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SCIENCE AND ITS SERVICE TO MAN[1]

The most striking feature of the world's history during the past hundred years is the extraordinary accession to man's knowledge of nature, the deepening of his insight into his own physical, intellectual and psychical characters and their correlations, and the recognition of the significance of environmental changes on his future earth-life. The twenty-three years of the present century show no sign of an abatement either in the rate of the extension of knowledge or in the significance of successive discoveries. The number of persons engaged on pure research, or on research into the possibilities of the application of scientific knowledge to human needs, was never greater than now. In many countries large sums have been devoted to reinforcing the means of carrying on these efforts, both as regards equipment and personnel. In not a few, men of wealth have vied with each other in creating and endowing great research laboratories, observatories and teaching institutions, and the financial means having been provided, personal devotion and qualification were not lacking.

One may well consider what this implies. The increase of human power through knowledge, the recognition of new resources in nature and of the means of utilizing them, and the enlarged ability to quicken and extend the boundaries of human relationships are such as disclose in some measure the peculiar significance of the past hundred years for future human life. The world has become indeed smaller, and touch between nation and nation speedier and greater. More clearly can it be seen that man has at his disposal very great, though practically unexplored resources; and he needs vision to see wherein opportunity lies. But increase of power carries also dangers which only fatuity can ignore. The Great War has revealed this unequivocally, and has signally shown that man's ability to wreck immensely transcends his power to ameliorate. So long as greed of wealth, national prejudices and readiness to misunderstand hold sway, so long will there be danger of this wreckage, and even upon a scale which more and more will greatly exceed the power of repair. The work of centuries may be destroyed in hours, of years in minutes. And it has, unfortunately, become more than ever a necessity to be prepared to destroy that one be not destroyed. To

[1] From the presidential address to the Australasian Association for the Advancement of Science at the New Zealand meeting.

this one may add that the exigencies of war involve the destruction of the fit: while sentiment often secures not only the survival of the unfit, but also even their reproduction. Truly, civilization may be wrecked by its own genius!

The quickening of human life and the extension of human powers call to young countries like the Dominion of New Zealand and the Commonwealth of Australia, rapidly growing into nationhood, for response in the details of their national life. For the short term of our civic existence, and judged by the average standards of the past century, we have perhaps done fairly well. That standard, however, is no longer adequate. Things are appropriately measured only by comparison; and one asks, therefore, "What, in the light of world-developments, are the scientific and other needs of Australasia to-day?" Our countries are, indeed, goodly heritages, and the right to them is effective occupation. None but the purblind can fail to note that the expansions of various populations are such that we here sorely need to survey our past development and our possible future in the light of world politics.

Considerations such as these put us upon inquiry and compel the question, "What part will Australasia play in extending and exploiting the realms of systematized knowledge, and in applying it to human needs?" I need hardly say that it is not enough merely to inherit the lore of the rest of the world; by our own contributions to the general store we must repay, or be classed among those who attempt to thrive on the genius of others.

There are, of course, among us those to whom the splendid generosities of the patrons of science call for no response of gratitude, and governments whose vision rises to that of statesmanship in providing for a better future in scientific inquiry are in their opinion but lavish and foolish. There are, however, also those who recognize that the British races must in the future—more than in the past—react to the fact that systematized knowledge is playing a rôle of new and ever-growing significance in world-affairs. Without acute national danger we can no longer ignore the need for creating for the rising generation the opportunity to become more thoroughly conscious of what is known of nature, and to become, moreover, instinct with the disposition to apply knowledge to practical ends.

