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ADDRESS OF THE PRESIDENT OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE[1]

The British Association for the Advancement of Science owes its origin, and, in great measure, its specific aims and functions, to the public spirit and zeal for the interests of science of Scotsmen. Its virtual founder was Sir David Brewster; its scope and character were defined by Principal Forbes. In constitution it differed from the migratory scientific associations existing on the Continent, which mainly served to promote the social intercourse of their members by annual gatherings, in that it was to be a permanent organization, with a settled establishment and headquarters, which should have not merely its yearly reunions, but which, "by methods and by influence peculiarly its own, should continue to operate during the intervals of these public assemblies, and should aspire to give an impulse to every part of the scientific system; to mature scientific enterprise; and to direct the labors requisite for discovery."

Although, for reasons of policy, it was decided that its first meeting of September 27, 1831, should be held at York, as the most central city for the three kingdoms, and its second and third meetings at the ancient Universities of Oxford and Cambridge respectively, it was inevitable that the association should seize the earliest opportunity to visit the metropolis of Scotland where, as an historical fact, it may be said to have had its origin.

The meeting in this city of September 8, 1834, was noteworthy for many reasons. It afforded the first direct proof that the association was fulfilling its purpose. This was shown by the popular appreciation which attended its activities, by the range and charac-

[1] Read at the Edinburgh meeting, September 7, 1921.

ter of its reports on the state and progress of science, by the interest and value of its sectional proceedings, and by the mode in which its funds were employed. In felicitous terms the president of the preceding year, the Rev. Professor Sedgwick, congratulated the gathering "on the increased strength in which they had assembled, in a place endeared to the feelings of every lover of science by so many delightful and elevating recollections, especcially by the recollection of the great men whom it had fostered, or to whom it had given birth." In a few brief sentences Professor Sedgwick indicated the great power which this association is able to apply towards the advancement of science by combination and united action, and he supported his argument by pointing to the results which it had already achieved during the three short years of its existence. Professor Sedgwick's words are no less true to-day. His contention that one of the most important functions of this philosophical union is to further what he termed the "commerce of ideas" by joint discussions on subjects of kindred interest, has been endorsed by the recent action of the council in bringing the various sections into still closer touch with each other with a view to the discussion of common problems of general interest. This slight reorganization of the work of the sections, which is in entire accord with the spirit and aims of the association, as defined by its progenitors and formulated in its constitution, will take effect during the present meeting. Strictly speaking, such joint sectional discussions are not unknown in our history, and their utility and influence have been freely recognized. But hitherto the occasions have been more or less informal. They are now, it is hoped, to be part of the regular official procedure of the meetings, to which it is anticipated they will afford additional interest and value.

Another noteworthy change in our procedure is the introduction of discussions on the addresses of the presidents of sections. Hitherto these addresses have been formally read and never discussed. To the extent that they have been brief chronicles of the progress of the special departments of science with which the section is concerned they have given but little opportunity for discussion. With the greatly increased facilities which now exist for every worker to keep himself informed of the development of the branch of knowledge in which he is more particularly interested, such *résumés* have in great measure lost their true purpose, and there has, consequently, been a growing tendency of late years for such presidential addresses to deal with contemporary topics of general interest and of fundamental importance, affording ample opportunity for a free exchange of opinion. The experiment will certainly conduce to the interest of the proceedings of the sections, and will contribute to the permanent value of their work. We see in these several changes the development of ideas connected with the working of the association which may be said to have had their birth at its first meeting in Edinburgh, eighty-seven years ago.

Sixteen years later, that is on July 21, 1850, Edinburgh again extended her hospitality to the British Association, which then honored itself by electing the learned principal of the United Colleges of St. Salvator and St. Leonard, St. Andrews, to the presidential chair—at once a tribute to Sir David Brewster's eminence as a natural philosopher, and a grateful recognition of his services to this body in suggesting and promoting its formation.

On the occasion of his inaugural address, after a brief account of recent progress in science, made with the lucidity of expression which characterized all the literary efforts of the learned biographer of Newton and versatile editor of the *Edinburgh Encyclopedia*, the *Edinburgh Magazine*, and the *Edinburgh Journal of Science*, the president dwelt upon the beneficent influence of the association in securing a more general attention to the objects of science, and in effecting a removal of disadvantages of a public kind that impeded its progress. It was largely to the action of the association, assisted by the writings and personal exertions of its members, that the government was induced to extend a direct national encouragement to science and to aid in its organization.

