wishes to substitute for Latin one of the sciences enumerated in Group II., it should be allowed a maximum of 3000 marks.

2 Powis Square, W. HENRY PALIN GURNEY.

"British and Irish Salmonidæ."

As your reviewer allows that he "intentionally omitted" five words from a sentence of mine which he quoted in order to criticise, I may well leave comments on such a proceeding to your readers. I willingly acquit him of having purposely made me to suggest utter nonsense, as I cannot help thinking that his knowledge of fish-culture was such that he was unaware he was doing so.

As to the second point he says, "I doubted and still doubt if there is any method practised in which layers of moss are used and are separated from the eggs by muslin and similar material." As he rejects the Howietoun account which I gave, I now submit extracts from two standard works, one American, the other English, which will, I believe, be conclusive to those who are ignorant of fish-culture, for every fish-culturist is aware that this plan is commonly adopted. Livingstone-Stone ("Domesticated Trout," ed. 3, 1877) remarked:—"Theodore Lyman recommends placing each layer of eggs in a fold of mosquito netting to keep them from mixing with the moss and so facilitate the unpacking of them. *This is a great improvement. By all means use mosquito netting*" (p. 149). Mr. Andrews, of Guildford, wrote thus in the Badminton Series ("Salmon and Trout," 1885):—"The plan of packing does not vary much with trout breeders. The eggs are placed in alternate layers between moss, and protected by a covering of mosquito netting, muslin, swans' down, calico, or butter cloth, so arranged that the eggs shall not be crushed or escape" (p. 447).

As regards the third point, your reviewer now appears to be convinced that *Salmo namaycush* is a char, as I stated it to be. It must be a matter of regret that he omitted to investigate the foregoing questions prior to authoritatively writing upon them in such a well-known publication as NATURE.

Cheltenham, February 4. FRANCIS DAY.

IN his last letter Mr. Day has certainly proved the correctness of the statement in his book that salmonoid eggs are packed with layers of moss from which they are separated by muslin or other textile fabric. If I had known as much about salmon-culture as he, I certainly should not have questioned the statement; it is to be noted that I only questioned and did not deny. If I had been as completely versed in the knowledge of Salmonidæ as Mr. Day, I should have written a book on the subject instead of reviewing his. But the essential point, which Mr. Day seems incapable of appreciating, is this: that there was nothing in the notes on the subject of packing in his book which confirmed the statement in the text; and although my doubts as to the correctness of that statement are removed by his letter, they were perfectly justifiable in a reader of his book. Mr. Day does not apparently suspect that people interested in the subject, including the reviewer, read his book for the sake of gaining information, and not because they already know as much about the subject as himself. All I had to do was to give my impressions of the book as I found it: the fitness of my criticisms is only the more established by the lengthening appendix to his book which Mr. Day is now publishing in your correspondence columns. YOUR REVIEWER.

MODERN VIEWS OF ELECTRICITY.[1]

PART III. MAGNETISM—(*continued.*)

VIII.

IT will now be perceived that a fly-wheel in rotation is the mechanical analogue of magnetism, or more definitely of a section of a line (or tube) of magnetic force; and that a brake applied to such a fly-wheel, with consequent slip, dissipation of energy, and production of heat, is in some sort a mechanical analogue of an electric current.

The field is regarded as full of geared elastic vortices or whirls, some of which are cogged together, so to speak, while others are merely pressed together by smooth rims.

[1] Continued from p. 348.

It is among these latter that slip is possible, and in the regions occupied by them that currents exist; the energy dissipated here being transmitted through the non-slippery or dielectric regions from the source of power, just as energy is transmitted from a steam-engine through mill-work or shafting to the various places where it is dissipated by friction.

Mechanical Force acting on a Conductor conveying a Current.

In Fig. 41 the conducting portion is shown with opposite rotations on either side of it. Now superpose a uniform rotation all in one direction upon this, so as to increase the spin on one side and diminish it on the other. Immediately the extra centrifugal force on one side will urge any movable part of the conductor from the stronger to the weaker portion of the field.

The field for a direct and return circuit may be similarly drawn by superposition of their separate whirls (see Fig. 40); and so it becomes evident why a circuit tends to expand so as to inclose the largest possible area, even if no other magnetic field than its own be acting on it.

