NATURE

A WEEKLY ILLUSTRATED JOURNAL OF SCIENCE.

" To the solid ground
Of Nature trusts the mind which builds for aye."—WORDSWORTH.

THURSDAY, MARCH 6, 1913.

SCIENTIFIC WORTHIES.

XL.—SIR J. J. THOMSON, O.M., F.R.S.

IT is impossible to think of the rapid and profound evolution which occurred in the fundamental conceptions of natural philosophy during the final years of the past century without one figure looming large in the mental picture—that of the celebrated physicist of the University of Cambridge. In effect, the new and fruitful trend assumed by the science of physics in recent years has been in great part due to the happy intuition of Sir J. J. Thomson and to the experimental researches unwearyingly pursued by him and his students in the celebrated Cavendish Laboratory.

One circumstance is particularly striking in that movement—the unforeseen opening out of new and vast horizons to the physicist precisely at the moment when the electromagnetic theory of light had been victoriously acclaimed—a theory which not only gathered into one marvellously harmonious synthesis all the phenomena of the physical world, but at the same time satisfied that natural scientific instinct, which seeks for the greatest simplicity in its explanation of natural phenomena, by attributing to a single medium, the æther, the double office of transmitting electrical and magnetic forces as well as the waves of light.

In spite of this, physicists were not able long to rest upon their laurels; for certain classes of phenomena, which, perhaps, it was hoped would find an easy explanation, proved quite resistant to elucidation unless accessory hypotheses were devised.

If we go back in thought fifteen or twenty years, it is plainly visible that, after the definitive triumph of Maxwell's theory in the experimental field with the work of Hertz and his successors, the great unknown which we call electricity was still considered by all, in its real nature, more or less as an incompressible fluid which could displace itself in dielectrics, overcoming a certain elasticity, or flow in a conductor; whilst the principal electrostatic facts, metallic conduction and some other phenomena could be considered as intimately known. But the propagation of electricity in electrolytes, and more especially in gases, remained in part problematical.

To these two classes of phenomena was not attributed the importance they should have merited. But even then was perceived one most important specific character of electricity in the case of its propagation in electrolytes, namely, its apportionment into small parts, identical among themselves, and representing the charges corresponding with each valence of the electrolytic ions. The significance of this fact could not escape the mind of Maxwell; and it led him to consider those charges as *atoms* of electricity. Nor could it escape Helmholtz, who acutely pointed out that the existence of such charges must be considered possible, even apart from the ponderable matter with which they are ordinarily accompanied, even if it were only during the short time in which, having left the ion, they are about to enter the electrode to feed the current in the metallic portion of the circuit.

The existence of atoms of electricity, or of "electrons," according to the felicitous expression proposed by Stoney, was accepted without hesitation as a fundamental hypothesis in the theories constructed by Larmor, Lorentz and other mathematical physicists; and the former of these so far back as 1894 succeeded in outlining an electrical theory of matter. But, however seductive these theoretical investigations appeared, and in their comprehensiveness they represented a considerable advance on earlier theories, the real existence of electrons could not be accepted by physicists until a satisfactory experimental demonstration of their existence was forthcoming.

To succeed in such a demonstration undoubtedly appeared to everyone a sufficiently difficult matter; yet such has actually been achieved, thanks to the study of the kathode rays, that is, of certain peculiarities presented by electrical discharge and already known for some considerable time.

The phenomena of discharge have always attracted the attention of physicists, and innumerable studies have been made in this field. The peculiarities which they present, varied as they are almost indefinitely, and certain brilliant aspects which they possess, even though not always of the highest scientific interest, have rendered these studies so attractive, that it is difficult for anyone who has once pursued them to free himself from their seductiveness and pursue other researches. A rich material of facts thus went on accumulating, between which, however, in the majority of cases there was no intimate connecting link; this material was later to be coordinated by the electronic theory, which in turn gained many indirect confirmations from it. Finally, when, with the perfecting of technique, it became an easy matter to produce the greatest rarefaction of gases, the phenomena of the kathode rays assumed their due importance in the eyes of physicists; and all those who, by natural disposition or as a result of long experience in physical researches, possessed that fine intuition which in certain cases appears almost as a true divination, presaged that from the study of the kathode rays would accrue results of capital importance, capable of throwing light on the nature of electricity.

The very brilliant and ingenious experiments described by Crookes, and the theory of "radiant matter" proposed by him to explain them, gave a great impulse in the direction which has led to the actual views of to-day. It is true that that theory was combated, unfortunately, even by physicists of such high reputation as Hertz; but there were some, at least, who at once welcomed it with enthusiasm.

