On Iron Crows' Nests.

THREE years ago, the removal of an old tree in the Cossipore Ordnance Factory, near Calcutta, brought to light a singular bird's nest, composed mainly of bent and twisted fragments of stout iron wire, such as is used to bind up bundles of bar iron for transport. The pieces, which were all about as thick as stout telegraph wire, were of considerable length and weight, and were keyed together by their own irregularities; but as there was no evidence by which to identify the builder, I merely made a note of the circumstances.

Last year, however, attracted by the laboured flight of a crow carrying in its bill a very unwieldy and apparently heavy load, I watched the bird until, frightened by a passing object when about two feet from the ground, it dropped its burden, which I at once secured. I found it to be a piece of crumpled iron wire, which on measurement in my laboratory proved to be $23\frac{1}{2}$ inches long between its apparent extremities (straightened out it measured $35\frac{1}{2}$ inches in length), to have a diameter of 0·125 inches (=No. 11 B.W.G.), and to weigh 55·72 grammes, or nearly 861 grains. The bird was in the main road, about 300 yards from the site of the original nest.

This evidence as to the ownership of the nest, and of the weight which an Indian crow can carry, may perhaps interest some of your readers. WALTER G. MCMILLAN.

Mason College, Birmingham, April 20.

Early Arrival of Birds.

MR. PRIDEAUX, in the last issue of NATURE, having recorded the unusually early arrival of the summer migrants in Surrey, it may perhaps be permissible to state the date of arrival here. The cuckoo, uttering its festive note, flew into a tree in my garden on March 25, attracting the attention of the whole household, and has been heard at intervals in the neighbourhood of Worcester ever since. The swallow and martin were here on the 4th inst., the willow warbler and the white-throat on the 7th, and the red-start on the 16th. Nidification was remarkably early this season. In my garden the long thrush, blackbird, and robin hatched out by March 30, and the missal thrush in an orchard close by was, as usual, earlier in its family arrangements. I heard the swift on the 26th inst. The spring flora was also early: lilac, hawthorn, bluebell, cowslip, primrose, wood anemone, spotted orchis, and orchis morio were in blossom on the 20th inst.; the sweet violet gone, and the dog violet blooming profusely in its place.

There is nothing wonderful in the cuckoo being here in March. The wonder is that it was then vocal.

J. LLOYD BOZWARD.

Henwick, Worcester, April 28.

Irritability of Plants.

IN your issue for April 19 (vol. xlix. p. 586) there is a short notice of a paper by Prof. Pfeffer on the "Irritability of Plants." In it you say: "Pfeffer instances the remarkable researches of Hegler on the effect of mechanical traction on growth stems, which when stretched by a weight, gain mechanical strength through the development of the mechanical tissues, which follows as a response to the pull to which they are subjected."

This recalls to mind the interesting passage in Tennyson's "Idylls of the King":

> So Gareth ere he parted flash'd in arms.
> Then as he donn'd the helm, and took the shield
> And mounted horse and graspt a spear, of grain
> Storm-strengthen'd on a windy site, and tipt
> With trenchant steel.

Derby, April 24. R. M. DEELEY.

The Action of Light on the Diphtheria Bacterium.

SOME time ago it was reported that colonies of the diphtheria bacterium do not thrive well when exposed to light, and it occurred to me that the electric light might afford a means of checking the development of the false membranes by projecting a very powerful arc light on the throat, for it is known that the tissues are to some extent penetrated by light. Or possibly the arc light could be sent into the throat through the mouth? I know that in Germany microscopic objects have been lighted with the aid of a lamp placed at some distance, and connected to the microscope by a curved glass rod, which conveyed the light by internal reflection. Incandescent lamps might be used in a similar manner, and some means could be devised in order to intercept the heat they produce, if it be objectionable.

