Note on the Iodobromite of A. v. Lasaulx

IN the *Jahresberichte für Mineralogie* for 1878 A. v. Lasaulx has described a new silver haloid mineral, having the composition Ag_2Br_2, Ag_2Cl_2, AgI, or $Ag_5Cl_2Br_2I$, which he cites as the first instance of the three haloids occurring crystallised together in nature. Several chloro-bromides of silver have been found in Chili in the silver mines of Chañarcillo, and, according to Dana, an iodobromide has also been detected. The present mineral, which should be called *chlorobromiodide*, was found associated with beaudantite in a mine in the district of Ems, Nassau, in the form of small yellow or olive green octohedrons never exceeding 3 mm. in size. The crystals are very malleable, and can be pressed flat with the blade of a knife, and they possess a good deal of lustre. On analysis they were found to contain:—

Silver	59·96
Iodine	15·05
Bromine	17·30
Chlorine	7·09
	99·40

In 1876 I prepared some of this substance artificially by fusing together the chloride, iodide, and bromide in the proportions of AgI 26·1692, AgBr 41·8708, AgCl 31·9600, which gives an ultimate composition of:—

Silver	60·1336
Iodine	14·1435
Bromine	17·8176
Chlorine	7·9053
	100·0000

The substance was prepared with other chlorobromiodides of silver in order to see the extent to which iodide of silver (which contracts considerably when heated from 142° to 145·5° C.) modifies the coefficient of expansion of the chloride and bromide, which do not present similar anomalies. The results obtained are given in the *Proc.* of the Royal Society, vol. xxv. p. 294, 1877, "On the Effects of Heat on some Chlorobromiodides of Silver," and they are of additional interest now that the substance has been found in nature.

The compound artificially prepared is a brittle yellowish-brown solid, giving a bright primrose-yellow powder, which turns green on exposure to light. (It is noticeable that some of the crystals found by Lasaulx were yellow, others green.) It is a crystalline solid which emits loud harsh noises while cooling from the molten condition. The fusing point is 330° C. The sp. gr. 6·152 when cooled quickly, but when fused and allowed to cool slowly in hot paraffine, the sp. gr. fell to 6·066. A. v. Lasaulx makes the sp. gr. of the mineral as low as 5·713. The artificially prepared compound was found to possess a coefficient of cubical expansion for 1° C. = 0·00012216 between 0° C. and 125·5. Between 125·5 and 131·5 it underwent slight contraction, while between 131·5 and the fusing point the coefficient was 0·0001 5882. It possesses two points of similar density, the one at 131·5° C., the other at or about 123° C. The volumes calculated from the coefficients, taking volume at 0° C. as unity, were found to be:—

Volume at	0° C.	= 1·000000
,,	125·5°	= 1·015331
,,	131·5°	= 1·015037
,,	330°	= 1·046666 (solid)
,,	330°	= 1·104050 (liquid)
,,	750°	= 1·177979

It is presumable that the other artificially-prepared chlorobromiodides described in the paper cited above will also be found in silver mines.

G. F. RODWELL

Inherited Memory

HAVING had my attention called, of late, to the subject of the migration of birds, I have of course been interested in the discussion between Dr. Weismann and Prof. Newton, and I cannot help fancying that I have hit on the "missing link" which connects the theory of the former with the facts of the latter.

Are there not scientific men (and is not Dr. Carpenter one of them) who consider that when we say an event has made "such an impression on us that we shall never forget it"—we are not merely using a metaphor, but stating a fact? Now if something analogous to "making an impression" on the brain really takes place whenever we commit anything to memory—is it not possible that if the impression be deeply fixed, the impressed brain may be transmitted by the parent to the offspring, who thus "inherits" its ancestor's memory?

When we remember that birds take the same journey year after year, generation after generation, century after century, nay, even for ages after ages, I think we shall feel that there are more marvellous things in nature than what I am asking you to consider, namely, the possibility that the young bird at last inherits a knowledge of the way, and is capable of performing the journey alone.

