

I. On the influence of the dew-point on vegetables, considered especially with reference to their temperature

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- I. *On the Influence of the Dew-point on Vegetables, considered especially with reference to their Temperature.* By D. P. GARDNER, M.D., Professor of the Physical Sciences, &c. in Hampden Sidney College, &c., Corresponding Member of the New York Lyceum of Natural History*.

THE object of this paper is to establish the mutual relation existing between the temperature of plants†, their evaporation, and the amount of vapour existing in the atmosphere. The subject will be examined under four heads, which have been suggested by the results of the experiments instituted, and are therefore gradual developments of the proofs by which the connexion between the dew-point and temperature of plants is sought to be established.

1st. Certain vegetables are without any specific heat.

2ndly. The variations plus or minus the atmospheric temperature observable in plants are owing chiefly to the state of the dew-point, its elevation causing an increase of heat by checking evaporation, and its depression by favouring evaporation producing coldness; in other words, the rate of evaporation, and its effect in producing a decrease of temperature in plants, is directly as the greatness of the *drying power*, and inversely as its diminution.

3rdly. The sensible heat of plants is directly as the atmospheric temperature, and the chemical action going on in their cells; and inversely as the evaporation, radiation and conduc-

* Read before the Linnæan Society, November 16th, 1841, and now communicated at the request of the Author, by J. J. Bennett, Esq., Sec. L.S.

† On the subject of the heat of plants, see Meyen's Report for 1839, in the Annals and Magazine of Natural History, vol. viii. p. 27; also the original paper by Vrolyk and De Vriese, in the same work, vol. vii. p. 161

—EDIT.

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tion of the soil and surrounding air: to this we add, chemical action increases with atmospheric temperature, &c. &c., and consequently the amount of heat resulting therefrom.

4thly. A review of the foregoing doctrine, with some remarks on apparent anomalies.

§ 1. That certain Vegetables are without any specific heat.

A number of insulated measures of the temperature of flowers has hitherto been admitted into the books on vegetable physiology as the whole of our information on the subject of vegetable heat; and these measures have been received with distrust or altogether denied. M. de Lamarck observed an increase of temperature in the *spadix* of *Arum vulgare*, which M. Sennebier afterwards measured and found equal to 7° C. above the atmosphere. The German naturalist Schultz found a flower of *Calladium pinnatifidum* at 19° to 20° C. when the surrounding air was only 15° C. Messrs. Hubert and Bory measured the temperature of the *spadix* of *Arum cordifolium* in the Isle of France, and found it at sunrise 44° to 49° C.; the atmospheric temperature being only 19° C. M. de Saussure carried his experiments further, and with the differential thermometer ascertained an increase of $\frac{1}{2}$ ° C. in the male flowers of the melon and other Cucurbitaceæ.

Hypotheses have not been wanting to explain the reason why flowers should enjoy a more elevated temperature than the other parts of the plant. Mr. Murray imagined it was due to their colour. Brongniart ascribed it to the increased action of the molecules interested in the process of fecundation. Others have adopted the more plausible idea, that it depended upon increased chemical action, as the absorption of oxygen by the petals, &c. of the flower.

But Messrs. Treviranus, Goppert and Schübler, altogether deny that flowers give any indications of an increase of temperature. M. Aug. de Candolle ascribes this denial to the erroneous conclusions at which these botanists arrived from experimenting on imperfect plants; since his experience at Montpellier had led him to the same opinion as Saussure and others.

Placed in so embarrassing a situation, our only resource was to undertake a new series of experiments upon the subject; for although the mass of evidence appears to be in favour of the existence of a specific temperature in flowers, yet the measures given are too dissimilar to prove satisfactory, and the experiments appear to have been performed in too loose a manner to silence opposition. The mere introduction of a thermometer into a flower is a process undeserving any

serious attention : the state of the atmosphere has been omitted, and in other respects the data are so imperfect, as to exclude the possibility of our repeating any of the experiments given under similar circumstances.

