definite patches; these are the cranial roof-bones. Around the mouth there are cartilages like those of the Lamprey and the Chimæra; but these yield in interest to the proper facial bars, which are as follows, namely :—

First pair, the "trabeculæ."

Second pair, the mandibular arch.

Third pair, the hyoid arch.

And fourth to seventh pairs: these are the branchials.

These are all originally separate pairs of cartilaginous rods; and from these are developed all the complex structures of the mouth, palate, face, and throat. The pterygo-palatine arcade is merely a secondary connecting bar developed, after some time, between the first and second arches.

Meckel's cartilage arises as a segmentary bud from the lower part of the second, and the "stylo-cerato-hyal," as a similar secondary segment, from the third arch.

By far the greater part of the cranium (its anterior two-thirds) is developed by out-growing laminæ from the trabeculæ, which after a time become fused with the posterior or vertebral part of the skull.

When the tadpole is becoming a frog, the hyoid arch undergoes a truly wonderful amount of metamorphosis.

The upper part, answering to the hyomandibular of the fish (not to the whole of it, but to its upper half), becomes the "incus," and a detached segment becomes the "orbiculare," which wedges itself between the incus and the "stapes." The stapes is a "bung" cut out of the "ear-sac." The stylo-cerato-hyal is set free, rises higher and higher, and then articulates with the "opisthotic" region of the ear-sac; in the toad it coalesces therewith, as in the mammal. The lower part of the hyomandibular coalesces with the back of the pair of the mandibular arch; and the "symplectic" of the osseous fish appears whilst the tadpole is acquiring its limbs and its lungs, and then melts back again into the arch in front; it is represented, however, in the bull-frog, but not in the common species, by a distinct bone.

This very rough and imperfect abstract must serve at present to indicate what has been seen and worked out in this most instructive vertebrate.

II. "Method of measuring the Resistance of a Conductor or of a Battery, or of a Telegraph-Line influenced by unknown Earth-currents, from a single Deflection of a Galvanometer of unknown Resistance." By Henry Mance, Superintendent Mekran Coast and Persian Gulf Telegraph Department, Kurrachee. Communicated by Sir Wm. Thomson. Received January 12, 1871.

The resistance of each part of a circuit, such as that shown in fig. 1, being known, the influence exercised by the shunt A B, as well as the

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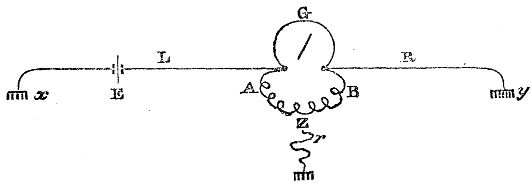
total resistance of the whole between x and y, can be easily ascertained by simple and well-known formulæ.

Fig. 1.



But let a leakage r, which we will suppose gives perfect earth, be applied at some point in the shunt A B, the deflection previously produced on G by a current arising in L will probably be considerably changed. I say probably, because by sliding the leakage r along the whole length of the shunt, we shall at last find a point Z at which the needle will return to its original deflection; the position of Z being ascertained, any resistance varying from infinity to "dead earth" may be applied without causing any change in the deflection of the needle.

It is evident that, although the total resistance of the circuit between x and y has been lessened by the insertion of the leakage, a proportionately larger amount of current is diverted from the galvanometer by that part of the shunt between L and the leakage at Z.

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

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

but after r is connected, the equation becomes

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

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

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

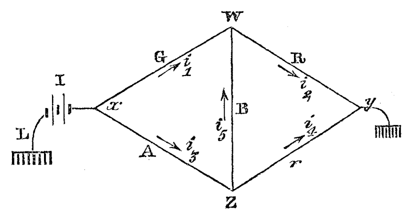
the resistance G being immaterial. It will therefore be seen that R always bears the same proportion to L that B does to A, the latter branches bearing some analogy to the proportion-coils of a Wheatstone testing bridge.

Under certain circumstances a test might be taken without any battery

at all. In a submerged cable there is frequently sufficient earth-current to supply the electromotive force in the branch L; if not, a small battery can be inserted to maintain a steady current, and the internal resistance of the cells afterwards deducted. The polarization-current from a leakage of low resistance in a cable would enable us to find the resistance from either side through the fault without the application of a battery. And, lastly, this method may be used to ascertain the internal resistance of a battery.

The above method occurred to me about two years since during some experiments made to determine the resistance of the bridge-circuit and the exact proportion of current traversing each branch of the Wheatstone balance when the potentials at W and Z are unequal.

Fig. 2.



