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## The Revolution in Physics.

ON April 19 last, Sir Oliver Lodge gave the nineteenth Kelvin lecture to the Institution of Electrical Engineers.[1] When he gave the fifth Kelvin lecture in 1914, he chose as his subject the electricity of the atmosphere—both natural and artificial. This year he took as his subject the revolution in physics and expounded it in his inimitable way. He controverted the statement so confidently made a few years ago that the effect of the revolution has been to abolish the ether of space. He considers that not only has the existence of the ether been established, but also that a rational theory of it has already begun. He points out what a tremendous discovery it would be if the universe could be proved to be finite. Possibly the finiteness of space only means that it is our particular cosmos that is finite. We cannot say what is beyond it ; there is no means of getting at what is beyond it. Still, absolute units have been discovered, that is, discontinuous things which can be counted ; for example, the electron and the quantum. Many years ago the discontinuity of matter was observed. Now the atom itself has been resolved into electric charges which are localised portions of energy embedded in the ether. It is a great discovery that matter is a form of energy.

There is a great conflict, beginning in ancient times and continuing ever since, between continuity and discontinuity. Every discontinuity discovered is a step in advance. But there is little doubt that continuity will conquer in the end. Twenty or thirty years ago it seemed that a great deal was known about the electron. Its size, mass, and so on could be computed. Some of this knowledge still remains valid, but the twentieth century has put everything back into the melting pot. We are ignorant of the nature and constitution of the electron, and we are now uncertain as to its size and speed. The mathematical methods now employed are of a novel and almost of an experimental kind. Mechanical theories of the ether have had to be abandoned. This is what is meant, or should be meant, by the statement that the ether no longer exists.

Electrons are what electrical engineers specially deal with. We have had these active little creatures harnessed for a good time, and have propelled many things by their aid, from telegraph messages to railway trains. But we have never been allowed to see them even metaphorically. They are

[1] *Jour. Inst. Elec. Eng.*, vol. 66, p. 1005; 1928.

cloaked, so that we are like a costermonger with a shrouded animal between the shafts; it may be a dog, a zebra, or a donkey. We can only infer its nature from its more or less tractable behaviour. Electrons have proved themselves very obedient to the smallest guidance, and very energetic.

The only semi-dynamical theory of the ether which seems likely to survive is the perfect incompressible fluid in vortex motion, the fine-grained rotational structure worked at by Kelvin and FitzGerald. A fluid in vortex motion is able to transmit transverse waves, for vortices have many of the peculiar properties of a gyrostat. Difficulties arose about stability. Nowadays, however, a doubt about stability is not fatal, since something unexpected like the quantum may turn up to stabilise matters. Bohr's orbits, for example, were not stable until the quantum arrived. Even now no one can fully explain the quantum, though admittedly it has stabilising qualities, since it emphasises whole units and declines to admit fractions. It refuses continuous emission, it favours jumps rather than slides, and prefers staircases to slopes. Jeans has said that if it were not for the quantum, matter would very quickly radiate itself away into space. The only reason why everything does not go off in a flash is because of the quantum. It has rendered matter permanent.

Modern physics aims at simplifying the complex by the aid of relativity and quanta, but it has raised difficulties where previously we detected none, and has made simple things complex. A beam of light seems a simple thing, but now the structure of light has become puzzling and has acquired some of the properties of matter. Reciprocally, matter has acquired some of the properties of light. The particle and the wave are more closely related than a few years ago we should have thought it possible to imagine. The quantum theory made waves behave something like particles; conversely, the new dynamics makes particles behave something like waves. Planck has said that in many of our theories we must build up again from the very beginning. In the nineteenth century everything was reduced to mechanics; now the very motion of matter itself is in need of explanation.

One difficulty in verifying experimentally theories in connexion with corpuscles and waves is that we cannot make direct experiments on the ether. We have no means of examining radiation in free space; we can only deal with it when it interacts with matter. Nevertheless, some experimental confirmation of the existence of a wave structure as part of a flying electron has recently been made by Prof. G. P. Thomson, of the University of Aberdeen. He sends cathode rays through a metal film of molecular thickness. He gets on the examination plate not a point, but a point with rings round it. He gets a diffraction pattern, and this must mean waves. The experiment is a verification of the theory which associates wave motion with rapid particles and enables us to calculate the wave-length from the potential drop which propelled the particles. Magnetic force deflects the waves, wiping out most of the pattern from its original place and putting it round the deflected spot. This is a very important discovery. The important difference between these rays with nuclei in them and ordinary X-rays must not be forgotten. One variety is affected by a magnetic field and the other is not. Matter is one extreme and light is the other. Here we recognise an intermediate thing which establishes the reality of light quanta.

