published in *The Ibis* (1903, pp. 11–18, pl. I.), by Professor H. H. Giglioli, entitled 'The Strange Case of *Athene chiaradiæ*,' a curious variant of *A. noctua*, having black instead of yellow irides, and some variations in the markings of the plumage from the normal form. The facts, and the speculations thereon by Professor Giglioli, are of much interest, and Mr. Scott thinks they help to confirm his view of the case of the two forms of *Helminthophila*. But the facts are not at all parallel, the nine specimens of the abnormal owl being traced back to, presumably, a single pair. This case has the essential features of a 'mutant,' as these peculiar owls were not the product of the union of two species, and hence not 'hybrids.' In other words, it is what Giglioli appropriately terms 'a case of *neogenesis*,' which might, should the progeny survive, constitute a new species. A further history of this case will naturally be awaited with great interest.

As already shown, I fail to see any good basis for Mr. Scott's attempt to employ the 'mutation' theory in explanation of the case of *H. lawrencei* and *H. leucobronchialis*, and believe still that these unstable and ever-varying forms are primarily the result of hybridity between *H. chrysoptera* and *H. pinus*, with which belief the known facts in the case are wholly consistent. Dichromatism may play a part, as several previous writers have suggested. The two forms are known to interbreed with each other and also with the parent stock, producing fertile offspring. They thus far, also, have been found (with the exception of a few migrating birds) only in the area where the breeding ranges of *H. chrysoptera* and *H. pinus* overlap. That they have not been found throughout this overlapping area is more than likely due to the absence from it of a sufficient number of expert observers. No section of the country within this range has a tithe of the expert field observers and collectors, proportionately to the area, that have been working for years throughout the limited district which has thus far almost exclusively produced the known examples of these birds. There seems to be no obvious reason why they should not occur sparingly westward over a narrow belt south of the Great Lakes to Wisconsin, where thus far they seem to have been almost wholly overlooked.

In taking up this subject, Mr. Scott appears to have proceeded without a very clear conception of either the essential facts of the warbler case or of the phenomena of 'mutants.' His assumption of the recent rapid increase of these forms rests on statements that are both misleading and irrelevant. The region of their occurrence is wholly outside of the fields of research of the ornithologists he mentions as evidence of the thorough knowledge of the ornithology of this region he assumes to have existed 'in the early part of the last century,' while, as regards numbers and methods, these early workers are not for a moment to be compared with those of the last few decades. Besides, it is only a few experts, who have made these birds a specialty, and know their haunts and notes, who have any success in their discovery. The facts, as already said, of the known relationships and the instability of these forms, harmonize poorly with the phenomena of mutations, shown by de Vries in relation to plants, in which the new forms arise with definite and stable characters, which they can transmit without modification to an apparently endless succession of generations.

J. A. Allen.

SPECIAL ARTICLES.

BATTERY RESISTANCE BY MANCE'S METHOD.

Among the many methods for measuring battery resistance, one of the oldest, and apparently least understood, is that known as 'Mance's method.' As usually discussed in text-books this method is described as being a modification of Wheatstone's bridge, in which the cell to be measured takes the place of the unknown arm and the usual battery is replaced by a simple key. When opening or closing this key produces no change in the steady deflection of the galvanometer the bridge is balanced and, 'therefore, the usual relation of Wheatstone's bridge is satisfied.' It is the object of this paper to show wherein many writers have erred in this explanation, and to indicate a direct and simple derivation of the desired relationship.

Wheatstone's bridge consists, essentially, of two circuits in parallel through which an electric current can flow. Let these circuits be represented by ABD and ACD, Fig. 1, and

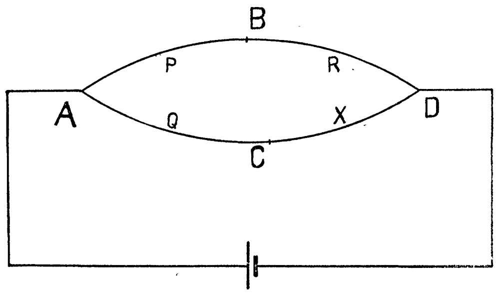

FIG. 1.

let the currents through the two branches be denoted by I and I'. Since the fall of potential from A to D is the same whichever path is considered, there must be a point C on one circuit, which has the same potential as any chosen point B of the other. If one terminal of a galvanometer is joined to B and the other terminal is moved along ACD the galvanometer will indicate zero deflection when the point C has been found. Since B and C have the same potential, the fall of potential from A to B is the same as from A to C, or in terms of the currents and the resistances,

$$IP = I'Q$$

where P and Q are the resistances of AB and AC, respectively.