If I equals the intensity of the current at x or y, and i_1, i_2, i_3, i_4, i_5 the intensities in the sections G, R, A, r, B, then

$$\frac{G.(B+R+r)+BR}{A.(B+R+r)+Br}+1=\frac{I}{i_1}. \quad\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\frac{A.(B+R+r)+Br}{G.(B+R+r)+BR}+1=\frac{I}{i_3}. \quad\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$\frac{R.(A+B+G)+BG}{r.(A+B+G)+AB}+1=\frac{I}{i_2} \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$\frac{r.(A+B+G)+BA}{R.(A+B+G)+BG}+1=\frac{I}{i_4} \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$\frac{B.(R+r)+(B+R+r).(A+G)}{Gr-AR}=\frac{I}{i_5} \ldots\ldots\ldots\ldots (5)$$

Or if the current in the branch B passes from W to Z,

$$AR-Gr$$

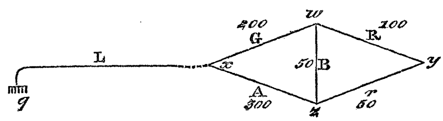
should be substituted for the denominator of the last equation.

Equations (1), (2), (3), and (4) give the shunt-coefficient of the respective branches A, G, r, R; thus if G were a galvanometer, the strength of the deflection recorded multiplied by equation (1) would give the value of intensity I.

If, then, we consider G a galvanometer and the resistance r a leakage applied at Z, we have a similar diagram to that given in fig. 1; and the first of the five equations given above will enable us to determine the shunt-coefficient for the part A which lies between L and the leakage at Z.

Now this, together with the plan of testing described in the first paragraph, suggests an easy method for ascertaining by calculation the combined resistance of any system of derived circuits connected in the form of the Wheatstone's parallelogram; thus if I wish to know the resistance offered to the passage of a current between x and y in fig. 3, I can find it

Fig. 3.



in the following manner.

First assume the existence at x of a sixth branch bearing (in resistance) the same proportion to R that A does to B; that is to say, the supposititious branch

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

Now disconnect r from the point Z, and we have again a diagram similar to that in fig. 1; and as we have provided that $\frac{A}{B}=\frac{L}{R}$, the connexion or disconnexion of r at the point Z will make no difference whatever in the quantity of current passing from L into the branch G. I may therefore assume that, although the total resistance of the circuit between q and y has been decreased, the branch A has at the same time been able to divert a proportionately greater amount of current from the side G, in which the intensity remains unaltered.

If, then,

R_1 equals the resistance between q and y when the branch r is disconnected,

S_1 the shunt-coefficient of A B which forms a shunt in the absence of r,

R_2 the resistance between q and y after r is connected at Z,

S_2 the shunt-coefficient for the part A ascertained by equation (1),

we have

$$R_1\times S_1=R_2\times S_2,$$

$$R_2=\frac{R_1S_1}{S_2};$$

and R_2 *minus* the supposititious branch $\left(\frac{RA}{B}\right)$ will give the required combined resistance of the circuit between x and y.

Let R_3 be the combined resistance. Commencing with the equation

$$\frac{\left\{\frac{RA}{B}+\frac{G\,.\,(A+B)}{G+(A+B)}+R\right\}\times\frac{A+B+G}{A+B}}{\frac{G\,.\,(B+R+r)+BR}{A\,.\,(B+R+r)+Br}+1}-\frac{RA}{B}=R_3,$$

we obtain

$$R_3 = \frac{\frac{R.(A+B+G)}{B} + G}{\frac{G.(B+R+r)+BR}{A.(B+R+r)+Br} + 1} - \frac{RA}{B}.$$

If the potential at Z equalled that at W, the formula

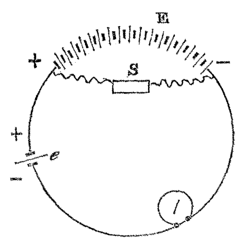
$$R_3 = \frac{(G+R).(A+R)}{G+R+A+r}$$

would of course be sufficient.

III. "Measurement of the Internal Resistance of a Multiple Battery by adjusting the Galvanometer to Zero." By Henry Mance. Communicated by Sir Wm. Thomson, LL.D., F.R.S. Received January 12, 1871.

The following method of taking the internal resistance of a battery will be found to give excellent results when several cells are to be tested.

Take one element from the rest of the cells and arrange the circuit as in the annexed figure. Connect the poles of the battery under observation by a shunt S, and adjust the resistance of the latter till zero is obtained on the galvanometer.



Let E be the number of cells tested,
 e number of cells opposed,
 S = resistance of shunt,
 R = internal resistance of E.

Then

$$R = S\frac{E}{e} - S.$$

In practice I usually returned the detached cell to the battery when S×E gave the internal resistance of the whole within a fraction of a unit.

It is assumed that the electromotive force in e equals that of the whole battery multiplied by $\frac{e}{E}$; the chance of error on account of this not being exactly the case would be lessened by detaching a larger number of cells than one when the internal resistance of the remaining portion would be given by the first formula.