Also if two circuits are arranged near each other in a plane, with their currents in opposite directions, they will more or less neutralize each other's effect on the space between them, causing (if equal) a region of no spin there. Their neighbouring portions will thus get urged together by the unbalanced pressure on the other side: or, currents in the same direction attract.

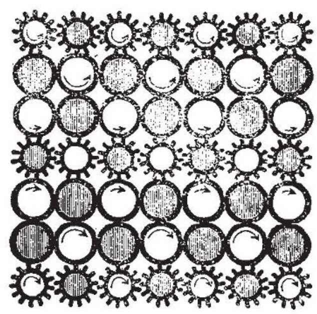

FIG. 44.—Two parallel conductors conveying equal currents in one direction and getting pushed together by the centrifugal force of the outside whirls, no whirl existing between them. The length of the arrows again suggests the distribution of magnetism in the conductors. Fig. 40 showed the correlative repulsion of opposite currents.

As for the effect of iron introduced into a circuit, it brings into the region of space it occupies some two or three hundred times as many lines of whirl as were there before, and these naturally contribute mightily to the effects, both those exhibiting mechanical force and those exhibiting inertia.

When one says, as roughly one may do, that iron brings 300 fresh lines into the field, one means that for every whirl otherwise excited, 300 more are faced round in the iron. And this process goes on while the field is increasing in strength until the total number of whirls in the iron begins to be called upon; when this point is reached the rate of addition is not maintained, and the iron is said to show signs of saturation. Ultimately, if ever all its whirls were faced round, the iron would be quite saturated; but long before this point is reached another cause is likely to make itself felt, viz. the falling off in the strength of the whirls already faced round, by the action of the strong magnetic induction, which is all the time acting so as to weaken the iron currents so far as it is able. And thus at a certain point hitherto unreached by experiment the iron may not only fail to increase the strength of the field any more, but may actually begin to diminish it.

The easiest way to picture the effect of iron is to think of its wheels as some two or three hundred times as massive as those of air, so that their energy and momentum are very great.

That which is commonly called magnetic permeability may in fact be thought of as a kind of inertia, an inertia per unit volume; though how it comes to pass that the ether inside iron is endowed with so great inertia one cannot say. Perhaps it is that the iron atoms themselves revolve with the electricity, perhaps it is something quite different. Whatever the peculiar behaviour of iron, nickel, &c., be due to, it must be something profoundly interesting and important as soon as our knowledge of their molecular structure enables us to perceive its nature.

Induction in Conductors not originally carrying Currents but moving in a Magnetic Field.

To explain the currents induced in a conductor moving through a uniform magnetic field is not quite easy, because none of the diagrams lend themselves naturally and simply to the idea of circuits changing in form or size.

If we take a rigid circuit in a magnetic field, like Fig. 45, and revolve it out of its plane 180°, it is obvious that a current will be excited in it, for the process is essentially the same as if the conductor were kept still and the field reversed.

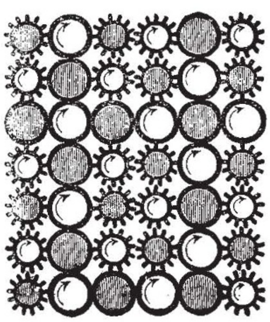

FIG. 45.—Section of a uniform magnetic field with two rails and a slider in it. If the slider be moved to or fro, the wheels inside get initially, compressed or extended, and thereby gain or lose energy respectively thus exciting the state of slip known as induced current.

But to understand the current excited in a closed circuit when a portion of it moves across the lines so as to embrace a greater number of them, one has to take into account the fact that the inside whirls are expanding and doing work in forcing the conductor away, while the outer whirls are resisting the motion, and being thereby compressed and rendered more energetic. Thus the wheels inside revolve slightly slower as the circuit expands, and those outside revolve slightly quicker. Both these processes cause a slipping of the gearing, first all round the inside and then all through the substance of the wire, whereby positive electricity moves forward in one direction round the circuit, the negative moving oppositely; and so a current is accounted for. It is not to be supposed, however, that any finite expansion of the wheels really occurs: the motion is rapidly equalized by diffusion through the wire, and fresh wheels come in round it from outside; hence directly after the conductor has stopped moving the field is again steady, but with many more wheels inside the contour than it possessed at first.

Representation of an Electrostatic Field again, and superposition of it on a perpendicular Magnetic Field.