Similarly for the other part of the circuits

$$IR = I'X.$$

Dividing one equation by the other gives

$$P : Q :: R : X$$

as the relationship of the resistances when the bridge is balanced. In the usual method of using the Wheatstone bridge three of these resistances are known and the value of the fourth is easily computed from the above relation as soon as a balance is obtained.

In teaching 'Mance's method' the attempt has been made to deduce directly the expression for the resistance of the cell similarly to the above deduction for the Wheatstone bridge. Some three years ago a careful search of the literature was made, with the result that no direct and simple explanation of the method could be found, while the best authorities, German, English and American, either made statements which are absolutely false or passed over the subject in silence.

The first edition of Maxwell, published a few months after Mance's original paper, gives the method as follows (the italics are my own):

The measurement of the resistance of a battery when in action is of a much higher order of difficulty, since the resistance of the battery is found to change considerably for some time after the strength of the current through it is changed. In many of the methods commonly used to measure the resistance of a battery such alterations of the strength of the current through it occur in the course of the operations, and therefore the results are rendered doubtful.

In Mance's method, *which is free from this objection*, the battery is placed in CD and the galvanometer in BC. The connexion between A and D is then alternately made and broken. If the deflexion of the galvanometer remains unaltered

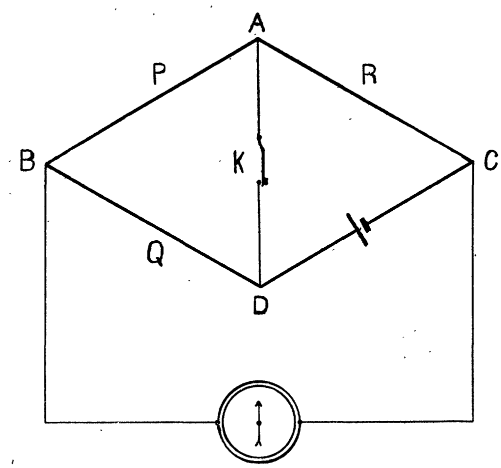

FIG. 2.

we know that AD is conjugate to BC, whence, $QR = PX$, and X, the resistance of the battery, is obtained in terms of known resistances P, Q, R. * * * In this method of measuring the resistance of the battery *the current in the battery is not in any way interfered with during the opera-*

tion, so that we may ascertain its resistance for any given strength of current, so as to determine how the strength of current affects the resistance.

A glance at Fig. 2 will show that in Mance's method the battery is joined in series with P, Q and R, and no two points having the same potential can be found on this circuit. The effect of closing K is to short-circuit P and Q, thus closing the battery through R alone, which frequently is not very large. Often the current from the cell is changed from a few ten-thousandths of an ampère to several tenths, *and this larger current flows through the key from A to D.* Thus it is readily seen that the points A and D are *not* at the same potential, and that the current in the cell is subject to considerable variation.

Lodge[1] pointed out this error in Maxwell and gives a very clear exposition of the method, but does not deduce any formula, concluding with the words:

I have entered into this matter at some length because the slip in Maxwell is getting repeated in other books, and it is well to get clear on the subject.

Had all later writers read this admirable account the present paper would be unnecessary. But even after this clear exposition Maxwell has gone through two editions with the only result that the last paragraph quoted above now reads:

In this method of measuring the resistance of the battery, the current in the galvanometer is not in any way interfered with during the operation, so that we may ascertain the resistance of the battery for any given strength of current in the galvanometer so as to determine how the strength of the current affects the resistance. [Which is meaningless.]

However, the makers of books have kept on as though nothing had been said, and some have fallen into a more grievous error in the attempt to deduce a formula for this method from its analogy with Wheatstone's bridge.