If "inherited memory" be accepted as a fact, what a flood of light is thrown on many puzzles which have hitherto been classed as "instincts"; such as the building of birds' nests; the pointing of pointer puppies, the knowledge possessed by young animals of right and wrong food, and of friends and enemies; I am not sure that it will not even throw light on some mysteries in human nature. When I was a child I had a dread of wolves (a very common thing with children), and I find the dread reproduced in one of my own children. Yet wolves have been so long extinct in England that we should probably have to go back many generations before we met with the nurses who quieted crying children by threatening to give them to the wolves. May not this be a case of "inherited memory?"

A. B.

Intellect in Brutes

SOME years ago the late Hon. Marmaduke Maxwell, of Terregles, took me to his stable to show me a cat which was at the time bringing up a family of young rats. The cat some weeks previously had a litter of five kittens, three were taken away and destroyed shortly after their birth; next day it was found that the cat had replaced her lost kittens by *three* young rats which she nursed with the two remaining kittens; a few days afterwards the two kittens were taken away, and the cat very shortly replaced them by *two* more young rats, and at the time I saw them, the young rats—which were confined in an empty stall—were running about quite briskly, and about one-third grown. The cat happened to be out when we went into the stable, but came in before we left; she immediately jumped over the board into the stall, and lay down; her strange foster-family at once ran under her and commenced sucking. What renders the circumstance more extraordinary is, that the cat was kept in the stable as a particularly good ratter.

Cargen, Dumfries, May 9

P. DUDGEON

Phosphorescence

IN regard to the effect of heat on phosphorescence, your correspondent in last week's number will find that almost similar phenomena have been observed by Dr. Draper, who treats of the whole subject very fully and satisfactorily in his "Scientific Memoirs."

G. S. THOMSON

Clifton, May 18

AN INDUCTION-CURRENTS BALANCE[1]

IMMEDIATELY upon the announcement of Arago's discovery of the influence of rotating plates of metal upon a magnetic needle (1824), and Faraday's important discovery of voltaic and magneto-induction (1831), it became evident that the induced currents, circulating in a metallic mass, might be so acted upon either by voltaic or induced currents as to bring some new light to bear on the molecular construction of metallic bodies.

The question was particularly studied by Babbage, Sir John Herschel, and by M. Dové,[2] who constructed an induction balance, wherein two separate induction coils, each having its primary and secondary coils, were joined together in such a manner that the induced current in one coil was made to neutralise the induced current in the opposite coil, thus forming an induction balance, to which he gave the name of differential inductor. In those days physicists did not possess the exquisitely sensitive galvanometers and other means of research that we possess to-day, but sufficiently important results were

[1] "On an Induction-Currents Balance, and Experimental Researches made therewith." By Prof. D. E. Hughes. Read at the Royal Society, May 15.

[2] De la Rive, "Treatise on Electricity," vol. i. chap. v. (London, 1853)

obtained to prove that a vast field of research would be opened if a perfect induction balance could be found, together with a means of correctly estimating the results obtained. In experimenting with the microphone I had ample occasion to appreciate the exquisite sensitiveness of the telephone to minute induced currents. This led me to study the question of induction by aid of the telephone and microphone. The results of those researches have been already published.[1]

Continuing this line of inquiry, I thought I might again attempt to investigate the molecular construction of metals and alloys, and with this object I have obtained, after numerous comparative failures, a perfect induction balance which is not only exquisitely sensitive and exact, but allows us to obtain direct comparative measures of the force or disturbances produced by the introduction of any metal or conductor.

The instrument which I have the honour to present to the Royal Society this evening, consists (1) of the new induction-currents balance; (2) microphone, with a clock as a source of sound; (3) electric sonometer, or absolute sound measurer, a late invention of my own; (4) a receiving telephone and three elements of Daniells' battery.

In order to have a perfect induction-currents balance suitable for physical research, all its coils, as well as the size and amount of wire, should be equal. The primary and secondary coils should be separate, and not superposed. The exterior diameter of the coils presented this evening is $5\frac{1}{2}$ centims., having an interior vacant circular space of $3\frac{1}{2}$ centims., the depth of this flat coil or spool is 7 millims.