A few days ago I noticed an article on Dr. Phillips' electric lamps, which he has employed to light the mouth, and the cavities between the mouth and the nose, and you recently published a paper read before the Royal Society, by Prof. H. M. Ward, on the bactericidal action of light, which partly confirms my views. It seems worth while, therefore, to make experiments with arc rays projected indirectly as above, and with incandescent lamps, and that especially upon diphtheria membranes. J. EREDE.

Rome, April 18.

Centipedes and their Young.

IN No. 1275 of NATURE (vol. xlix. p. 531), Mr. Urich, of the Trinidad Field Naturalists' Club, asks for information about the breeding habits of centipedes.

Similar observations to those made by the members of the Trinidad Club, and described by Mr. Urich, have been published by Kohlrausch ("Beitrage zür Kenntniss der Scalapendriden." Diss, Marburg, 1878), and these are referred to in the standard work on Myriapoda by Latzel ("Die Myriapoden der Osterreichisch-Ungarischen Monarchic." Wien, 1880, p. 136), and also in the "Lehrbuch der nerglischenden Entwicklungsgeschichte" (Jena, 1890), by Korschelt and Heider, p. 725.

Czernowitz, April 25. R. v. LENDENFELD.

Marsupites in the Isle of Wight.

IN a recent visit to the Isle of Wight, plates of *Marsupites* were found by Mr. R. M. Brydone and myself at Freshwater.

The locality is one in which these fossils might be expected to occur, but so far as I know they have not been recorded hitherto from any part of the island; certainly not by Barrois, nor in the last edition of the "Survey Memoir."

Winchester College. C. GRIFFITH.

POINCARÉ ON MAXWELL AND HERTZ.[1]

AT the time when Fresnel's experiments compelled all researchers to admit that light is due to the vibrations of a very subtile fluid filling the interplanetary spaces, the researches of Ampère made known the mutual actions of currents, and founded electrodynamics.

But one step more was required to suppose that this same fluid, the ether, which is the cause of luminous phenomena, is at the same time the vehicle of electrical actions. This step Ampère's imagination enabled him to take; but the illustrious physicist, while announcing this seductive hypothesis, did not see that it was so soon to take a more precise form, and receive the beginning of its confirmation.

It was still, however, but a dream without consistence, till the day when electric measures indicated an unexpected fact—a fact recalled by M. Cornu in the last *Annuaire*, at the end of his brilliant article devoted to the definition of electric units. To pass from the system of electrostatic units to the system of electrodynamic units, a certain transformation-factor is employed, the definition of which I will not recall, as it is to be found in M. Cornu's article. This factor, which is also called the ratio of unities, is precisely equal to the velocity of light.

The observations soon became so precise that it was impossible to attribute this concordance to chance. One could not doubt therefore that there were certain intimate relations between the optic and the electric phenomena. But the nature of these relations would perhaps still have escaped us if Maxwell's genius had not guessed it.

[1] Translation of an article by M. Poincaré, in the *Annuaire* of the Bureau des Longitudes for 1894.

Currents.

Everyone knows that bodies can be divided into two classes: conductors where we prove the transference of electricity, that is to say, of voltaic currents, and insulators or dielectrics. To the old electricians dielectrics were purely inert, and their part consisted in opposing the passage of electricity. If this were so, we could replace any insulating body by another of a different kind without changing the phenomena. Faraday's experiments have shown that it is nothing of the kind. Two condensers of the same shape and dimensions put in communication with the same sources of electricity will not take the same charge (even if the thickness of the isolating wire be the same), if the *nature* of the isolating matter differs. Maxwell had made too deep a study of Faraday's works not to understand the importance of dielectric bodies and the necessity of restoring to them their proper function.

Besides, if it be true that light is but an electric phenomenon, it follows that when it is propagated through an insulating body, this body is the place of the phenomenon, therefore there must be electric phenomena localised in dielectrics; but of what nature are they? Maxwell answers daringly: they are currents.

All the experiments up to his time seemed to contradict this; currents had never been observed except in conductors. How could Maxwell reconcile his audacious hypothesis with such a well-founded fact? Why do the hypothetical currents under certain circumstances produce manifest effects, which under ordinary conditions remain absolutely unobservable?

