From these points of view, the cancerous patient is a phenodeviant in antagonistic symbiosis with a lethal parasite. This processional system emerges from the anlagen of the embryo, and after a variable latent period crosses the thresholds of manifestation and autonomy to encompass the death of the host. Throughout its course the cancer is embedded in a reticulum of biological equilibria, genetic and environmental pressures, and homœostatic reactions. The resultant of these forces determines the number, site, nature and behaviour of the lesions.

It is apparent that experimental and clinical cancer are not identical diseases. The principal divarication between the oncological disciplines pertains to carcinogenesis. The genesis of experimental cancer is mainly exogenous and mutagenic, and a 'cause' is specified. Human cancer, on the other hand, arises in a complex genetic phenomenon and evolves with the ontogeny of the host. No 'cause' can be postulated until the physiology of gene action and of normal ontogeny have been reduced to precise physicochemical terms (Lerner).

The "Novum Organum" (LXXXI) lays it down that "it is not possible to run a course aright when the goal itself has not been rightly placed". The prevention of human cancer is probably eugenic, but neither science nor society can yet confront and assimilate this proposal. The goals in contemporary clinical oncology are therefore readily defined if the present cure-rate is to be augmented. First, to devise a test which will distinguish the cancerous sub-population and permit the cure of their precancerous and cancerous lesions before autonomy supervenes. Second, to reduce ineradicable autonomous cancer to 'latency'.

These proposals demand novel studies in human metabolism; but there is some evidence to show that they are now within the ambit of modern scientific techniques. Success in this ambition would suppress this *genius ater* which pervades society and rob cancer of its terrors.

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A FORERUNNER OF TWENTIETH CENTURY PHYSICS

A RE-VIEW OF LARMOR'S "AETHER AND MATTER"

By LANCELOT LAW WHYTE

IN 1900 there appeared a work which, though little read to-day, is of considerable retrospective interest, for it records the ideas of a brilliant theoretical physicist immediately prior to Planck's discovery of the quantum constant and Einstein's formulation of the special theory of relativity.

"Aether and Matter", by Joseph Larmor, F.R.S. (1857–1942, later Sir Joseph Larmor, member of Parliament, Lucasian professor of mathematics at Cambridge, 1903–32) was issued by the Cambridge University Press as an Adams Prize Essay. A thousand copies were printed, which were sold by 1912. It has never been re-printed or translated, and is now rare; I purchased a damaged copy in 1921 for 3*s*. 6*d*. and another in 1953 for £1 10*s*. 0*d*. The most important references to the book are in the original reviews, the obituary notices at Larmor's death in 1942, and Whittaker's "History of the Theories of Aether and Electricity" (2 vols. 1951, 1953), where there are twenty-six references to Larmor, including six to "Aether and Matter".

The full title of the book reads: "Aether and Matter, a Development of the Dynamical Relations of the Aether to Material Systems on the Basis of the Atomic Constitution of Matter, including a Discussion of the Influence of the Earth's Motion on Optical Phenomena". The book is a study of the relation of micro-discontinuity to macro-continuity, of atomic matter to the electromagnetic aether, on a classical pre-1900 basis. The text was written by 1898, but parts of it had already been published in the *Phil. Trans. Roy. Soc.* and elsewhere between 1894 and 1897. Thus the ideas expressed in it were formulated some years before the decisive discoveries which opened the quantum and relativity physics of our century. "Aether and Matter" expresses the point view of an able mind taking advantage of the facts and theories as at 1894/98.

It is not surprising that Larmor's book has been forgotten. Though Larmor was a profound thinker, he never achieved any outstanding basic result and his work had relatively little influence on the advance of fundamental theory. Much of what was most useful in "Aether and Matter" (the 'Larmor rotation', and other contributions to electron theory) had already been published elsewhere, and by 1905 it was largely out of date, owing to the work of Lorentz, Planck and Einstein. Moreover, Larmor's careful analysis of the historical development of his subject, leaving none of its difficulties concealed, makes heavy going for those who have benefited by the clarifications achieved since. Even the best minds have found "Aether and Matter" indigestible; though Bohr took from it the 'Larmor rotation', which he made famous by applying it to quantized electron orbits[1].