The present writer can boast that he was one of this small band, and that he drew from the theory the inspiration of numerous experiments, demonstrating the existence of electrified particles (ions) in gases under atmospheric pressure transmitting the discharge, and capable of producing with their movements regulated by electrical forces phenomena of "electrical shadows" similar to those produced by the kathode rays.

Meanwhile, shortly afterwards and independently of the explanation given of the kathode rays, various physicists sought to explain by the presence of mobile charges the conducting properties possessed by gases in certain circumstances, and it then appeared that they could not do better than apply to gases the mechanism imagined in the case of electrolytes. Schuster, Arrhenius, Elster, Geitel and others obtained noteworthy results in this field, bringing forward numerous proofs of the existence of ions in gases, and basing on the facts observed the explanation of divers phenomena.

It was not easy, however, to apply directly to gases the electrolytic theory. In the first place, an enormous difference exists between the two orders of phenomena as regards the difference of potential required to bring about a transmission of electricity, this difference being exceedingly small in the case of liquids and relatively great in the case of gases. Another formidable difficulty also presented itself in the fact that, whilst it is a most natural thing for atoms of different chemical nature to carry charges of different sign, so that, for example, there are negative ions of oxygen and positive ions of hydrogen, it was not easy to conceive that, in a given simple gas, there could exist ions of the same chemical nature but some charged positively and some negatively.

But this difficulty disappeared when, by the classical experiments of J. J. Thomson, it was rendered probable, and demonstrated, so far as this is humanly possible, that negative electrons or "corpuscles" exist and form an integral part of the structure of the atoms.

The suggestive fact having been observed by Perrin, and then by Thomson, of the effective transport of negative charges by the kathode rays, a fact which suggested the hypothesis that such rays consisted of the movement of particles expelled from the kathode, Thomson commenced in 1897 those famous experimental researches in which he succeeded in measuring, at the same time, the ratio e/m between charge and mass of the said particles and their velocity v. Having obtained for v a value clearly inferior to the velocity of light, and, above all, a value for e/m nearly two thousand times that corresponding with the ion of hydrogen, and, moreover, as it could be shown that the same identical particles always resulted on changing the substances dealt with in the experiments (electrodes, gases, &c.), it was revealed that those particles were neither atoms nor molecules, but the electrons themselves, contained in and expelled from the atoms. Others had previously employed the action of a magnetic field on the kathode rays to obtain the foregoing determinations, and Thomson himself had made a similar attempt, but without attaining immediately the results indicated.

It is here clearly seen how a theoretical concept or a happy hypothesis devised to guide the experimenter can be of the greatest assistance in obtaining far-reaching results. In fact, it is difficult to decide which most to admire in Thomson—the ability of the proved experimenter or the felicitous intuition of the keen thinker which leads him to foresee and anticipate the final interpretation of the facts observed. Even to-day it would require most prolonged and difficult experimental work to show in a rigorous manner that the ratio e/m is really (save the influence of v on the value of m) constant on all occasions, whatever be the circumstances in which the kathode rays originate (the nature of the electrodes, of the rarefied gas, the pressure of the latter, &c.). But with inspired generalisation, Thomson, conscious of the accuracy of his own measurements, and with great faith in the conceptions that were becoming matured in his mind, did not hesitate to proclaim that his experiments furnished the proof of the existence of particles negatively electrified and having a mass not greater than one two-thousandth part of the mass of the atom of hydrogen.

With this was assumed that the charge of each was equal to that corresponding with one atomic valence; but in strictness the results obtained could have been interpreted alternatively by attributing to the said particles somewhat large charges and a mass of atomic magnitude. However probable the first interpretation seemed, there still remained a gap to fill in. Thomson succeeded in this by utilising the studies carried out in his laboratory by C. T. R. Wilson, who had recognised that electrified particles, and more particularly the negative ones, acted as nuclei of condensation for water vapour. The experimental method adopted by Thomson, which enabled him to evaluate the charge of each single corpuscle, is a true model of ingenuity. The numerical result obtained was perfectly favourable to the interpretation adopted in the earlier experiments; and if not at first very exact, was soon corrected by the later experiments of H. A. Wilson and of Thomson himself.

When the results were first communicated to the British Association in 1899, they were so favourably received that it may be said that from that date the new ideas on the nature of the kathode rays were accepted by the majority of physicists.

Meanwhile other discoveries of considerable importance were made, which brought unexpected confirmation to these hypotheses. The phenomenon discovered by Zeeman, which was at once explained by the electronic theory of Lorentz, and the discovery of radio-activity by Becquerel, came at the most opportune moment in support of the electrical theory of matter, which now became almost irresistible and had its basis in the experiments of Thomson which have been recorded.