It is because dielectrics oppose to the passage of electricity, not a greater resistance than the conductors, but a resistance of a different kind. A comparison will make Maxwell's thought clearer.

If we endeavour to bend a spring, a resistance is encountered which increases in proportion as the spring is bent. If, therefore, we have at our disposal only a limited force, a moment will come when the resistance being unsurmountable, the movement will stop and equilibrium be established; at last, when the force ceases to act the spring will bound back, giving back all the work expended to bend it.

Suppose, on the contrary, that we wish to move a body immersed in water. Here again we meet with resistance which will depend on the velocity, but which, if this velocity remains constant, will not increase in proportion as the body advances; the movement will therefore continue as long as the force acts, and equilibrium will never be attained; finally, when the force ceases to act, the body will not tend to return, and the energy used for making it advance cannot be restored; it will have been entirely transformed into heat by the viscosity of the water.

The contrast is manifest, and it is necessary to distinguish between *elastic* and *viscous* resistance. Then dielectrics would behave, for electric movements, like elastic solids in the case of material movements, whilst conductors would behave like viscous liquids. Hence two categories of currents: current of displacement or Maxwell's currents which traverse dielectrics, and the ordinary conducting currents which circulate in conductors.

The first, having to overcome a sort of elastic resistance, can be but of short duration; for, this resistance increasing continually, equilibrium will be rapidly established.

The currents of conduction, on the contrary, having to overcome a sort of viscous resistance, can consequently last as long as the electromotive force which causes them. Let us look again at the convenient comparison which M. Cornu has borrowed from hydraulics. Suppose we have water under pressure in a reservoir; let us put this reservoir in communication with a vertical tube; the water will rise in it, but the movement will stop so soon as the hydrostatic equilibrium is reached. If the tube is large, there will not be any friction, or loss of charge, and water thus raised could be used for producing work. We have here a picture of displacing currents.

If, on the contrary, the water of the reservoir flows out by a horizontal tube, the movement will continue so long as the reservoir is not empty; but if the tube is narrow, there will be a considerable loss of work, and a production of heat by friction. We have here a picture of conducting currents.

Although it is impossible and of little use to try to represent to ourselves all the details of this mechanism, one may say that all happens as if the displacement currents had a number of little springs to bend. When the currents stop electrostatic equilibrium is established, and the springs are so much the more bent as the electric field is more intense. The work accumulated in these springs, that is to say, the electrostatic energy, can be wholly restored so soon as they can unbend themselves. It is thus that mechanical work is obtained when the conductors are allowed to obey the electrostatic attractions. These attractions would thus be due to the pressure exercised on the conductors by the bent springs. Finally, to follow the comparison to the end, the disruptive discharge must be likened to the rupture of over-strained springs.

On the other hand, the work employed for producing conduction currents is lost and wholly transformed into heat like that expended in overcoming the friction or the viscosity of fluids. *It is for this reason that the conducting wires get hot.* From Maxwell's point of view there are only closed currents. For the old electricians this was not so; they looked upon a current as closed which circulates in a wire joining the two poles of a battery. But if, instead of reuniting the two poles directly, one puts them in communication respectively with the two armatures of a condenser, the instantaneous current, which lasts until the condenser is filled, was considered open; it went, it was thought, from one armature to the other across the wire of communication and the battery, and stopped at the surface of the two armatures. On the other hand, Maxwell supposed that the current traverses the insulating plate, which separates the two armatures, under the form of a displacement current, and that it is thus completely closed. The elastic resistance which it meets on the passage explains its short duration.

Currents can manifest themselves in three ways: by their calorific effects, by their action on magnets and currents, by the induced currents to which they give rise. We have already seen why conduction currents develop heat, and why displacement currents do not do so. On the other hand, however, according to Maxwell's hypothesis, the currents which he imagines, must, like the ordinary currents, produce electromagnetic, electrodynamic, and inductive effects.