The instrument with which their measures have been made is altogether too bulky in such delicate researches; for although the bulb of a thermometer may be thrust into a pumpkin flower or tulip with *tolerable facility*, yet the contact of the circumambient air is not completely cut off by the shape of the flower; and if the fingers or any other contrivance be used as a means of closing the corolla upon the thermometer, the temperature of the new body complicates the result. Even when introduced with all care, a bulk of mercury or air of as many cubic lines as the flower has superficial measure, in either case an imperfect conductor, can only give a doubtful result. It is too large in most cases, and must be confined to experiments upon a few scattered flowers; nor can it in any instance be made use of to obtain a set of measures over the whole plant; most stems would be crushed in attempting to introduce it; and even if we succeeded so far, the measure obtained must be imperfect, from the injury inflicted upon the plant and the small amount of mercury or air in absolute contact.

These considerations have induced me to make use of a thermo-electric pair and the galvanometer as the most suitable thermoscope. The pair consists of a tinned iron and copper wire, each $\frac{1}{16}$ th of an inch in diameter, soldered together at one extremity with tin for $\frac{1}{10}$ th of an inch, and sharpened so as to enter with slight force any part of a plant; the wires used were about nine inches long, and were passed through a large bung, so that the fingers might not approach the junction, the cork serving as a non-conducting handle, and being sufficiently removed to hinder the possibility of producing a current of thermo-electricity by radiation from the hand. The galvanometer employed was the simple multiplier of Schweigger; the axis being suspended by a fibre of raw silk and bearing two needles perfectly *astatic*, and also at the lower end a parallelogram of tin-foil which was immersed in a vessel of water beneath the galvanometer; the object of this addition is to steady the vibrations of the needles, as shown by Dr. Draper (Phil. Journ.). The whole arrangement was covered by a glass bell-jar, having a graduated arc pasted on the inside at an appropriate height, which by moving the glass vessel can be brought to any place so as to arrange the *zero* point with great facility; the upper needle also bore a fine wire standing up at right angles from its extremity, which as the needle is

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deflected plays across the arc and tends to assist the admeasurement.

The thermo-electric pair and galvanometer can be made an extremely delicate differential thermometer; and from experiments already made by Drs. Forbes, Ritchie, Draper, &c., we are justified in stating that the degree of variation of the astatic needles is very uniform for equal increments of heat, in cases where the total amount of variation is as limited as in the following.

In obtaining the numbers of the tables, or the measures of temperature, the pointed extremity of the *pair* was thrust into the parts of the plant specified, care being taken to avoid contact by the fingers with either the plant or thermoscope; the numbers given are the mean of at least five measures made by forming and breaking the electric circle. The same *pair* and galvanometer were used throughout, and the value of a degree of the index equals two elevenths of a degree of Fahrenheit, or $1^{\circ} \text{ F.} = 5^{\circ} \cdot 5$ galvanometer. It is well to observe here that the whole of the junction of the thermo-electric pair must be introduced into the plant, otherwise the current of electricity does not circulate freely through the length of the wires, but passes round from the warm to the cold parts of the junction, forming a circle that does not include the galvanometer, and therefore producing no deflection of the needles.

The dew-point marked in the tables was taken immediately before and after each series of measures, and if any difference existed, the mean adopted.

The height of the thermometer is marked both at the time of the deposit of dew upon the exterior of a glass of iced water and its vanishing. The *drying power*, which is Dr. Dalton's expression for the difference between the dew-point and atmospheric temperature, is also marked in the tables; and it is well to remark, that that great philosopher has ascertained that the amount of evaporation is the same for all temperatures if the drying power be the same.

The experiments were performed in the shade, every disturbing cause, as currents of air, motion, &c. being avoided. The thermometer hanging at the side of the galvanometer, and the dew-point, &c., were all estimated at the same spot.

