Hampshire, which, according to the same authority, has an elevation of 6,285 feet. The lowest depression in this watershed, with the exceptions to be next mentioned, is in Pennsylvania, and has an elevation of a little less than 2,000 feet. Further north the whole system is cut through by the valley of the Hudson nearly to its base, and also by the valley of the St. Lawrence. The latter, together with the basins of Lakes Ontario and Erie, form a narrow trough between the Atlantic and the Mississippi valley, along which the flow of air may locally affect the climate. The position of the Alleghany Mountains, however, does not as much affect the meteorology of the country as from the magnitude of the system we might at first suppose; and this results from the fact that their direction is from the southwest towards the northeast, which, as we shall see hereafter, is the prevailing direction of the fertilizing wind of the United States. They do not, therefore, obstruct its course; it flows on either side of them and along the valleys between them. They do, however, in a considerable degree, modify the character of the easterly winds as felt upon the coast, depriving them of their moisture.

By a reference to the map accompanying this Report, compiled from the surveys of the officers of the Topographical Corps of the U. S. Army, the fact will be shown that the Rocky Mountain system occupies one-third of the entire breadth of the United States, and that the remaining two-thirds are divided into nearly two equal portions by the Mississippi river, beginning at its source. This great western mountain system of the North American continent, which produces the most important modifying influence on the climate of the United States, may be described as a broad, elevated swell or plateau of land, the prolongation of the base of the system of South America, to which the Andes belong, extending northward in the general direction of the Pacific coast, with varying elevation and width, to the Arctic circle. It occupies nearly the whole breadth of Mexico, from the Rio del Norte to the Pacific, and, as it extends northward, becomes still broader, occupying at the latitude of 40°, as has just been said, one-third of the breadth of the whole continent. Resting upon this great swell of land is a series of approximately parallel ridges, the principal of which are the Rocky Mountain ranges on the east and the Coast ranges on the west, with ridges of less magnitude between, the general direction of which is north, inclining towards the west. Between these ranges are a series of extensive elevated valleys of extreme dryness, and, in the summer, of intense heat.

As we proceed north from the high plains of Mexico, the base of the system declines to about the 32d parallel of north latitude, where its transverse vertical section presents the least amount of land above the general level. It has, however, an average elevation in the principal part of about 4,000 feet, and the lowest notch or pass in the ridge on the eastern side is 5,717 feet above the ocean. Along the 35th parallel the vertical section across the mountain system is considerably greater in width and elevation. The general height above the ocean is at least 5,500 feet, and the lowest pass of the principal ridge is here 7,750 feet. The section of the system between the parallels of 38° and 40° has an elevation of 7,500 feet, and the lowest notch in the principal ridge is 10,032 feet above the level of the sea. From this section, as we pass to the north, the altitude and width decline; and along the parallel of about 47° the mountain base is much contracted in breadth, and has a general altitude of 2,500 feet. The lowest pass, however, of the most elevated ridge of this section is 6,044 feet. We have no definite information as to the mountain base north of this line. It however appears to continue at a lower elevation, and consequently to produce less influence upon the climate of the country to the east of it than the portion within the boundary of the United States.

From the eastern edge of what we have called the mountain system—that is, from the foot of the Rocky Mountain chain to the Mississippi river—a space comprising, as was said before, about one-third of the whole territory of the United States, the surface consists of an extended inclined plain, which slopes eastward to the Mississippi and southward to the Gulf of Mexico, having at the greatest elevation, near the intersection of the parallel of 40° and longitude 105°, a height of upwards of 5,000 feet, whence it gradually declines to the Mississippi river to about 1,000 feet. At the parallel of 35° it has very nearly the same elevation; and thence it slopes to the bed of the Mississippi about 450 feet, and south to the level of the sea at the Gulf of Mexico. This extended plain is traversed by a number of approximately parallel rivers flowing east and southward to the Mississippi river and the Gulf of Mexico, which have their rise principally in the mountain system, and are chiefly supplied by the melting of the snow and the precipitation of vapor which takes place at the summit of the ridges. The rivers are sunk deeply below the general surface of the plain, and give no indication of their existence from a distance, except the appearance of the tops of the cotton-wood trees which skirt their borders. The surface towards the southeast is slightly diversified by a low range of mountains, denominated the Ozark, which probably have some slight influence on the local climate of Kansas.

