SCIENCE

VOL. 86 FRIDAY, SEPTEMBER 10, 1937 No. 2228

SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. MCKEEN CATTELL and published every Friday by

THE SCIENCE PRESS

New York City: Grand Central Terminal
Lancaster, Pa. Garrison, N. Y.

Annual Subscription, $6.00 Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the Association may be secured from the office of the permanent secretary, in the Smithsonian Institution Building, Washington, D. C.

RESEARCH IN ENGINEERING[1]

By Sir ALEXANDER GIBB, G.B.E., C.B., F.R.S.

ENGINEERING started as an art; at a later stage it developed into a somewhat scientific but purely empirical practice; it is now the final stage of applied science.

That engineering is a science has not always—and still in some quarters is not—recognized or appreciated, even among engineers themselves. For that we have no one to blame but ourselves. Too long were we content to act by the light of accumulated experience, not always fully assimilated. But engineering has now for some time past realized that, without research, progress and improvement are impossible.

Engineers have sooner or later always made use of the discoveries of science; but the connection with science has been casual and haphazard. "It seems exceedingly doubtful if Watt or any other inventor," wrote Professor Lea, "would have thought of the independent condenser, if it had not been for the fundamental work of a purely scientific character done by Toricelli, Boyle and others, on the pressure of the atmosphere, and that by Black and Watt which led to the discovery of the latent heat of fluids, and thus to a quantitative appreciation of the heat units involved in changing water into steam."

But organized research was then something still unknown. For the first fifty years of its life the Royal Society had to bear the jeers and sneers of the pulpit, the platform and the literary world. When Harvey published his tract describing the circulation of the blood it was received with ridicule, as the utterance of a crack-brained impostor, and he was deserted by almost all his friends. This attitude of distrust on the part of the public lasted into the nineteenth century. But scientific research was at last becoming a matter not only for the individual crank and dilettante, but for scientific cooperation. The encouragement of research and the advancement of useful knowledge were

[1] Address of the president of Section G—Engineering, British Association for the Advancement of Science, Nottingham, September 2, 1937.

indeed among the objects of the foundation of the Institution of Civil Engineers in 1818.

It may be interesting at this stage to remind ourselves very briefly of the history of research, and how very recent is its growth.

The Royal Commission, appointed to administer the surplus of £213,000 made by the Great Exhibition of 1851, used the money to purchase a large piece of land in Kensington Gore, on which are built the South Kensington Museum, Schools of Science and Art, the Natural History Museum, the Museum of Scientific Instruments and others that I need not mention. In addition to this many science scholarships have been provided.

From 1850 the government gave an annual grant of £1,000 (increased by £4,000 a year in 1877) to the Royal Society for the promotion of scientific inquiries, which went to aid research in mathematics, physics, astronomy, biology, chemistry and general purposes. The society also benefited from many donations from its own fellows. And from time to time private individuals, by donations or bequests, endowed fellowships.

But in Great Britain original research continued to be mainly the task of individual scientists, chiefly at their own expense. Industry had certainly not yet recognized its value, and it was to be a full generation before it was fully and practically accepted that scientific and industrial research is an essential factor in our industrial and national existence.

In Germany greater progress had been made. The lessons learned in the Franco-Prussian War led to the institution in 1872 of the Reichsanstalt and the Materials Testing Department. The former was established in two divisions—the one devoted to pure science and the other to its application to the advancement of industry and manufacture. At the same time technical colleges for research and the training of research students were founded at Charlottenburg, Darmstadt and other centers. German industrialists quickly recognized the value of the work of these institutions. The A.E.G., Siemens and Halske and such great companies at an early date set up private research laboratories. The development of the dye industry is a perpetual warning and incitement, for it was Perkin who first discovered, in 1857, the manufacture of aniline blue; but it was left to the Dye Company of Germany to create from his discovery the great German dye industry, for which purpose huge sums were spent in developing new methods and evolving new dyes.

To return to our own country and engineering. In 1893 Sir William Anderson wrote: "The days are past when the engineer can acquit himself respectably by the aid of mother wit alone or of those constructive instincts, which in the past led our predecessors to such brilliant results." Four years later the government appointed a committee under the chairmanship of Lord Rayleigh to consider and report upon the desirability of founding a National Physical Laboratory. The setting up of this committee was incidentally largely due to the agitation, led by Sir Oliver Lodge, at meetings of the British Association and elsewhere.