Upon this box-wood spool are wound 100 metres of No. 32 silk-covered copper wire. I use four of such coils, formed into two pairs, the secondary coil being fixed permanently, or by means of an adjustable slide, at a distance of 5 millims. from its primary; on the second similar pair there is a fine micrometer screw, allowing me to adjust the balance to the degree of perfection required.

These two pair of coils should be placed at a distance not less than 1 metre from each other, so that no disturbing cause should exist from their proximity.

The two primary coils are joined in series to the battery, the circuit also passing through the microphone.

In place of the telephone I have sometimes used a magnetic pendulum, the swing or the arc described indicating and measuring the forces.[2] I am at present engaged upon a very sensitive voltameter, which shall indicate and measure the force of rapid induced currents. The telephone, however, is well adapted as an indicator, but not as a measurer of the forces brought into action. For this reason I have joined to this instrument an instrument to which I have given the name of electric sonometer. This consists of three coils similar to those already described, two of which are placed horizontally at a fixed distance of 40 centims. apart, and the communication with the battery is so arranged that there are similar but opposing poles in each coil; between these there is a coil which can be moved on a marked sliding scale divided into millimetres; in a line with these two opposing primary coils, the centre coil is the secondary one, and connected by means of a circuit changing key with the telephone in place of the induction-balance. If this secondary coil is near either primary coil we hear loud tones, due to its proximity. The same effect takes place if the secondary coil is near the opposing coil, except that the induced current is now in a contrary direction, as a similar pole of the primary acts now on the opposite side of the induction-coil; the consequence is that as we withdraw it from one coil approaching the other, we must pass a line of absolute zero, where no current whatever can be induced, owing to the absolute equal forces acting equally on both sides of the induction-coil. This point is in the exact centre between the two coils, no matter how near or distant they may be. We thus possess a sonometer having an absolute zero of sound; each degree that it is moved is accompanied by its relative degree of increase; and this measure may be expressed in the degrees of the millimetres passed through, or by the square of the distances in accordance with the curve of electro-magnetic action.

If we place in the coils of the induction-balance a piece of metal, say copper, bismuth, or iron, we at once produce a disturbance of the balance, and it will give out sounds more or less intense on the telephone according to the mass, or if of similar sizes, according to the molecular structure of the metal. The volume and intensity of sound is invariably the same for a similar metal. If by means of the switching-key the telephone is instantly transferred to the sonometer, and if its coil be at zero, we should hear sounds when the key is up or in connection with the induction-balance, and no sounds or silence when the key is down or in connection with the sonometer. If the sonometer-coil was moved through several degrees, or through more than the required amount, we should find that the sounds increase when the key is depressed; but when the coil is moved to a degree where there is absolute equality, if the key is up or down, then the degree on scale should give the true value of the disturbance produced in the induction-balance; and this is so exact that if we put, say, a silver coin whose value is 115°, no other degree will produce equality. Once knowing, therefore, the value of any metal or alloy, it is not necessary to know in advance what the metal is, for if its equality is 115°, it is silver coin; if 52, iron; if 40, lead; if 10, bismuth; and as there is a very wide limit between each metal, the reading of the value of each is very rapid, a few seconds sufficing to give the exact sound-value of any metal or alloy.

During the course of these experiments with this instrument I noticed that my own hearing powers varied very much with state of health, weather, &c., that different individuals had wide differences of hearing, and that nearly in all cases one ear was more sensitive than the other; thus whilst my degree of hearing was 10°, another might be 60 in one ear and 15 in the other.[1]

Dr. Richardson, F.R.S., who upon my invitation investigated this subject, became so impressed with the value of the instrument as an absolute measurer of our hearing powers, and its capabilities of throwing much light upon its relation with health, that he has undertaken a series of researches which will extend over some time, and which I think, from some facts already gained, will be of great value to the medical profession. These experiments are now in his very able hands, and he will in due time announce the results to the Royal Society.