None the less, parts of the book are fascinating, for both historical and contemporary reasons. First, he gives a masterly analysis of the history of ideas[2] relating atomic matter to the macroscopic electric continuum; and secondly, he shows (though he did not know this himself) how far his mind could reach out towards issues which are still obscure sixty years later, on the basis of the facts and theories of 1898 strongly interpreted in terms of fundamental physical ideas. This second aspect is the one with which I am here concerned: "Aether and Matter" as evidence that a perceptive application of basic ideas can point beyond established theories.

There is no need to describe the facts and theories of 1898. The fundamental ideas which Larmor employed in interpreting them can conveniently be expressed in five antitheses: atomic discontinuity/macroscopic continuity, matter/electricity, scale-fixed molecules/scale-free similarity in the macro-realm, chiral/non-chiral phenomena, and reversibility/irreversibility. By using these ideas to analyse the theories of the time, Larmor was led to identify the following issues, and to make comments on them which are still valid: the need for a characteristic length providing definiteness of scale in atomic theory; the existence of pure numbers of importance for fundamental theory; the role of chiral properties; the compatibility of molecular indeterminacy with the determinacy.

It is the fact that Larmor could use basic principles to see so far ahead that has led me back to "Aether and Matter" many times during the thirty years since these same pure numbers and the presence of natural lengths in atomic theory began to receive widespread attention. For while in 1960 we tend to consider these issues in terms of the characteristic discoveries of the twentieth century (Planck's constant, relativistic invariance, quantized fields, new particles, etc.) in 1900 Larmor reached them from very general considerations, which in some sense may be deeper. Thus something can be learnt from his achievement in recognizing the importance of these four issues.

I will now consider each of them in turn.

Need for Definiteness of Scale

Larmor was the first[3], known to me, to enunciate (pp. 189/193) the principle that to account for the definiteness of scale of material bodies and of their radiations atomic theory must contain at least one constant with the dimensions of a length, or the equivalent. These are not his words, but they express his idea. (Eddington, in his "Fundamental Theory", 1946, p. 16, called such systems 'scale-fixed', as against the scale-free systems lacking any such length.) Larmor regarded this necessity for scale-fixed atomic expressions as one aspect of the more general problem of reconciling the discreteness of material structure with the continuity of fields, which was the main theme of his book. For convenience I shall call the above recognition 'Larmor's principle'.

He used the method of dynamical similarity to show that the use of point electrons and electric actions depending only on e^2/m (for example, not on velocities) led to a "deficiency of definite scale", any steady system of such electrons being alterable to any other linear scale, in accordance with the similarity property of all scale-free systems*. But "this indefiniteness of linear scale in a material body cannot exist". Larmor reasoned that this indefiniteness might be eliminated in various ways, by introducing into the laws (a) a finite size of the electron; (b) other residual terms important at small distances; or (c) actions dependent on electron velocities—all of which methods are now in use in relativistic theories, though they may not be directly relevant to the structure of material bodies.

He did not anticipate the main scale-fixing method which proved necessary: the introduction of a new constant h, representing discreteness of action or angular momentum, which yielded two classes of scale-fixing constants: (a) in combination with $(k.T)$ and c, a statistically unique wave-length λ_m, which is a function of the temperature, through the use of the dimensionless group $(hc/\lambda k.T)$; and (b) in combination with e^2, m and c, a series of basic lengths, defining (with numerical factors) the scale of atoms, molecules, and characteristic optical and other wave-lengths.

Yet the fact that Larmor did not anticipate the dimensions of the necessary constant does not lessen the interest of his principle that a scale-fixing constant absent in 1898 is indispensable. For both relativity theory (by employing combinations with c, for example, e^2/mc^2) and quantum theory (by introducing h and powers of the fine-structure constant) have 'incidentally'—as we may think—achieved precisely what Larmor asserted was necessary[4]. Both theories introduced scale-fixing natural lengths into fundamental theory, and all the empirical data by which these theories are supported represent scale-fixed phenomena. All the quantum and the relativistic modifications of classical theories are necessarily scale-fixed, since by combining either h or c with the 'classical' constants GM, e, m, natural lengths are introduced into the laws.

