

round the parenchyma of that organ, yet there is to be seen in many preparations a curious similarity in that respect also.

The present communication does not go beyond a statement of points of resemblance. The *corpus luteum*, which enters so largely into the comparison, is itself as much an unsolved problem as the suprarenal. It may be said, however, to afford better opportunities of study; and if the resemblance above outlined be a resemblance in essentials, a sound theory of the suprarenal as a whole will probably be found to depend upon a sound theory of the *corpus luteum*.

December 13, 1877.

Sir JOSEPH HOOKER, K.C.S.I., President, in the Chair.

The Presents received were laid on the table, and thanks ordered for them.

Among the Presents was a transparent positive photograph of the sun on glass, taken at Meudon by M. Janssen, For. Mem. R.S., and presented by him to the Society.

Pursuant to notice given at the last Meeting, Marcellin Berthelot, Joseph Decaisne, Emil Du Bois-Reymond, Adolph Wilhelm Hermann Kolbe, Rudolph Leuckart, Simon Newcomb, and Pafnutij Tscheybyschew were balloted for and elected Foreign Members of the Society.

The following Papers were read:—

- I. "On Electrostriction." By EDMUND J. MILLS, D.Sc., F.R.S., "Young" Professor of Technical Chemistry in Anderson's College, Glasgow. Received August 7, 1877.

If the bulb of an ordinary thermometer be coated chemically with silver, and then electrically with a metallic deposit, the mercury will traverse some portion of the scale, and finally take up a definite position, independently of temperature. To this phenomenon I have given the name *electrostriction*. Of the metals hitherto worked with, copper, silver, iron, and nickel constrict the bulb; zinc and cadmium distend it.

The general conditions under which the experiments were made were as follow:—A thermometer coated with silver by immersion in a solution of ammoniacal argentic tartrate was placed vertically near a bare thermometer at one side of a depositing cell; the anode stood at a distance of 11 centimetres. The bulbs of the thermometers were about their own depth below the surface of the electrolyte; the covered one was turned half round at every comparison. The source of electricity was a pint

Daniell's cell, having a porous diaphragm, and the circuit included a galvanoscope. Observations were made at definite intervals of time, immediately after stirring the liquid; and the difference between the two scales, after suitable reduction, was registered as electrostrictive effect. The temperature was in all cases the unrestricted temperature of the laboratory.

Copper.—The thermometer ("454") first used had a cylindrical bulb, which was slightly concave towards its vertical axis. The electrolyte consisted of the ordinary acidified solution of cupric sulphate, containing zincic sulphate.

In the following Table the column below x contains the time in hours; that below y the number of scale-units ("degrees" C.) remaining to be traversed. The latter are compared with a series of values calculated from the equation—

$$y = 9.859 (.96363)^x + 1.358 (.71841)^x.$$

TABLE I.

x .	y .	y calc.	Temp.
1	10.520	10.476	12.2
2	9.917	9.856	12.9
3	9.316	9.325	13.9
4	8.822	8.863	14.7
5	8.467	8.452	15.5
6.5	7.825	7.907	16.1
8	7.359	7.427	16.7
9	7.276	7.133	17.4
10	6.979	6.856	18.1
48	2.302	1.665	12.2

Mean temperature 15.0

The difference between experiment and calculation in the last value of y is doubtless due to the considerable amount of stratification observed in the electrolyte, which had not been stirred subsequently to the last observation. Omitting this result, the probable error of a single comparison of the calculated with the found values of y is .056. The calculated total ascent is 11.22 scale-units. By continuing the preceding experiment, but with two Daniell's cells, for $23\frac{1}{2}$ hours longer, 10.933 units were actually attained.

A thermometer ("502") having a very nearly spherical bulb was next employed; its polar axis (a line representing the prolongation of the mercurial thread) measured 11.73 millimetres, its equatorial axis 11.55 millimetres. This instrument was prepared in the same manner as the preceding, immersed vertically in the electrolyte, and turned halfway round every half-hour. Even deposition on a sphere is, under such circumstances, out of the question, most of the metal being precipitated on

its equatorial, and much less on the polar regions. The registered rise was the height of the mercury in melting ice. After the twenty-second hour, and as soon as the scale had been read with the kathetometer, the mercury rose spontaneously 0.16 of a unit. The subsequent observations are accordingly lessened by this amount. The equation is—

$$y = 9.728 (\cdot 87074)^x - 4.979 (\cdot 83117)^x.$$

TABLE II.

x .	y .	y calc.	Temp.
1	4.613	4.332	16.2
2	3.996	3.936	16.6
3	3.556	3.563	16.8
4	3.270	3.216	15.7
5	2.941	2.894	16.5
7	2.321	2.328	15.5
9	1.815	1.856	14.7
11	1.462	1.471	12.7
13	1.242	1.159	15.7
15	0.973	0.909	16.3
17	0.708	0.710	17.2
19	0.553	0.553	17.2
21	0.475	0.430	15.2
23	0.335	0.332	16.5
25	0.251	0.257	14.5

Mean temperature 15.8

The above values of x are convertible into hours by multiplying by 2.