An electrostatic strain is, we know, caused by a displacement of positive electricity one way along the lines of force, and by an equal displacement of negative the other way. Half the process was indicated crudely in Fig. 6; we may now represent it rather more fully with the help of our elastic cells by Fig. 46.

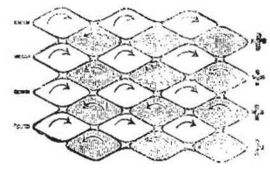

FIG. 46.—A portion of an electrostatic field between two oppositely charged bodies, with its lines of force going from right to left, and showing a tension along and a pressure at right angles to them, due to the elasticity of the cells (which elasticity may be due to their containing fluid in a state of whirl). Magnetic lines of force perpendicular to the paper are also shown in section. While this magnetic field was being excited and propagated from below upwards, a slight strain would be produced in the elastic cells, like but immensely less than that shown; as contrasted with its normal condition (Fig. 37). Conversely, while this electrostatic strain was being produced, the positive whirls would be infinitesimally quickened and the negative ones retarded during the displacement, thus producing a minute magnetic effect. If the medium is not magnetized, the whirls are not necessarily absent, only faced all ways.

Here the positive cells have been pulled one way, the negative the other way; and when the distorting force is removed, the medium tends to spring back to its normal condition, exerting an obvious tension on bodies attached to it in the direction of its lines of force, its elongated direction, and an obvious pressure in all perpendicular directions, its compressed directions.

Now, if all the cells are full of parallel whirls, as in the preceding magnetic diagrams, it is not improbable that this electrostatic distortion or "shear" of the medium may affect its magnetic properties slightly, and that, if the direction of electrostatic strain were rapidly reversed, a small magnetic oscillation would also ensue; but the exact details of these mutual actions are difficult to specify at present.

Disruptive Discharge.

Disruptive discharge may be thought of as a pulling of the shaded cells violently along past the others; the process being accompanied by a true disruption—a sort of electrolysis—of the medium, and a passage of the two electricities in opposite directions along the line of discharge.

Consider the locomotion of any one horizontal row of shaded cells in Fig. 46 during the occurrence of such a disruption of the medium. The cells slide on towards the right, and, as they slide, the spin of the negative cells above them is retarded while that of those below them is accelerated; consequently a true magnetic effect is produced, just like that accompanying a current, and a disruptive discharge has therefore all the magnetic properties of a current.

Effects of a Moving Charge.

This locomotion of a set of positive cells, or of negative cells the other way, as just considered, is very near akin to the motion of a charge through a dielectric medium.

A charge can only exist at the boundary between a dielectric and a conductor, or at least between one dielectric and another of greater density. So, when a charged body moves along with extreme rapidity, it can be thought of as exciting a rotation in the cells most closely in contact with it greater than that which it excites in the opposite kind of cells, and thus produces the whirl proper to a magnetic field. Thus does a moving charge behave just like a current of a certain strength.

It may be, indeed, that this is the customary way of exciting a voltaic current; for the chemical forces in a cell cause a locomotion of charged atoms, and thus set up a field, which, spreading out in the way Prof. Poynting has sketched, reaches every part of the metallic circuit and excites the current there.

Electrostatic Effects of a Moving or Varying Magnetic Field.

Just as we have seen that a moving or varying electrostatic field may produce slight magnetic effects, so one can perceive that a moving or varying magnetic field brings about something of the nature of an electrostatic strain.

For a spreading out field is continually propagating the rotation on from one layer of wheels to the next. If there is any slip, we thus get induced currents, and the rate of propagation is comparatively slow, being a kind of diffusion; but even if there is not any slip, yet, unless the wheel-work is absolutely rigid, the rate of propagation will not be infinite. The actual rate of propagation is very great, which shows that the rigidity of the wheels is very high in proportion to their inertia, but it is not infinite; and accordingly the propagation of rotation is accompanied by a temporary strain. One part of the field is in full spin, another more distant part is as yet unreached by the spin; between the two we have the region of strain, the wheel-work being distorted a little while taking up the motion. Thus does a spreading out magnetic field cause a slight and temporary electrostatic strain, at right angles both to the direction of the lines of force and to the direction of their advance.

Generation of a Magnetic Field. Induction in Closed Circuits.