It is considerations such as those expressed which will govern this matter of my address on this occasion, and I would add that the destiny of Australasia calls upon us to attend immediately to many things in which we have as yet made only a beginning—among these our equipment for research and for instruction in the whole range of the sciences. In this connection be it said that it is not, however, the material results that are the main concern. The world in which we live and the physical creations of man are but tools at our disposal, of value for our training and self-expression. Moreover, we live in a world of rivalries—here generous, there cruel and unscrupulous—and our equipment in a knowledge of nature will be a great factor in our destiny. It is not inappropriate, therefore, to consider for a moment the intrinsic character of that knowledge upon which so much depends, and at the head of which stands what has been called the "queen of the sciences," *Mathematica,* and her no less splendid sister, *Astronomia.*

I propose, then, to refer not only to the intrinsic nature of science, and to the need for creating and nurturing institutions for pure research and for inquiry into possible applications of its results to practical ends, but also to certain notable features of its recent developments.

THE NATURE OF THE HIGHER ELEMENTS OF SCIENCE

The essential elements of any science are, as it were, the basis of its higher claim upon our attention. Nevertheless, it may serve material ends. Thus mathematics and astronomy, for example, while of great value in relation to physical life—the first in the reach of its applications in physics, electricity, engineering, metallurgy, chemistry, biology, and so on, and the latter because of its services in regard to navigation, time, etc.—are of the highest value as ends in themselves, as indeed also are the higher elements of every other science. They provide a nobler discipline for the mind.

It is, moreover, a curious fact in the history of science that great discoveries have been made not by those who were thinking of practical applications, but by those whose sole aim was to reach a deeper understanding of nature. Minerva bestows her favors not on those who think they may use her to obtain a sort of Pandora's box, but on those who worship her for herself. The highest product of civilization is not the mere maintenance of man on the planet, but such maintenance as makes him a student of that vast universe of which physically he forms so utterly insignificant a part—a student, developing faculties by means of which he can appreciate beauty, magnificence, majesty, and, indeed, the whole range of things spiritually apperceived or intellectually grasped—a student capable of solving the most apparently hopeless problems.

Epoch-making conceptions flash into the mysterious world of mind as meteors in the celestial vault, and humanity is then enriched. Often revolutionizing older conceptions, their significance is in some measure realized by the prepared minds through whom they come. When a Heraclitus or a Bergson is overwhelmed with the fact that the problem of ontology is summed up in the phrase παντα ῥδυ, a philosophy has been created. When an Archimedes bursts forth with his εὗρηκα εὗρηκα, a conception of far-reaching consequence is added to the science of physics. A Newton, seizing the idea of universal gravitation, develops the *Principia,* said by Laplace to be the greatest monument of human genius ever created. A Carnot, a Joule, a Mayer lays the foundations of the theory of heat; an Abel, reenvisaging the work of Legendre, establishes a new branch of mathematics. A Poincaré, stepping into a carriage, grasps a new mathematical truth; his technical command of mathematical reasoning enables him to establish it formally. Illustration after illustration could be given of the fact that it is to the cultivated mind that the truth appears, and so appears that its place in the world of knowledge is recognized.

The importance of a scientific conception inheres in two things: one is that it coordinates and thus systematizes our theoretical constructions of nature, making it possible to keep the manifold of phenomena within our grasp; the other, that it confers creative power in our dealing with matter. One may perhaps refer for a moment to the latter aspect.

The Creative Power of Science

It was well said by Stieglitz, of Chicago, that "it is important . . . that the public should awaken to a clear realization of what the science of chemistry really means to mankind, to the realization that its wizardry permeates the whole life of the nation as a vitalizing, protective and constructive agent." He urged that the layman should understand that chemistry is the "fundamental science in the transformation of matter." To justify this dictum fully one must, no doubt, substitute for "chemistry" a wider term. It is to chemistry coupled with mathematics, physics and technology generally that the dictum more truly applies.

We are, of course, apt to see more clearly the significance only of the realms of knowledge with which we are best acquainted. The field of acute vision is restricted, and the *fovea centralis* of the specialist eye can hardly be expected to embrace the world-picture. Thus, when with great lucidity Berthelot said that "chemistry creates its object" he spoke truly; when he added that it possesses this creative faculty in a more eminent degree than the other sciences, that assertion may be regarded as applicable rather to what may be called the "larger chemistry" than to chemistry in the more restricted sense.