Brewster had a lofty ideal of the place of science in the intellectual life of a community, and of the just position of the man of science in the social scale. In well-weighed words, the outcome of matured experience and of an intimate knowledge of the working of European institutions created for the advancement of science and the diffusion of knowledge, he pleaded for the establishment of a national institution in Britain, possessing a class of resident members who should devote themselves wholly to science—with a place and station in society the most respectable and independent—"free alike," as Playfair put it, "from the embarrassments of poverty or the temptations of wealth." Such men, "ordained by the state to the undivided functions of science," would, he contended, do more and better work than those who snatch an hour or two from their daily toil or nightly rest.

This ideal of "combining what is insulated, and uniting in one great institution the living talent which is in active but undirected and unbefriended exercise around us," was not attained during Brewster's time; nor, notwithstanding the reiteration of incontrovertible argument during the past seventy years, has it been reached in our own.

I have been led to dwell on Sir David Brewster's association with this question of the relations of the state towards research for several reasons. Although he was not the first to raise it—for Davy more than a century ago made it the theme of presidential addresses, and brought his social influence to bear in the attempt to enlist the practical sympathy of the government—no one more consistently urged its national importance, or supported his case with a more powerful advocacy, than the principal of the University of Edinburgh. It is only seemly, therefore, that on this particular occasion, and in this city of his adoption, where he spent so much of his intellectual energy, I should specially allude to it. Moreover, we can never forget what this association owes to his large and fruitful mind. Every man is a debtor to his profession, from which he gains countenance and profit. That Brewster was an ornament to his is acknowledged by every lover of learning. That he endeavored to be a help to it was gratefully recognized during his lifetime. After his death it was said of him that the improved position of men of science in our time is chiefly due to his exertions and his example.

I am naturally led to connect the meeting of 1850 with a still more memorable gathering of this association in this city. In August, 1871—just over half a century ago—the British Association again assembled in Edinburgh under the presidency of Lord Kelvin—then Sir William Thomson. It was a historic occasion by reason of the address which inaugurated its proceedings. Lord Kelvin, with characteristic force and insistence, still further elaborated the theme which had been so signal a feature of Sir David Brewster's address twenty years previously: "Whether we look to the honor of England," he said, "as a nation which ought always to be the foremost in promoting physical science, or to those vast economical advantages which must accrue from such establishments, we can not but feel that expermiental research ought to be made with us an object of national concern, and not left, as hitherto, exclusively to the private enterprise of self-sacrificing amateurs, and the necessarily inconsecutive action of our present governmental departments and of casual committees."

Lord Kelvin, as might have been anticipated, pleaded more especially for the institution of physical observatories and laboratories for experimental research, to be conducted by qualified persons, whose duties should be not teaching, but experimenting. Such institutions as then existed, he pointed out, only afforded a very partial and inadequate solution of a national need. They were, for the most part, "absolutely destitute of means, material, or *personnel* for advancing science, except at the expense of volunteers, or of securing that volunteers should be found to continue such little work as could then be carried on."

There were, however, even then, signs that the bread cast upon the waters was slowly returning after many days. The establishment of the Cavendish Laboratory at Cambridge, by the munificence of its then chancellor, was a notable achievement. Whilst in its constitution as part of a university discipline it did not wholly realize the ideal of the two presidents, under its successive directors, Professor Clerk-Maxwell, the late Lord Rayleigh, and Sir J. J. Thomson, it has exerted a profound influence upon the development of experimental physics, and has inspired the foundation of many similar educational institutions in this country. Experimental physics has thus received an enormous impetus during the last fifty years, and although in matters of science there is but little folding of the hands to sleep, "the divine discontent" of its followers has little cause for disquietude as regards the position of physics in this country.