ARUM WALTERI (*foliis sagittatis*) was preferred for experiment; because it was in this genus Lamarck, Sennebier, &c. noticed the striking variations of temperature recorded in the commencement of this section; it moreover flourished in my immediate neighbourhood, and was of convenient size to establish a complete series of measures upon. The plants were dug from the marsh in which they grew, with several pounds

of native soil around their bulbs, shortly after sun-rise, placed in a wooden box and carried at once to the place of destination about 200 yards distant; after having been left a sufficient time to allow the soil to radiate any excess of heat, or about two hours under any circumstances, the measures were commenced, and recorded at the time. Other examinations of the same group of plants took place however at different periods in the day, the plants being uninjured and vigorous.

It is necessary I should observe here, that all attempts made to examine plants *in situ* failed from various causes; the difference of temperature between parts exposed to the sun and those in the shade; the impossibility of managing the delicate thermoscope in the open air; the disturbing effects of currents, gusts of wind, &c.; nor does it appear to me at all necessary that such examinations should be made, even if the results could be depended upon. The measures derived from a vigorous plant removed under the foregoing circumstances are fully as trustworthy; and when the great deviations of the needles come to be considered, even the most sceptical will allow that the difference of situation would not have influenced the result beyond a few degrees; in which I may possibly be in error; but upon the general fact there cannot be any dispute.

So far the tables introduced may be regarded as exhibiting the measures made upon one species; but although it has not been considered necessary to tabulate the other results, yet a similar series of experiments were made on the undermentioned plants, as far as it was found practicable, but none offered the advantages possessed by *Arum*.

The examination of these plants gave the same general result, and they may therefore be dismissed, after simply stating that they corroborate in all respects the observations hereafter to be made on the subject of vegetable temperature, &c.

Symphytum officinale, *Pastinaca sativa*, *Cicuta maculata*, *Asclepias obtusifolia et syriaca*, *Arctium Lappa*, *Sagittaria sagittifolia*, *Rumex crispus*, *Lobelia cardinalis*, *Daucus Carota*, *Datura Stramonium*, *Delphinium consolidum*, *Cynoglossum officinale*, &c.

The botanist will recognise in this list, plants of sufficient bulk to allow of the introduction of the thermo-electric pair. They are also very frequently met, and were chosen partly from this cause, as well as from their proximity to the laboratory. The list could be elongated indefinitely if a smaller pair were used, but it is unnecessary to introduce other cases, as each observer can modify his apparatus as to the fineness of the elements according to his pleasure.

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Lest the deviation of the needle of the galvanometer should be due to any other cause than a current produced by the temperature of the plants, several experiments were made to decide this point. The magnetic influence of the tinned iron, the action of vegetable acids, friction, radiation from the person or surrounding objects, were all examined, and it was found, that under the precautions adopted, all these disturbing causes were neutralized, so that *all the measures given are solely attributable to the presence of sensible heat in the plant.*

Where more than one measure is recorded, it was either made upon different parts of the same plant, or at different times upon different parts; in the latter case, the time, which had elapsed between the measures is also recorded.

Table A.

June 8th, 1839. A vigorous group of *Arum Walteri* with well-developed spathe, and several pounds of mud *in situ*.

Thermometer 66° Fahr. Dew-point 54°. Drying power 12°. Clear.

Parts of the plant examined.	Two hours after collection.	Three hours after collection.	
Ovary	+14.8		All in degrees of galvanometer.
Male part of spadix	+14.8		
Fully developed leaf stem	0		
Stem (or rather collection of petioles) one inch below soil without adherent earth	-7.15		{ Agreeing with the mercurial thermometer, or 3° 8 Fahr. below the atmospheric temperature.
Stem, six inches below soil, covered with adherent earth ...	-20.9	-20.9	
Temperature of soil	-20.9	.....

Table B.

June 11th. *Pastinaca sativa* in flower, with adherent soil. Thermometer 81° Fahr. Dew-point 66°. Drying power 15°. Clear.