If an observer's hearing is limited to 10°, how can we hear results below this line? I should have stated that when used to measure the hearing power, we determine on a constant standard of force such as one element Daniell, but if we increase the number of elements we in the same ratio increase the inductive disturbance, and thus by a large increase of force bring within our range results too feeble to be heard without its aid, the sonometer constantly, however, giving the same degree for equality as the increased force is also used on this instrument. Thus in our measurements we can entirely neglect the amount of battery, as its comparative results remain a constant.

As a rule three Daniell elements will be found quite sufficient, and even this weak force is so exquisitely sensitive that it will find out the smallest fraction of difference in weight or structure of metals. Thus two silver coins such as a shilling, both quite new, and both apparently of the same weight, will be found to possess a

[1] *Comptes Rendus*, December 30, 1878, and January 20, 1879; Society of Telegraph Engineers, March 12, 1879.

[2] *Telegraphic Journal*, December 15, 1878.

[1] To this portion of my instrument when used as a measurer of our hearing powers, we have given the name of audiometer.

difference of weight which the instrument at once indicates.

The following experiments will show its exceeding sensitiveness and its wide field of usefulness as an instrument of research.

1. If we introduce into one pair of the induction coils any conducting body, such as silver, copper, iron, &c., there are set up in these bodies electric currents which react both upon the primary and secondary coils, producing extra currents whose force will be proportional to the mass, and to its specific conducting powers. A milligramme of copper on a fine iron wire, finer than the human hair, can be loudly heard and appreciated by direct measurement, and its exact value ascertained. We can thus weigh to an almost infinitesimal degree the mass of the metal under examination; for instance, if we take two English shilling pieces fresh from the Mint, and if they are absolutely identical in form, weight, and material, they will be completely balanced by placing one each in the two separate coils, provided that for these experiments there is an adjustable resting-place in each pair of coils, so that each coil may lie exactly in the centre of the vacant space between the primary and secondary coils. If, however, these shillings are in the slightest degree worn, or have a different temperature, we at once perceive this difference, and if desired, measure it by the sonometer, or, by lifting the supposed heaviest coin at a slight distance from the fixed centre line, the amount of degrees that the heaviest coin is withdrawn will show its relative mass or weight as compared with the lightest. I have thus been able to appreciate the difference caused by simply rubbing the shilling between the fingers, or the difference of temperature by simply breathing near the coils, and in order to reduce this sensibility within reasonable limits, I have only used in the following experiments 100 metres of copper wire to each coil and three cells of battery.

2. The comparative disturbing value of discs of different metals, all of the same size and form of an English shilling, and measured in millimetre degrees, by the sonometer, is the following:—

Silver (chemically pure) ...	125	Iron (chemically pure) ...	45
Gold ,, ,, ...	117	Copper (antimony alloy)	40
Silver (coin)	115	Lead	38
Aluminium	112	Antimony	35
Copper	100	Mercury	30
Zinc	80	Sulphur (iron alloy) ...	20
Bronze	76	Bismuth	10
Tin	74	Zinc (antimony alloy) ...	6
Iron (ordinary)	52	Spongy gold (pure) ...	3
German silver	50	Carbon (gas)	2

These numbers do not agree entirely with any lists of electrical conductivity I have yet met with; the numbers are, however, invariably given by the sonometer, and the divergence may be due to some peculiarity of structure of the metals when formed into disks. Future investigations with this instrument will, no doubt, give more correct values than I have been able to obtain with my limited means of research.