In the establishment of the National Physical Laboratory we have an approach to the ideal which my predecessors had so earnestly advocated. Other presidents, among whom I would specially name the late Sir Douglas Galton, have contributed to this consummation. The result is a remarkable testimony to the value of organized and continuous effort on the part of the British Association in forming public opinion and in influencing departmental action. It would, however, be ungrateful not to recall the action of the late Lord Salisbury—himself a follower of science and in full sympathy with its objects—in taking the first practical steps towards the creation of this magnificent national institution. I may be allowed, perhaps, to refer to this matter, as I have personal knowledge of the circumstances, being one of the few survivors of the committee which Lord Salisbury caused to be formed, under the chairmanship of the late Lord Rayleigh, to inquire and report upon the expediency of establishing an institution in Great Britain upon the model of certain state-aided institutions already existing on the continent, for the determination of physical constants of importance in the arts, for investigations in physical problems bearing upon industry, for the standardization and verification of physical instruments, and for the general purposes of metrology. I do not profess to give the exact terms of the reference to the committee, but, in substance, these were recognized to be the general aims of the contemplated institute. The evidence we received from many men of science, from departmental officers, and from representatives of engineering and other industrial establishments was absolutely unanimous as to the great public utility of the projected laboratory. It need hardly be said that the opportunity called forth all the energy and power of advocacy of Lord Kelvin, and I well remember with what strength of conviction he impressed his views upon the committee. That the National Physical Laboratory has, under the ability, organizing power, and business capacity of its first director, Sir Richard Glazebrook, abundantly justified its creation is recognized on all hands. Its services during the four years of war alone are sufficient proof of its national value. It has grown to be a large and rapidly increasing establishment, occupying itself with an extraordinary range of subjects, with a numerous and well-qualified staff, engaged in determinative and research work on practically every branch of pure and applied physics. The range of its activities has been further increased by the establishment since the war of coordinating research boards for physics, chemistry, engineering and radio-research. Government departments have learned to appreciate its services. The photometry division, for example, has been busy on experiments on navigation lamps for the Board of Trade, on miners' lamps for the Home Office and on motor-car head-lamps for the Ministry of Transport, and on the lighting of the National Gallery and the Houses of Parliament. Important work has been done on the forms of ships, on the steering and manœuvring of ships, on the effect of waves on ship resistance, on the interaction between passing ships, on seaplane floats, and on the hulls of flying-boats.

It is also actively engaged in the study of problems connected with aviation, and has a well-ordered department of aerodynamical research.

It can already point to a long and valuable series of published researches, which are acknowledged to be among the most important contributions to pure and applied physics which this country has made during recent years.

I may be pardoned, I hope, for another personal reference, if I recall that it was at the Edinburgh meeting, under Lord Kelvin's presidency, fifty years ago, that I first became a member of this association, and had the honor of serving it as one of the secretaries of its chemical section. Fifty years is a considerable span in the life of an individual, but it is a relatively short period in the history of science. Nevertheless, those fifty years are richer in scientific achievement and in the importance and magnitude of the utilitarian applications of practically every branch of science than any preceding similar interval. The most cursory comparison of the state of science, as revealed in his comprehensive address, with the present condition of those departments on which he chiefly dwelt, will suffice to show that the development has been such that even Lord Kelvin's penetrative genius, vivid imagination, and sanguine temperament could hardly have anticipated. No previous half-century in the history of science has witnessed such momentous and far-reaching achievements. In pure chemistry it has seen the discovery of argon by Rayleigh, of radium by Madame Curie, of helium as a terrestrial element by Ramsay, of neon, xenon, and krypton by Ramsay and Travers, the production of helium from radium by Ramsay and Soddy, and the isolation of fluorine by Moissan. These are undoubtedly great discoveries, but their value is enormously enhanced by the theoretical and practical consequences which flow from them.

In applied chemistry it has witnessed the general application of the Gilchrist-Thomas process of iron-purification, the production of calcium cyanamide by the process of Frank and Caro, Sabatier's process of hydrogenation, a widespread application of liquefied gases, and Haber's work on ammonia synthesis—all manufacturing processes which have practically revolutionized the industries with which they are concerned.

In pure physics it has seen the rise of the electron theory, by Lorentz; Hertz's discovery of electro-magnetic waves; the investigation of cathode rays by Lenard, and the elucidation of crystal structure by Bragg.

It has seen, moreover, the invention of the telephone, the establishment of incandescent lighting, the electric transmission of force, the invention of the cinematograph, of wireless telegraphy, the application of the Röntgen rays, and the photographic reproduction of color.

In physical chemistry it has witnessed the creation of stereo-chemistry by Van't Hoff and Le Bel, Gibbs's work on the phase rule, Van't Hoff's theory of solutions, Arrhenius's theory of ionic dissociation, and Nernst's theory of the galvanic cell.