Why have we hitherto been unable to put these effects in evidence? It is because a displacement current, however feeble, cannot last long, in the same direction; for the tension of our springs, ever increasing, would soon stop it. There cannot therefore be in dielectrics, either continuous currents of long duration, or sensible alternating currents of long period. The effects will, however, become observable if the alternation is very rapid.

The Nature of Light.

According to Maxwell, this is the origin of light. A luminous ray is a series of alternating currents produced in dielectrics, or even in the air or the interplanetary vacuum, which changes its direction a thousand billion times every second. The enormous induction due to these frequent alternations produces other currents in the neighbouring parts of the dielectric, and it is thus that the luminous waves spread from point to point.

Calculation shows us that the rate of spreading is equal to the ratio of the units, that is to say, to the velocity of light.

These alternating currents are a kind of electrical vibrations; but are these vibrations longitudinal like those of sound, or transversal like those of Fresnel's "ether"? In the case of sound the air undergoes condensation and rarefaction, alternatively. On the contrary, Fresnel's ether, when vibrating, behaves as if it were formed of incompressible layers, capable only of sliding one over the other. If there were *open* currents, the electricity going from one extremity to the other of one of these currents would accumulate at one of the extremities; it would condense or rarefy itself like air; its vibrations would be longitudinal. But Maxwell admits only closed currents; this accumulation is impossible, and electricity behaves like Fresnel's incompressible ether; its vibrations are transversal.

Experimental Verification.

So we find again all the results of the undulatory theory. But this was, however, not enough to induce the physicists, who were more charmed than convinced, to accept Maxwell's ideas. All that could be said in their favour was that they did not contradict any of the observed facts, and that it was a great pity if they were not true. But experimental confirmation was wanting; it had to be waited for during twenty-five years.

A divergence had to be found between the old theory and Maxwell's, which was not too delicate for our rough means of investigation. There was only one which afforded an *experimentum crucis.*

The old electrodynamics required electromagnetic induction to be produced instantaneously; but according to the new doctrine it must, on the contrary, be propagated with the velocity of light.

The question was therefore to measure, or at least to ascertain, the rate of propagation of inductive effects; this has been done by the illustrious German physicist, Hertz, by the method of interferences.

This method is well known in its applications to optical phenomena. Two luminous rays issuing from the same source interfere when they meet at the same point after having followed different paths. If the difference of these paths is equal to the length of a wave—that is to say, to the path traversed during one period, or a whole number of wave-lengths—one of the vibrations is later than another by a whole number of periods; the two vibrations are therefore at the same phase, they are in the same direction, and they reinforce each other.

If, on the contrary, the difference of path of the two rays is equal to an odd number of half wave-lengths, the two vibrations are in contrary directions, and they neutralise one another.

The luminous waves are not the only ones susceptible to interference; all periodic and alternating phenomena propagated with a finite velocity will produce analogous effects. It happens with sound. It ought to happen with electrodynamic induction, if the velocity of propagation is finite; but if, on the contrary, the propagation be instantaneous, there will not be any interference.

But one cannot put these interferences to the proof if the wave-length is greater than our laboratories, or greater than the space that the induction can traverse without becoming too feeble. Currents of very short period are absolutely essential.

Electric Exciters.

Let us first see how they may be obtained with the help of an apparatus which is a veritable electric pendulum. Suppose two conductors united by a wire; if they are not of the same potential, the electric equilibrium is broken in the same way as the mechanical equilibrium is deranged when a pendulum is swung from the vertical. In the one case as in the other, the equilibrium tends to re-establish itself.

A current circulates in the wire, and tends to equalise the potential of the two conductors in the same way as a pendulum seeks the vertical. But the pendulum will not stop in its position of equilibrium; having acquired a certain velocity, it passes this position because of its inertia. Similarly, when our conductors are discharged, the electric equilibrium momentarlly re-established, will not maintain itself, and will be destroyed by a cause analogous to inertia; this cause is *self-induction.* We know that when a current stops it gives rise in the adjacent wires to an induced current in the same direction. The same effect even is produced in the wire in which the induction current circulates, which finds itself, so to speak, continued by the induced current.