General Character of the Surface.—The general character of the soil between the Mississippi river and the Atlantic is that of great fertility, and as a whole, in its natural condition, with some exceptions at the west, is well supplied with timber. The portion also on the western side of the Mississippi, as far as the 98th meridian, including the States of Texas, Louisiana, Arkansas, Missouri, Iowa, and Minnesota, and portions of the Territory of Kansas and Nebraska, are fertile, though abounding in prairies and subject occasionally to droughts. But the whole space to the west, between the 98th meridian and the Rocky Mountains, denominated the Great American Plains, is a barren waste, over which the eye may roam to the extent of the visible horizon with scarcely an object to break the monotony. From the Rocky Mountains to the Pacific, with the exception of the rich but narrow belt along the ocean, the country may also be considered, in comparison with other portions of the United States, a wilderness unfitted for the uses of the husbandman; although in some of the mountain valleys, as at Salt Lake, by means of irrigation, a precarious supply of food may be obtained sufficient to sustain a considerable population, provided they can be induced to submit to privations from which American citizens generally would shrink. The portions of the mountain system further south are equally inhospitable, though they have been represented to be of a different character. In traversing this region, whole days are frequently passed without meeting a rivulet or spring of water to slake the thirst of the weary traveller. Dr. Letherman, surgeon of the United States army, at Fort Defiance, describes the entire country along the parallel of 35° as consisting of a series of mountain ridges, with a general direction north and south inclining to the west, and broken in many places by deep cracks, as it were, across the ridge, denominated cañons, which afford in some cases the only means of traversing the country, except with great labor and difficulty. The district inhabited by the Navajo Indians has had the reputation of being a good grazing country, and its fame has reached the eastern portions of the United States; but, taking the region at large, it will be found that, with regard to abundance of natural pasturage, it has been vastly overrated, and we have no hesitation in stating, says the same authority, that were the flocks and herds now belonging to the Indians doubled, they could not be sustained. There is required for grazing and procuring hay for the consumption of animals at Fort Defiance, garrisoned by two companies, one of which is partly mounted, fifty square miles; and this is barely sufficient for the purpose. The barrenness and desolation so inseparably connected with immense masses of rocks and hills scantily supplied with water, are here seen and felt in their fullest extent. The character of the district lying across the mountain system along the 32d parallel, which has been still more highly lauded for its productiveness, is, from reliable accounts, in strict accordance with the *a priori* inferences which may be drawn in regard to its climate from the influence of the mountain ranges and the direction of the prevailing winds. Dr. Antisell, geologist to one of the exploring expeditions, describes the country along the parallels of 32° and 33° as equally deficient in the essentials of support for an ordinary civilized community. On the west, within these parallels, occurs the great Colorado desert, extending to the river of the same name, which empties into the Gulf of California. From the Colorado river, which is generally regarded as the eastern edge of the Colorado basin, in its southern portion, the land rises eastward by a series of easy grades, until the summit of the main ridge of the mountain system is gained, a point about 500 miles east of that river. For the first 250 miles the ascent is across a series of erupted hills, of comparatively recent date, and similar in constitution to the line hills and ridges which are dotted over the various levels of the basin country. The entire district is bare of soil and vegetation, except a few varieties of cactus. Over the greater portion of the northern part of Sonora and the southern part of New Mexico sterility reigns supreme.

At the mountain bases may exist a few springs and wells, and in a few depressions of the general level of the surface sloping to the Pacific may be a grassy spot; but such are the exceptions. A dry, parched, disintegrated sand and gravel is the usual soil, completely destitute of vegetable matter and not capable of retaining moisture. The winter rains which fall on the Pacific coast, west of the Coast range of mountains, do not reach to the region eastward. This is partly supplied with its moisture from the Gulf of California, but chiefly by the southeast wind from the Gulf of Mexico, flowing up between the ridges of mountains. We hazard nothing in saying that the mountains, as a whole, can be of little value as the theatre of civilized life in the present state of general science and practical agriculture. It is true that a considerable portion of the interior is comparatively little known from actual exploration; but its general character can be inferred from that which has been explored. As has been said before, it consists of an elevated swell of land covered with ridges running in a northerly direction inclining to the west. The western slopes, or those which face the ocean, are better supplied with moisture, and contain more vegetation, than the eastern slopes; and this increases as we approach the Pacific, along the coast of which, throughout the whole boundary of the United States to the Gulf of California, exists a border of land of delightful climate and of fertile soil, varying from 50 to 200 miles in width. The transition, however, from this border to a parallel district in the interior is of the most marked and astonishing character. Starting from the sea-coast and leaving a temperature of 65°, we may, in the course of a single day's journey, in some cases, reach an arid valley, in which the thermometer in the shade marks a temperature of 110°. We have stated that the entire region west of the 98th degree of west longitude, with the exception of a small portion of western Texas and the narrow border along the Pacific, is a country of comparatively little value to the agriculturist; and, perhaps, it will astonish the reader if we direct his attention to the fact that this line, which passes southward from Lake Winnepeg to the Gulf of Mexico, will divide the whole surface of the United States into two nearly equal parts. This statement, when fully appreciated, will serve to dissipate some of the dreams which have been considered as realities as to the destiny of the western part of the North American continent. Truth, however, transcends even the laudable feelings of pride of country; and, in order properly to direct the policy of this great confederacy, it is necessary to be well acquainted with the theatre on which its future history is to be enacted and by whose character it will mainly be shaped.

Temperature.—Let us now consider the distribution of temperature of the wide belt across the continent of North America which forms the territory of the United States. To illustrate this, especial attention is requested to the lines drawn from east to west across the small map so frequently referred to. (Plate IV.) These, it will be seen, are of three kinds: first, the black, indicating the mean or average temperature of the year; second, the red, denoting the mean temperature of summer; and, third, the blue, that of winter. These lines are drawn through portions of the earth's surface having equal temperatures for the periods mentioned, and are protracted from the result of numerous observations. They do not, however, in all cases exhibit the actual temperature of the surface; for, in order to show their relations, and render them comparable with each other and with similar lines in other parts of the world, it is necessary that the observed temperatures in elevated positions should be reduced to that of the level of the sea; and in the construction of this map, allowance has consequently been made for decreasing temperature of one degree for every 333 feet of altitude. The map, therefore, will present to the eye the lines along which the temperature of the air would be equal for the periods mentioned, were we to suppose the mountain ranges entirely removed and the air brought down to the level of the ocean.