Parts of the plant examined.	Galvanometer.		
Stem, near umbel with young seed	+ 8.	+8.	{ Corresponding with a depression of a little more than 3.5° of Fahrenheit's thermometer.
Junction of flower stems	0	0	
Stem at 3 feet, 2½ feet and 1 foot above soil	0	0	
Stem six inches above ground...	-1.4		
Stem one inch above ground ...	-10.6		
Main root	-20		
Larger branches of root	-20		
Temperature of the soil	-20	

Table C.

June 12th. *Arum Walteri*, a fresh group, &c. Thermometer 86° Fahr. Dew-point 64°. Drying power 22°. Clear.

Parts of the plant examined.	Galvanometer.				<div> Agreeing with the thermo- metric tempera- ture of 30°6 Fahr. below the air. </div>
Male & female portions of spadix	0	0	0	0	
Scape one inch from spadix.....	0	0	0	0	
Petioles	0	0	0	0	
Midribs of different leaves	+ 1	+1·2	+1·5	+1	
Collection of leaf-stems (stem)	0	0	0	0	
Stem three inches above soil ...	-1·4	-1·4			
Stem beneath soil	-20·5	-20·5			
Bulb	-20·5				
Soil	-20·5	...	...	...

Table D.

June 7th. *Arum Walteri*, &c., three hours after collection. Thermometer 64° Fahr. Dew-point 51°. Drying power 13°. Fahr. Clear.

Parts of the plant examined.	Galvanometer.				<div> Agreeing with the thermo- metric measure. </div>
Spadix in vigorous { male part...	+13	...	...	+ 8
action..... { female part	+13·7	...	...	+11
Petioles of various leaves	+ 8·8	+ 8·8	+ 7	+ 7	
Midribs of various leaves	+13	+12·5	+12		
Stem (collection of petioles)	+ 2				
two inches above soil					
Stem one inch above soil	- 2·5				
Stem surrounded by soil	-14	- 14	-14	-14	
Temperature of soil	-14	...	...	...

To these tables many others might be added, as they all tend to establish the same point. If we examine them solely to ascertain whether they afford any proof of the existence of a certain specific or vegetable heat, we are irresistibly led to acknowledge that the proof is against any such vital agent, and we deduce this,—

1st. Because in the four tables the atmospheric temperatures quoted are 66°, 81°, 86° and 64° respectively, and yet the plant varies with each.

2d. We observe that the temperature of the soil is the same as that of the subterrene stem or root, and that the excess of temperature, if any such exist, is found in parts remote from the soil, and in which vital action is taking place. It is natural that the root should be of the same temperature as the earth, for along its vessels are passing the fluids derived from the soil; and the conducting power of the latter must tend to

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keep down the heat of the root, even when chemical action is taking place most actively in its structure.

We are therefore justified in asserting that *vegetables (so far as annuals and perennials)* possess no specific heat similar to that belonging to mammals, &c., but that their temperature varies with the atmosphere within certain limits.

§ 2. That the variations plus or minus the atmospheric temperature are partly owing to the state of the dew-point, &c. (p.1.)

It is well known that evaporation cannot take place from any surface unless the temperature and dew-point differ; for as a given bulk of air is only capable of retaining a certain amount of watery vapour in solution at a known temperature, it follows, that if the dew-point indicates that amount of saturation, all evaporation must cease so long as these conditions are maintained. It is also well known, that the heat produced by chemical and vital actions taking place in the highest animals is antagonized by evaporation from the skin and lungs, the tendency of which is to produce coldness. We have here therefore a source of heat and its opposite which likewise exists in plants, with this difference, that whilst the former power is considerably lessened, the latter is increased in consequence of the extensive surface from which evaporation takes place.

But the rapidity of evaporation is dependent upon several circumstances, as the amount of drying power, velocity of the wind, extent of surface, &c.; of these the first is the most important and easiest of examination. To show its influence, we introduce three other tables, selected as illustrating the influence of the amount of drying power most extensively.