The observation that "science" is creative is, however, just, if the word be understood in the sense of "systematized and coordinated knowledge." Certain branches of knowledge are but little more than a systematic record of facts—*i.e.,* they are in a broad sense "descriptive"—and their accumulation is somewhat of the nature of cataloguing, while others penetrate to the inner significance of things and result in new and fecund constructions of the world-concept. In short, one may say that science is three-phased: it is descriptive, analytic and synthetic. It is preeminently to the synthetic phase that we are most deeply indebted for creative power. Thus, one may say that the discoveries of the small shell-fishes that furnished Tyrian purple (*Ianthina, Purpura* and *Murex*) are overmatched by the chemist who synthetically made the identical but purer substance dibromindigo.[2] Nevertheless, it is well to remember that the descriptive and analytical elements are, after all, necessary means to an end.

In the broader view we see that we owe to science not merely the products of synthetic chemistry, the multitude of chemical and pharmaceutical products, the myriads of splendid dyes, the perfumes and flavoring-substances, the explosives, the viscoses, celluloids, xylonites, bakelites, etc., but the various metallurgical processes, the steels and alloys that have made practicable, and have greatly cheapened, construction, and that have created new possibilities in manufacture. Other things being equal, the people whose national equipment includes the creative laboratories, the people whose instinct is to explore the great world about them in order to know and understand its nature, the people who desire to exploit its resources, using its crude substance as raw material with which to fashion things for its requirements—these are they who must become dominant. That is in the very nature of the case. In short, not in physical toil lies the secret of national success, but in intellectual achievement in the realm of nature-knowledge and in the power attained through such achievement.

The field of exploration in nature embraces now the micro-world of the subatomic as well as the vast depths of space. Man's senses are limited, and he has been forced to extend their range by artifice.

The Need for Research

Education in the proper sense does not merely involve the acquisition of the immense stores of information now available, but also—and this is supremely important—the development of *faculty*; *i.e.,* power and facility in the use of the acquired knowledge, and the awakening of insight and inventiveness, a love for inquiry into natural phenomena and for the systematizing of knowledge. It has been fortunate for the world that individuals have devoted very large sums of money for the purposes of research—

[2] The color secreted by the shell-fish is 6:6′ dibromindigo, and is not as fine as the 5:5′ dibromindigo manufactured cheaply by the synthetic chemist in large quantities.

e.g., Prince Demidoff in Russia; Lick, Rogers, Rockefeller, Carnegie, etc., in the United States of America; the late Prince of Monaco, etc.; and Cawthron here in New Zealand—and, owing to what the war revealed, governments have begun to realize that research is an essential for national safety and progress. For example, the British Government recently granted £1,000,000 for industrial-research associations, and over £200,000 for a fuel-research station, £35,000 on a low-temperature-research station, and during last financial year expended, moreover, £204,000 on the National Physical Laboratory. Japan is establishing a national-research laboratory at a cost of over £300,000, to which the Mikado himself contributed £100,000. One business firm alone in Germany, the Badische Soda-und-Anilin Fabrik, is said to have devoted no less than £1,000,000 and to have spent seventeen years in research before a satisfactory production of artificial indigo was achieved. At the beginning of this century Germany was paying annually £600,000 for indigo. At the outbreak of war she was selling annually £2,500,000 worth of dye. In the United States of America the annual expenditure on the Department of Agriculture alone is £7,506,000; the Carnegie Institution has a revenue of £220,000; the Mellon Institute for Industrial Research cost £100,000 to build and equip, and has an annual expenditure of £77,000. Among the efforts of business firms may be mentioned the General Electric Company, which has a research staff of 150 persons, and the Eastman Kodak Company, which spends annually about £30,000. The Pennsylvania Railway Companies' laboratories cost £60,000, and employ therein 360 persons on research.