In 1898 Lord Rayleigh's committee issued its report, recommending that a public institution should be founded "for the standardizing and verifying of instruments, for testing materials and for the determination of physical constants," and that it should be under the control of the Royal Society. The scheme was drawn up in 1899 and Dr. Glazebrook, F.R.S. (afterwards Sir Richard Glazebrook) was appointed its first director, a position which he held until 1918.

The year 1900 is, too, an important dividing line in another sense. The National Physical Laboratory was founded just before it; and two years after it, 1902, the British Engineering Standards Association was established, by the cooperation of the Institution of Civil Engineers, the Institution of Mechanical Engineers, the Institute of Naval Architects and the Iron and Steel Institute, under the chairmanship of Sir John Wolfe Barry, the great civil engineer. Since 1900 research has been on the whole recognized as a question of national importance.

The history of the National Physical Laboratory has been one of continual expansion. From Kew it removed immediately to Teddington to have greater space. In 1901 the Engineering Laboratory was completed. In quick succession followed departments dealing with electrotechnics, electrical standards, optics, thermometry, pyrometry, tide-predicting, road material, physics, metallurgy, aeronautics, ship model testing, to mention only a few of its manifold activities. By 1918 when it became part of the larger organization known as the Department of Scientific and Industrial Research, it had already an expert staff of 600. It has now over 1,900.

The original committee of eight, under the chairmanship of Sir John Wolfe Barry, that controlled the British Engineering Standards Association has now expanded into a body of 870 committees with 4,850 members.

In later years, coordination has become recognized as essential. "In any earlier age," said Mr. Thomas Midgley, on the occasion of the award to him this year of the Perkin Medal of the Society of Chemical Industry, "when science and industry were simple individualistic processes, it is conceivable that some person, by his efforts alone, could have advanced applied chemistry to have justified your committee to bestow upon him the Perkin Medal. To-day this is no longer so. To advance applied chemistry even a little requires the organized efforts of many individuals. Since you

have chosen me as the recipient of the Perkin Medal for 1937 it is only fitting that I acknowledge at this time the aid which I have received from others in solving the two problems for which you are rewarding me." Such ascription of merit would have to be made by every research worker of to-day.

The same is true generally in industry and manufacture. Every important industry and many manufacturers devote considerable expenditure to research. It is in fact the only means of continuous progress in an increasingly competitive world. It is almost the exception now to find a firm of any standing that has not its research department, and some of the most extensive and elaborate laboratories in the country are under the control of great manufacturing firms. The modern state is founded on scientific research—not like the French judge in 1794, who, in sentencing to death Lavoisier, one of the founders of modern chemistry, said that the Republic has no need of scientists!

Nowadays a vast amount of state-aided research is being carried out by state departments, private research laboratories, research associations, scientific institutions, universities and technical colleges and still by private individuals.

The engineering world has not kept pace with the scientific world; and it has been fortunate that the two distinguished directors who administered the activities of the National Physical Laboratory for the first thirty years of its existence, Sir Richard Glazebrook and Sir Joseph Petavel, should have been men of the widest views. Before 1914 the work of the National Physical Laboratory was very valuable, but during the war, it became indispensable both to government and to industry. In due course it was found that a wider organization was wanted to link in a more definite way the relation between science and engineering research and industry. A Joint Board of Scientific Societies formed a deputation under the leadership of Sir Joseph J. Thomson to stress the importance and urgency of the question on the government.

The outcome was the establishment, in 1915, of the Department of Scientific and Industrial Research, under the control of a Committee of the Privy Council, with an Advisory Council of scientific men of the highest rank in the country; and in 1918 the National Physical Laboratory became part of the newly created department, though the Royal Society continued to control its scientific activities.

A glance at the summary of the latest report of the Department of Scientific and Industrial Research affords some idea of the immense engineering field it now covers in its work. It includes fuel research, food investigation, building research, steel structures, roads, road tar, forest products research, researches on water pollution, metallurgy and radio, chemical research, illumination, lubrication, atmospheric pollution, furnace design, industrial respirators, radium beam therapy, x-ray analysis, and I may add, almost any problem you may like to put before them.

