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SCIENCE AND INDUSTRY

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That the cultivation of science bears an important relation to the national welfare is being more and more widely realized in civilized communities. A more important place in education is being assigned to it. An ever increasing body of manufacturers are recognizing in science the true source of the monumental results achieved by certain corporations, which have placed their trust in the laboratory. Great establishments, both public and private, for scientific and industrial research, are being founded. The constituted authorities of more than one country are repenting them of their neglect of science in the past and are giving tangible evidence of their intention to do better in the future.

Among the governments of the world it was, unfortunately, that of Germany which first arrived at some adequate conception of the potentialities which lie in the application of science to industry. This was not due to any sudden inspiration on the part of the German authorities, but was a natural outgrowth of the development of research along purely scientific lines which had been taking place in the universities. To supplement the work in the older universities great technical universities were established. Institutions for industrial research were founded. Big industries based on research grew up during the last decades of the nineteenth century and wealth accumulated.

In the industrial expansion taking place in Germany, the British people saw no greater menace than an increased trade competition. They failed to realize the significance of Germany's military organization with its will to power. They did not correctly estimate the influence of the Prussian military clique whose members counted every economic gain and restlessly looked forward to "The Day," framing meanwhile schemes of conquest which a few years earlier they themselves would have classed with the fantastic and utterly unattainable.

Whatever other lessons the peoples have learned from the war, it has brought home to them the power of science. This power, too, it is realized, may be used for good or for evil. Before the war the British Government paid scant attention to the claims of science. In spite of the blindness of her rulers, however, Great Britain had the good fortune to possess a group of very able scientists who, on the declaration of war, hastened to offer their services to the Government. Their counsels, it is true, have not always evoked as prompt a response as might have been desired. In the course of more than three years, however, things have changed considerably. In the country where, before the war, official eyes saw nothing, or next thing to nothing, in science which had a bearing on the national welfare, there now exists a "State Department of Scientific and Industrial Research." A fund of a million pounds has been placed at the disposal of the Department for the furtherance of research. Among its other activities it has been getting manufacturers in the same industry together for the founding of laboratories on a co-operative basis, the Department defraying part of the cost. The Department also subsidizes individual investigators. There is no dearth of problems for investigation but the available supply of scientifically trained men has been considerably curtailed by the call of the front. Nevertheless, valuable results have been achieved in many directions. Studies are being made of the light alloys, of refractories, of concrete, on the corrosion of non-ferrous metals, on insulating oils, and many other matters of vital interest to industry are being investigated.* Appreciable economies have been effected in the recovery of tin from the mines in Cornwall. Porcelains imported in considerable quantity from Germany before the war have been replaced by very satisfactory substitutes made from British clays.

A good instance of what may be accomplished by scientific research is to be found in the discoveries made in connection with optical glass. For many years the best optical glass had been manufactured by Zeiss, of Jena. The processes employed in its manufacture were secrets, and in the earlier stages of the war the British authorities found themselves at a disadvantage when it came to the question of supplying the army and navy with optical instruments. A series of investigations undertaken by Professor Jackson of King's College, London, under the auspices of the Government, uncovered the secret processes in question and over and above this, led to the discovery of several new glasses possessing properties which it had never before been possible to associate with glass. There would appear to be no good reason then why Great Britain at the close of the war should not take over from Germany the leadership in the production of optical instruments.

One cannot but make a mental commentary on the fact that the British authorities have found it necessary to order the translation of several German text-books on optical instruments, on the ground that

* See Report of the Committee of the Privy Council for Scientific and Industrial Research for the Year 1916-17.

competent texts on the subject do not exist in English. Let us, however, not be too precipitate or one-sided in our commentary on the erstwhile deficiencies of the Motherland. It is well to remember that we in Canada have been and still are far behind Great Britain in most things that pertain to science.

It may be pointed out that in several British industries, native raw materials are now being utilized where before the war such materials were imported from the continent simply because the manufacturer did not happen to know that ample supplies of the same were at his very door, a fact of which he would have been informed had he consulted competent scientific authorities. This is well illustrated in the case of one of the largest steel corporations in England which, until 1914, had been importing from Austria, through a German firm, a certain material for lining its converters. When war was declared it congratulated itself on the fact that it had a two years' supply on hand. As time wore on, however, and the supply diminished, complacency gave place to anxiety. Finally the directors decided to call in scientific advice. They were referred to the geologists who informed them that a bountiful supply of the material in question was available in the immediate vicinity of their plant. The information was acted on and a shaft was sunk at no great distance from their furnaces, with the result that the company is now mining in sufficient quantity on its own account, the material formerly imported from Austria at many times the present cost.