In order that research in Australasia shall be what national progress and national safety demand two things are eminently desirable: (1) The more complete equipping, staffing and endowing of our universities and technical colleges, so as to enable research work to be carried on by the teaching staffs and graduate students; (2) the development and adequate equipment and endowment of a great research institute for Australia, so that it may fulfil the functions indicated in such an act as that creating the Institute of Science and Industry. Far removed from the centers of intense intellectual and scientific life, we stand in the greater need of such assistance; and the heritage which it is our privilege to possess will, for its retention and defense, need to produce far more material wealth, and to carry a population vastly greater than is ours at the present day.

I would point out that even in apparently simple matters research is needed. The need is often by no means so self-evident as is commonly imagined, and fatuous ignorance may regard it as unnecessary. It is easy, however, to multiply illustrations to the contrary. Will you permit me to make reference, by way of an instructive example, to a very commonplace matter—the elimination of what has been called "knock," "pinking" or "detonation" in internal-combustion engines. Independently, and as far back as 1881, Bertholet and Le Chatelier found that the propagation of flame in some mixtures of air and certain combustible gases, and in appropriate mixtures of oxygen with nearly all combustible gases, set up a detonation wave; Mallard and Le Chatelier later ascertaining that the development of this wave was always instantaneous, not progressive, and was marked by intense luminosity. The velocity of the wave was shown by Berthollet and Vieille to be constant, and Dixon held that during detonation the flame traveled with the velocity of sound at the temperature of the burning gases. Pressures of 25 to 78 atmospheres lasting an exceedingly brief period were produced, these being about four times as great as the maximum "effective pressure" developed by the explosion. The intensity of such detonation increases with the degree of the compression, with temperature, with advance of the spark-timing and with the extent of carbon deposits. Even when without danger it operates to reduce the efficiency of an engine, and as a consequence researches have been directed to means of reducing or eliminating it. Mathematical and physical examinations of the question showed that during normal combustion the pressure-differential is very small, but a flame-front moving with the velocity of sound produces an enormous pressure-differential, heard as the "knock." Iodine and certain organic compounds, containing selenium, tellurium, tin and lead, were found to retard the velocity of the combustion. When mixed with various fuels, benzene, which does not itself detonate even at compressions of, say, 14 or 15 atmospheres, reduces their tendency to detonation. Again, though present in the molecular proportion of only 1 in 50,000 of, say, kerosene-air mixture, diethyl telluride was found also to prevent detonation, and in the same circumstances lead-tetraethyl in the molecular proportion of only 1 in 215,000. One molecule of diethyl telluride was equal in effect to 330 molecules of benzene. When lead-tetraethyl is mixed to the extent of 1 volume with 1000 volumes of gasolene, perfect smoothness of running is secured.

Now, the mere recital of the above results shows that to attack even such an apparently simple question as "the best means of running an internal-combustion engine" an enormous amount of difficult research is required, and much ingenuity is demanded. But when the solution is attained the economic and general advantages are very great indeed.[3]

[3] See the researches of Midgley and Boyd, of the General Motor Research Corporation, Dayton, Ohio.

I will give another instance, an unsolved problem so far—*viz.*, the production of *light without heat.* Any notable increasing of the efficiency of light-producing apparatus is self-evidently of high economic importance. The wave-lengths of visible light range between 7,600 and 4,000 Angström units (*viz.*, ten millionths of a millimeter), and ether undulations of wave-lengths outside those limits are practically valueless for lighting purposes. Moreover, even within such limits the relative intensities vary for different sources of light, being, for example, characteristically different for sunlight, the electric arc and gaslight. The problem of light-efficiency is that of insuring, in the production of radiant energy, that it shall lie wholly within the luminous limits, and, moreover, be so distributed therein that the maximum luminosity shall be obtained; this last depending, however, upon the subject—*viz.*, man of normal vision. (It is different for color-blind persons, and in general for those possessed of vision which is in any way abnormal.) Research has shown that a 4-watt carbon glow-lamp has a luminous efficiency of only 0.43 per cent., while the luminous efficiency of the firefly is no less than 99.5 per cent. The most perfect of artificial illuminants has an efficiency of only about 4 per cent. —say, one twenty-fifth of that of the firefly. This fact has inspired a large number of investigations on the nature of light produced by plants or animals; about 290 papers have been written on the subject, and the distribution of light-producing organisms in the plant and animal kingdoms has been well ascertained.[4] There appears, however, to be no order in either in the distribution of the luminescence.