Such a list is far from complete, and might be greatly extended. But it will at least serve to indicate the measure of progress which the world owes to the development and application during the last fifty years of the two sciences —physics and chemistry—to which Lord Kelvin specially referred.

The more rapid dissemination of information concerning the results of recent or contemporary investigation, which Lord Kelvin so strongly urged as "an object to which the powerful action of the British Association would be thoroughly appropriate," has been happily accomplished. The timely aid of the association in contributing to the initial expense of preparing and publishing monthly abstracts of foreign chemical literature by the Chemical Society is gratefully remembered by British chemists. The example has been followed by the greater number of our scientific and technical societies, and the results of contemporary inquiry in every important branch of pure and applied science are now quickly brought to the knowledge of all interested workers. In fact, as regards the particular branch of science with which I am more directly concerned, the arrangements for the preparation and dissemination of abstracts of contemporary foreign chemical literature are proving to be a veritable embarrassment of riches, and there is much need for cooperation among the various distributing societies. This need is especially urgent at the present time owing to the greatly increased cost of paper, printing, binding, and indeed of every item connected with publication, which expense, of course, ultimately falls upon the various societies and their members. The problem, which has already received some attention from those entrusted with the management of the societies referred to, is not without its difficulties, but these are not insoluble. There is little doubt that a resolute and unanimous effort to find a solution would meet with success.

The present high cost of book production, which in the case of specialized books is about three times what it was in 1914, is exercising a most prejudicial effect upon the spread of scientific knowledge. Books on science are not generally among the "best sellers." They appeal to a comparatively limited and not particularly wealthy public, largely composed of the professional classes who have suffered in no small measure from the economic effects of the war. The present high price of this class of literature is to the public detriment. Eventually it is no less to the detriment of the printing and publishing trades. Publishers are well aware of this fact, and attempts are being made by discussions between employers and the executives of the Typographical Association and other societies of compositors to reach an equitable solution, and it is greatly to be hoped that it will be speedily found.

All thinking men are agreed that science is at the basis of national progress. Science can only develop by research. Research is the mother of discovery, and discovery of invention. The industrial position of a nation, its manufactures and commerce, and ultimately its wealth, depend upon invention. Its welfare and stability largely rest upon the equitable distribution of its wealth. All this seems so obvious, and has been so frequently and so convincingly stated, that it is superfluous to dwell upon it in a scientific gathering to-day.

A late distinguished admiral, you may remember, insisted on the value of reiteration. On this particular question it was never more needed than now. The crisis through which we have recently passed requires it in the interests of national welfare. Of all post-war problems to engage our serious attention, none is more important in regard to our position and continued existence than the nation's attitude toward science and scientific research, and there is no more opportune time than the present in which to seek to enforce the teaching of one of the most pregnant lessons of our late experience.

It is, unfortunately, only too true that the industrial world has in the past underrated the value of research. One indication that the nation is at length aroused to its importance is to be seen in the establishment of the Department of Scientific and Industrial Research, with its many subordinate associations. The outbreak of the Great War, and much in its subsequent history, revealed, as we all know, many national shortcomings, due to our indifference to and actual neglect of many things which are at the root of our prosperity and security. During the war, and at its close, various attempts, more or less unconnected, were made to find a remedy. Of the several committees and boards which were set up, those which still exist have now been coordinated, and brought under the control of a central organization—the Department of Scientific and Industrial Research. Research has now become a national and state-aided object. For the first time in our history its pursuit with us has been organized by government action. As thus organized it seeks to fulfil the aspirations to which I have referred, whilst meeting many of the objections which have been urged against the endowment of research. It must be recognized that modern ideas of democracy are adverse to the creation of places to which definite work is not assigned and from which definite results do not emanate. This objection, which strikes at the root of the establishment of such an institution as Sir David Brewster contemplated, is, to a large extent, obviated by the scheme of the Department of Scientific and Industrial Research. It does not prescribe or fetter research, but, whilst aiding by personal payments the individual worker, leaves him free to pursue his inquiry as he thinks best. Grants are made, on the recommendation of an advisory council of experts, to research workers in educational institutions and elsewhere, in order to promote research of high character on fundamental problems of pure science or in suitable cases on problems of applied science. Of the boards and committees and similar organizations established prior to or during the war, or subsequent to it, with one or two exceptions, all are now directly under the department. They deal with a wide range of subjects, such as the Building Research Board, established early in 1920 to organize and supervise investigations on building materials and construction, to study structural failures, and to fix standards for structural materials. The Food Investigation Board deals with the preservation by cold of food, and with the engineering problems of cold storage, with the chemistry of putrefaction, and the agents which induce it, with the bionomics of moulds, and the chemistry of edible oils and fats. The Fuel Research Board is concerned with the immediate importance of fuel economy and with investigations of the questions of oil-fuel for the navy and mercantile marine, the survey of the national coal resources, domestic heating, air pollution, pulverized fuel, utilization of peat, the search for possible substitutes for natural fuel oil, and for practicable sources of power alcohol.