It was not, in fact, possible to conceive how the kathode rays could be composed of corpuscles always identical whatever the nature of the bodies present, or taking part in their formation, without supposing that such corpuscles pre-existed in the atoms of every substance, and were thus identical with the electrons already assumed to be constituent parts of the atoms. From this to the hypothesis that the atoms consist only of electrons is a short step. And, in truth, the mass of the corpuscles may be entirely electromagnetic, that is, due solely to the motion with which the electrical charges are possessed. The well-known experiments of Kaufmann also came at an opportune moment in support of this opinion, demonstrating as they did that the mass of the electrons emitted by radio-active bodies appears so much the greater the greater their velocity. Thus, from experiments on the kathode rays a theory was evolved the philosophical import of which is evidently of the highest, inasmuch as it enables one to eliminate one of the fundamental or primitive entities (matter) which have been invoked to give an explanation of the phenomena of the physical world.

One can conceive, in fact, the possibility of building up a system of philosophy with only æther and electrons as a basis; a system all the more seductive on account of the simplification that it carries with it.

The known dualism of electricity of two signs, which causes differences more or less considerable in every fact, becomes accentuated when the single electrons are considered. In fact, in spite of the numerous and varied attempts that have been made to demonstrate the existence of positive electrons, that is, of positive charges endowed with a mass (electromagnetic) of the same order of magnitude as that of the negative electrons, all such efforts have ended in failure. It is, therefore, natural to consider only the negative electrons, from which one may eliminate the adjective, and admit that in the positive ions each valence is due, not to the addition of a positive electron, but to the subtraction of a negative electron or electron strictly so called. This naturally led Thomson to attribute to positive electricity certain special characters within the atoms, and to assume for these a special structure in which the negative electrons have a preponderating influence; which view is in conformity with known facts, and, in particular, with the Zeeman effect, from which is deduced, as is well known, that the emission of light has its origin in the vibration of negative electrons.

Taking, as point of departure, an idea suggested by Lord Kelvin's "Aepinus Atomised" (according to the picturesque expression employed by him), Thomson assumed that a neutral atom is composed of a sphere of positive electricity in which are immersed negative electrons, the total charge of which is equal in absolute value to that of the sphere. The electrical force which acts on each of these throughout the positive sphere is proportional to the distance from the centre, and maintains them in closed orbits, the stability of which needs a special distribution of the electrons themselves.

Some concrete idea of such a species of solar systems was opportunely found in the old experiment of floating magnets, due to the physicist Mayer, which was thus rescued from the unmerited oblivion in which it had been left.

This hypothesis of the structure of the atoms, although most daring, seems to respond to all exigencies. It may be modified with the progress of time, and certainly needs completion; but it is probable that its essential features will be retained by the science of the future.

A necessary complement of the present-day theory of the kathode rays is found in the theory elaborated in much detail by J. J. Thomson to explain the production and nature of the rays discovered by Röntgen. It presents such a character of evidence, and, in short, is so intuitive, that everyone feels that he could have conceived it himself, which idea, however, is only one of many similar illusions of *amour propre*. Indeed, how can one avoid admitting the production of sudden electromagnetic perturbations in the æther, at the spot where the electrons are entirely arrested or retarded, as occurs when the kathode rays encounter an obstacle? It will naturally follow, I believe, that the X-rays will be considered as the manifestation of those perturbations, in spite of there having been proposed recently a new hypothesis, according to which these rays are of a corpuscular nature and composed of the motion of neutral couples (one negative electron and one positive). It will be necessary at least to bring proof on proof for this new hypothesis before Thomson's theory is abandoned. And in such a case it will be necessary to establish what happens to the perturbations due to the variations of velocity of the electrons constituting the kathode rays, which undoubtedly are produced.

In creating the actual current of ideas relative to the nature of matter and the common prime cause of phenomena of light and electromagnetism, in addition to the experimental work of Thomson other discoveries of recent years have contributed, above all, that of Zeeman (1897), to which I have already alluded, and that of radio-activity—the latter thanks to the very simple and ingenious explanation given by Rutherford and Soddy. If from the measurements carried out on the kathode rays was demonstrated the existence of the electrons as integral parts of the atoms, the facts of radio-activity lead us further—to the view that the atom is a complex structure of negative electrons and positive ions, or at least that at a given moment, perhaps in consequence of the continuous irradiation of part of its energy, there can separate electrons and positive ions, the latter being, at any rate in the cases studied as yet, not other than bivalent ions of helium. This interpretation of radio-active phenomena seems so natural as to give rise easily to the illusion that the phenomena themselves could have been foreseen. On the other hand, they may make the importance of Thomson's work appear to some less than it undoubtedly is; but it is necessary to go back in mind to the period at which it was carried out and take account of the mode of thought prevailing at the time, to appreciate the acuteness and originality of mind which were necessary in order to dare to snatch from the atom its dogmatic prerogatives of indivisibility and invariability.