A standard English work written in 1887 says:

In the Wheatstone bridge diagram, if the battery be placed in the X arm so as always to send a current through the galvanometer, then, by the principle of the bridge which we have already explained, when $P:Q=R:X$, the opening or closing of the key can have no influence on the current in the galvanometer, *inasmuch as the two points A and D are at the same potential.* This is the principle of Mance's method, in which adjustments are made of P, Q and R until the current in the galvanometer remains the same, whether the key is open or closed.

[1] O. J. Lodge, *Phil. Mag.*, 1877, Vol. 3, p. 515.

One of the largest and best German treatises, written in 1893, puts the matter more explicitly.

But as no current can flow through the bridge (AD, containing the key) the potential at A is the same as at D, and the fall of potential over P is equal to that over Q and the fall of potential over R is equal to that over X. So then if there is no current through the bridge the same current, i, flows through the entire circuit BAC, and the current i' flows through the entire circuit BDC, and

$$iP=i'Q, \quad iR=i'X, \quad P:Q=R:X,$$

from which the desired resistance is obtained.

Of still more recent date are two American manuals, excellent in many respects, which follow the example set by the older books. One of these, written in 1898, puts the matter thus:

If the cell, X, is placed in the branch CD of the bridge, and a key, K, inserted in place of the battery in the branch AD, there will, of course, always be a current through the galvanometer, and its needle will be deflected. But if, on making and breaking the key K, there is no change in this deflection, *A and D must have the same potential;* otherwise some of the current would have gone through AD when the key was closed and so a different quantity would have gone through the galvanometer. If, however, A and D have the same potential,

$$P:Q::R:X.$$

* * * Under this condition no current flows through the branch containing the key K.

The other book, written only last year, is simply another echo.

The adjustment consists in finding such a point of contact, A, that opening and closing the bridge does not alter the galvanometer reading. Then *A and D are at the same potential,* and the resistances are in the following proportion.

$$P:Q::R:X.$$

It will now be of interest to turn to the original paper by Mance.[2] This was communicated to the Royal Society of London in 1871 by Sir Wm. Thomson. Mr. Henry Mance was superintendent of the Mekran Coast and Persian Gulf Telegraph Department and was especially interested in telegraph lines and cables and the detection of faults. He considers such a line, well grounded at each end and containing a battery and a galvanometer shunted by a circuit AB. The current through the galvanometer

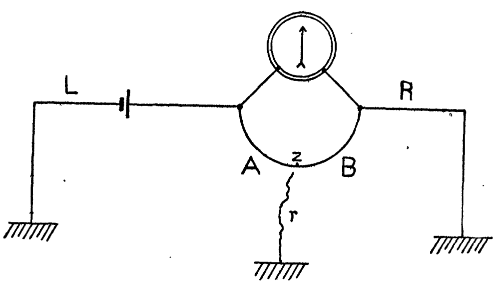

FIG. 3.

can be readily computed. But now let a leakage be applied to a point on the shunt. In general the deflection of the galvanometer will be changed, but by moving the leakage along AB a point can be found for which the galvanometer gives the original deflection. And this deflection will remain the same for all values of the leakage from 'dead earth' to infinity.

Presuming the electromotive E in L to remain constant, and taking $r=0$, we have the intensity of the current passing through G represented by the equation

$$\frac{E}{\left\{L+\dfrac{G(A+B)}{G+(A+B)}+R\right\}\left\{\dfrac{G+(A+B)}{A+B}\right\}}$$

but after r is connected, the equation becomes

$$\frac{E}{\left\{L+\dfrac{\left(G+\dfrac{RB}{R+B}\right)A}{A+G+\dfrac{RB}{R+B}}\right\}\dfrac{G+\dfrac{RB}{R+B}+A}{A}}$$

[2] Henry Mance, *Proc. Roy. Soc. Lond.*, 1870, Vol. 19, p. 248.

As the condition that the galvanometer deflection remains unchanged, the first of these equations must be equal to the second, from which we obtain the formula

$$L=R\frac{A}{B},$$

the resistance G being immaterial. It will, therefore, be seen that R always bears the same proportion to L that B does to A, the latter bearing some analogy to the proportion coils of a Wheatstone testing bridge.