But apart from the immense importance of the scientific work done, the department is the focus for linking together all the research going on in the country. This it made from the outset one of its primary objects; and one of the chief ways in which it accomplishes this is by the encouragement of the formation of research associations. These associations are self-governing bodies formed on a national basis in various industries for research in the interest of the industries they serve. Each association is, or aims at being, a cooperative unit representing all the firms who belong to that particular industry. There is no fixed subscription, it being based on the size of each firm, so that for a very small sum a small firm may have the benefits of an organization which is spending thousands of pounds annually on fundamental research of interest to the whole industry. The associations work in close contact with the Department of Scientific and Industrial Research, to which each one submits a yearly report of the work it has done and the problems which it is studying. The department's help does not, however, stop at this point. In addition to advice and technical help, it contributes to the funds of the research associations by making a £1 for £1 addition for every sum provided by the members.

Of equal importance is the work carried on in the various research bodies under the management of the great scientific institutions. These again are largely cooperative in their aim. Some, indeed, as for instance the Research and Standardization Committee of the Institution of Automobile Engineers, are affiliated to the Department of Scientific and Industrial Research as research associations, and receive the department's £1 for £1 contribution to their funds.

Nearly all the universities now have research departments, which not only carry out practical work of importance, but also act as training centers for students who are to make research work their livelihood; while as already mentioned private research laboratories are maintained by the more important and wealthier firms—as well as by quite humble businesses. Their primary object is naturally the furthering of private interests, but they are not entirely isolated units. Many such research departments belong to one or other of the research associations and frequently pass on problems of a fundamental nature to them to deal with. All can work in contact and correspondence with the Department of Scientific and Industrial Research—if they desire.

I have tried to indicate the rise, growth and present

state of research in this country. Some idea of the recency of its growth may be gained from the fact that in the eleventh edition of the Encyclopedia Britannica, published in 1910, the subject receives rather less than half a paragraph.

The early years of the twentieth century saw on the whole much greater research activity abroad and in America than here. It is quite impossible to enter on any account of these, but I might mention that the National Academy of Sciences was founded in the United States as early as 1863, to deal with all phases of national research; and its influence in the United States is comparable to that of the Royal Society in our own country. In 1916 the academy created the National Research Council to assist the government in organizing the scientific resources of the country, which proved of such great service during the period of the great war that it was decided to maintain it as a permanent organization. One of its main branches was that of engineering and industrial research.

The first years of the new century, also as with us, saw the setting up of the National Bureau of Standards by the United States Government, which covers an immense field and whose technical bulletins and other publications are the means of making widely known many of the latest scientific discoveries. America has indeed always been forward in promoting international standardization in engineering and cooperation in research work, considering that the two matters must run together—as is so. The Bureau of Standards includes as part of its organization a close cooperation with the research department of the universities and other institutions in every state.

In America, too, industry and manufacture have taken a leading part in the research movement, and some of their great laboratories eclipse our own in size. The United States have developed a form of cooperative research of their own, of which the Mellon Institute is the best known example, founded in 1913 by the brothers Richard and Andrew Mellon. Since its origin 1,150 research fellowships have been established in 275 technological subjects and 650 processes or products have been invented or developed. In ten instances new industries have resulted.

In Canada, where I was very recently, I was greatly struck by the action the Dominion Government is taking in the promotion of research. The National Research Council, with headquarters at Ottawa, where it has a magnificent new building, is not only carrying out a very wide program of practical research, but is aiming at training a big body of research-minded engineers and scientists.

One could continue the story of research abroad, but I must stop. I have omitted much that those acquainted with the subject would have expected to be included. But I have done enough to show what a great deal has been done to establish research in our generation.

There is no finality. Every day extends the bounds of knowledge. We have only just begun to understand how to conduct organized research. "The historian of the future," writes Lord Rutherford, in the last Report of the Department of Scientific and Industrial Research, "will probably point to the last five years as a period marking an important development in the industrial outlook of this country. These years have witnessed the fruition of the policy adopted by several large industrial undertakings of setting well-balanced teams of research workers, including chemists, physicists, engineers and where necessary biologists, to solve a particular problem or to develop a new product. This method of attack has led to the steady improvement of the efficiency of electric lamps, to the position this country has won in high definition television, to the development on a commercial scale of the huge plant for the conversion of coal into oil by hydrogenation, to the growth of the plastics industry and to many other important advances. . . . Cooperation can never win the fullest success until the contacts between men of ideas in industry and men of ideas in science are as closely knit as possible."

Although I have dealt so briefly with the subject I hope I have made evident that research divides itself into several categories. It is, I think, very necessary to bear this in mind.