These lines, at a glance, exhibit remarkable curvatures, particularly in the western portion of the United States, indicating a great increase of temperature in this region beyond that of the eastern and middle portion. Let us first consider the black lines representing the mean temperature of the year. These, and indeed all the lines, are given for each ten degrees of Fahrenheit. Too much complication would be introduced were lines drawn for intermediate degrees on so small a map, though they have been projected on a larger one from which this has been reduced.

The first black line, beginning at the top of the map, is that of the mean temperature of 40°. It commences near the northern part of Nova Scotia, passes through Canada and the middle of Lake Superior, slightly diverging from parallelism with the line of 45° of latitude until about the 95th meridian, when it more rapidly curves northward and leaves the United States for the British possessions at about the 103d meridian, passing out at the top of the map at the 110th. The next line of mean temperature is that of 50°. It commences a little south of Nantucket, passes almost directly west, nearly parallel to the line of the 40th degree of north latitude, to about the 95th meridian of west longitude, whence it curves more rapidly to the north, meeting the coast of the Pacific in about the 48th degree of north latitude, near Puget's Sound. It thus exhibits the fact that the mean temperature of a point near

Rhode Island is the same as that at a point on the Pacific, of at least six degrees of latitude further north. The next line of mean temperature for the year, given on the map, is that of 60°; commencing near the mouth of Chesapeake Bay it inclines a little downward toward the 35th parallel of latitude until the meridian of about 98°, whence it rapidly ascends to the north, gains its greatest altitude at the 115th meridian, thence gradually declines southward to about the 125th, and thence, with a remarkably short bend, it passes parallel to the coast to about the latitude of 34°. By comparing the course of this line with that of the 35th parallel, it will be seen that the mean temperature is a little less near the Mississippi river than it is on the seaboard; but that in the great mountain system, in the same latitude as the mouth of the Chesapeake, the temperature of a place is nearly equal to 70° instead of 60°, since the curve of 70° reaches almost as far north. The curve of the mean temperature of 60°, as has been stated, terminates on the shores of the Pacific, at about latitude 34°; whereas, on the Atlantic, it commences at about 37°, indicating a lower temperature along the 35th parallel of latitude on the Pacific than on the Atlantic shore. The next is the curve of 70°. This commences in about latitude 28° on the coast of Florida, passes through New Orleans, and thence to a point on the Pacific in the latitude of 30°. It presents an upward curvature in that portion which passes through the Gulf, indicating that New Orleans is warmer than a corresponding place on the Atlantic, or on the shores of Texas. It thence curves rapidly to the north, though indicating the greatest temperature near the eastern edge of the mountain system. It terminates on the Pacific at a point at least two degrees higher than its point of commencement on the Atlantic, thereby indicating that along the 30th parallel the mean temperature is a little greater on the east than on the west side of the continent. It should be constantly borne in mind, in these descriptions, that the temperatures are those which would be exhibited were the mountain system of the country removed and the whole reduced to the level of the ocean. This system of lines, therefore, exhibits the extraordinary fact that, eliminating the effect due to elevation, there remains a cause of a remarkable degree of abnormal heating beyond that due merely to the latitude of the place. In other words, that at every point within the mountain system, whatever may be its elevation, the temperature is far above that of the same elevation of a point in free space having the same latitude, when compared with the eastern and western coast.

The red lines indicate the temperatures of summer. The first of these given on the map is that of 70°, and commences near Long Island, ascends rapidly towards the north, and then descends towards the large lakes, passing through Lake Erie; it reaches its greatest northern declination at about the 110th meridian, and thence turning nearly parallel to the coast, meets the Pacific in the latitude of about 34°. The portion of this curve along the coast of the Pacific shows the remarkable fact, that the summer temperature is nearly the same from latitude 32° to 45°, or through a distance of 13 degrees, the whole having the same temperature as that of 41° on the Atlantic coast. This curve also clearly exhibits the great effect which the vicinity of the lakes has on the temperature of summer. While the black lines indicating the mean temperatures of 40° and 50° are not at all affected by their proximity to these large bodies of water, the mean temperature of the summer is materially reduced. We may here call attention to the fact that the blue line, denoting the winter, suddenly bends up at the same place, indicating an increase of temperature due to the vicinity of the same reservoirs of water. The line of 80° commences near Charleston, South Carolina, and extends rapidly upward through the valley of the Mississippi, thereby indicating that the temperature of summer in the interior, along this parallel, is much higher than on the seaboard. The western portion of this curve also exhibits great intensity of summer heat in the mountain system, and a remarkable degree of uniformity along the Coast range of mountains parallel to the Pacific. The short lines of 82°.5 and 85° denote a high temperature of uniform intensity, extending to the north, and indicate the great summer heat of the western plain.