In other words, a current will persist after the disappearance of the cause which produced it, as a moving body does not stop when the force, which had put it in motion, ceases to act.

When the two potentials shall have become equal, the current will therefore continue in the same direction, and will make the two conductors take opposite charges to those which they had to start with.

In this case, as in that of the pendulum, the place of equilibrium is passed; in order to re-establish it, a backward movement is necessary.

When the equilibrium is regained, the same cause immediately destroys it, and the oscillations continue without ceasing.

Calculation shows that the duration depends on the capacity of the conductors; it suffices, therefore, to diminish sufficiently this capacity, which is easy, to have an electric pendulum susceptible of producing alternating currents of extreme rapidity.

All this was well established by Lord Kelvin's theories and by Feddersen's experiments on the oscillating discharge of the Leyden jar. It is, therefore, not this which constitutes the original idea of Hertz.

But it is not sufficient to construct a pendulum; it must also be put into movement. For this, it is necessary for some agent to move it from its position of equilibrium, and then to stop abruptly—I mean to say, in a time very short in relation to the duration of a period; otherwise the pendulum will not oscillate.

If, for example, we move a pendulum from its vertical position with the hand, and then, instead of loosing it suddenly, we let the arm relax slowly without unclasping the fingers, the pendulum, still supported, will arrive at its place of equilibrium without velocity, and will not pass it.

We see then, that with periods of a hundred-millionth of a second, no system of mechanical unclamping could work, however rapid it might appear to us with regard to our usual units of time. This is the way in which Hertz has solved the problem.

Taking again our electric pendulum, let us make in the wire, which joins the two conductors, a cut of some millimetres. This cut divides our apparatus into two symmetric halves, which we will put in communication with the two poles of a Ruhmkorff coil. The induced current will charge our two conductors, and the difference of their potential will increase with a relative slowness.

At first the cut will stop the conductors from discharging themselves. The air plays the part of an insulator, and keeps our pendulum away from its position of equilibrium.

But when the difference of potential becomes large enough, the jar spark will pass, and will make a way for the electricity accumulated on the conductors. The cut will all at once cease to act as an insulator, and by a sort of electric unclamping, our pendulum will be freed from the cause which prevented it returning to its equilibrium. If the complex conditions, well studied by Hertz, are fulfilled, this unclamping is sudden enough to enable oscillations to be produced.

The apparatus, called an "exciter," produces currents which change their direction from 100,000,000 to 1,000,000,000 times per second. Because of this extreme frequency they can produce inductive effects at a great distance. In order to render these effects simple, another electric pendulum, called a "resonator," is employed. In this new pendulum, the cut and the coil, which only serve for the unclamping, are suppressed; the two conductors reduce themselves to two very small spheres, and the wire is bent back in a circle in a way to approach the spheres to each other.

The induction due to the exciter will put this resonator in vibration the more easily as the periods of the two are less different. At certain phases of the vibration, the difference of potential of the two spheres will be large enough to produce sparks.

Production of Interferences.

We have thus an instrument which shows the effects of an inductive wave emitted from the exciter. We can study what happens in two ways: either expose the resonator to the direct induction of the exciter at a great distance, or else make this induction work at a short distance on a long conducting wire, along which the electric wave will go, and which will work in its turn by induction at a short distance on the resonator.

Whether the wave propagates itself along a wire or across the air, one can produce interferences by reflection. In the first case, it will reflect itself at the extremity of the wire, which it will follow again in an inverse direction; in the second, it will reflect itself on a metallic leaf which acts as a mirror. In the two cases the reflected wave will interfere with the direct wave, and we can find places where the spark of the resonator will cease to pass.