There are other examples in the history of physical science of discoveries made at short intervals of time converging to a truth which the discovery of a final fact put into a clear light. It is usual then to say that that truth was "in the air," as if any person in favourable circumstances would have been able to discover it. I do not believe, in any case, that the same can be said of the discoveries of which we are speaking; moreover, such an opinion, too frequently repeated, should be rejected. If one looks closely, it is possible to recognise that, in the majority of cases, not blind fortune is the aid of the happy discoverer, but the special attitude of mind and the scientific preparation he possesses. In the concrete case it is evident that Thomson, from the commencement of his researches, was unconsciously preparing himself for the grand discovery of the true nature of the kathode rays. It is sufficient in proof of this to cite his noteworthy memoir of 1881, relative to the electrical and magnetic effects produced by the motion of electrified bodies, for which Crookes's theory of radiant matter had furnished the inspiration.

The work published by Sir J. J. Thomson during recent years constitutes the complement and crown of his principal achievement. Thus, in a short time he was able to collect into a body of doctrine everything which relates to the propagation of electricity in gases, and of which his well-known treatise on the subject is the embodiment of the faith—a work that is consulted by all who conduct experimental researches in this field, which is very far from having yielded all its fruits. In this volume are treated with much detail the production of ions in gases, their disappearance, their velocities under certain contingencies, &c. Frequently the original experiments of the author and his students have rendered possible the completion of the explanation of a particular phenomenon, or put in evidence some new detail or the laws which it obeys. Moreover, making use of the facts thus accumulated and the relationship existing between them, Thomson had at his disposal the elements necessary to found a theory of electrical discharge more comprehensive than any previously proposed, which, although not yet complete and definitive, has enabled him to point out the relations between facts apparently disparate which previously could only be described separately and disconnectedly.

Quite recently the activity of the Cambridge physicist seems to have been concentrated on the study of the properties of the positive rays, and especially of the so-called canal rays. This is a field of studies in which several most daring workers (Wien, Stark, &c.) have amassed a rich harvest of most important results; none the less, J. J. Thomson, by the adoption of ingenious experimental arrangements, in part new, and especially by virtue of happily inspired and most original interpretations, has drawn, and continues to draw, from his researches consequences the import of which far surpasses the limits in which they might have been expected to be confined.

Of these researches physicists await with some impatience the publication of a treatise which shall present them not merely in order of date, but with that arrangement, clearness and concision which are precious characteristics of Thomson's writings.

However insufficient and incomplete, the foregoing considerations will help to make clear the signal value of Thomson's work. Such, at least, has been my intention. Although compelled to abandon an analysis of the extensive scientific productions of the great physicist, I trust that all will be, like myself, convinced that his work belongs to the category of those investigations which leave an indelible impress on the progress of science.

Augusto Righi.

AN ENGLISH TEXT-BOOK OF PROTOZOOLOGY.

An Introduction to the Study of the Protozoa: with Special Reference to the Parasitic Forms. By Prof. E. A. Minchin, F.R.S. Pp. xi + 520. (London: Edward Arnold, 1912.) Price 21*s.* net.

THIS work on the Protozoa by Prof. Minchin may be considered as an attempt to confine a knowledge of the philosophical and the practical side of the modern science of protozoology within the limits of one volume.

After discussing the one-celled organisms grouped for convenience under the term Protista, their modes of life are considered. Various types of nutrition—purely animal, plant-like, feeders on decaying matter, and finally parasitic methods—are described and illustrated. The "mutual aid" associations of the animal world known as symbiotic unions are charmingly portrayed, and in contrast the interrelations of hosts and parasites are set forth. A most interesting study in animal mechanics is presented, together with a broad account of the organisation of the Protozoa. To the cytologist there is much of interest in the chapter dealing with the nucleus and nuclear structure. The author draws a distinction "between organisms of the 'cellular' grade, with distinct nucleus and cytoplasm, and those of the 'bacterial' grade, in which the chromatin does not form a distinct nucleus." He considers that a "bacterial type of organism" is "not to be regarded as a cell, but as representing a condition antecedent to the evolution of the true cellular type of structure." Such a distinction seems somewhat arbitrary and unnatural, and tends to overlook the importance of intermediate forms.