In France a great national Physical and Mechanical Laboratory for scientific and industrial research is being established under the auspices of the Academy of Science. It has ample funds at its disposition for its own needs and will be able to offer financial assistance to similar laboratories with which it will be affiliated in other parts of the country. Also a Society for the Promotion of Industrial Chemistry has been founded in Paris. This society will have branches in all parts of the country. It will initiate research and will keep the French manufacturers in touch with chemical developments all over the world.

In Japan a sum of two million dollars is being spent on the building and equipment of an Institute for Physical and Chemical Research, this expenditure being shared equally by the Government and the manufacturers. The site for the building was donated. A Japanese dyestuff industry has been started with a capital of $4,000,000, on which the Government guarantees 8% annually for ten years. The like guarantee has been given to a newly founded glycerine industry with a capital of $1,500,000. These and other moves on the part of the Japanese authorities indicate an intention on their part to place the country in an advantageous position for the international trade competition which will follow the close of hostilities. In its ventures referred to above it may be remarked that the Government of Japan has had the benefit of expert American advice in addition to that of the Japanese scientists.

In the United States a great scientific movement has been getting under way during the past quarter of a century. This movement derived its initial impetus from the German universities, in whose class rooms and laboratories, year after year, hundreds of American students pursued advanced studies and became familiar with methods of research. Associated with the movement in later years has been a development on the side of the application of science to industry, thus, in a way, completing the parallel with the growth of the corresponding movement in Germany.

The war has acted as a great stimulus to industrial research in the Republic to the south of us. Big industries based on research are springing up. Among others, many plants have been erected for the production of dyestuff intermediates and for the manufacture of alloys for high-grade steels, on the strength of investigations brought to a successful completion by American chemists. For the products just referred to, America was almost entirely dependent on Germany and Austria before the war. For her potash, too, she looked to Germany, and when the supply was cut off, the glass industry, in certain of its branches, was threatened with collapse. There were firms, however, which, acting on competent scientific advice, were able to sidestep the difficulty by replacing one combination of ingredients entering into the manufacture of their glass, and including potash, by another combination not containing that ingredient. The lack of potash has also proved a hardship to the fertilizing industry. The United States has found, however, that large potash resources in various forms exist within her own borders and these she is now developing.

When the United States entered the war she found the same difficulties in regard to optical glass which had confronted Great Britain a couple of years earlier. Scientific investigators were assigned to the problem and considerable progress has been made, so we are told.

The director of a large laboratory in the United States, in conversation with the speaker, reproached the American manufacturer with being too prone before the war to exploit the American rights on a German patent instead of developing new industry on his own account by establishing a research laboratory in connection with his plant. To whatever extent this reproach may have been justified, the war has thrown the American manufacturer on his own resources, with a result which promises to be, in effect, a declaration of complete industrial independence of Germany.

Last summer I had occasion to visit a number of laboratories in the United States and to discuss with those in charge matters pertaining to industrial research. Everywhere it was the same story of threatened paralysis of one or more activities of an industry by the cutting off of the supply of some important article. But almost invariably, too, this was supplemented by the more cheerful account of how the situation had been saved by the resources of industrial research. The responsible head of one of the largest industrial research laboratories in the country recounted to me the story of how they had to "sweat blood" to replace a certain indispensable article which, before the war, they had imported from Europe. Their efforts, however, were eventually crowned with success. In the same laboratory the endeavor to discover a substitute for another imported article resulted in finding something which proved to be vastly superior to what they had been using.

A cheering feature of the situation in the United States is the attitude of the big industrial establishments to science. Here at least the debt of industry to pure science is freely acknowledged. The ancient delusion about the scientist not being a "practical man" has pretty well disappeared in the larger industries. If one is to take as a standard the power to bring things to pass, the real scientist, that is to say the research worker, is the most practical man in the world. If, however, his practicality is to be measured by the effort he expends on accumulating a fortune for himself, he is, and will remain, unpractical.