It will be seen, by examining the blue lines, that the temperature of winter in the middle of the Mississippi valley, about the 95th meridian, is lower than on either the eastern or western coast; also, that the line of 30°, which is only two degrees above freezing, starts at the east end of Long Island, passes through Lake Erie, thence down to the 40th parallel, in longitude about 91°, and thence rapidly rises to the north, and leaves the United States at the 118th meridian. The line of 40° of winter temperature commences at the mouth of the Chesapeake, follows nearly the same general direction, and meets the Pacific ocean near Puget's Sound; indicating the remarkable fact that this place and Norfolk, on the Atlantic, have about the same winter temperature. The line of 50° is also similar to that of the last; also the line of 60°, which indicates in the Gulf of Mexico a lower degree of temperature in winter than exists on the Atlantic or Pacific coasts. In examining these winter lines attentively, it will be seen that the rise is not uniform from the 95th to the 105th degree, but the bend is most sudden about the 103d; which is probably caused by the occasional descent along this region of the polar winds to the Gulf of Mexico.

It has been stated that, in reducing the lines to the level of the sea, 333 feet of elevation have been taken for each degree of Fahrenheit's scale. Therefore, the actual temperature of any part of the United States may be readily determined, provided its elevation above the sea is known, by subtracting from the temperature given on the chart as many degrees as there are spaces of 333 feet in the elevation. Let us take, for example, the junction of the Kansas with the Missouri river, on the 95th meridian. This point, it will be seen by inspecting the map, is midway between the mean isothermal lines of 50° and 60°, and its temperature will therefore be approximately 55°. It has an elevation of about a thousand feet, which will give three degrees for the reduction; and hence its temperature will be about 52°.

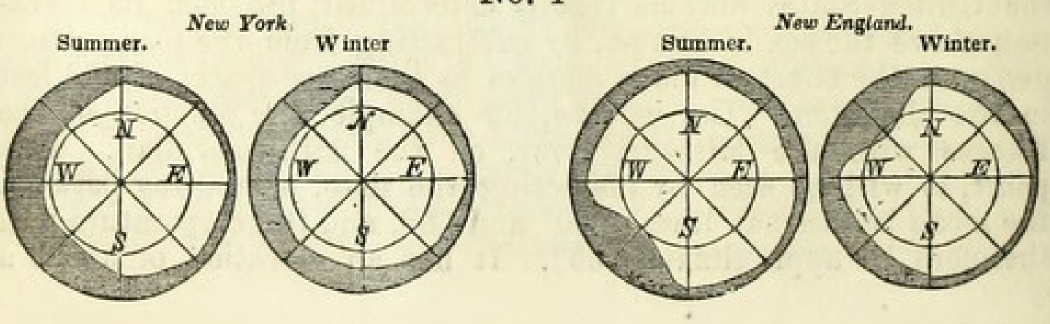
On a little reflection it will be clear that it would have been impossible to draw these lines on the uneven surface of the earth. The variation of temperature due to height would mask that due to latitude and other climatological causes. For example, a greater elevation of mountain peaks at the south would represent a colder local temperature than regions further north, would entirely hide from view the results which are due exclusively to the peculiarities of conformation of the country, and would give no means of comparison.

Winds of North America.—We have said that the whole mountain system of the western portion of the United States presents a remarkable abnormal elevation of temperature above the eastern and middle portion of the continent, and the question naturally presses itself upon us as to the cause of this surprising difference. The simple statement that the western side of Europe is also warmer than the eastern side of Asia does not explain the phenomenon; it merely points out an analogy, but not a cause. It is evident that the position of the mountain system, and the direction of the ridges with reference to the prevailing winds, must have some connection with this phenomenon. It will be well, therefore, before proceeding to this branch of the subject, to give a brief statement of some of the results which have been reached by deductions from actual observations in regard to this powerful agent in modifying climate. For the materials used for this purpose we shall be indebted to the valuable labors of Prof. Coffin, of Lafayette College, in connection with the Smithsonian Institution. In addition to this, the westerly aerial current, as it is principally derived from the equatorial regions, must in itself be warmer than the temperature due to the latitude of the belt in which it is moving.

In order that the facts may be the more readily comprehended, and produce a more indelible impression upon the mind, since ideas received through the eye are the most definite and lasting, we shall represent the direction and amount of the wind by means of diagrams such as are exhibited in the accompanying figures. The lines indicated by the letters N. E. S. W. represent the cardinal points of the compass, and the breadth of shading along any of these lines the relative amount of wind in the course of a given period observed at a particular place.

Thus, for example, in No. 1, in the circle on the right hand side,

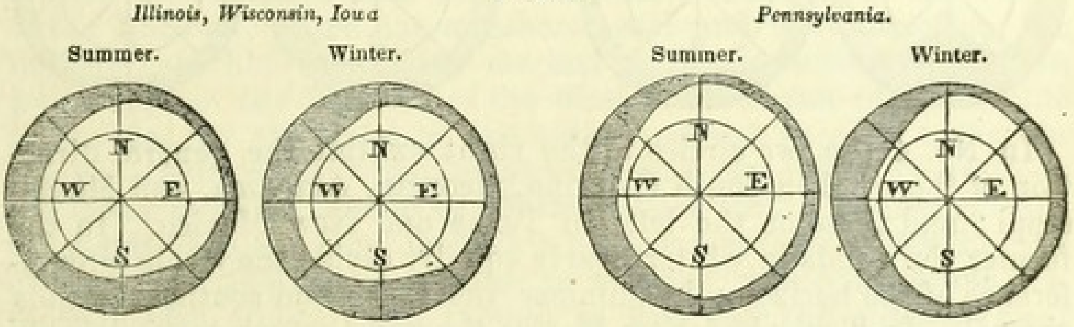
No. 1



the shading represents the amount of wind from the different points of the horizon during the winter months in New England, from the average of a large number of observations at different places. Hence it will be seen that the predominant wind during the winter, in this part of the United States, is from the northwest; the next in amount is from the northeast and southwest, the eastern and southeastern portion of the horizon during the winter exhibiting but little wind. The next circle to the left shows the great preponderance of wind in New England from the southwest during the summer. The winds exhibited in the two circles combined will produce a general resultant from the west. The next circles to the left exhibit the amount of wind in summer and winter in the State of New York. In winter the greatest amount is from the northwest, and in summer from the southwest.