Table E.

June 12th. *Arum Walteri*; soil extremely wet, and consequently adhering less firmly than in the previous cases. Thermometer 85°. Dew-point 60°. Drying power 25°. Clear.

Parts of the plant examined.	Galvanometer.				
Unopened spatha.....	-5	-5	-5	-5	} With thermo- meter.
Spatha open and { male portion	-5	-5	-3.6	-5	
spadix active { female	-5	-5	-5	-5	
Male spadix giving off pollen ...	0	0	- .2	0	
Unfolding leaf, stem.....	-2	0	- .2		
... .. base of midribs.....	0	0			
Young expanded leaf-stem	-9				
... .. midrib.....	+2				
Expanded leaf, midrib.....	-7.5	-8.	-7.5		
Stem, or collection of petioles	-24	-24			
Stem at surface of ground	-27				
Stem three inches below soil ...	-30				
Temperature of the soil	-30	

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In this table we are presented with an unusually high amount of drying power, the effect of which is to produce so rapid an evaporation, that the heat generated in the most active parts of the plant is neutralized. This group of plants, although very vigorous when examined, was drooping in six hours after from excessive evaporation.

Table F.

June 14th. *Arum Walteri*, with plenty of moist earth. Thermometer 86° Fahr. Dew-point 62°. Drying power 24°. Clouds rising.

Parts of the plant examined.	Galvanometer.		
Young spadix, male portion ...	-4		
... .. female.....	-4.5		
Expanded spatha { male spadix	-5	-5.5	
female	-5	-5	
Young expanded leaf, stem.....	-5	-6	
... midrib ...	-5	-5	
Fully expanded leaf, stem	-9	-9	
... midrib	-6	-6	
Main stem one inch above soil	-36		
... .. three inches below	-55		
Temperature of soil	-56	...	{ Agreeing with the thermometer.

Table G.

The same group as in Table E, again examined six hours after collection, about half an hour after the falling of rain. Plants very vigorous. Thermometer 75° Fahr. Dew-point 65°. Drying power 10°. Clearing.

Parts of the plant examined.	Galvanometer.		
Young spatha, male part.....	+8	+9	
... .. female.....	+8	+7.8	
Expanded spatha, male	+8.5	+8.8	+10
... female	+8	+9	
Young expanded leaf, midrib ...	+10		
... stem.....	+ .5	0	
Unfolded leaf, midrib	+12	+8	
Main stem, above ground.....	-2		
... .. six inches below ...	-30		
Temperature of soil	-32	...	{ Agreeing with the thermometer.

In tables E, F and C of the previous section the drying power is extremely high, 22°, 24°, and 25° Fahr.; the effect according to hypothesis should be an exalted evaporation, and we find accordingly that all parts of the plant in these three tables exhibit a temperature below that of the atmosphere.

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The tables G and A and D of section the first are of a different class ; in these the drying power varies from 10° to 12° and 13° ; being about half of the power in the above tables, and representing the air more saturated with watery vapour, and therefore less conducive to evaporation. In these tables we remark an uniform elevation of temperature in all the highly organized parts of the plant ; notwithstanding the minus measures of the root from contact with a moist and therefore evaporating soil ; a good illustration, *en passant*, of the non-conducting nature of living vegetable tissues.

Not to become diffuse, we perceive in these results,—

1st. An uniformity which recommends them to our reason.

2ndly. They are in conformity with the experience of mankind. The effects of moist air on vegetation is known to all, the rapid growth, the vigour of plants, or to speak more scientifically, the activity of the chemical and organic actions which maintain life are fully manifest. The result is an increment of temperature in exact proportion to the varying activity of each organ, whether in the respiration of the leaf or the generative functions of the parts appointed to the reproduction of the species.

The effects of a drought are no less apparent ; the leaves hang down ; there is an air of listlessness about plants very analogous to the effects of heat upon the human frame, and due to the undue evaporation.