Thus in a special, but instructive sense, Larmor might be called the unconscious father of twentieth-century physics. For Larmor did not know in what manner his principle would be satisfied, nor apparently did either Planck or Einstein know (for they never referred to this interesting fact) that the two theories they had initiated both satisfied a single principle formulated by Larmor: that fundamental theory must be scale-fixed. Indeed, twentieth-century

* The following notation is used: e, electron charge; m, electron mass; M, proton mass; c, velocity of light; h, Planck's constant; G, gravitational constant; K, Boltzmann's constant; T, absolute temperature. Also V_a, characteristic electron velocities in atoms; l_a, diameter of any atom or molecule; λ, wave-length of any characteristic optical radiation; λ_m, wave-length of the maximum in the black-body radiation law; α, fine-structure constant.

physics has 'out-Larmor-ed Larmor'. He said: introduce a scale-fixing length. Physics has done this not once, but many times: by discovering h, by employing relativistic corrections, and finally by discovering particles to which a series of theoretically arbitrary masses have to be ascribed in order to fix the linear scale of their respective fields and orbits. So the question arises: Why does contemporary fundamental theory employ not merely the one length that is necessary but very many, the ratios of which are (a) powers of the fine-structure constant, and (b) the pure numbers relating the mass spectrum of the elementary particles? This leads us to the next point.

Fundamental Pure Numbers

It has been clear to most, from Newton onwards, that physics is primarily concerned with numerical ratios, and Larmor's interest in the dimensional aspects of fundamental theory, including the known existence of certain universal constants (e^2, m, c, G) and the suspected existence of others (mass of positive particle, characteristic electron velocities in atoms), led him to a remarkable achievement: the identification of what are to-day recognized as functions of three fundamental pure numbers: (1) the fine-structure constant; (2) the ratio electron/proton mass; (3) the ratio gravitational/electric actions.

Larmor did not, of course, anticipate all the fundamental pure numbers now known, such as those of the particle mass spectrum, the ratios of the lives of the particles discovered since 1932, or those arising in nuclear and high-energy systems. But he identified, and used in arguments which are still valid, functions of the above three numbers ten years before Einstein (1909) directed attention to the importance of the dimensionless group e^2/hc, and twenty-five years before many workers—Eddington, Dirac, Milne, Jordan, and others—took up the study of these fundamental empirical numbers (1925 onwards). This achievement deserves attention, not only for the sake of justice and the historical record, but also because of the challenging question which arises in one case: How could Larmor identify an expression of the fine-structure constant before h was discovered?

The Fine-Structure Constant

At any time, from 1817 onwards, when Thomas Young had made observational estimates of both magnitudes, it was possible for a physicist to meditate on the ratio of the wave-lengths of the radiation from material systems to the diameters of the 'molecules' of which they were composed. For example, Cauchy suggested that the order of magnitude of the sizes of 'molecules' might be inferred from dispersion properties, but this proved wrong. After 1880, when the conception of electrical particles was being established and the empirical data were more reliable, increasing attention was paid to this ratio[5]. But Larmor was probably the first to consider it in the light of dimensional arguments applied to the theory of electrons moving in an electromagnetic continuum.

Larmor stated (p. 233) that "the very striking fact that the wave-lengths of free radiant vibrations of molecules [in which he includes atoms] are such large multiples of their diameters has always invited explanation. . . . On the dynamical conception here employed [radiation from rapidly moving electrons] it involves that the orbital velocities of the electrons are about of the same order of smallness, exceeding 10^{-2}, compared with the velocity of radiation, as are the molecular dimensions compared with the wave-lengths". Or:

$$V_e/c \doteqdot l_0/\lambda$$

which corresponds to the quantum mechanical relation:

$$A \,.\, V_e/c = \frac{B \,.\, h^2/4\pi^2me^2}{C \,.\, h^3c/8\pi^3me^4} = \alpha$$

where A, B, C, are numerical factors which are functions of quantum numbers.

Thus Larmor correctly recognized the existence of a fundamental pure number, involved in electronic systems, which (with small numerical factors) must determine the ratios both of characteristic lengths and of characteristic velocities. The experimental facts led him to estimate this geometrical and kinematic ratio as of the order of 10^{-2}. Moreover, he gave the correct reason why V_e/c must be small, since "the energy of orbital groups moving with greater speeds would be through time sensibly dissipated through radiation, so that such groups could not be permanent". In fact, condensing Bohr's statement in 1932, the concept of stationary states only works because $\alpha \ll 1$, and the transition coefficients therefore small enough to be negligible in a first approximation.