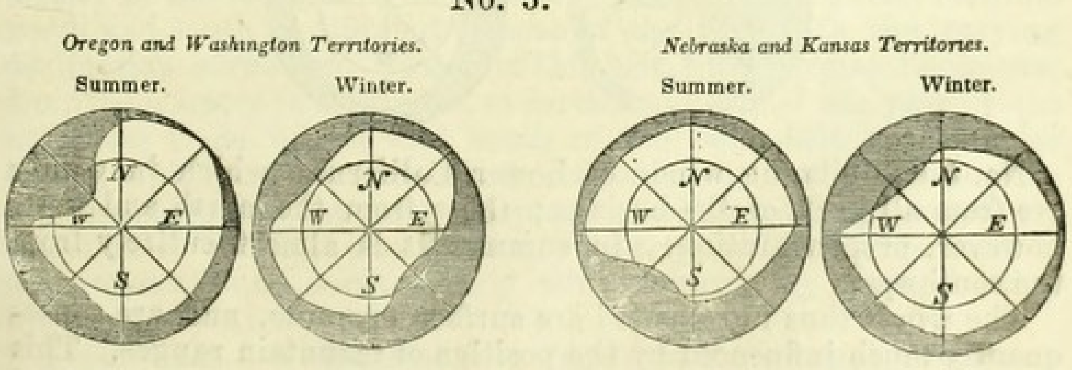
No. 2 represents the winds in Pennsylvania, Illinois, Wisconsin, and Iowa.

No. 2.



From these it will be seen that in Pennsylvania the wind is more westerly in winter than in New England, but still the greatest amount is from a point north of west. In summer the greatest amount is found a little south of west. During winter in the States of Illinois, Wisconsin, and Iowa, generally, the greatest prevalence is from the northwest, and in summer from the west and south. The maximum is a little east of south; the southwestern half, however, of the horizon in both seasons has the greatest amount.

No. 3.

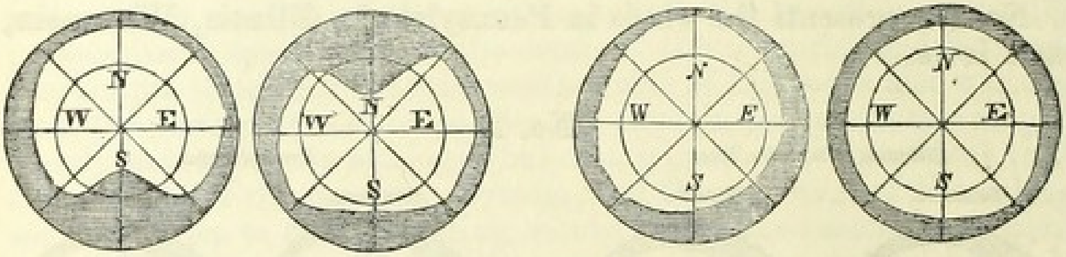


The circles in No. 3 indicate that in Nebraska and Kansas the greatest amount of wind in the winter is from the northwest, and in the summer from the southwest. In Oregon and Washington Territories the greatest amount of wind in the winter is from the southeast, and the next greatest from the northwest, these two principally dividing the season between them. In summer a very large proportion is from the northwest, which is a remarkable inversion of the winds as observed in other parts of the United States. The principal current in winter being in the direction of the coast, from the southeast, consequently tends to mitigate the cold; while in summer it is in the opposite direction, and therefore tends to produce a similar effect in diminishing the intensity of the heat.

No. 4.

Texas and New Mexico. *S. C., Ga., Ala., Miss.*

Summer. Winter Summer. Winter.

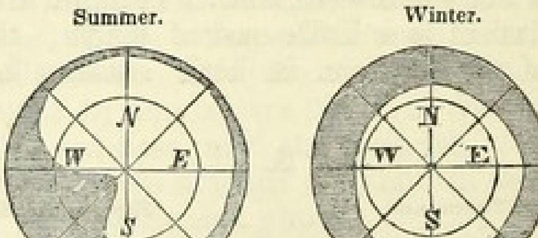


In No. 4 the two circles to the right exhibit the general direction of the wind in South Carolina, Georgia, Alabama, and Mississippi; and those on the left, in Texas and New Mexico. In the former the winds in winter nearly equally divide the whole circumference of the horizon; in summer the south and southeast winds prevail. In Texas and New Mexico the wind in winter is largely from the north, and often from the south; in summer its preponderance is greatly in favor of the south.

No. 5.

Lower California.

Summer. Winter.