How firm and succulent is the state of a leaf during moist weather ; how exsiccated and flabby during a dry season ! of this the tobacco planters in Virginia are so well aware, that they esteem moist foggy weather favourable when gathering their crop. It is somewhat curious that these remarks apply to the human family ; the natives of moist countries, as the Netherlands, England, &c., being of fuller habit than those who live in arid regions ; this similitude does not however extend so far as in plants, from the effects of the diseases prevalent in swampy countries. It gives me great pleasure here to recommend the paper of Mr. Hopkins in the London and Edinburgh Philosophical Magazine for February 1839, on Malaria, in which he examines the influence of the hygrometrical state of the air upon animal life.

At this stage of the investigation it is necessary to meet an objection already urged against the foregoing doctrine, that it levels the principle of life in vegetables to mere chemical action. We do not hold any such view. We simply claim that the sensible caloric generated by plants is the result of internal action ; the amount of caloric is also more or less, according to the activity of the evaporation, the influence of high

temperature radiation, and conduction of the soil. The organic molecule of plants is not a mere compound atom, for it is beyond the art of the chemist to create it synthetically.

But, further, to meet objections of this kind, and convince ourselves of the influence exercised by evaporation upon the temperature of vegetable substances, we resolved to have recourse to experimental proof of a direct nature. For this purpose an experiment made by Dr. Hales (Statistical Essays, exp. 30) upwards of a century ago, was repeated with such modifications as to suit our purpose.

A green apple, about $1\frac{1}{2}$ inch in diameter with a cluster of leaves, was plucked from the tree; and the stem introduced through a cork into a glass tube filled with water, to the lower end of which a smaller tube was cemented, the extremity passing downwards into a cistern of decoction of logwood; the apparatus being supported in the vertical position by a retort-stand, as represented in the sketch; and being found air-tight, the following experiments were made. The temperature of the apple was estimated at given intervals with the thermo-electric pair, at the same time the drying power and elevation of the coloured fluid in the smaller tube was examined, and the measures tabulated for the purpose of examining the connexion of these phenomena at a *coup d'œil*. A further experiment was then made by covering the apple and its leaves with a delicate caoutchouc bag, so as to arrest evaporation, and after a given interval examining the temperature of the fruit and elevation of the coloured fluid. These experiments were repeated many times, but it is unnecessary to adduce more than two series in this place.

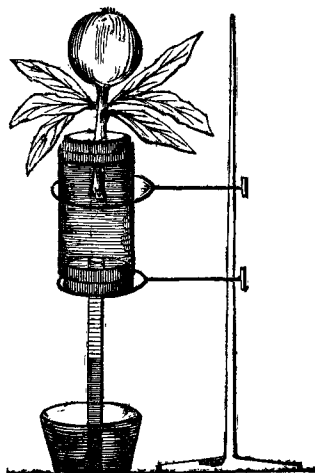


Table H.

June 14th. An apple with twelve leaves, examined immediately after collection at 1^h 45' p.m.

Examined at intervals of	Height risen in interval.	Galvano. meter.	Temp. by Therm.	Dew. point.	Drying power.	State of the Atmosphere.
15'	$\frac{8}{100}$ inch.	0	84 F.	64	20	Cloudy.
18'	$\frac{9}{100}$	+ .5	84	65	19	Very cloudy.
15'	$\frac{5.5}{100}$	+ 3.6	80	63	17	Thunder, &c.
15'	$\frac{5}{100}$	+ 5.5	76	63	13	Rain storm.

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After a delay of 12' the caoutchouc bag was used and tied tightly around the stem, and after 17' the bag was pierced by the electric pair, the results being,—

Examined at intervals of	Height risen in interval.	Galvano-meter.	Temp. by Therm.	Dew-point.	Drying power.	State of the Atmosphere.
17'	$\frac{6}{10}$	+13.75	80	67	13	Clear.