The probable error of a single comparison of theory with experiment is .057. After the fiftieth hour the operation was left unattended for 28 hours, when an additional rise of .25 was found to have taken place.

On other occasions an ascent of 12.87 was obtained, with thermometer 454, in twenty-four hours, the thickness of the deposit being approximately .29 millimetre. An ascent of 11.50 was also observed with thermometer 455, the thickness of metal being probably not less than a millimetre. The zero of thermometers was found to be nearly the same after electrostriction and stripping as at first; it had not risen more than 0°.03.

Silver.—Thermometer 454, slightly coated with silver by electro-deposition, was used in the following experiments: the coating was first sand-papered and polished. Observations were made and the thermometer semirotated every half-hour until the fifth hour; the electrolyte was not stirred between the fifth and twenty-third hours, but after this interval the ordinary course of observations was resumed. The equation is—

$$y = 10.826 (\cdot 96179)^x + 1.535 (\cdot 82044)^x.$$

TABLE III.

<i>x</i> .	<i>y</i> .	<i>y</i> calc.	Temp.
1	11.670	11.671	19.1
2	11.010	11.047	19.7
3	10.517	10.479	20.2
4	10.062	9.959	20.6
5	9.400	9.480	20.7
23	4.358	4.435	15.1
24	4.250	4.263	15.7
25*	4.193	4.099	16.3

Mean temperature 18.4

The probable error of a single comparison is .047.

Iron.—The bulb of thermometer 455 was prepared as usual, and then coated during two hours with copper. Electro-deposition of iron was next proceeded with, and the following results recorded. Between the third and fourth hours a slit was seen to form at the bottom of the bulb, and gradually extend to the shoulder.

TABLE IV.

Hours.	Total ascent.	Temp.
1	0.883	17.5
2	1.775	17.3
3	2.193	17.4
4	1.648	17.6

It must be extremely difficult to obtain a coating of iron of any considerable thickness.

Nickel.—Thermometer 454 was used. The anode and kathode were 95 millimetres apart. The electrolyte consisted of a neutral solution of ammonio-nickelous sulphate; the anode of nickelous carbide.

TABLE V.

Hours.	Total ascent.	Temp.
2	0.096	18.6
3	0.474	19.2
4	0.759	19.8
5	0.856	20.6
6	2.314	19.8
24		

When last observed the deposit had split outwards, beginning at the side opposite the anode.

* Mean of 24.5 and 25.5.

Zinc.—Two pint Daniell's cells were employed, and thermometer 454. The results were as follows :—

TABLE VI.

Hours.	Total descent.	Temp.
0·5	0·352	12·4
1·0	0·308	12·5
1·5	0·366	12·7
2·5	0·404	13·2
3·5	0·382	13·8
4·5	0·574	14·5
47·0	0·749	11·6

It is probable, from the graphic projection of these numbers, that the descent attained after the forty-seventh hour would have been little, if at all, exceeded by prolonging the experiment.

Cadmium.—The conditions were those of the preceding set of observations.

TABLE VII.

Hours.	Total descent.	Temp.
1·0	0·185	15·0
2·0	0·274	15·5
3·0	0·164	15·8
5·0	0·166	16·8
23·5	0·207	15·3

At the end of the experiment the deposit was found to be somewhat corrugated, but fairly satisfactory. The electrolyte had the disadvantage of being freshly prepared, and not having been continuously worked prior to this deposition.

Value of the Electrostrictive Effect.

