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The Norman Lockyer Memorial Lecture.

ON Monday last, the first Norman Lockyer lecture, under the auspices of the British Science Guild, was delivered by Sir Oliver Lodge in the hall of the Goldsmiths' Company, his subject being "The Link between Matter and Matter." It is fitting that the Guild should thus honour the memory of the man who, more than any other, was responsible for its formation, and no happier choice for the first lecturer could have been made than that of Sir Oliver Lodge. Lockyer was essentially a man of wide vision; his mind sought instinctively for generalisations. A fact was to him only of importance in so far as it was related to the general principles which underlie all facts. He was not content with a laboratory; he would have an observatory. He was not content even with an observatory; he would have a theory which would embrace all the revelations of the laboratory and the observatory and bind the whole physical universe into a single entity. The key to Lockyer's scientific career is to be found in this overpowering tendency to generalise, and no one who is not to some extent under the dominance of the same tendency can rightly interpret the apparently erratic course which his genius led him to pursue.

Sir Oliver spoke briefly of his personal association with Lockyer, which began so far back as the year 1873 when Lockyer was working in rooms generously placed at his disposal by Frankland in the new School of Science at South Kensington. He then referred to the discovery of helium, which, for twenty-six years after Lockyer had found it in the sun, remained a mere spectroscopic curiosity, but which, since Ramsay's isolation of the element from cleveite, has been instrumental in bringing about some of the most important advances of modern physics and astronomy. "Thus it is," he said, "that little discoveries, at first apparently isolated and without obvious meaning, turn out not to be little at all, but fundamentally important, being systematised by future workers until they furnish the clue to a magnificent series of discoveries about the constitution of matter." Lockyer, however, did not wait for future workers. He had his ideas about the constitution of matter long before helium was generally admitted to exist even in the sun, and he was fundamentally right.

Sir Oliver went on to speak of the human aspect of Lockyer's work. "Lockyer's work and speculations were never really remote from humanity; he kept before himself continuously, and eloquently urged upon others, the necessary bearing of all scientific discovery on human and social progress." It was the conviction that science was the chief factor in the material progress of nations that led him to found the British Science Guild, and to choose for the subject of his presidential address to the British Association in 1903, not the development of his own individual researches, wide as they were, but the importance of science to national progress—"The Influence of Brain-Power on History," as he called it. The same conviction was an important factor in his determination, in the year 1869, to inaugurate a new journal of science—NATURE—in order that the progress of science might be followed by all, and not only by those actively engaged in scientific pursuits.

Coming to the subject indicated by the title of his address, Sir Oliver defined "the link between matter and matter" as "the impenetrable uniting ingredient, or cosmic unit, which connects the otherwise dissociated or dissevered atoms of matter, and enables them to act on each other even from a distance. This ingredient . . . is essentially 'radiation,' that is to say, a disturbance in the ether, or in space, which travels at one absolute velocity, which journeys without loss or dissipation of energy, and produces even at enormous distances its singular and striking results." This link between matter and matter is required to explain gravitation and the propagation and chemical action of light. One of its surprising characteristics is the power—commonly known as photo-electric action—"of unlocking the atom and enabling it to fling away one of its constituent electrons." Sir Oliver raised the question "whether the energy of . . . photo-electric emission is applied instantaneously by the radiation stimulus, or whether it is gradually accumulated in the atom up to some critical point, when it can wait till radiation of the right frequency pulls the trigger." He is of the opinion that there is something to be said for the second alternative, and that the discontinuity of the quantum might be found in the discontinuity of atomic construction rather than in "the otherwise demonstrated continuous activity or continuity of etheric radiation."

Radio-activity is another example of an apparently spontaneous process, but this also might really be due to the impact of radiation of critical frequency. "I believe that some people, I for one, are beginning to suspect that all atomic changes are due to radiation. And I would even venture to surmise that this etheric mode of inter-communication, the transmission of waves from one piece of matter to another, has more influence on ordinary, the most ordinary—even mechanical—processes than we are yet prepared to admit." The pressure of light, for example, has lately been found in certain circumstances to be very large and of cosmic importance—for instance, in the interiors of stars. Sir Oliver was not prepared to say whether or not it ought to be taken into account in the intimate structure of atoms. The stability of Bohr's atomic orbits was a fact which had not yet been accounted for, and our aim should be to explain this and other facts on dynamical principles—"perhaps not the ordinary dynamics but etherial dynamics."

Some attempt has already been made to assimilate matter with radiation "by the very unlikely path of thermodynamics." Radiation has been treated almost like a gas, and results have been arrived at which, though they have not yet been rationally accounted for, are nevertheless true. Thus we can speak of the "temperature" of space or of radiation, and we form the conception of matter in thermodynamic equilibrium with radiation. Developing the conceptions thus generated we arrive at the quantum. "If the energy could be absorbed or emitted continuously, all the energy of matter would go into the ether, and the universe would fade away. The effect of discontinuous emission and absorption saves the universe from destruction, and makes the planet possible."