Beyond this period it is impossible to examine the gauge, for the included stem begins to give off gas into the water, and therefore partially arrests the ascent of the coloured fluid.

Table I.

June 15th. Experiment as before, time of collection 9^h 35'.

Examined at intervals of	Height risen in interval.	Galvano-meter.	Temp. by Therm.	Dew-point.	Drying power.	State of the Atmosphere.
9 ^h 35'	0	—3.0	73	53	20	Fair.
20'	$1\frac{1}{10}$ inch.	—2.5	72	55	17	Cloudy.
35'	$1\frac{6}{10}$	—1.6	72	57	15	Cloudy.

The fruit and leaves were entirely covered with the caoutchouc at 10^h 40', and pierced after 35' delay.

35'	$\frac{7}{10}$	+15.0	74	59	15	Cloudy.
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The coldness of the fruit in the three first measures of the table I. was due to the presence of a little external moisture, and the greater temperature of the room than the external air.

In both these tables the effect of arresting the evaporation is extremely apparent by an elevation of $8\frac{1}{4}^{\circ}$ and $16^{\circ}6$ respectively; it is to be observed, however, that the drying power given in the two additional tables represent the external and not internal measure; the saturation within the caoutchouc-bag being probably greater. In the table H. there is another coincidence worthy of remark, the gauge marks a decreasing power of suction on the part of the apple as its temperature increases and the evaporation decreases, showing a compensation between the amount of perspiration of the leaves and fruit and the supply of fluid.

Without detaining the reader, it appears that the foregoing tables prove,—

1st. *That the temperature varies with the drying power.*

2ndly. *That the amount of evaporation and its effects in pro-*

ducing coldness is directly as the greatness of the drying power, and inversely as the approximation of the dew-point to the atmospheric temperature.

§ 3. *The sensible heat of plants is directly as the atmospheric temperature and the chemical action going on in their cells, and inversely as the radiation, evaporation and conduction together, &c. (p. 1.)*

We have introduced this postulate rather to give completeness to the subject than to enter into any lengthened examination. That it is true, can be readily shown by a few references to the foregoing tables; the proofs drawn may be conveniently ranged under three heads:—

1st. The temperature of plants varies nearly with the atmosphere, the greatest difference measured being about 5° Fahrenheit.

2ndly. The parts in which the greatest exhibitions of temperature above the air have been witnessed are the seat of active chemical and organic action, as the ovaries, male spadix, midrib of leaves, &c., the stem being seldom above or below the external temperature.

3rdly. Roots and subterrene stems are of the same temperature as the soil, and generally below the atmosphere, in consequence of evaporation taking place from the earth. This diminished temperature in the plant must depend partly upon conduction. That vegetables also lose heat by radiation, is shown by the copious deposit of dew seen upon their leaves after a clear chilly night.

§ 4. *A review of the subject, with some remarks on apparent anomalies.*

Since the preceding experiments were made there has been published in the *Journal de Chimie*, an article on vegetable heat by M. Dutrochet*. He inclosed a dead and living plant in an atmosphere saturated with moisture, and examined their temperature with Breschet's physiological pair. The result of his experiments brought him to the conclusion, that living plants possessed a temperature that exceeded the atmospheric temperature by one-third centigrade as a maximum. Van Beck has since repeated the experiments of M. Dutrochet and arrived at an opposite conclusion, viz. that the living plant betrayed two-thirds centigrade as a maximum below the dead plant.

Independently of the discordance in these measures, we cannot understand how a plant can be said to possess a spe-

* The author did not see the original paper, but an extract in the Edinburgh Philosophical Journal of Professor Jameson, 1840.

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cific temperature that varies within one-third plus or minus the atmospheric temperature, which may be 90° Fahr. at noon, and 40° in the evening. The real cause of the elevation or depression measured, is to be found in the more or less perfect saturation of the atmosphere in which the experiments were conducted. There is, however, a great difference between the amount of heat measured by M. Dutrochet and myself; but whatever may be the cause of the discrepancy, the measures given in the tables are certainly free from error, since most of them were authenticated by the simultaneous examination of my friends at Hampden Sidney College.