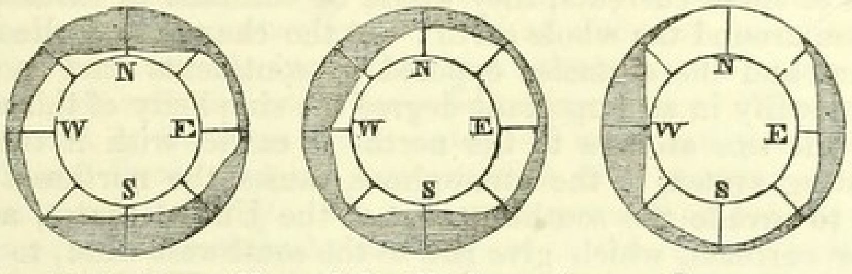


No. 5 exhibits the winds of Lower California, which in winter are from all parts of the horizon; those from the north and west, however, preponderating. In summer it is almost entirely from the southwest.

The winds thus represented are surface currents, and are consequently much influenced by the position of mountain ranges. This is strikingly shown in No. 6, which represents the mean annual wind at Hudson, Albany, and Utica, in the State of New York.

No. 6

Hudson, N. Y 8 years. *Albany, N. Y.* 12 years. *Utica, N. Y.* 12 years.



Hudson is in the valley of the Hudson river, a long, narrow glen extending in a north and south direction; and, as the figure indicates, the winds are principally confined to the same course, blowing down the glen to the south in winter, and in the opposite direction in the summer. Albany is situated at the junction of the wide Mohawk valley with that of the Hudson, and the wind accordingly is from the northwest and from the south. Utica is in the valley of the Mohawk, which has a general east and west direction, the influence of which is strongly marked by the prevailing winds. In a like manner the direction of the wind on the coast of the Pacific is modified by the trend of the coast and the parallel mountain chains. Almost every position at which meteorological observations are made is liable thus to be affected by the local topography; but the result of this is eliminated in a great measure by computing the average direction from a number of stations within a limited distance of each other. Yet, though in this way the opposite local influences in particular districts may be made to balance each other, those of great mountain systems still remain. These in turn, however, may be merged in a series of observations, extending across continents, or entirely around the world. In this way, by collecting all the reliable observations which have been made on the winds in the northern hemisphere, so far as they were accessible to the Smithsonian Institution, Prof. Coffin has established the fact, before mentioned, that the resultant motion of the surface atmosphere between latitude 32° and 58° in North America is from the west, the belt being twenty degrees wide, and the line of its greatest intensity in the latitude of about 45°. This, however, must oscillate north and south at different seasons of the year with the varying declination of the sun. South of this belt, in Georgia, Louisiana, &c., the country is influenced at certain periods of the year by the northeast trade winds, and north of the same belt by the polar winds, which, on account of the rotation of the earth, tend to take a direction toward the west. It must be recollected that the westerly direction of this belt here spoken of is principally the resultant of southwesterly and northwesterly winds alternately predominating during the year.

From what has been stated in regard to the general circulation of the atmosphere, it would appear that these winds are due to the returning upper currents which flow over from the heated region of the equator, producing a southwest, a west, or a northwest wind, according to the distance to which they extend northward before they commence to descend to the earth. If the sun continued on the equator during the year, and there were no obstacles to the free motion of these currents, they would be constant in intensity and direction around the whole earth; but the change in declination of the sun, and the obstacles opposed by continents and mountain chains modify in an important degree the simplicity of this motion. When the sun ascends to the north, it carries with it the whole circulating system of the atmosphere, causes the northeast trade-winds to invade the southern part of the United States, and the inferior currents, which give rise to the southwest wind, to flow in summer over a large portion of our territory. The latter, charged with the vapor from the Atlantic and the Gulf of Mexico, impart warmth and fertility to all parts of the surface on which they descend. The higher currents, which produce the west and northwest winds, flow in summer above us, to descend further to the north. Their course, however, is marked by the almost invariable direction of the upper clouds and of the summer thunder storms, which, in the greater part of the United States, pass from the west to the east. The curving course of the returned currents, when the sun is south of the equator, is, perhaps, best marked by the direction of the hurricanes, which exactly follow the path we have described as that of the atoms of air in the general circulation so often referred to. This will be seen by examining the storm tracks on one of the maps of the lamented Redfield.