3. It will be seen from the above that the instrument gives very different values for different metals or alloys; consequently, we cannot obtain a balance by employing two disks of different metals, and the instrument is so sensitive to any variation in mass or matter that it instantly detects the difference by clear loud tones on the telephone. If I place two gold sovereigns of equal weight and value, one in each coil, there is complete silence, indicating identity or equality between them. But if one of them is a false sovereign, or even gold of a different alloy, the fact is instantly detected by the electrical balance being disturbed. The instrument thus becomes a rapid and perfect coin detector, and can test any alloy, giving instantly its electrical value. The exceeding sensitiveness of this electrical test I shall demonstrate by experiment this evening. Again, as regards coins, it resolves an almost magical problem. Thus, if a person puts one or several coins into one pair of coils, the amount or nominal value being unknown to myself, I have only to introduce into the opposite coils, different coins successively, as I should weights in a scale, and when perfect balance is announced by the silence, the amount in one box will not only be the same nominal value, but of the same kind of coin.

4. We find by direct experiment with this instrument that the preceding results are due to electric currents, induced by the primary coil, and that it is by the reaction of these that the balance is destroyed, for, if we take an insulated spiral disk or helix of copper wire, with its terminal wires open, there is no disturbance of the balance whatever, notwithstanding that we have introduced a comparatively large amount of copper wire; but on closing the circuit the balance is at once very powerfully disturbed.

If the spiral is a flat one, resembling a disk of metal, and circuit closed, we find that loud tones result when the spiral is placed flat, or when its wire is parallel to those on coils; but if it is held at right angles to these wires no sound whatever is heard, and the balance remains perfect. The same thing occurs with disks of all non-magnetic metals, and a disk of metal placed perpendicular to the coils exerts no influence whatever. The contrary result takes place with a spiral of iron wire or disk of iron, the induced current circulating in the spiral is at its maximum when the spiral lies flat or parallel with the coils, giving no induced current whatever when at right angles, but the disturbances of the induction-balance is more than four-fold when perpendicular to the wires of the coils, than when parallel with the same. That this result is simply due to the property of magnetic bodies of conduction of magnetism, we shall see in some following experiments.

That the currents in non-magnetic metals travel in a circle corresponding to that of the primary coil, may be seen with spongy gold. In its first extremely divided state it falls below our zero of hearing, on slightly shaking the bottle we have 2° as its value; on pressing it its value rapidly increases with the pressure, until when formed into a solid disk its value becomes 117°.

5. The instrument proves that a very remarkable difference exists in bars of iron of the same exact form and size, but of different provenance or treated in a different manner; in point of fact, no two bars, cut off of the same rod, and treated alike, are exactly of the same value, or induce a complete balance.

Mr. Stroh, the eminent instrument-maker, has kindly furnished me with numerous samples, varying in value in degrees of the sonometer from 100 to 160.

Chemically pure iron was found to be the best, but still very slightly superior to ordinary iron, which had been drawn into a wire of the required thickness. The fibrous condition thus developed being highly favourable (if softened by heat) for the conduction of magnetism. From numerous examples I select a few indicative values:—

	Softened.	Tempered.
Chemically pure iron	160	130
Forged soft iron	150	125
Wire-drawn iron	156	120
Cast steel	120	100

6. As yet the instrument has given no indications of molecular change produced by magnetism in non-magnetic bodies, but the great change which takes place in all magnetic bodies, except hard-tempered cast steel, indicates that a molecular change of structure, analogous to that of tempering, takes place upon iron, steel, and nickel.

If we place a disk of iron in one of the coils, we find that the balance is destroyed, and that the iron has weakened the induction by the absorption of work done in inducing the circular currents. This can be perfectly balanced by placing a small coin or disk of silver or copper in opposite coils; but if an iron wire or rod is placed perpendicular to the coils, then increase of inductive force takes place in those coils by the conduction of induced magnetism from primary to secondary, and the iron can no longer be balanced by silver, copper, or any non-magnetic metal. The coils must be either removed farther apart, so as to reduce the increased force, or balanced by an equivalent amount of iron or magnetic conduction in opposite coils.

An interesting case of both reduction and increase of force in the same pair of coils occurs if we place a disk of iron, not in the centre of coils, but in the vacant space between the coils. We thus reduce the force by 150°. If, in addition to this, we place iron wires perpendicular and in the centre, there is increase of force, and if this increase is so proportioned as to be 150°, we immediately restore the balance, and we have here in the same coil two separate pieces of iron, each disturbing the balance and giving out loud tones, but producing no effect whatever, when both are introduced at the same time, complete silence being the result.