Using Nutting's light-sensibility curve (1911), Coblentz, Ives, Emerson and others deduced the number of lumens[5] per watt, and found it to be 2.6 for the carbon incandescent lamp, 8.0 for the tungsten, 19.6 for the "Mazda" of type C, 42.0 for the quartz-mercury arc, and no less than 629 for the firefly (*Photinus*). Newton Harvey has recently ascertained that of the photogenic substances, luciferase and luciferin, the former is probably a complex protein, the latter a natural proteose, or at least not a protein. The luciferases and luciferins obtained from closely allied forms will interact to produce light—*e.g.*, Photuris luciferin with Pyrophorus luciferase, and *vice versa*—but unless closely allied they may produce no light whatsoever.

The remarkable fact regarding luminescence is the very small amount of substances necessary to cause a visible emission of light: for example, the impinging of a single α particle—*i.e.*, a single helium atom—upon a crystal of zinc sulphide is readily seen as a bright flash. It has been found also that 1 part of luciferase in 1,700 million parts of water will give light when luciferin is added, and similarly in regard to a soluton of luciferin when luciferase is added. This figure is *not uncertain,* for assuming that the luminous gland of *Cypridina* is wholly luciferase, it has been experimentally verified. The action involves oxidation and is easily reversible, but the luminescence itself appears to depend upon the attainment of a certain reaction velocity. It may also be noted that the greater the concentration of luciferin the longer the luminescence lasts, and the greater the concentration of luciferase the shorter it lasts. Temperature has an effect, and there is an optimum value beyond which the light decreases again. The *Photinus* firefly emits an orange and the *Photuris* a greenish-yellow light, and different colors may be obtained by using different combinations of luciferases and luciferins.

The research, so far, does not appear to have yielded any solution of the practical problem of confining the production of energy wholly within the wave-lengths, which furnish a maximum luminescence and involve no losses through heat or actinism, etc. But they are a beginning, and are systematic, and I have no doubt that the present enormous waste of energy in the production of light will be overcome, if not by a continuation of this particular study, yet by studies which exemplify the methods of such researches as those here referred to.

CREATION OF A NATIONAL APPRECIATION OF SCIENCE

As a people we lack a due appreciation of systematized knowledge. The change must come through change of our environment. Its power, however, to affect our character, mental habit, etc., if it exists at all, diminishes with our age; hence the means by which a nation is to be so taught the physical sciences that interest therein will grow with the lapse of time must be called into requisition in the youngest years of individual lives. Nearly all young children appear by nature to have that inquisitiveness which constitutes the appropriate foundation of the scientific habit, and they instinctively follow the heuristic method with but slight leading. Elementary schools whose teachers had even a smattering of scientific knowledge, and whose equipment included the means of instruction in intuitional mathematics, in physics and chemistry, and in natural history, could—even in a generation—produce a change in the mental caste of the people. Scientific nescience on the part of the teaching staff could be made good by the issue of appropriate primers, the supply of apparatus, and by giving them special lectures. National destiny will

4 It may be mentioned that luminosity may arise from bacterial infection, and in the case of a frog which had had a large meal of fireflies the light shone through his body.

5 The flux emitted per steradian by a uniform point source of one "international candle."

be profoundly affected by this method; for by it we can develop an instinctive disposition to rely upon the aids which science can afford in practical affairs.

The aim of a good educational system is to engender an interest in the world of mind and in its physical environment so as to ensure our being advised as to what is already known, and being endowed so as to be able to utilize the resources of nature, thus making us alert to the opportunities about us; this assuredly not in order that we may live more luxuriously, but that we may live—so to speak—more expressively.