It is evident, from theory as well as from every day observation, that the currents of the belt of the northern hemisphere in which the United States is situated must be subject to many perturbing influences, and that this region is well entitled to the denomination of the zone of variable winds. While the great circulation which we have described is going on, particularly above us, every rain that occurs, and every variation of temperature, tends to disturb its regularity at the surface of the earth. According to the views here presented, the following winds of the United States belong to the general circulation, namely, the southwest, west, northwest, north, and northeast; while those from the opposite quarters of the horizon are principally due to abnormal atmospheric disturbances. We say principally, because a portion of the surface northeast trade wind in summer probably blows over Florida and the lower part of Louisiana. These views have been strengthened by a series of observations collected by M. De Doue, from which it is shown that the winds from the western half of the horizon, as indicated by the clouds, preponderate over those from the east, as indicated by the wind vane at the surface; or, in other words, that there is a greater tendency to a movement, even in our latitude, in the upper strata of air from the western half of the horizon, and in the lower from the eastern—a result in conformity with the general principles we have endeavored to explain. The circulation in the region of variable winds may often be inverted, and the compensation take place by means of winds in different parts of the hemisphere. It must be evident, from mechanical principles, that, to balance every current of wind which flows to the north over any parallel of latitude along any meridian, an equal amount must flow back to the south either along that meridian or some other. If the compensation takes place at the same meridian, one current must flow above and the other below. If at different meridians, the compensating currents may both be at the surface or both above. The fact that very different temperatures prevail at different parts of the world at the same time under the same latitude favors the idea of Prof. Dove, that the compensation does in many cases take place in the latter way. Mr. Espy supposes that our southwest wind is produced mainly by the descent of the return trade winds at about the 30th parallel, and by rains accompanied with an elevation of temperature, and consequently an ascent of air, at the parallel of 58° or 60°, and that it returns again in an upper current, over the belt we have described, towards the south. That whatever air reaches the polar regions should descend there and flow southward, and then rapidly decline to the west, appears to be an evident consequence of well established laws. The rapid inclination of the air on account of the great increase of rotation in the surface of the earth in this latitude would tend to produce a wind in a westerly direction along the parallel of 60°, which would conflict with the currents from the south, and thus produce a low barometer, a tendency to rain, and form a natural boundary between what may be denominated the polar winds and the belt of westerly winds, due, as we have supposed, to the returning trades. The region of the middle belt must be one of great irregularity, occasionally encroached upon by the polar winds of the north on one side, and the intertropical winds of the south on the other, tending to restore the equilibrium in some cases in the mode suggested by Prof. Dove, and again in that proposed by Mr. Espy. We are, however, inclined to believe that all these are perturbations in the general circulation.

That the great western mountain system of North and Central America produces an important effect on these currents cannot be doubted, when it is recollected that one-third of the whole atmosphere is below its higher portions. It prevents the northeast trade wind from passing to the coast of the Pacific in about the latitude of 30°, and probably deflects northeastward a part of the lower portion of the upper return wind, giving more force and quantity to the southwest summer currents than they would otherwise have. This is the view adopted by Mr. Robert Russell, of Scotland, one of the most industrious and promising of the younger meteorologists of Europe, who visited this country about three years ago for investigating its climate and agriculture. It would appear, from what has been stated before, that a northwest current most generally prevails in the higher regions, and that the southwest current is a more superficial one. According to Mr. Russell, all the disturbances of the atmosphere in this country are produced by the unstable equilibrium occasioned by the superposition of the northwest wind on that of the southwest; and this, we think, in connection with the evolution of heat, according to the principles of Mr. Espy, will account for all the violent commotions of our atmosphere, whether they appear in the form of winter storms, thunder gusts, or tornadoes. This subject, however, will be resumed in the next Report.

TERRESTRIAL OR UNDERGROUND CLIMATE.

An opinion has long prevailed that a climate cannot be changed to suit certain plants, but that the constitution of those plants may be so altered as to be adapted to a certain climate; and the process by which this effect is believed to be gained is called acclimatizing. But, notwithstanding this opinion, in most instances the truth is just the reverse, and the proposition should stand thus: "The constitution of plants, in general, cannot be altered to suit climate, yet climate may be altered to suit plants." When we limit the word "climate," however, to the conditions of the atmosphere in which birds and quadrupeds move, we express a particular state of things which concerns those parts of the creation, but we omit what is essential in considering the climate necessary to plants. And hence it is that, in the popular sense of the term "meteorology," cultivators derive less benefit from that science than it is capable of furnishing. The climate in which the roots of plants or trees are placed is at least as important, if not more so, to their successful growth, than that which sustains their branches, leaves, flowers, or fruits. It may with propriety be called "terrestrial," in contradistinction to "atmospheric" climate, and is one which it is in the power of almost any farmer or gardener to improve by artificial means.

The roots of plants, it is well known, although they burrow below the surface of the ground, are not on that account insensible to the influences which are felt by the stem and branches above. On the contrary, they are fully as sensitive to the extremes of moisture and dryness, or of heat and cold. Thus, if leaves and flowers wither beneath the scorching air, so do roots when the earth around them becomes parched; if the verdant foliage rejoices in the invigorating rain-drop, not less is it grateful to the earth-bound root; if cold checks or destroys the blossom and compels the foliage to shrink and perish, in like manner also the roots are affected. On the other hand, that warmth which causes the blossom to unfold, and the leaf to open to the influences of the gentle breath of spring, is equally propitious to the root under ground, exciting it to growth, and putting into action all that dynamic force by which the leaves and flowers are nourished. Nor is the access of air less important to one than to the other; both extremities of plants feed on air—the roots more than the leaves. Put a plant in a place where air can have no access to its leaves, and they fall, to be followed by the decay of the stem. Roots existing under the same circumstances will gradually shrink and die. Hence it is that the condition of the air which circulates in the ground, the temperature of the soil itself, and the moisture contained therein, require to be regulated, as well as that of the atmosphere above; and hence the importance that underground climate should be thoroughly understood.