The experiments made with the long wire are easier; they furnish us with very precious instruction, but they will not serve as *experimenta crucis;* for in the old as well as the modern theory, the quickness of an electric wave along a wire must be equal to that of light. The experiments on the direct induction at a great distance are, on the contrary, decisive. They show that not only the quickness of propagation of induction across the air is finite, but that it is equal to the quickness of the wave propagated along a wire, complying with the ideas of Maxwell.

Synthesis of Light.

I shall insist less on other experiments of Hertz, more brilliant, but less instructive. Concentrating with a parabolic mirror the wave of induction taken from the exciter, the German savant obtains a veritable cluster of electric rays, capable of reflecting and refracting themselves regularly. The rays, if the period, already so small, were a million times shorter still would not differ from the luminous rays. We know that the sun gives out several kinds of radiation, some luminous because they act on the retina, others obscure ultra-violet or infra-red, which manifest themselves by their chemical or calorific effects. The first only owe their qualities, which make them appear to us of a different nature, to a kind of physiological chance. To the physicist the infra-red does not differ more from the red, than the red from the green; the length of a wave is only greater; those of the hertzian radiations are much greater still, but there are only differences of degree, and one may say, if Maxwell's theories are true, that the illustrious Professor of Bonn has realised a veritable synthesis of light.

Conclusions.

But our admiration for so much unhoped-for success must not make us forget the progress which still remains to be accomplished. Let us therefore try to exactly summarise the results which are definitely attained.

First, the velocity of direct induction across the air is finite, without which the interferences would be impossible. The old electro-dynamics are therefore condemned. What must one put in its place? Is it Maxwell's theory (or at least something approaching it, for one would not expect the divination of the English savant to have foreseen the truth in all its details)? Although the probabilities accumulate, the complete demonstration is not yet reached.

We can measure the length of a wave of hertzian oscillations; this length is the product of the period by the velocity of propagation. We should, therefore, know this velocity if we knew the period; but this last is so small that we cannot measure it; we can only calculate it by a formula due to Lord Kelvin. This calculation leads to numbers which agree with Maxwell's theory; but the last doubts will only be done away with when the velocity of propagation has been directly measured.

This is not all: things are far from being so simple as one might think, from the above short account. Diverse circumstances come to complicate them.

First, there is round the exciter a radiation of induction; the energy of this apparatus radiates, therefore, externally, and as no fresh source comes to supply it, it soon disperses, and the oscillations die out very rapidly. It is here that one must look for the explanation of the phenomenon of multiple resonance, which was discovered by MM. Sarasin and De la Rive, and which at first appeared irreconcilable with the theory.

On the other hand, we know that light does not precisely follow the laws of geometrical optics, and the difference which produces diffraction, is more considerable as the length of the wave is greater. With the great length of the hertzian undulations these phenomena must assume an enormous importance, and trouble everything. No doubt it is fortunate, for the moment at least, that our means of observation are so coarse, otherwise the simplicity which seduced us at the first sight would give place to a labyrinth where we should be lost. It is from this probably that different anomalies arise, which have hitherto not been explained. It is also for this reason that the experiments on the refraction of rays of electric force have, as I said above, but little demonstrative worth.

There still remains a difficulty which is more serious, but which is no doubt not insurmountable. According to Maxwell, the coefficient of electrostatic induction of a transparent body ought to be equal to the square of its index of refraction. This is not so; the bodies which follow Maxwell's law are exceptions. We are evidently in the presence of phenomena much more complex than we thought at first; but one has not been able to explain anything, and the experiments themselves are contradictory.

There still remains, therefore, much to be done; the identity of light and electricity is from to-day something more than a seducing hypothesis: it is a probable truth, but it is not as yet a proved truth.

THE RECENT WORK OF THE CATARACT CONSTRUCTION COMPANY.

SOME arrangements recently made by the Cataract Construction Company show that the works are extending in a very satisfactory manner. The Niagara Falls Paper Company is now well under way. They make paper from wood pulp, and a large amount of power is used for grinding the trees down into pulp. They have fixed turbines in their own wheel-pit, and take water from