Mance proceeds to point out several applications of this method, concluding, 'lastly, this method may be used to ascertain the internal resistance of a battery.' There is nothing difficult or uncertain in this presentation and it seems strange that this original simplicity should have been so completely lost by later writers.

The clearest discussion of this method that I have seen in print is that given by Lodge in the paper referred to above, but this is descriptive rather than mathematical. However, he introduces a modification of the method which greatly increases the range of its application. This consists in using a condenser in series with the usual galvanometer, so as to detect variations in difference of potential instead of variations in current. By this means the method becomes a null one, and, moreover, the measurements can be made in a much shorter time as there is no waiting for the needle to come to rest in its deflected position. This is of especial advantage with cells which polarize rapidly. To eliminate the effect of any change in E.M.F. after the circuit is closed, Lodge devised a special key which broke the galvanometer connection immediately after the bridge circuit is made. It is better, however, to use a short-circuiting key on the galvanometer as suggested by Guthe.[3] The key is opened just before the discharge passes through the galvanometer and closed immediately afterwards to avoid any changes due to a variation in the E.M.F. of the cell.

However, as all cells polarize more or less rapidly, especially just after closing the cir-

[3] K. E. Guthe, 'Laboratory Exercises,' 1903.

cuit, it is not possible to work all the keys by hand quickly or uniformly enough to obtain the best results. By using a two-pole multi-circuit switch the various keys can be combined in one, and a single motion of the hand works them all in the order required. The switch s (Fig. 4) consists of two blades, m

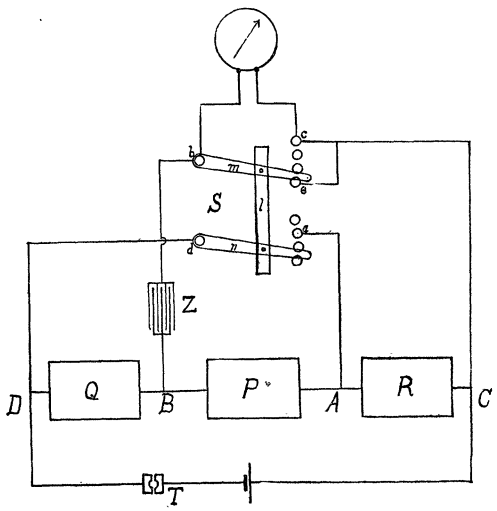

FIG. 4.

and n, pivoted at b and d and both moved by the connecting piece, l, over a series of four contact points. Thus, used as a two-pole switch, b and d can be connected to any one of four different circuits; but in the present case only a few of the contacts are utilized, and these are connected so as to make and break the various connections in the order desired as the switch is quickly moved from one side to the other.

The arrangement then is as follows: The cell, or other resistance to be measured, is joined in series with three resistances, R, P and Q, Fig. 4. The points A and D are joined to a and d, and are connected whenever n rests upon the third contact point. The galvanometer is joined to the points b and c, while c and e are permanently connected, thus short-circuiting the galvanometer when contact is made on either point, but when m is moved from e to c the short-circuit is raised for an instant. It is during this instant that the points a and d are connected by n passing over its third contact.

The points b and c are also joined to B and C, the former through the condenser Z. When the key T is closed this condenser is charged to the difference of potential between B and C, the charge passing through the blade m and leaving the galvanometer at rest. When the switch is thrown over to the third point, A and D are connected, which practically cuts P and Q out of the circuit, leaving only the battery and R. With this shorter circuit the condenser is charged to the difference of potential between A and C (since D, B and A are all at the same potential) and if this is the same as that formerly existing between B and C there will be no change in the charge and, therefore, no deflection of the galvanometer which, for this position of the switch, is not short-circuited. As the switch is moved further the galvanometer is short-circuited again before the connection ad is broken, thus eliminating the back kick of the galvanometer as the charge in the condenser returns to its former value.

Having set up the apparatus as indicated in the figure, the manipulation is as follows: The key T is closed and the switch quickly moved from e to c. If there is a deflection of the galvanometer the key is opened, the switch set back to its first position, and the values of P and Q changed until zero deflection is obtained when the switch is thrown. The arrangement is then 'balanced' and $X = R\,Q/P$.