Sir Oliver made a suggestion of the possible structure of an electron. He imagines it to be a minute bubble or minute cavity in the continuous structure of the ether. To produce such a hollow against the enormous pressure must involve the expenditure of a great amount of energy. Lines of strain permeate the ether in all directions from the hollow. These constitute the electrostatic field. The energy resides not only in the hollow but also in the inseparable electrostatic field. If we call $c$ the 'constitutional' velocity of the ether, its pressure will be $\rho c^2$ where $\rho$ is the density. This is an enormous pressure, but when we consider that the ether has to transmit gravity and all the other forces we apply to it, the magnitude of its properties must vastly exceed those of the substances we are familiar with. The hollow sustains itself because of its electric charge. The electric charge produces a tension tending to make it expand. This is balanced by the external pressure. Calculations are given to show that the radius of the hollow computed in this way is of the same order as the recognised electronic charge.

Recent recondite speculations in mathematics and physics were barely touched upon. These theories are so striking that some of us who saw their beginning in the nineteenth century can scarcely follow their developments, let alone their eccentricities. The mathematical speculators are doing more than going out of our depth; they are soaring up into the clouds of tensors and matrices, with any number of dimensions of space and imaginary operators. In the old days, explorers used captive balloons, and we might

occasionally swarm up the rope or haul them back to earth. Now they have no earth attachment and have quite gone out of sight. We can only follow their progress when they drop a bomb. Then we sit up and attend. But the bombs, although perturbing, are not destructive ; when they are opened they are found to contain interesting things, more like seeds than explosives, and those which take root flourish exceedingly and overshadow the ancient fields. The older method was to plant a seed quietly in the ground so that we could watch it grow. Radioactivity was one, the electron was another, and so also was Bohr's theory. We must now recognise that wave mechanics is the beginning of one branch of a theory of the ether, which must be contemplated by every physicist who is interested in physical reality.

## Continental Drift.

*Theory of Continental Drift : a Symposium on the Origin and Movement of Land Masses, both Inter-Continental and Intra-Continental, as proposed by Alfred Wegener.* By W. A. J. M. van Waterschoot van der Gracht, Bailey Willis, Rollin T. Chamberlin, John Joly, G. A. F. Molengraaff, J. W. Gregory, Alfred Wegener, Charles Schuchert, Chester R. Longwell, Frank Bursley Taylor, William Bowie, David White, Joseph T. Singewald, Jr., and Edward W. Berry. (Published under a Fund established by the New York Committee for the Mid-Year Meeting of the Association, November 1926.) Pp. x + 240. (Tulsa, Oklahoma : The American Association of Petroleum Geologists ; London : Thomas Murby and Co., 1928.) 15*s.* net.

THE complex problem of continental drift has everywhere been the subject of animated discussion in geological circles during recent years, and the publication of the papers presented at a symposium held in New York late in 1926 serves a valuable purpose in bringing together the considered opinions of some of the leading geologists of America and Europe. The American Association of Petroleum Geologists is to be congratulated not only on having staged a spirited and fruitful discussion, but also on its enterprise in making the contributions available in printed form to a world-wide audience. The book opens with a broad-minded and constructive review of the problem by Dr. van der Gracht ; this is followed by papers from thirteen other authors, for the most part severely critical ; and finally, Dr. van der Gracht summarises the various arguments brought forward, and restores the balance by showing that many of the objections raised need not stand unanswered.

There is a general agreement that Wegener's methods in advocating his particular group of hypotheses are to be condemned. His plausible selection of data, frequently erroneous age determinations, faulty analysis of causes and devious reasoning, have undoubtedly had the effect of weakening his case. There is, indeed, a distinct danger that the easy disproof of large sections of the Wegener hypotheses may be mistaken for a demonstration of the impossibility of continental drift as a geological process. The important issue is now not so much to prove Wegener wrong as to decide whether or not continental drift has occurred, and if so, how and when.

Schuchert, Longwell, and White wonder what forces can have conspired to hold the sial together in one great land-mass—Pangæa—until Mesozoic time, when the alleged fracturing and drifting apart began. There is, of course, neither proof nor probability that there ever was a single 'Pangæa,' and it is reasonably suggested by van der Gracht that there may have been a pre-Carboniferous 'Atlantic' which was closed up by the Caledonian diastrophism. He is careful, however, to commend Wegener for not leading us into a discussion of remote periods, regarding the palæogeography of which our evidence is still lamentably meagre.

Several authors are concerned to prove that the opposing shore lines of the Atlantic do not fit so closely as Wegener supposes. Van der Gracht rightly lays no stress on the validity of geographical pattern as an argument, for surely if drift has occurred it is mechanically impossible that the sial blocks should have moved without internal and peripheral distortion. Argand's conception of varying plasticity is a valuable corrective to the exactly fitting coast lines of Wegener's too dogmatic maps. Schuchert presents a valuable summary of the geological similarities and differences between the opposing Atlantic lands. He admits that Wegener is correct in connecting the Caledonian trends of Britain with those of Newfoundland, but denies that the Hercynian trends of Europe connect with the Appalachians. Against this we may refer to Mr. E. B. Bailey's statement of the comparison in NATURE of Nov. 5, 1927. Mr. Bailey is by no means one of Wegener's sponsors, yet he says, "It is as if the Atlantic did not exist or, in other words, as if Wegener, after all, were a true prophet." Attention should also be directed to the recent discovery of Caledonian overthrusts along the east coast of Greenland, apparently representing