Picture to oneself an unmagnetized piece of iron: its whirls are all existent, but they are shut up into little closed circuits, and so produce no external effect. Magnetize it slightly, and some of the closed circuits open out and expand, with one portion of them in the air. Magnetize it strongly, and we have a whole set of them opened out into vortex cores, still with the whirl round them, and constituting the common magnetic lines of force. There is no need to think of iron and steel in this connection. In air or any substance the whirls are still present, though much fewer or feebler, and their axes ordinarily form little closed circuits—it may be inside the atoms themselves. But wrap a current-conveying wire round them, and at once they open out into the lines of force proper to a circular current.

Again, think of an iron ring, or a hank of wire as bought at an ironmonger's: wrap a copper wire several times

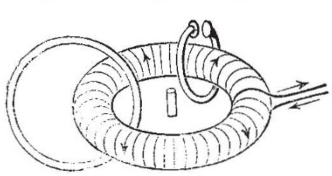

FIG. 47.—Closed magnetic circuit like Fig. 42, with a single-ring secondary circuit, and another open secondary loop; also with a short conducting-rod standing up in it.

round it, as a segment of a Gramme ring is wound (Fig. 47), and pass a current. The closed vortices in the iron at once expand: a portion of each flashes out and across the air-space inclosed by the ring (not by any means confining itself to a plane, of course), and enters the ring on the opposite side; so that directly the current is steady the lines all lie inside the iron again, but now inclosing an area—the area of the ring—instead of being shut up into infinitesimal links. In a sense the iron is still unmagnetized, for its lines of force still form closed contours within it, and none protrude any part of themselves into the air, except for irregularities. But in another sense it is highly and permanently magnetized round and round in itself, the magnetism being not easy to get out of it again, except by judiciously arranged reverse currents.

It is now like one great electric vortex ring instead of like a confused jumble of microscopic ones. Its section was shown in Fig. 42.

During the variable period, while the current is increasing in strength, or while it is being reversed, the region inclosed by the ring and all around it is full of myriads of expanding lines of force flashing across, broadside on, from one side of the iron to the other, and there stopping. It is the presence of these moving lines, changing rapidly from a "simply-connected" into a "multiply-connected" state, or *vice versâ*, which causes the powerful induced currents of "secondary generators."

In every case of varying magnetic field, in fact, we have lines moving broadside on, propagating their whirl, and more or less disturbing the medium through which they move.

Next consider a moving or spinning magnet. Its lines travel with it, and, being closed curves, they also must move broadside through the field, so that in this case we may expect just the same effect as can be obtained from a varying magnetic field.

If a broadside-moving line of force cut across a conductor, its motion is delayed, for its wheels slip and only gradually get up a whirl inside the ill-geared substance; thus, as we know, causing an induced current (see Fig. 43).

If a conducting ring is looped with the iron ring previously mentioned, as a snap-hook is looped with an eye, then every expanding vortex, while the ring is being magnetized, has necessarily to cut through the conducting ring once and no more, no matter what its shape or size. The electromotive force of induction is in this case therefore perfectly definite, and simply proportional to the number of turns made by the secondary round the core of the ring (Fig. 47).

Instead of supposing a closed conducting secondary circuit, imagine an open one: there is still an E.M.F. in it, though rather less than before because a few of the expanding lines flash through the gap and produce no effect, so the electricity must surge to and fro in the conductor as water surges up and down in a tilted trough, and a small condenser attached to the free ends will be alternately charged and discharged. The gap might become so large that nothing is left but a short rod (Fig. 47): in this also similar oscillations would occur.

But now suppose no secondary conductor at all; nothing but dielectric inclosed by the ring. In it there must be an electric displacement excited every time the magnetism of the ring is reversed. It may be an oscillatory displacement, but still on the whole in one direction during rise of magnetism, and in an opposite direction during reversal of magnetism. A charged body delicately suspended within the ring may feel the effect of the minute electrostatic strain so magnetically produced.

To see the mode in which an electrostatic displacement arises in the space embraced by the ring we have only to turn to Fig. 42, and look at the set of wheels along the line A B separating one half the section from the other. They cannot steadily rotate either way, for they are urged in opposite directions by the two halves; in other words, there is no magnetic field near such a ring, as is well known; but, nevertheless, during a change of magnetism, while the whirls inside are changing in speed, the rub on the dielectric necessary for checking the outer wheels of the conductor is either increased or diminished; and if the wheels have any elastic "give" in them, as we know they have, the electrostatic strain in the field is thereby altered during the varying stage of the magnetism.

OLIVER J. LODGE.

END OF PART III.

(*To be continued.*)