The Geological Survey Board has taken over the Geological Survey of Great Britain and the control of the Museum of Practical Geology. The maintenance of the National Physical Laboratory, originally controlled by a general board and an executive committee appointed by the president and council of the Royal Society, is now transferred to the Department of Scientific and Industrial Research. A Mines Research Committee and a Mine Rescue Apparatus Committee are attached to the department. The former is concerned with such questions as the determination of the geothermic gradient, the influence of temperature of intake and return air on strata, the effect of seasonal changes on strata temperature of intakes, the cooling effect due to the evolution of fire-damp, heat production from the oxidation of timber, etc. The department is also directing inquiries on the preservation and restoration of antique objects deposited in the British Museum. It is concerned with the gauging of rivers and tidal currents, with special reference to a hydrographical survey of Great Britain in relation to the national resources of water-power. In accordance with the government policy, four coordinating boards have been established to organize scientific work in connection with the fighting forces, so as to avoid unnecessary overlapping and to provide a single direction and financial control. The four boards deal, respectively, with chemical and physical problems, problems of radio-research, and engineering. These boards have attached to them various committees dealing with special inquiries, some of which will be carried out at the National Physical Laboratory. The government have also authorized the establishment of a Forest Products Research Board.

The department is further empowered to assist learned or scientific societies and institutions in carrying out investigations. Some of these were initiated prior to the war, and were likely to be abandoned owing to lack of funds. Whenever the investigation has a direct bearing upon a particular industry that had not hitherto been able to establish a research association, it has been a condition of a grant that the institution directing the research should obtain contributions towards the cost on a £ for £ basis, either directly through its corporate funds or by special subscriptions from interested firms. On the formation of the appropriate association the research is, under suitable safeguards, transferred to it for continuance. The formation of a number of research associations has thus been stimulated, dealing, for example, with scientific instruments, non-ferrous metals, glass, silk, refractories, electrical and allied industries, pottery, etc.

Grants are made to research associations formed voluntarily by manufacturers for the purposes of research, from a fund of a million sterling, placed at the disposal of the research department for this purpose. Such associations, to be eligible for the grant, must submit articles of association for the approval of the department and the Board of Trade. If these are approved, licenses are issued by the Board of Trade recognizing the associations as limited liability companies working without profits. Subscriptions paid to an association by contributing firms are recognized by the Board of Inland Revenue as business costs of the firms, and are not subject to income or excess profits taxes. The income of the association is similarly free of income tax. Grants are ordinarily made to these associations on the basis of £1 for every £1 raised by the association between limits depending upon the particular industry concerned. In the case of two research associations grants are made at a higher rate than £ for £, as these industries are regarded as having a special claim to state assistance on account of their "pivotal" character. The results of research are the sole property of the association making them, subject to certain rights of veto possessed by the department for the purposes of ensuring that they are not communicated to foreign countries, except with the consent of the department, and that they may be made available to other interested industries and to the government itself on suitable terms.

These arrangements have been found to be generally satisfactory, and at the present time twenty-four of such research associations have been formed to whom licenses have been issued by the Board of Trade. Others are in process of formation, and may be expected to be at work at an early date. These research associations are concerned with nearly all our leading industries. The official addresses of most of them are in London; others have their headquarters in Manchester, Leeds, Sheffield, Birmingham, Northampton, Coventry, Glasgow, and Belfast.

The department has further established a Records Bureau, which is responsible for receiving, abstracting, filing and collating communications from research workers, boards, institutions, or associations related to or supervised by the department. This information is regarded as confidential, and will not be communicated except in writing, and after consultation with the research worker or organization from which it has been received. Also such non-confidential information as comes into the possession of the department which is of evident or probable value to those working in touch with the department is collected and filed in the bureau and made generally available.