Elsewhere (p. 346), Larmor argues that the internal energy function of the atom may be separated from the energy of the radiation, "for a disturbance in the aether can travel over about 10^3 diameters of the molecule during the period of a single vibration".

The radiative model on which Larmor based this analysis was that of systems of orbital negative electrons the net radiation of which was determined by the total resultant electric polarity of the atom. Though this model has been discarded, the dimensional relations underlying Larmor's argument remain valid. We call the above ratio the 'fine-structure constant' for reasons connected with relativistic dynamics, but from another point of view the associations of this name may be misleading. For Larmor's argument emphasizes that α may be regarded as a geometrical and kinematic ratio, a ratio of lengths and of velocities, into which mass enters only secondarily when it is necessary to compare radiative (electron and photon) processes with nuclear and other particle processes. Larmor's model gave the correct dimensional relations, but no model is yet known which can account for the empirical value of this ratio. While Larmor's principle asserts that a natural length is necessary in atomic theory, it does not explain why one is not sufficient.

My conclusion is that it was possible for Larmor to identify the fine-structure constant before h was discovered because this constant has geometrical and kinematic, as well as dynamical, consequences. This suggests the possibility that a geometrical and kinematic interpretation of the constant may one day help to throw light on its origin and value.

Ratio Electron/Proton Mass

In a discussion of the Zeeman effect (p. 341) Larmor first assumes, for simplicity, that e/m has the same constant value for all the electrical particles involved, and then shows that approximately the

...ne result will be obtained if there are additional ...rticles for which e/m is small in comparison with the ...ue for all the others. "We may for example ...ppose the charges to be the same for all the ions, ...d the effective masses of the positive ones to be ...ge compared with those of the negative ones . . . ...e velocities of the positive ones will be the smaller, ...ersely as the ratio of their masses."

During the 1890's values for e/m were becoming ...ailable from various sources, first indirectly and in ...8 from direct measurements; e had been estim...ed from 1870 onwards; and the masses of atoms ...d been determined from 1875 onwards. Thus it was ...ural during the 1890's to infer that positive charges ...re associated with much larger masses than that ...the negative electron. But it seems that Larmor ...s one of the first to develop dimensional arguments ...ploying the ratio electron/proton mass. Indeed, ...formulated the conditions under which the motions ...heavier particles can be neglected relatively to ...se of electrons; for example, in calculations ...the Zeeman effect, in which the influence of the ...gnetic field is treated as equivalent to a uniform ...armor') rotation of the system.

The Ratio Gravitational/Electric Actions

Larmor was interested in the weakness of gravita...al relative to electrical actions and in the bearing ...his on the problem of a unified theory of the two ...ds. In this connexion he posed the question, ...re the linear equations of the Aether exact?" ...86). Clerk Maxwell's equations are linear, indeed ...y must be so if all kinds of radiations are to travel ...h the same speed in the celestial spaces". But ...rmor noted that the theory of the propagation of ...nd involves the neglect of terms (normally unob...able) of the order of the square of the ratio ...ecular velocities/velocity of sound. He therefore ...ed: "Why then, should not relatively minute ...nomena like gravitation be involved in similar ...linear terms, or terms involving differentials of ...her orders . . . which are as insignificant compared ...h the main ( ) linear terms as is the gravita...n between two electric systems compared with ...r ( ) electric forces?"

...e considers the difficulties in this assumption, and ...ests that the smallness of the optical dispersion ...ould arise from such non-homogeneity of the ...r "may be estimated by comparing the electric ...e between two ions with their gravitational ...ction". Larmor's conclusion, on the basis of ...facts available to him, was that "there is little ...e urged in favour of leaving this loophole for ...xplanation of gravitation". This in conformity ...h doubts that he and others (for example, A. N. ...tehead) felt as to whether a heterogeneous con...um, without severe restrictive conditions, can ...de a sufficiently stable basis for a theory of ...ematic measurements, that is, for the observed ...ntitative consistency between phenomena separ...d in space and time.