There is what one may call true fundamental research—splitting the atom, or extreme low temperature investigation. No one can doubt that the results will ultimately have their effect on human life. No one, however, can now say who will be benefited, or how. Such work must always be expensive, it must depend on endowments and generous gifts. It is not with this type of research that engineering is directly concerned.

I am concerned with applied research, and it has its divisions. We have in the first instance work of more or less universal application—such as agricultural research, the breeding of new wheats or methods of storage of fresh fruits; or investigations in regard to river pollution. The results once attained become immediately available to all the world. Such work too depends on endowments and government support. This type of research, as fundamental research, often finds its home in our universities, and where there is still opportunity of individualism.

Then there is the research that deals wholly with the problems of a particular industry—aircraft building, or the development of welding. Here the whole work has a much more restricted field and definite goal. New truths are not sought; but the means of

turning the inventions of others to practical use and the economic solutions of the problems of those concerned in the particular industry, whatever it may be. The results can be more or less restricted to the members of the industry that support the research, and the admitted object is to benefit those members.

The Mellon Institute in the United States typifies a rather different type of coordinated research. The institute has a limited membership. Only one representative of each class of interest is admitted. For instance, there is only one yeast firm that is a member. No other would be able to become a member. But of course the boundaries of the interests of many member firms necessarily overlap. The result is that while applied research is being carried on in many different fields in the Mellon Institute, all the members may benefit sooner or later from researches into problems not directly connected with them. The institute is extremely ably run. The results have been considerable, and private research is enabled to be carried out on a broader basis than would otherwise be possible.

Finally there is the private research department, large or small, of every progressive company. Here while the results can be kept entirely confidential, obviously the scope is in some ways more restricted. Most companies find it necessary to pool inventions, and even so where research is carried on more or less in secret, there is danger that errors of approach may not be realized, until much damage has been done or time lost.

With these remarks, I turn to the all-important question of finance. Research is expensive. Who is to pay? In the early days of discovery it was inevitably at the expense of the individual, and in this way many private fortunes were spent for the ultimate good of industry and humanity.

In the nineteenth century, apart from the scientists who spent their private fortunes, research was largely dependent on the endowment of public-spirited benefactors, and to scientific societies. Government, as I have already said, more far-seeing than the general public and in spite of futile criticism, began to aid in a small way from the middle of the century onwards. Generally speaking, industry had not realized the importance of research and its attitude was almost hostile until the twentieth century was well on its way. The £54,000 raised for the Ramsey Memorial Fellowships, after his death in 1916; Sir Alfred Yarrow's £100,000 in 1923, are earlier examples of the efforts of individuals which have their modern counterparts in Lord Austin's and Lord Nuffield's gifts to Oxford and Cambridge Universities.

But it is now sufficiently admitted that research should be paid for by those who benefit by it—the community and industry. The attitude of industry has changed from indifference to support. "It is not easy to assess over a period of twelve months the change that is taking place," writes Lord Rutherford in the report I have already quoted. "Comparison of the attitude of to-day with that of ten years ago indicates more definitely what is happening. In one field of our work industry affords each year clear and tangible evidence that the forward movement which it has been our aim to encourage is gathering momentum. The steady increase in the total sum which industry as a whole provides annually for the development of research associations gives us good reasons for taking an optimistic point of view."

In the year 1932–33 a total sum of £167,370 was supplied by all the industries concerned for the support of the research associations organized by them. In 1935–36 the figure had grown to £232,468—an increase of 40 per cent. in three years. But even so the position is not yet satisfactory, and industry still lags behind in its support of these associations, in spite of the liberal encouragement of government. I have no doubt, however, that this stage of affairs will not last. In the past year several important steps forward have for instance been taken—the opening of the splendid new laboratories of the Printing and Allied Trades Association, the Perivale Laboratories of the Electrical Research Association, the new laboratories of the Research and Standardization Committee of the Institution of Automobile Engineers, the extensions to the Shirley Institute and the Research Station of the Paint Research Association at Teddington.