It is also a function of the bureau to effect economy in preventing repetition and overlapping of investigations and in ensuring that the fullest possible use is made of the results of research. Thus, the programmes of research associations are compared in order to ensure that researches are not unwittingly duplicated by different research associations. Sometimes two or more research associations may be interested in one problem from different points of view, and when this occurs it may be possible for the bureau to arrange a concerted attack upon the common problem, each research association undertaking that phase of the work in which it is specially interested and sharing in the general results.

As researches carried out under the department frequently produce results for which it is possible to take out patents, careful consideration has been given to the problems of policy arising on this subject, and other government departments also interested have been freely consulted. As the result, an interdepartmental committee has been established with the following terms of reference:—

1. To consider the methods of dealing with inventions made by workers aided or maintained from public funds, whether such workers be engaged (*a*) as research workers, or (*b*) in some other technical capacity, so as to give a fair reward to the inventor and thus encourage further effort, to secure the utilization in industry of suitable inventions and to protect the national interest, and

2. To outline a course of procedure in respect of inventions arising out of state-aided or supported work which shall further these aims and be suitable for adoption by all government departments concerned.

About forty patents have been taken out by the department jointly with the inventors and other interested bodies, but of these, nine have subsequently been abandoned. At least five patents have been developed to such a stage as to be ready for immediate industrial application.

It will be obvious from this short summary of the activities of the department, based upon information kindly supplied to me by Sir Francis Ogilvie, that this great scheme of state-aided research has been conceived and is administered on broad and liberal lines. A considerable number of valuable reports from its various boards and committees have already been published, and others are in the press, but it is, of course, much too soon to appreciate the full effects of their operations. But it can hardly be doubted that they are bound to exercise a profound influence upon industries which ultimately depend upon discovery and invention. The establishment of the department marks an epoch in our history. No such comprehensive organization for the application of science to national needs has ever been created by any other state. We may say we owe it directly to the Great War. Even from the evil of that great catastrophe there is some soul of goodness would we observingly distil it out.

T. EDWARD THORPE

(*To be concluded*)

LIFE IN OTHER WORLDS

DOES life—especially intelligent life—exist elsewhere than on the earth? Three letters in recent numbers of SCIENCE discuss this age-old problem. And it is noticeable that, as usual, the astronomers take the affirmative and the biologists the negative side of the argument. There may be two reasons for this.

1. Astronomers, physicists, mathematicians, are accustomed to hold a more receptive attitude, an open mind, toward hypotheses that can not be definitely disproved. This frame of mind is natural and adapted to their work. They are accustomed to deal with problems which can be solved by mathematical and deductive methods. A limited number of solutions appear, all of them to be receptively considered until they can be definitely disproved.

The biologist, on the other hand, deals with a different sort of problem. His evidence is almost always inductive, experimental. His subjects are far too complex, too little understood, to admit of mathematical analysis, save in their simpler aspects. And always he is compelled to adopt toward the illimitable numbers of possible explanations, a decidedly exclusive attitude, and to leave out of consideration all factors that have not something in the way of positive evidence for their existence. If he fails to do so, he soon finds himself struggling hopelessly in a bog of unprofitable speculations. A critical rather than a receptive frame of mind is the fundamental condition of progress in his work.

2. The second reason is that the astronomer or cosmologist has in mind when he thinks of this problem, the physical and chemical conditions that would render life possible. If these be duplicated elsewhere he sees life as possible, and by the incidence of the laws of chance probable or almost certain, if they be duplicated often enough. Viewing the innumerable multitude of stars, each of them a solar system with possible or probable planets analogous to our own, he sees such multitudinous duplications of the physical conditions that have made life possible on our earth, that it appears to him incredible that all stand empty and lifeless.

The biologist, on the other hand, has at the forefront of his mind the history and evolution of life on the earth. He knows that although these conditions favoring the creation of living matter have existed on earth for many millions or hundreds of millions of years, yet life has not come into existence on earth save once, or at most half a dozen times, during that time. The living beings on earth are reducible at most to a few and probably to one primary stock, all their present variety being the result of the evolutionary processes of differentiation and adaptation. It must appear therefore to him that the real conditions for the creation of life on earth have involved, not merely the favoring physical conditions, but some immensely complex concatenation of circumstances so rare that even