We are much more concerned by the apparent anomalies exhibited by Nature. Why are not all plants destroyed by frost? Why do not tubers, bulbs, &c. perish during winter? For if there be no specific heat in these organized substances, their fluids should freeze and thereby produce disorganization. In reply to this we remark, that the fluids of vegetables congeal at temperatures below the freezing point of water in consequence of the presence of mucilage and acids, &c. Again, the degree of succulence of the plant and strength of the tissues, as well as their non-conducting nature, must not be lost sight of. It is remarkable that all northern evergreens have more or less coriaceous leaves. The vegetation of countries invaded by cold is hardier than that found in the tropics; in the former localities the majority of plants are annuals or perennials, or trees which cast their leaves; whilst in the south evergreen trees abound which are incapable of enduring exposure to one frost. Our trees are often found with their sap frozen without the texture being destroyed; and in the *Annales de Chem. et de Phys.*, tom. xv. p. 84, there is an account of a parcel of young trees which were kept in a frozen state for twenty-one months and yet finally vegetated when gradually thawed and planted out, showing conclusively that the woody fibre resisted the disruptive force of the expanding water when in the act of freezing. The non-conducting nature of the bark and wood is another powerful protection; we witnessed a poplar tree cut down in the depth of winter; on the northern side of the trunk the wood was quite dry and the sap probably frozen, whilst on the southern exposure the sap was fluid: this fact proves the necessity of paying every attention to the exposure of trees which are transplanted in the winter, especially evergreens.

Many roots, tubers, bulbs, &c. may be exposed with apparent impunity during winter, but if we examine the conditions necessary to secure them, it is found that they must be either covered with soil or are naturally of a dry and amylaceous

nature. The protective power of a slight covering of soil or vegetable matter is extraordinary; some potatoes were covered with about two inches of earth and others left exposed on the surface of the ground at the same spot of the garden in November; a frost occurred at night, the thermometer sinking to 28° Fahr., and it was found that all the uncovered potatoes were frozen, their cellular tissue being broken up; whereas the buried specimens were entirely free from the action of the cold. The temperature of springs is worthy of notice as a proof of the non-conducting nature of the earth, whereby it is well calculated to preserve organic structures from the effects of frost.

These conjectures are advanced not as satisfactory arguments against the apparent objections detailed, but only as throwing out hints for future researches. These objections do not invalidate our measures, for they are demonstrable. The deductions may be in error, but we are content to offer the experiments as a contribution to the science of botany.

D. P. G.

II. *Notices of the Results of the Labours of Continental Chemists.* By Messrs. W. FRANCIS and H. CROFT.

[Continued from vol. xx. p. 225.]

On the Oils of Fennel, Anise, and Star-anise (Illicium anisatum).

M. CAHOURS has examined the stearopten of these three oils, and has found them to be perfectly identical; the substance used for the experiments was generally made from the oil of anise, because from this oil it can be obtained in larger quantities than from either of the others. The solid oil can be very easily obtained pure by expression and crystallization in alcohol. It crystallizes in white shining leaves. Its specific gravity is nearly equal to that of water. It is pulverisable at 0°, melts at 18° C., and boils at 222°. On being converted into vapour it appears to suffer some change, so that the observed density of the vapour does not agree with that calculated from the formula. In a solid state it is not changed by exposure to the air, but if kept fluid for a length of time it is converted into a resin; chlorine and bromine act violently on it; alkalies have no action except when employed in the manner proposed by Dumas and Stass, in which case an acid product is obtained. Strong acids, as the sulphuric, phosphoric acids, &c., change it into an isomeric body. The atomic weight of the solid anise oil was determined by measuring the quantity of hydrochloric acid absorbed by it. The formula is $C^{20} H^{24} O^2$.