These are all fundamental considerations, and it is characteristic not only of Sir Oliver Lodge but also, to some extent, of the age in which we live, that they should be so. We are deeply involved now in problems which, fifty years ago, could not be said to have existed: they are expressible only in terms of conceptions which had not then been formed. We see now no clear dividing lines between mechanics, physics, chemistry, geology, and astronomy. None of these departments of science is complete without the others, and it is becoming increasingly clear that the physicist can no longer exclude even the principles of metaphysics from his field of inquiry. Our age is prospective; it builds the unity of the cosmos. But in Lockyer's day things were far otherwise. The progress of that time, very real though it was, lay mainly in the discovery of isolated facts, which were interpreted in the light of old and long-established principles. "Our age is retrospective," wrote Emerson; "it builds the sepulchres of the fathers."

Into this age, with its rigid formulation of the fundamental bases of a number of discrete sciences, Lockyer came with his iconoclastic, unifying mind. He was as one born out of due time into a generation unprepared for his message. Much of his work which now suggests itself as so obvious a line of research to follow, and in which the mistakes present themselves so clearly to our view, must be seen against the background of the prevailing ideas of the time in order to be estimated at its true value. Although Kirchhoff had shown in 1859 how the solar spectrum was to be interpreted by laboratory experiments, no one before Lockyer (in 1869) combined the work of the observatory with that of the laboratory.

Because the atom was held to be indivisible, no one but Lockyer believed that physical conditions could influence the spectrum of an element. Lockyer at once cut across current ideas by proving the contrary in the laboratory and pointing to the spectra of the sun and stars for further evidence, not hesitating for a moment even to declare the atoms to be dissociated in order to explain his observations. Although in 1859 Darwin had finally established the conception of evolution in biology, no one before Lockyer spoke of the evolution of the chemical elements and of the stellar universe. It is easy, with our wider knowledge, to point to his mistakes in the formulation of his conceptions, and to the "obstinacy" with which he held to details now finally discredited. It is not so easy to estimate how great an influence his courageous individualism and breadth of vision have had in preparing the way for the relative enlightenment of our own day.

"All Lockyer's information," said Sir Oliver, "was derived from a study of radiation. The chromosphere, the partitioning of the solar atmosphere into regions, and the observation of red flames without an eclipse—represent the broodings of his genius on the information brought him by tremors or quivers in the ether of space." That is true, but Lockyer did not explicitly concern himself with radiation at all. To him it was not the link which bound matter to matter; it was the instrument which told him what he wanted to know about matter itself. Of the two great physical entities (or must we now call them one?) matter and energy, he confined his attention to matter alone. Perhaps with his mental and physical equipment he could have done no other, yet it appears that it is to the ether and radiation that we must now look for the completion of Lockyer's ideas. His two great generalisations—the dissociation hypothesis and the meteoritic hypothesis—were in error mainly in so far as they ignored the radiation factor. He saw that atoms might be dissociated, but he did not conceive that absorption of radiation was the agency through which the dissociation was brought about, and herein lies the relative barrenness of his view when compared with its modern equivalent, ionisation. He saw also that stars with similar spectra might be very different in physical state, but he did not imagine that the difference was related to the pressure of radiation and the generation of etherial energy from mass, which is the source of the fruitfulness of our latest conceptions. He could not, of course, have foreseen these things. Essential as they were to the completion of the ideas he held, he had no data from which they could have been suspected; yet, single-handed and faced by many obstacles, he came nearer to the conceptions which we now hold than any of his contemporaries. H. D.

A History of Mathematics.

History of Mathematics. By David Eugene Smith. Vol. 2: *Special Topics of Elementary Mathematics.* Pp. xii+725. (Boston, New York and London: Ginn and Co., 1925.) 21*s.* net.

THE two volumes of this history (the first of which was noticed in NATURE of November 15, 1924) deal with the subject from two different aspects. The first volume, described as a "General Survey," is devoted to showing "the growth of mathematics by chronological periods with due consideration to racial achievements," and to "relating the development of the science to the development of the race, revealing the science as a great stream rather than a static mass, and emphasising the human element." Details of the lives of mathematicians, their dates, and their relation to contemporary history accordingly find their place in the first volume, which in this respect follows the plan adopted by most of the writers of histories of mathematics, both English and foreign. The first volume is thus comparable with such useful and popular histories as those of Rouse Ball, Cajori, Günther-Wieleitner, and others. It contains, however, features of additional interest in the many portraits of mathematicians, pictures of mathematical instruments and illustrations of their use, facsimiles of pages from printed books and manuscripts, which are given in their proper places.

The second volume now before us, called the "Topical Survey," deals with special topics of elementary mathematics. (We may perhaps observe incidentally that, as the sub-title of each volume limits its scope to elementary mathematics, it might have been better if, with the view of avoiding misapprehension, the whole work had been called a "History of Elementary Mathematics," rather than a "History of Mathematics" simply.) That is to say, the history is here arranged according to subjects. As the author remarks in the preface:

"The teacher of arithmetic will now see, in three or four chapters, a kind of moving picture of the growth of his subject,—how the world has counted, how it has performed the numerical operations, and what have been the leading lines of applications in which it has been interested. In geometry he will see how the subject arose, what intellectual needs established it so firmly, what influences led to its growth in various directions, and what human interest there is in certain of the great basal propositions. In algebra he will see, partly by means of facsimiles, how the symbolism has grown, how the equation looked three thousand years ago, the way its method of expression has changed from age to age, and how the science has so adjusted itself to world needs as now to be a necessity for the average citizen instead of a mental luxury for the selected few."