In order to ascertain the value of the electrostrictive effect, thermometer 454 was adjusted in a water-pressure apparatus capable of indicating about $2\frac{1}{4}$ atmospheres: it was then submitted to uniform compression, and the resulting ascent of the mercury in its stem noted. Two sets of observations at higher pressures showed, after the usual reductions, that a unit of scale corresponded to 8·2 and 8·5 atmospheres respectively; the mean is 8·3 atmospheres. After this the bulb of the instrument was unfortunately broken, while preparing it for considerably increased compression. I have, however, little hesitation in accepting this result as a datum for calculating the total electrostrictive effect at much higher readings. Similarly with thermometer 502, a depression of 0°·199 C. was caused by opening; this would correspond to 5·03 atmospheres per scale-unit. Again, ten experiments with thermometer 455 were conducted in an Andrews's duplex apparatus (a most admirable

instrument for such a purpose), at pressures varying from 49·4 to 133·6 atmospheres. By these it was found that a scale-unit corresponds, in this case, to 9·44 atmospheres, with a probable error of 0·1 atmosphere for a single determination.

The above data have led to the construction of the following table.

TABLE VIII.

Metal.	Therm.	Effect.	Extreme effect	
			in scale-units.	in atmospheres.
Cadmium	454	Distension	0·274	2·3
Zinc	"	"	0·749	6·2
Nickel	"	Compression	2·314	19·2
Iron	"	"	2·193	18·2
Silver	"	"	8·006	66·4
Copper	"	"	10·933	90·7
"	"	"	12·87	106·8
"	502	"	14·707*	74·0 †
"	455	"	11·50	108·5

It thus appears that the extreme force at work on the bulbs must have been very considerable.

Subsidiary Experiments and Remarks.

(1) An instrument having a general resemblance to a thermometer was constructed with a cylindrical caoutchouc bulb, about 30 millimetres long by 11 millimetres wide. The bulb was rendered conductive, and then made a kathode in the copper bath already referred to; it was frequently turned half round. In the course of a day it had become coated with a sufficiently thick layer of metal, and had then undergone most palpable collapse. We have here, therefore, a real case of local constrictive effect.

(2) Two flat microscopic slides of the usual size were silvered chemically and then made the kathode in a similar circuit. After twenty-four hours, the deposited copper on both slides was found to be arched downwards and inwards, towards the anode; the deposits were in fact, owing to their contiguity, to a great extent united. The upper parts of the deposits had torn themselves away from the glass; and two close parallel lines cut through the silver of one of the plates had the copper between them curled inwards like a gutter. From this evidence it was inferred that the cylindrical deposit, if cut in the direction of its length, would spring open. Such was found to be actually the case even with the copper deposited on the caoutchouc bulb; and to a still greater extent with copper overlying some of the same caoutchouc, where that material was stretched over a glass shoulder for the purpose of fastening, and there did not admit of collapse. The opening backwards of nickel and iron films has already been noticed.

* Calculated. † This number may be wrong in either direction by $1\frac{1}{2}$ atmosphere.

(3) The electrostrictive effect brings vividly to the mind the ordinary phenomenon of contraction during cooling—differing, perhaps, but little from that phenomenon, except in the circumstance that it is brought about without necessary change of temperature. The electrolyte is, in a manner, a melted metal. This view did not, of course, admit of experimental illustration in the case of the metals to which reference has been made. It was, however, conceived that substances other than metallic should yield the result in question, and a specimen of hard paraffin was selected for trial. This was heated to a point not far from that of fusion, and thermometer 454 was dipped into it several successive times. The following table shows the constriction obtained.

No. of dip.	Total ascent.	Temp.
1	·256	49 ^o
2	·444	30
3	·633	—
4	·447	30
5	·369	30
6	·321	30

These results were confirmed by a second set of experiments. In each set, the coating of paraffin was found to be vertically fissured before the conclusion of the observations; this accounts for the gradual diminution of the effect.

(4) Electrostricting metal appears to be in a partially unstable condition. Thus a decided fall is observable in a coated thermometer after the deposit has had its surface disturbed by sand-papering or filing; this was noticed both with silver and copper. On the other hand, the constrictive effect is increased by heating the deposit to 100°, or by keeping in ice. Thermometer C, for example, having had its zero raised electrostrictively to 3°·52, showed an elevation to 5°·00 after heating for ten minutes to 100°, afterwards falling permanently to 4°·86. Thermometer 50 had its zero raised in a similar manner to 1°·87; this was increased to 2°·96 by a temperature of 100°. In another experiment with the same thermometer, a like increase from 0°·65 to 0°·79 was recorded; the latter number rose spontaneously to 0°·90 in the course of six months. Again, two similar thermometers (103 and 104) were electrostricted at about 10° C., and the zero was found to rise by heating, as before. The zero of 103 then fell gradually, during nine months, from 4°·73 to 4°·37; that of 104 fell during two months from 2°·01 to 1°·80, and then rose during seven months to 2°·14. Thermometer 101, made exactly on the same pattern, but left uncoated, exhibited the usual continuous ascent of zero during the same period, viz. from 0°·07 to 0°·31 in nine months. *All three thermometers showed identical and normal readings at 100°.* Facts like these prove that the nature of the deposit requires further elucidation. In any case the best evidence of electrostrictive effect is gained,

with copper at least, at the melting-point of ice; and it is not improbable that copper deposited at or near 100° would not show any such effect at any temperature. One circumstance may be mentioned as bearing on this point, viz. that the electrostrictive effect is greater, and more rapidly produced, at the winter temperature than at that of summer. It may be added that soft metallic deposits are, as a rule, obtained from heated electrolytes.