7. These coils prove what has already been long known, viz., that hard steel has a far less conducting power for magnetism than soft iron, although the hard steel has a far higher retaining power. This instrument demonstrates a point, which I have not yet seen remarked, that magnetism does not in itself change the conducting powers, but that it produces a molecular change of structure in iron, analogous to that of tempering; for if we balance two soft iron rods against each other, the balance being made perfect by the addition of fine iron wires on the weakest side, we find that on strongly magnetising this bar, by drawing it across a strong compound magnet, and on replacing it in its coil, it has lost 30 per cent. of its conducting power; or if, instead of magnetising we make this iron red hot and plunge it in cold water, the loss of conducting power will be very similar—25° to 30°. If these experiments are repeated upon various degrees of iron approaching steel in character, we find that as it already possesses hardness or temper, it is less and less affected by magnetism, until we arrive at hard cast steel, where magnetism no longer produces any change in its conducting powers. From this I draw the conclusion that the effect of magnetism is very similar to that of temper, and shall show under the effects of strain and torsion that magnetism produces this temper or strain perpendicular to the lines of magnetic force.

8. The instrument shows that a remarkable change takes place in the magnetic conducting power of iron and steel on subjecting the wire under examination to a longitudinal strain; for if we pass an iron wire through the centre of both coils, half a millimetre diameter and 20 centimetres or more in length, so arranged by a winding key that we can apply a strain to this wire, we find a magnetic conducting value, unstrained, of 100, but on applying a slight strain its value rapidly increases, being more than double at its breaking point. If during this strain we strike the wire, we hear its musical tone, and no matter how much we may wind or unwind it, provided we do not pass its limits of elasticity and similar wire is used, that the same musical tone will invariably give the same magnetic value. Thus the note A, or 435 complete vibrations per second, gave always the magnetic value of 160, or 60 per cent. increase of power over the unstrained wire. If whilst this wire is strained, giving the value 160, we magnetise it by drawing over it a strong compound magnet, the note remains the same, showing no difference of tension, but its magnetic value has fallen 80°, being now 80 instead of 160; and this wire can never again be brought by strain up to its previous high conducting powers. Now as we have seen that magnetism produces no change in hard tempered steel, but that it does so in soft iron very analogous to that of temper, and as the effect of strain would be also to harden the fibres by bringing them all parallel to the line of mechanical strain; and as this improves its conducting power, while magnetism instantly destroys all the benefits of the longitudinal mechanical strain, we can only draw the conclusion that magnetism produces a strain analogous to temper, but contrary to that of the longitudinal mechanical strain; in other words, that the magnetic strain is produced perpendicularly to its lines of force.

This view is sustained by the effects of torsion; for if, in place of straining the wire, it is twisted, instead of increasing, it rapidly decreases in magnetic conductive value, each turn or twist decreasing its power of conduction in a remarkable constant line of decrease. At eighty turns of this wire there was a decrease of 65 per cent.; at eighty-five turns the wire broke, and on testing it to see if magnetism had any decreasing effect on it, I found that it produced no change whatever; but this twisted soft iron wire had now remarkable permanent retaining powers of magnetism, being superior to tempered cast steel.

Again, if we take three similar pieces of soft iron wire, leave the first for comparison in its natural condition, strain the second by a longitudinal strain until it is broken, and twist the third by a torsion-key until it also is broken; we find on magnetising equally these three wires, and allowing ten minutes' repose, that the first or untouched wire has a retaining power of magnetism of 100, the second only of 80, and the third, or twisted wire, of 300. I hope by the light thus given soon to be able to produce a magnet whose force shall be greatly in excess of what we have hitherto possessed, our difficulty at present being that in order to temper steel we must heat it to redness, and this allows the molecules to rearrange themselves contrary to the object we have in view.