However that may be, we are to-day no more ...an than Larmor was whether or not electrical ...ns correspond to the main terms and gravitational ...sidual ones in a non-linear field.

Chiral Properties

In a section "On Dynamical and Material Sym...try" (p. 140) Larmor considers the invariance ...erties of electrical systems under two transforma-tions: time reversal, or the substitution of $-t$ for $+t$, and mirror reflexion, or the substitution of $-x$ for $+x$; invariance under changes of linear scale is treated elsewhere (pp. 176, 189). He is particularly interested in chiral[6] properties, and discusses these in several contexts (pp. 27, 142, 208).

Larmor enters into a detailed analysis of the influence of motion relatively to the aether on chiral properties, and discusses the connexions between chirality, reflexion, sign of electric charge, magnetic fields, and optical rotation properties. Part of his argument was challenged at the time, and it is now largely superseded.

Yet even here Larmor's insight is remarkable. One example (p. 27) will suffice: "The duality arising from the assumption of two kinds of electrons, only differing chirally so that one is the reflexion of the other in a plane mirror, will present nothing strange to those physicists who regard with equanimity even the hypothesis of the possible existence of both positive and negative matter". This was written in 1898.

Atomic Indeterminacy

Larmor divided physics into two related realms: (i) the fundamental 'molecular' phenomena (now called 'atomic') largely obscure to him, where discreteness plays a basic role; and (ii) the 'mechanical' phenomena of the macroscopic smoothed-out averages of electromagnetic actions in the aether. He believed (at least until 1898) that the true connexion of the two realms would be discovered by interpreting fundamental electrical particles as knots, foci, or small regions of strain in the aether. Though this model for particles may seem naïve to-day, his clarity regarding the logical and mathematical inter-relations of micro- and macro-phenomena is impressive. Throughout the book his main concern is the nature of the relation of discrete actual distributions (mainly electric particles) to continuous macroscopic and directly observable actions (mainly the effects of currents and fields).

An eloquent passage (p. 272) describes the advance of physics from the macro- to the micro-realm "by the gradual reclamation of an empirical fringe surrounding the settled domain of the science". One cannot help thinking of Bohr's Correspondence Principle as one reads: "Here progress has been effected mainly by transferring to the molecule, considered as itself a material system [that is, for Lamor, atomic], dynamical ideas the same as or analogous to those that hold good in the mechanics of sensibly continuous bodies". He was aware of the contemporary ignorance regarding the atomic realm, and believed that the progress that was being made was only possible because the individual molecule is "a nucleus in that universal aethereal *plenum* that is the transmitter of half our impressions" and therefore must in some degree conform to laws based directly on macroscopic observation.

Yet "there can be an unlimited amount of molecular structure and function in a given system, which is unconnected with any mechanical effect occurring in that system treated as continuous matter" (p. 287). "Mechanical determinateness thus need not involve molecular determinateness".

Conclusion

By the time "Aether and Matter" was in print, Larmor had overcome the tendency to demand mechanical models of the aether (medium with rotational elasticity, vortex rings, wheels with bands, etc.) which had been prevalent between 1860 and 1890. Whittaker[7] considered that it was "chiefly under the influence of Larmor [that] it came generally to be recognized that the aether is an immaterial medium *sui generis*, not composed of identifiable elements having definite locations in absolute space".

Larmor's contributions to electro-magnetic and electron theory are fully reported in Whittaker's "History". Here I have been concerned with a different task: to show that Larmor saw far beyond the typical problems of 1900 to issues that are still unresolved. This was possible, I believe, because a radical theoretical analysis, applied with judgment, can sometimes lead beyond contemporary theories and help to open up new problems the solution of which may lie well ahead.

Certainly the main theme of Larmor's book, the relation of basic discreteness to macroscopic continuity, is far from exhausted to-day. There is no golden rule for discovering the new ideas which will prove fertile in relation to this problem, for example, in nuclear processes. But there is a rational method of preparing the ground: to analyse the known facts and the hitherto successful theories, with as little prejudice as possible in terms of basic principles which appear worthy of confidence. It would be of great value to-day to be able to identify issues lying as far ahead as those Larmor recognized in 1900.