There is a widespread misapprehension among laymen in regard to the nature of science. They have, as a general rule, an impression that there are two types of science. On the one hand they believe that pure science was invented for the diversion of university professors and theorists in general. It has, they assume, no point of contact with, or influence on, everyday life, either immediate or remote. On the other hand they conceive of applied science as a disconnected something which dispenses with the subtleties of pure science and takes a short cut to results. The director of a big commercial laboratory across the line told me that the short-cut men had cost the Government of the United States millions of dollars. There is, as a matter of fact, no other science than pure science and "applied science" is simply that science applied.*

In the great laboratory of the General Electric Company at Schenectady, I was informed that the research workers are discouraged from thinking of financial results, as discoveries are more likely to be made by those who are working in the scientific spirit. This laboratory is main-

* In this connection the writer would recommend the perusal of a little volume recently published by the Cambridge University Press, under the title "Science and the Nation." Its contents consist of an introduction by Lord Moulton, and thirteen essays by as many different writers, each one an authority in his own special department.

tained at an annual cost of over $500,000 and employs seventy-five investigators, including among them several who are eminent in the world of pure science. One of the products of the Schenectady Laboratory is the tungsten lamp which is now manufactured by twenty-two factories scattered over the country. This lamp, according to a very careful estimate made in 1911, was at that time effecting a power saving valued at $240,000,000 per annum. Since then, the consumption of this type of lamp has increased three-fold and further research has increased its efficiency of light production nearly 25%.

Recently the General Electric Company brought out a new form of amplifier called the Pliotron. This serves as a relay and amplifier for use in wireless telegraphy and telephony. At the time of my visit, among other things, the Company was preparing to put two improved types of rectifier on the market. One of these, a modified form of the kenotron, is adapted to the rectification of low current and high voltage. The other is likely to find a large field in connection with the automobile industry. Studies are being made of the properties of silicon steels and their relation to the size of the grain of the metal. Elaborate investigations of insulating materials are under way. In particular, insulation at higher temperatures is being studied. A great deal of work is being done in connection with X-rays, both in inventing new apparatus and in making applications of the rays. Here it would be in place to draw attention to the portable X-ray outfit, devised for Red Cross work by the General Electric Company. It is also to be noted that the Government of the United States has announced its intention of equipping every million of men it puts into the field with 6,000 Coolidge tubes, that very excellent invention of the head of the X-ray department of the General Electric Company.

It may be mentioned that one of the war problems which has been successfully handled in the Schenectady Laboratory is that of finding an effective glass for the protection of X-ray operators. The lack of such a glass, I was informed, has resulted in grave injury to many of those who had charge of X-ray work at the front. A war problem at present under investigation is that of the breakdown of insulation in connection with the spark plug in aeroplanes, a difficulty which has given considerable trouble to the British air service.

It will perhaps surprise some of my readers to learn that there are research workers in the General Electric Laboratory who are busied on purely scientific problems without having any definite commercial objective in view. One such problem, for example, is that of determining the atomic structure of the molecules of certain substances. Work of this character, conducted under commercial auspices, is justified on the ground that great and unforeseen developments in industry follow from fundamental discoveries in science. The place assigned to the scientific spirit and to pure science in the conduct of the great laboratory of the General Electric Company by its distinguished Director, Dr. W. R. Whitney, is naturally gratifying to the scientist. The results achieved are at the same time eminently satisfactory to the directors of that great commercial concern, whose very existence is rooted in research and whose activities cover a continent.

Besides the research establishment at Schenectady, the General Electric Company maintains at an annual cost of $50,000 what is known as the Nela Laboratory, at Cleveland. This is a purely scientific foundation of a highly specialized character, which confines itself to the investigation of phenomena relating to light. In addition to the regular scientific staff employed in this laboratory, a number of outside scientists make use of its facilities gratis by permission of the company, a graceful acknowledgment on the part of this great commercial organization of its debt to science.