9. There is a marked difference of the rapidity of action between all metals, silver having an intense rapidity of action. The induced currents from hard steel or from iron strongly magnetised are much more rapid than those from pure soft iron; the tones are at once recognised, the iron giving out a dull, heavy, smothered tone, whilst hard steel has tones exceedingly sharp. If we desire to balance iron we can only balance it by a solid mass equal to the iron to be balanced. No amount of fine wires of iron can balance this mass, as the time of discharge of these wires is much quicker than that of a larger mass of iron. Hard steel, however, can be easily balanced, not only by steel but by fine iron wires, and the degree of the fineness of these wires required to produce a balance gives a very fair estimate of the proportionate time of discharge. The rapidity of discharge has no direct relation with its electrical conductivity, for copper is much slower than zinc, and they are both superior to iron.

10. The instrument shows a marked difference in all metals, if subjected to different temperatures. The value is reduced in non-magnetic metals, and this we should expect from the known influence of temperature on the electrical conductivity; but in the case of iron, steel, and nickel (as it has already been remarked by many), the contrary takes place, namely, a far higher degree of magnetic conductivity. A bar of soft iron, whose value at the temperature of the room, 20° C., was 160, became on heating it to 200° C., 300, that is to say, its value was nearly doubled. A bar of pure nickel, whose value at 20° was 150, became on heating it to 200°, 320; thus, in the case of nickel, its value for magnetic conductivity was more than doubled, and at this heat it surpassed the chemically pure iron at the same heat, giving a magnetic value of 320 against 300 for the iron, but at the normal temperature of 20° the iron had more magnetic power of conduction than nickel. Heating nickel by simply plunging it into boiling water increased its force from 150

to 250, plunging this same bar into ordinary cold water reduced its value to 130; thus the mere difference of the normal temperature of the air in the room and water which had been in this room some hours produced 20° of difference. In fact, I found that the radiant heat from the hand would raise the magnetic value several degrees, and thus nickel may be regarded as a magnetic thermometer far more sensitive than the ordinary mercurial centigrade.

The instrument also measures the electrical resistance of wires or fluids. In order to make it do this we have only to place the resistance to be measured across the two wires of one induction-coil and on the other known resistance units. In this way we can produce a perfect balance, for it then becomes an induction bridge, the results and modes of testing of which are somewhat similar to Wheatstone's bridge.

It measures also the electrostatic capacity of Leyden jars or condensers, and is sufficiently sensitive to appreciate and measure a surface of tinfoil not larger than four inches square, the condenser being simply placed between the wires of one pair of coils, and the disturbance produced being measured on the sonometer.

I could cite many more interesting experiments in other branches of physical research for which this instrument offers a wide field of observation; but my object this evening is neither to broach new theories nor to correlate at present the results obtained with views already advanced by Ampère and others.

My only desire has been and is to show the wide field of research the instrument opens to physical inquirers. I trust that in more able hands it may serve to elucidate many physical phenomena.

ON THE EVOLUTION OF THE VERTEBRATA[1]

III.

CROCODILIA.—The crocodiles form another group of reptiles which has become isolated from all the contemporary groups or orders. The most perfect antithesis of the bird, the crocodile, is, nevertheless, in essentials, in strict conformity with the bird pattern; or, rather, both it and the bird conform to the pattern of some ideal or vanished reptile.

This likeness can be shown in the body, but it is most evident in the head; although unlike the bird's skull in general specialisation, that of the crocodile is, in all essential respects and in numberless details, like that of a young bird. Compare the strong, solid, and dense skull of the crocodile, with its thick, pitted, and rugose bones, and accurate and dentated sutures, with that of a parrot, a toucan, or a hornbill—scarcely a suture left, the bone looking like polished ivory and the substance so completely spongy within that its weight is but little more than that of a few quills of the same bird. Yet these lightest and most delicate of all skulls had once all the sutures seen in that of the crocodile, and the two types of skull developed each "centre" in the same manner and on a similar model; in the middle of the incubating period they were so much alike that one diagram might have served to illustrate both.