(5) Uniform external pressure on a cylinder takes effect chiefly on the diameter, and less on the length; and these results are practically independent of each other*. If we conceive such pressure to be produced by the electric deposition of successive layers of metal (as was actually the case with thermometer 502), it seems reasonable to suppose that each of the layers will have nearly the same constrictive effect. But the first layer constricts the bulb alone; the second constricts the first also; the third its predecessors, and so on. Hence the observed effect upon the bulb should diminish at compound interest. If y be the total obtainable effect after a time x , D the portion of it due to diametral constriction, L the portion of it due to longitudinal constriction, and d and l the respective geometric factors, we have, in the case of the cylindrical thermometer,

$$y = Dd^x + Ll^x,$$

D being always greater than L . On the other hand, the spherical thermometer necessarily receives more metal upon its equatorial region than can be deposited above or below, that region being nearer to the anode; and the longitudinal constrictive action must tend to bulge the equatorial part, opposing the constriction at work there.

Hence we have, for the sphere,

$$y = Dd^x - Ll^x,$$

D being the greater as before. Nevertheless it appears probable that in both cases, at the early stage of deposition, the difference between diametral and longitudinal compression is but slight, not having yet been much multiplied by the increased stress. Hence, during that period, an equation

$$y = Dd$$

may doubtless more accurately represent the experimental results. Subject to this and some other minor considerations (the close discussion of which would be out of place in mere indicative work) there is a fair agreement between theory and experiment. The probable error, in fact, of a single observation does not on the whole exceed .053 of a scale-unit, being about .4 per cent. on the total quantity determined; and this reduces to less than .3 per cent., if we exclude the first comparisons made at a lower temperature, in Table I.

* Fairbairn, Phil. Trans. 1858, p. 404.

(6) We have seen in (4) that metals may be deposited on a thermometer bulb and then deprived of a determinate part of their electrostrictive power, and that there is an experimental possibility of depositing them with none of this effect. We are therefore in a position to compare, one with the other, the two states of the same metal. The electrostricted metal (submitted, as may have been the case, to more than a hundred atmospheres' compression) must oppose the effect of a solvent much more than that which is soft and no longer the subject of electrostriction. In other words, a gramme of the former should require more of a reagent to dissolve it than should the latter, under the same conditions. But this excess corresponds to a known amount of electrostrictive effect, which, again, is known in atmospheres pressure. We ought therefore to be in a position to measure chemical effect in atmospheres pressure.

My best thanks are due to Professor Sir William Thomson for the loan of an Andrews's apparatus; to Professor George Forbes, for a pressure machine; and to Mr. W. H. Walenn for much practical advice in connexion with electro-metallurgy.

II. "The Examination of Air." By R. ANGUS SMITH, Ph.D., F.R.S. Received August 11, 1877.

It is now many years since I first began to examine air so as to obtain decidedly those bodies which have from the earliest times been supposed to exist in it, bringing with them, on certain occasions, some of the worst results. About eight years ago (that is, in 1869), after giving a short summary of some of my work in the *Journal of the Scottish Meteorological Society*, I used these words:—"For a satisfactory investigation of the subject, one must look to the multiplication of these experiments, and perhaps to the establishment of a department at some Observatories for Chemical Climatology and Meteorology."

Afterwards, in 1872, I published an octavo volume on *Chemical Climatology*, embodying many of my results, and intended to be a beginning of work to be continued by a public body. Indeed some of the work was done whilst I was acting under the Government and was published in Government Reports. It was often my intention to begin a movement which might result in a fuller recognition of the claims of Chemical Climatology; but I have not gone further than speaking of it to Mr. Scott, and proposing it to the Local Government Board, since the time when I published the proposal alluded to; at least I may say I have not gone further in a distinct public manner.

I should have been glad had my work caused in this country a beginning such as has been made lately at the observatory of Mont Souris, at Paris, or at least resembling it; and I blame myself for not pushing forward the idea,