Another extensive Research Laboratory is located on the water-front in New York. This is included under, and is a part of, what is known as the Engineering Department of the Western Electric Company and constitutes, as a matter of fact, the research end of the Bell Telephone System. The Engineering Department of the Western Electric Company, which numbers some 3,600 employees, devotes its attention to development and scientific work in connection with transmission of intelligence and in particular with telephony. The scientific workers in the Research Laboratory number 318, and are divided into four groups, of which the largest contains 125. The problems handled by the members of this group are purely scientific. They do not originate in service, but are initiated by the workers, and may have anything to do with the transmission of the human voice. Directly on the four groups a sum of $1,000,000 is expended annually. The Engineering Department, of which the Research Laboratory is a part, costs, all told, inclusive of the laboratory, $4,000,000 annually. According to Lieut.-Col. F. B. Jewett, the able Chief Engineer, the reason that America leads the world in telephony and telegraphy is to be found in this laboratory. Its thought product, I was told, keeps about 25,000 workers busy in a factory located in Chicago.

A certain amount of co-operative research is done in laboratories maintained by associations of firms in the same industry as, for example, in the case of the "Association of Cement Manufacturers," but research under this form of organization is not being carried out on anything like the scale contemplated in Great Britain and is small compared with that done in the laboratories of individual firms.

A good deal of research work is of course done by consulting chemists, physicists and engineers for firms which may or may not possess laboratories of their own. Usually this work will consist in handling specific problems. In some cases, however, the consulting specialist devotes a definite portion of his time to the supervision of the regular research work carried on in the laboratory connected with an industrial plant.

Research on a large scale, for the benefit of science and industry, is conducted at that great institution maintained by the Federal Government at Washington, D.C., and known under the name of the Bureau of Standards. This establishment employs about three hundred scientific workers and handles the greatest diversity of problems. It tests papers, textiles, structural and other steels, building and roofing materials, cements, paints, inks, chronometers, thermometers, barometers, electrical apparatus of all sorts, radio-active preparations, and in fact anything and everything to which a mechanical, physical or chemical test can be applied. It tests the supplies purchased by the various departments of the United States Government. It has eliminated all fraud in this connection and has saved the country many millions of dollars. It is studying the telephone service, street railways, gas, electric light and power, etc. It furnishes manufacturers' chemists with standard samples of chemicals with which to compare their own product. It is investigating the magnetic properties of iron and steel. It is studying the properties of materials at low temperatures. It is engaged on the problem of standardizing radium. It is carrying on researches in connection with wireless telegraphy. It is conducting experiments on rubber in order to determine, if possible, the relation of its commercial properties to its chemical constitution. It is laying the foundations of an American ceramic industry by its study of native clays. It is standardizing colors for the benefit of the industries. It has recently been requested by Sears, Roebuck & Company, of Chicago, to undertake a pedimetric census of the United States with a view to the standardization of lasts as a measure of national economy. The fractional enumeration here made of some of the present day activities of the Bureau of Standards gives but a faint suggestion of the scope and multiplicity of the functions of that admirable institution.

Another type of industrial research organization is represented by the Mellon Institute. This is an endowed institution associated with the University of Pittsburgh. The building and equipment, costing over $500,000, are the gift of Messrs. Andrew William Mellon and Richard Beatty Mellon, of Pittsburgh, who also provide a yearly allowance for running expenses. The general equipment and facilities of this laboratory are at the disposition of the manufacturer gratis. He pays, however, the salaries of one or more scientific workers, called fellows, who are selected for him by the Institute and who devote their time to the solution of his problems. The fellowships are of different amounts, but average about $3,500 a year. In the summer of 1917 the total number of fellowships was forty-two, the number of fellows employed on them being sixty-four. In some cases a bonus is attached to a fellowship, such bonus to be paid only in the event that a discovery of sufficient importance is made. Discoveries are patented, the patents becoming the property of the manufacturer who has donated the fellowship.

Among the fellowships in successful operation at the time of the visit of the writer to the Mellon Institute may be mentioned the Bread Fellowship of an annual value of $6,500. With this fellowship is associated a bonus of $10,000, which has been paid three times over in the course of the past six years. As a result of investigations carried on in connection with the Gasoline Fellowship, several plants have already been erected. A million-dollar carbohydrogen concern operating in Pittsburgh was founded on the strength of discoveries made on a fellowship at the Institute in the years 1912-14. The Illuminating Glass Fellowship proved a godsend to its donor when, with the outbreak of war, the supply of potash was cut off.

There are fellowships which have for their respective objects recovery of the by-products of coffee roasting, utilization of the citrus waste of Florida, synthesis of drugs formerly imported from Germany. A number of fellows are studying processes for the reduction of iron, copper, and aluminum ores. Others again are investigating methods for the production of acetylene and hydrogen. Several fellows on the same foundation are busied on problems connected with the petroleum industry. There are fellowships on phosphate, coke, fire brick, glass refractories, etc. To convey an adequate idea of the variety of the work of the Institute it would be necessary to reproduce a complete list of the fellowships.