In their covering, as well as in their general form, the crocodiles contrast strongly with the birds; instead of a soft plumage, often gorgeous in colour, they are invested with a coarse armour of segmental rows of rough plates of bone (dermostoses), coated over with horn. Representatives of the turtle's plastron are seen in the so-called abdominal ribs—which must not be confounded with like structures of the same name seen in the chamæleon and *Hatteria*—and in the inter-clavicle, which is fixed to the under-surface of the breast-bone.

The frame-work of the body is well ossified in the adult, and the vertebræ and ribs are very similar to those of a bird, the greatest difference being in the neck, which is much shorter and stouter, and has much larger rudimentary ribs, which remain permanently distinct. In the young of the *Ratitæ* (Emeu, &c.), however, all the cervical vertebræ except the atlas and axis, have a pair of ribs, which remain distinct for a considerable time in the upper part and permanently in the lower part. The crocodile's sacrum also, instead of being composed of a large number of joints, has merely two, that carry the pelvis, whilst the tail, instead of being arrested, as in living birds, is developed, as in the ancient *Archæopteryx*. The vertebræ of the crocodile are for the most part *procœlous* (concave in front and convex behind), and thus resemble those of the dorsal region of plovers, penguins, and some other water-birds. The setting in of the ribs and their overlapping (*uncinate*) processes are also similar to what is seen in birds.

The rhomboidal sternum is cartilaginous, and sends out behind a pair of *xiphoid* processes, being defended in front by the bony interclavicle, which is the counterpart of the leg of the Y-shaped merrythought of the fowl. The shoulder-girdle is composed of a pair of cartilages with a gentle curve and of a moderate width; each is ossified by two bones, an upper, the *scapula*, and a lower, the *coracoid*.

In the head, all distinction between dermal scutes and sub-cutaneous bones is lost; a thick web is ossified throughout, and has only left a thin layer of the skin soft, as a "quick" to the horny coat. From the snout to the exit of the optic nerves, the internal cranium is unossified, while the posterior part is well ossified, as are also the basal region up to the pituitary body, the capsules of the ear, and the alisphenoids. The labyrinth of the nose is very simple. A hard palate is formed by the maxillaires, palatines, and pterygoids, thus causing the nasal passages to open far back in the throat, this specialisation being of advantage to the crocodile while drowning his prey.

The structure of the organ of hearing agrees with that of the tortoises and the higher lizards, the drum cavity being formed inside the quadrate, into which an air-tube (*siphonium*) opens into the mandible, as in birds. The two drum cavities communicate in a passage running over the skull behind. A rudiment of this passage exists in birds, and in the higher kinds opens into the spongy tissue which lies between the two tables of the skull.

Birds.—The lower tentative forms of birds have for the most part evidently come and gone during the time the crocodiles have been in existence. The palæontologists, however, are beginning to show us how thoroughly intermediate between the true reptiles and birds the extinct birds of the chalk and the oolite were. The most ancient or generalised types of living birds, the ostrich tribe, are all incapable of flight, but the oldest bird known in the fossil state—*Archæopteryx*—was well fitted for flight.

Interesting connecting links between the ostrich tribe and the higher forms are seen in the southern world (*Notogæa*), where many of the birds have a much lower and more reptilian structure than their northern relatives, their power of flight being less, their brain smaller, and in many cases they are deficient in the inferior larynx or *syrinx*. Thus the South American *Tinamous*, which are intermediate between the ostrich tribe and the grouse, have a very small brain, and consequently such low intelligence that they have not the sense to use their own wings; moreover, their flesh resembles that of a reptile, they possess lacertilian super-orbital bones, and a considerable number of the sutures in the head remain permanently open. These birds do not so much resemble the South American Rhea as the Australian *Apteryx*, representative species being often found in these two regions which correspond with each other, but are far more ancient than, and do not correspond with, the types found north of "Wallace's Line."

[1] Abstract of Prof. Parker's Hunterian Lectures, delivered at the College of Surgeons, commencing on February 10. Continued from p. 64.