See Bohr, N., *Phil. Mag.*, 27, 506 (1914) (see p. 529).

See Larmor's "Mathematical and Physical Papers" (2 vols., 1929) for several additional historical surveys.

I have already discussed Larmor's originality in this respect; see "On the History of Natural Lengths", *Annals of Science*, 10, 59 (1954).

For an analysis of this characteristic of twentieth century physics see Whyte, L. L., *Z. Phys.*, 56, 809 (1929), "The Presence of a Universal Constant with the Dimensions of a Length". To ensure that I had understood "Larmor's principle" correctly, I sent him a copy of this paper. For his reply (Sept. 27, 1929), see *Brit. J. Phil. Sci.*, 4, 337 (1954).

Particularly after the discovery of *h*. For references to papers dealing with it before Bohr, see Bohr, N., *Phil. Mag.*, 26, 1 (1913), especially p. 6.

Larmor adopts this term from Kelvin (1884). For references and an improved definition of 'chirality' (not assuming, as Larmor does, any unique axis or helical properties), see Whyte, L. L., *Nature*, 182, 198 (1958).

[7] Whittaker, E. T., *loc. cit.*, 1, 303. See also, Larmor, J., Brit. Assoc. Reports (1900), p. 618.

OBITUARIES

Dr. Andrew McKellar

Astrophysicists have learned with great regret of the death, at the early age of fifty, of a well-known and very popular colleague, Dr. Andrew McKellar, assistant director of the Dominion Astrophysical Observatory, Victoria, B.C. McKellar was first brought into contact with astronomy as a summer student at the Dominion Astrophysical Observatory about thirty years ago, when he was an undergraduate at the University of British Columbia, Vancouver. He proceeded from there to the University of California, Berkeley, where he gained his Ph.D. and laid the foundations of the spectroscopic technique which later served him so well. After two years in the spectroscopic laboratories of the Massachusetts Institute of Technology as a National Research Council Fellow, he returned to Victoria, to become a permanent member of the staff, and spent the rest of his life there.

McKellar was the first to identify molecules in the interstellar gas, a matter of great importance for problems of interstellar matter, especially in relation to the equilibrium between gas and dust. These questions are part of larger problems involving the formation of stars from interstellar matter, about which so much is said and so little understood. McKellar's identification of these molecules was far more than an achievement of the obvious: the molecules are unsaturated, their bands in the conditions of interstellar space are reduced to one or two lines only, and these are usually quite faint.

McKellar was also one of the leading authorities on molecular bands in stellar spectra. He did a great deal of exploratory work in the red and near infra-red, discovering and identifying hitherto unrecognized bands. His most noteworthy achievement in this field, however, was to show that the ratio of abundance of the carbon isotopes carbon-12 and -13, while about 90 in some stars (as on Earth) is about 3½ in certain *R* stars, a significant fact for nuclear physicists and all who are interested in the origin of the elements. While working in the red region he also found that some carbon stars contain considerable quantities of lithium, an element which is normally present in stars only in very small quantities, presumably because it is easily destroyed by nuclear processes in stellar interiors.

Among other work, McKellar made important contributions in the rather difficult field of spectroscopy of comets. He was one of the first to aluminize a large telescope mirror. He took a leading part in the design of spectroscopic equipment at the Dominion Astrophysical Observatory. He was also a leader of the small group concerned with unusual eclipsing binaries such as ζ Aurigae, 31 Cygni, VV Cephei, where a comparatively small hot star is eclipsed by a large and cool supergiant. Absorption lines due to the atmosphere of the cool star appear near the beginning and end of eclipse and can be used to study the outer structure of the supergiant. Apart from the Sun, this is our only fairly direct means of exploring a stellar atmosphere. The results suggest an irregular field of huge and variable prominences, quite unlike the stratified layers of conventional theory.

Perhaps the most important feature of McKellar's work was his ability to obtain significant results without burdening astronomical literature with over-lengthy papers and irrelevant detail. He himself with characteristic modesty attributed this to economy of effort imposed by a very long illness, which he knew must eventually prove fatal. His many friends will miss "Andy's" quiet humour and charm, and will mourn an astronomer who had the gift of courage as well as of scientific insight. He leaves a widow and a son and daughter.

R. O. Redman