We have been experiencing a revival, and hopes are high again. This always makes it easier to get money. Unfortunately, when industry is depressed, and when research is all the more necessary, the necessary support is not forthcoming. I might instance the William Froude Laboratory. The work of the institution was made possible by the benefactions of two leading members of the ship-building industry, Sir Alfred Yarrow in its early days and Sir James Lithgow in its more recent developments. The maintenance of the research work, however, depends largely upon its provision of funds by the shipping and ship-building industries. Actually, the major portion of the expenditure has been met by payments for tests by individual members, while the industry as a whole has contributed only about £2,000 a year, an inadequate sum to deal with the immense field that has to be covered. In the years 1935–36, 73 ship designs involving the making and testing of 160 model hulls were dealt with. Four of the designs were improved in hull and propeller by more than 20 per cent., and effective improvements were made in 54 out of the 73 designs. "It has been calculated," we are told, "that if only one ship were built to each of the im-

proved designs resulting from one year's work at the Tank, the annual saving in the cost of operating the vessels would be more than enough to cover the cost of running the William Froude Laboratory for a year."

Of course, here as always in research, it is the case that the greater the success of research, the more immediate and drastic the effect on existing plant and equipment. That is where the rub sometimes lies. Millions are necessarily sunk in fixed assets which may in a year or two be made obsolete by the development of new methods. Obsolescence is indeed so rapid nowadays that it is not unusual for new plant to be written off in four years; and many valuable inventions have been bought up by vested interests and suppressed in order to save the greater loss that their exploitation would involve to already operating plant. It is therefore not surprising that there is not always an enthusiasm for unrestricted research or a readiness to praise it. But it is a shortsighted policy.

I have glanced at the rise and growth of the modern research movement. Coordination and cooperation have done much to link together the various elements, but there has as yet been no general national plan. For totalitarian states such things are not so difficult; but for that reason democratic countries too must organize and cooperate more closely than ever before. Groups of unrelated, often competitive, bodies can not be really effective. In my opinion the time must come when every research organization will be linked by some form of affiliation to a central controlling body. This would become inevitable in time if only to prevent hopeless overlapping and duplication, with attendant waste of energy, time and money. There is another direction where centralization is equally necessary. I refer to publication. At present if the results of research are not kept as trade secrets, they are often broadcast in such a multitude of journals, books, papers, addresses, etc., that it is almost impossible for one who is studying any particular branch to avoid unwittingly covering ground already covered by previous workers. We have all experienced the difficulty of trying to collect all the latest information on the subject we have been called upon to deal with. I believe that approximately thirty thousand scientific periodicals are published throughout the world, each of which no doubt may contain the results of research in some form or other. In our own country no definite and practical scheme has yet been conceived for making available the results of research. There should, moreover, be some type of clearing-house of engineering information, such as would collect, collate and make immediately available all new data discovered. Some partial success has been attained in this direction in more than one way. The Executive Council of Imperial Agricultural Bureaux, for instance, an autonomous authority that deals with the finance and administration of ten scientific bureaus, works in close touch not only with all the councils but with other research centers such as the Low Temperature Research Station at Cambridge, the Building Research Station at Watford, and so on. If it be impossible even to work out a similar organization for engineering on a national or world-wide basis, it can not be impossible to establish at least a clearing-house system at a relatively small expense in cooperation with the Department of Scientific and Industrial Research. This department, with the research associations which it partly finances and others with which it is associated, provides the ideal nucleus for such an information service, but engineering must work out its own scheme.

I am afraid I have no definite proposals to make—at least at this juncture. All I have desired to do is to ventilate a subject of paramount importance to engineering. I would thank you for so courteously listening to me; there is no more useful work that the British Association does than offer opportunities for the ventilating of the vital problems and questions of the day. I am satisfied that at the moment in the engineering world—which after all means in the whole commonwealth—there are two outstanding questions, the coordination of effort and the promotion of intensive research.

SCIENTIFIC EVENTS

ADDITIONS TO THE COLLECTIONS OF THE NATURAL HISTORY MUSEUM, SOUTH KENSINGTON

THE London *Times* records that the Natural History Museum, South Kensington, has received as a gift from J. L. Chaworth-Musters the collections made by him in the early part of this year in the High Atlas Mountains, above Marakesh. The specimens include a few small mammals and 82 birds belonging to 31 species.

Among the birds are the rare crimson-winged finch, an Alpine accentor and local forms of the dipper and shore lark. Mr. Chaworth-Musters also brought back 391 carefully preserved specimens of plants, which he has given to the Department of Botany. Of these five are ferns, 28 lichens and the remainder flowering plants.

Major W. R. Barker, of the Game Preservation Department, Khartoum, has presented a young female white rhinoceros and the skin and skeleton of an ant-bear, and the Rowland Ward Trustees have given a number of mounted heads of mammals. A collection