It is not an easy matter to obtain reliable information with regard to manufacturers' profits and where such information is furnished it is in general understood to be confidential. I have some interesting data relating to the financial returns from research, but for the reason just indicated, I am not at liberty to give much detail. In one case an industry founded with a capital of $25,000 had accumulated $200,000 of assets at the end of two years and was doing a business of $1,000,000 annually. In another case an industry started in a like small way was making a monthly profit of $50,000 at the end of eighteen months, during the first six months of which the business was in the experimental stage. The third case which I will cite is one in which an initial investment of less than $100,000, gradually increased to between $300,000 and $400,000, resulted in an industry which was disposed of for $1,500,000 at the end of two years. The fourth case is that of a plant which cost $25,000. At the end of four months it had paid for itself and was making a profit of $1,500 a day. The industries here referred to are of a permanent character and have all been founded since the war began.

An instance which might be cited is that of an old-established firm which decided about three years before the war to see what there was for it in research, with a result that $1,000,000 has been added to its annual profits. This was achieved at an average annual cost approximating $12,000. The research work was done by three men who improved the processes and replaced important agents by cheaper and more effective substitutes. Another instance could be given of a firm which saved $180,000 through the resourcefulness of a single research man in the first year after he had begun work on its problems.

The examples of the financial results just given cover four different kinds of industry. The profits represent actual values created by research. Certain of the firms in question, it may be noted, have adopted the bonus system, whereby the wages of the workmen increase as the profits of the company augment through improvements in the processes.

The benefits of research are, of course, not always as conspicuous as in the cases here cited. That the results to be obtained are not, however, to be regarded as a matter of haphazard, is evidenced by the policy of those commercial concerns which, in the light of their experience, willingly spend hundreds of thousands of dollars annually for the maintenance of a research laboratory. The experience of the Mellon Institute, too, is that a very small proportion of the manufacturers endowing fellowships are out of pocket through their investment.

Canadian manufacturers should have within reach all the facilities for industrial research which are placed at the disposal of manufacturers in other countries. Within the not distant future there should be established at Ottawa an institution corresponding to the Bureau of Standards at Washington, D.C., and the National Physical Laboratory in England. The need of an establishment like the Mellon Institute to consider specific problems offered by individual manufacturers for solution is also pressing. The cost of building and general equipment might well be borne by the Government, as also the cost of general maintenance. Ultimately the greater part of the expense would fall on the individual manufacturers for whom definite work was being done, for they would have to pay specific costs connected with that work, including the salaries of the scientific workers. The reward of the manufacturer would lie in the possession of patents taken out on the discoveries made. The Government might stipulate that the results of investigation conducted in the laboratory should be published after the lapse of a certain number of years. It might also, by the collection of a small per cent. of the royalties on the patents, ultimately make the institution self supporting.

The scientific workers in the laboratories just referred to and in those laboratories which already exist or which in the natural course of events will develop within the plants of private corporations in Canada should, for the most part, be graduates of our Canadian universities. Much good industrial research work can be done under direction by men who have had an undergraduate course in a scientific department. The directive function should, however, belong to men who have had a more advanced training. This implies that in the leading universities of Canada the research ideal should be more in evidence, and that developments in graduate work should take place. Nowhere in Canada is there a university adequately equipped and manned for such work. This is a reproach which should not remain.

How can we tolerate the thought that in Germany provision is made for training men in advanced research which is not made in Canada; that positions exist for men so trained which do not exist in Canada! What excuse can we Canadians offer in extenuation of the fact that the leading universities of the United States have left our universities far behind in the matter of research? If the people of Canada realized the significance of the modern scientific movement, they would see to it that the necessary funds were forthcoming, and they would surely insist, as a matter of national pride, on our universities taking their place alongside the foremost in the world. This would mean on the one hand more time, and in some cases better equipment, at the disposal of the members of the staff in order that they might be scientifically more productive. On the other hand, it would mean adequate inducement held out to young men of requisite ability to prolong the period of their studies and prepare themselves more effectively for research work, either in pure science or in the application of science to industry.