The more advanced elements of this system will be a good series of text-books, appropriate apparatus for schools and colleges, qualified teachers, well-equipped and adequately staffed technical colleges and universities, so that the staffs shall have abundant time for research and for guiding post-graduate work. The means for carrying out such research is also sorely needed. Beyond this the scientific departments of government—*e.g.*, agriculture, etc.—would require staffs to carry on their appropriate researches, in addition to their routine duties. Finally, as before said, we need institutes for pure research, and also institutes concerned both with research and with all applications of science to industry. To these institutes persons interested might go freely for guidance, at a payment only of such fees as are needed to prevent unreasonable use of the institution. If the world be so organized as to admit of it, it were better to find hundreds of millions for such work as this than for perpetual readiness to destroy. The education and control of peoples; the means of solving the social, economic and financial problems of international life; the question of control and distribution of populations; the inauguration of a scheme of national and international life in which a spirit of service shall take the place of the spirit of merciless competition—these will need all the elements of the problems to be under review, and will call for the exercises of the most complete knowledge both of external nature and of human character. The alternative would appear to be wreckage and the spread of poisons and of disease, and these might even destroy civilization, so that knowledge, instead of having rendered noble service, would have cursed the world whose genius had called it into being.

Our hope is to see a new spirit born here. One may ask, to what end? It may be that we can not say. No one knows what lies on the knees of the gods. But there is something within the mind and heart of any great people that responds to the dream of excellence, and inflames when the vision of national destiny is before it. Our mother-land has had a great past. Is its offspring here in southern seas, illumined by "the gem-pointed cross and the blazing pomp of Orion," to rise to material, to intellectual and to moral greatness among earth's peoples? If so, the path is strenuous but glorious. All visions of ease and luxury are but opiates and lead to destruction. We shall need to gird ourselves for the task, and create for ourselves a world where our sons, knowing something of the splendid mysteries of the boundless universe, and also of our own little world, will excel in the art of using to the full the heritage our nation has given us. Then, indeed, will science have rendered noble service to the sons of Australasia.

GEORGE H. KNIBBS

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H. FREEMAN STECKER

IN the death of Dr. H. Freeman Stecker, ranked as one of the leading mathematicians of the world, which occurred after six months of illness, in the Mercy Hospital, Baltimore, on October 29, the Pennsylvania State College lost one of its best known scientist faculty members. He had served the college for twenty years, and in that time presented over twenty papers on mathematical subjects.

The following memorial was spread upon the minutes of the faculty organization of the School of the Liberal Arts at the Pennsylvania State College at a recent meeting:

The School of the Liberal Arts of the Pennsylvania State College, wishing to place upon its records a memorial tribute to the worth and work of Dr. Henry Freeman Stecker and to give expression to the distinct sense of professional loss which the college and school have sustained in the passing of our friend and colleague, adopts the following minute:

Dr. Henry Freeman Stecker was born at Sheboygan, Wisconsin, June 3rd, 1867, and died in the Mercy Hospital at Baltimore, October 29th, 1923. He entered the University of Wisconsin in 1889, receiving the degree of Bachelor of Science in 1893; Master of Science in 1894, and Doctor of Philosophy in 1897. He was also fellow in mathematics 1893 to 1895, and honorary fellow in 1897. During the academic year, 1900–1901, he studied at the Universities of Göttingen and Berlin. He also spent the summers of 1911 and 1912 in Paris attending lectures on mathematics, and on the latter occasion participated in the meeting at Cambridge, England, of the International Congress of Mathematicians.

His career as a teacher began in his undergraduate days, as assistant in mathematics, 1890–1895. He served at Northwestern University from 1897 to 1900, and after his year of study abroad was called to Cornell University as instructor in mathematics, where he remained until 1903. In the fall of that year, he was elected to an instructorship at the Pennsylvania State College, and by zeal and devotion to his profession rose in academic rank and preferment to a full professorship in mathematics. Dr. Stecker was a member of Sigma Xi, and of the fol-