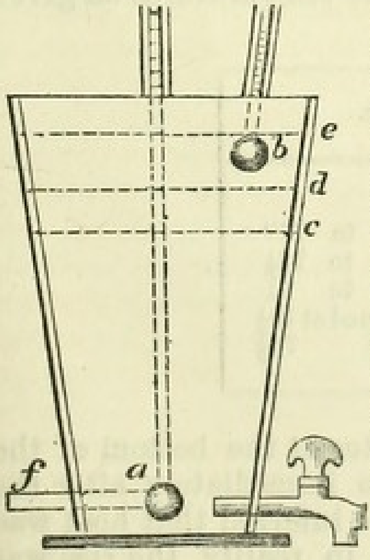
In order that a cultivator may not experience so much mysterious disappointment where he often expects the best success, he need only be told that his remedy lies alone in the perfect and skillful drainage of his soil. For, under-drained land is not merely wet, but "water-logged," all the interstices between the particles of earth being filled with water, and consequently destitute of air, except a small quantity which may be contained in the water. By this means, the plants are deprived of the most essential part of their food. But when the water is removed, air takes its place and holds in suspension sufficient moisture for the roots to subsist upon; for it is not water in a fluid state which plants in general prefer, but when it has assumed the state of air-borne vapor, the best of all food for roots.

But those who imagine that this is the whole explanation of the effects of drainage upon crops, overlook another circumstance of the highest importance: "Drained land, in summer, may be from 10° to 20° F. warmer than water-logged land." Hence it is evident that drainage produces the very important effect upon land of raising its temperature, communicating what gardeners call "bottom heat;" and those who are most conversant with plants know the value of this, as soil requires to be heated in some degree for all plants, but some kinds demand a higher temperature than others.

The reason why drained land acquires an increased temperature, and water-logged land is always cold, consists in a well known fact, that heat cannot be transmitted downwards through water. This may readily be seen by the following experiments, which any one can repeat for himself.

Experiment No. I.

A box was made of the form represented by the annexed diagram, 18 inches deep, 11 inches wide at the top, and 6 inches wide at the bottom. It was filled to *c* with peat, saturated with cold water, forming a sort of artificial bog to the depth of 12½ inches. The box was then filled with cold water to *d*. A thermometer *a* was plunged so that its bulb was within 1½ inches of the bottom. The temperature of the whole mass of peat and water was found to be 39½° F. A gallon of boiling water was then added, which raised the surface of the water to *e*. In five minutes, the thermometer *a* indicated a temperature of 44°, owing to the conduction of heat by the tube of the thermometer and its guard. At ten minutes from the introduction of the hot water, the thermometer *a* showed a maximum tempera-



ture of 46°. Another thermometer *b* was then introduced, dipping under the surface of the water at *e*, and the following are the indications of the two thermometers at the respective intervals, reckoning from the time the hot water was supplied:

Time.	Thermometer *a*.	Thermometer *b*.
h. m.		
0 20	46°	150°
1 30	45	101
2 30	42	80½
12 40	40	45

The mean temperature of external air to which the box was exposed during the above period was 42°; the maximum being 47° and the minimum 37°.

Experiment No. II.

With the same arrangement as in the preceding case, a gallon of boiling water was introduced above the peat and water, when the thermometer *a* indicated a temperature of 36°. In ten minutes it rose to 40°. The cock was then turned for the purpose of drainage, which was slowly effected, and at the end of twenty minutes the thermometer *a* still indicated 40°; in twenty-five minutes 42°, while the thermometer *b* stood at 142°. In thirty minutes, the cock was withdrawn from the box, in order to afford a freer egress of the water. In thirty-five minutes, the flow of water was no longer continuous, at which time the thermometer *b* indicated 48°. The mass was now drained and permeable to a fresh supply of water. Accordingly another gallon of boiling water was poured over it, and the thermometer *a* indicated, at the respective intervals, reckoning from the time it was supplied, the temperatures as given in the table below:

Time.	Temperature.
h. m.	
0 3	The mercury rose to 77°
0 5	" " fell to 76½
0 15	" " " to 71
0 20	" " remained at 70½
1 50	" " " 70½

In these two experiments, the thermometer at the bottom of the box indicated a sudden rise of temperature immediately after the hot water was added; and hence it might be inferred that heat was conveyed downwards by the water. But in reality the rise was owing to the action of the hot water upon the bulb and guard of the thermometer, and not to its action upon the cold water. To prove this, the perpendicular thermometers were removed. The box was filled with peat and water to within 3 inches of the top; a very delicate horizontal thermometer *a, f*, having been previously secured through a hole made in the side of the box by means of a tight-fitting cork, in which the naked stem of the instrument was grooved; a gallon of boiling water was then added, and the thermometer was not in the least affected by it as it was poured in at the top of the box.

The intelligent cultivator will at once see the application of these experiments. The wooden box is a field; the peat and cold water represent the water-logged portion; rain falls on the field and becomes warmed by contact with the surface soil, which may be, perhaps, of a temperature of 130°, and is thus heated, say 100°, and so descends into the earth, but is stopped by the cold water in the undrained land, and the heat will go no further. So that, if hot water were to be rained on a water-logged field for a month, the temperature of the soil would not be raised to the depth of a single inch below the surface where the cold water naturally stands. On the contrary, if the soil be open, and not water-logged, the warm rain descends through the crevices in the earth, carrying with it the high temperature it has gained at the surface, imparts it to the soil as it passes downward, and thus produces that bottom heat which is so essential to plants.

The nature of deep-draining, then, is, in fact, such as to change the underground climate by admitting an additional access of air and warm rain to the roots of plants too inconsiderable to be appreciable. It is only when deep draining and deep trenching accompany each other that much increased access of air to roots beyond what is customary can be anticipated. Where both are secured, the effect on vegetation will certainly appear like magic.

D. J. B.