This relation is easily deduced. The potential to which the condenser is charged in the first case, viz., that between B and C, is

$$e = I(R+P) = \frac{E(R+P)}{R+P+Q+X}$$

where E is the E.M.F. of the cell and X its resistance. When P and Q are short-circuited the condenser is charged to the difference of potential between A and C, which is

$$e' = RI' = \frac{ER}{R+X}.$$

When the galvanometer shows no deflection, $e = e'$, or

$$\frac{R+P}{R+P+Q+X}=\frac{R}{R+X},$$

which readily gives the relation

$$X=R\frac{Q}{P}.$$

It is true this result appears in the same form as that deduced for the Wheatstone bridge, but beyond a superficial analogy there is nothing in common between the two methods. The Wheatstone's bridge method consists in dividing two parallel circuits in the same ratio. Mance's method, on the other hand, consists in subtracting from the two portions of a single circuit such resistances that the two portions shall still maintain the same ratio to each other.

In this connection it may be of interest to look at the results of a few measurements by this method. The resistance measured consisted of a medium-sized storage cell in series with a coil marked '2 ohms.' This gives a definite resistance with an E.M.F. not easily polarized. The results of thirty measurements are shown in the table below. R was varied from one ohm to forty ohms, and P was given such values that Q would be a little over 4,000 ohms. Each balance was sensitive to a change of 1 ohm in Q, and often the 0.5-ohm coil was used. The results are tabulated in the order obtained, reading across the table from left to right. As the room became warmer the resistance grew larger, each column showing the same increase of 0.002 ohm. It is seen from these results that the method is as sensitive as a post-office box, and by using a larger condenser the sensitiveness can be still further increased. From this limited data it is hardly safe to draw a general conclusion, but it may be noted that the smaller values of R, in other words, the larger currents in the storage cell, give smaller values of X, the same as with ordinary cells.

Temperature of Room.	Resistance of '2 Ohms' Plus Storage Cell.					
	$R=1.$	$R=2.$	$R=3.$	$R=4$	$R=10.$	$R=40.$
12.°0	2.0265	2.0280	2.0295	2.0295	2.0300	2.0300
12.°6	2.0265	2.0290	2.0305	2.0310	2.0315	2.0320
13.°0	2.0280	2.0297	2.0315	2.0312	2.0315	2.0320
13.°2	2.0282	2.0300	2.0315	2.0315	2.0317	2.0320
13.°5	2.0285	2.0302	2.0315	2.0315	2.0317	2.0320

The following results were obtained from a large 'Gonda' cell, a porous cup type of Leclanche cell. It had been in constant use in the laboratory for five months with no change of electrolyte. As it polarized rapidly for the first ten seconds after closing the circuit through one or two ohms, its resistance was measured with values of R of 40, 60 and 80 ohms. The values obtained were as follows:

Temperature of Cell.	Resistance of 'Gonda Cell.'		
	$R=40.$	$R=60.$	$R=80.$
13.°0	1.388	1.386	1.388
	1.392	1.392	1.388
	1.392	1.392	1.384
13.°2	1.389	1.392	1.388

The average of these twelve determinations is 1.389 ohms, and the mean variation from this value is 0.002 ohm, while the probable error of this result is 1 part in 2,600.

But it is not my present purpose to discuss experimental data except in so far as it shows that Mance's method is not without some merit. It has been shown that this method is fully as accurate as is required for laboratory use, whether the resistance to be measured be of the first or second class. The purpose of this paper will be fully attained if it has clearly shown the principle underlying this method, and pointed out the very obvious error which has crept into many of the text-books from Maxwell down to the present.

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February 11, 1905.

ORGANISMS ON THE SURFACE OF GRAIN, WITH SPECIAL REFERENCE TO BACILLUS COLI.

THE recent note by Dr. Erastus G. Smith on the occurrence on grain of organisms resembling the *Bacillus coli communis*[1] appears to warrant preliminary publication of some of the results of my studies of the micro-organisms normally present on the flowers and fruit of certain plants in the Piedmont region and the rice belt of South Carolina. These studies, originally undertaken as a side issue

[1] SCIENCE, May 5, 1905.