BASIC PRINCIPLES OF ORGANISATION OF SCIENTIFIC RESEARCH.

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The movement for organisation of scientific research in the interests of the people has not a long history behind it. If we wish to have a clear grasp of the basic principles for organisation, which must be followed in order that the movement in this country may lead to success, we must not forget the elements in human character which are responsible for the growth of science. An audience like the present one need hardly be told that growth of scientific knowledge since medieval times has been mostly due to private enterprise, and the greatest contributions have been almost exclusively due to the efforts of persons of outstanding ability actuated by a spirit of enquiry, enterprise and exploration. But this is as much true of modern as of earlier times. If we take a stock of the fundamental discoveries in science for the last 50 years, we can hardly dissociate personality from any grand achievement. And it seems to be a fundamental axiom that if progress in science, which is the basis of all technical advancement, is to be maintained, the personal element has to be fostered, and given the fullest scope for development.

It appears to be otherwise when we turn to the steps by which great discoveries in pure science have been translated to industry. It is well known that almost all the discoveries in the physical and chemical sciences which have given birth to the great industries of steam engine transport, power, fuel, synthetic chemicals, and metals, telegraphy, telephony, radio, automotive engineering—have their roots in researches carried out almost exclusively by persons actuated by the spirit of search after Truth and with no motive for profit; but the methods of big business which translated these to industry appeared almost to run diametrically opposed to the principles of advancement of science. Here success appeared to depend on finance, routine, organisation, secretiveness, and suppression of personality. The great basic discoveries in the medical and biological sciences have followed the same course, though their utilisation by Big Business has followed somewhat more tardily.

It was first the German industrialists who sensed the advantage of employing scientific men for inventing new processes and improving older ones. The stories of synthetic indigo and synthetic ammonia, both the result of happy union of scientists and industrialists, are so well known that they need no repetition.

The German State was not behind their industrialists. It is true that whenever any new invention or discovery has held out prospects of increase of political and industrial power, States and potentates have not hesitated to take advantage of them. The best known examples are those of the French Governments during the French Revolution, and the various scientific expeditions sent out by the British, French and Dutch Governments to the South and the Pacific Oceans during the eighteenth and nineteenth centuries. But these lessons were apparently forgotten by the end of the nineteenth century, probably owing to the dazzling growth of new industries by private enterprise. It was Germany which first saw the advantage of organising scientific research in the interest of industry and national work and the movement found a concrete expression in the organisations known as the Kaiser Wilhelm Institutes. The object of the organisation was described by Dr. Glum, the general director of the Society, in the following words:—

> 'The Society's work is to supplement those done by universities, polytechnics, academies, libraries and museums and not to compete with those.
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> 'This is sought to be achieved firstly by undertaking those studies which cannot be done in the above-mentioned institutions, secondly, by providing research institutes for those gifted investigators whose time is too much taken up by the routine work of teaching and administration in universities and high schools, and thirdly, by providing places for those young academicians of promise who have taken their doctorates from

the universities, but have not yet got any situation where they can develop their natural gifts and carry on further research work in their own lines.

'In order that these ideals may be fulfilled it is necessary that the Society should keep an intelligent watch on the newer currents in scientific investigations and try to further its ideals by creating facilities for new lines of investigation and getting the right man for them. The object has thus been expressed by the President, Adolf V. Harnack, "The K.W. Society shall not first build an institute for research and then seek out the suitable man, but shall first pick up an outstanding man, and then build an institute for him". Experience has often shown that it is rather useful not only to call an outstanding man to the headship of an institution, but also to a group of associated institutions at one place and under a loose federation. This should be the case for a very big science like biology, which can be satisfactorily advanced only if the various associated sub-groups work in co-operation for a long time. Therefore it is necessary to unite in one institute experts in different lines who are otherwise quite independent of one another. The directors of these institutes are, therefore, chosen from the ranks of experienced investigators who have retired or given up their teaching work in the universities, high schools, and other places, and the workers are to be chosen from such graduate doctors who have shown exceptional ability in a line of work. It has very often happened that after working for some time in the K.W. Institutes, they have qualified for professorships in the universities. In this way, the K.W. Institutes have served a very useful purpose in the educational and scientific life of Modern Germany.

'The group of K.W. Institutes, so far in operation, include two types: one for carrying on pure researches on basic sciences like chemistry, physics, zoology, botany, and medicine; the other group for applying the knowledge of theoretical sciences and to industry, and thereby making them useful to the economic life of the nation.'

The State organisation of scientific research in Germany has undergone wide expansions since the last War and during the Nazi regime, but there is no reason to suppose, as it is often given out, that the basic principles enunciated above have undergone any wide variation. Pure research is as much encouraged as research in applied subjects, e.g. one of the greatest discoveries in physics, viz. that of Uranium Fission was made in the Kaiser Wilhelm Institute for Physics in Berlin-Dahlem in 1939.

The World War of 1914.

The World War of 1914 was a great eye-opener, and all other great States of the world as well as the big industrial concerns woke up to the necessity of large-scale organisation of scientific research in the interest of industries and national welfare, as pointed out by our President. These organisations, viz. the Department of Scientific and Industrial Research in the U.K., and the National Research Councils in the U.S.A. and other countries, have now been working for over a quarter of a century, and it is desirable to make a critical examination of their fundamental policies, organisation and experience. In India, though the movement started during the last War, it was at first confined to agriculture and medicine. The Indian Research Fund Association was started in 1911 and the Imperial Council of Agricultural Research in 1930. The larger question of general organisation of all scientific researches in the interest of the people has been engaging the attention of Indian scientists since 1925, but the public and the Government have been alive to it only during the last three or four years and that also in a spirit of hesitancy and indecision. I consider that our efforts are still in the experimental stage, and unless the new-born baby is properly cared for, it may become a permanent invalid.

Lord Rutherford on the Organisation of Scientific and Industrial Research in India.

Fortunately for myself, I found most of these basic principles clearly enunciated in the presidential address which the late Lord Rutherford wrote for the Silver Jubilee

Session of the Indian Science Congress and probably for the consumption of the rulers of India. I need hardly remind you that Rutherford was not only one of the greatest experimental scientists of all times, but he acted as Chairman of the Advisory Committee of the Department of Scientific and Industrial Research of the United Kingdom for eight years, from 1930–1938. Coming from a great man and a great scientist and one who had devoted lot of his time to actual direction of the work of organisation of scientific research in the United Kingdom, the observations are entitled to the most serious consideration by all who have to deal with such work. A good deal of his address to the Silver Jubilee Session was devoted to the question of organisation of scientific research in India on the lines of the Department of Scientific and Industrial Research, the necessity for which he foresaw clearly, as a result of his talks with some Indian scientists. The first necessity in this connection was the question of scientific personnel, their recruitment and training and ultimate absorption. To quote his views in his own words:

'This is in a sense a scientific age where there is an ever-increasing recognition throughout the world of the importance of science to national development. A number of great nations are now expending large sums in financing scientific and industrial research with a view to using their natural resources to the best advantage. Much attention is also paid to the improvement of industrial processes and also to conducting researches in pure science which it is hoped may ultimately lead to the rise of new industries.

'It is natural to look to the universities and technical institutions for the selection and training of the scientific men required for this development. In India, as in many other countries, there is likely to be a greater demand in the near future for well-trained scientific man. With the growth of responsible government in India, it is to be anticipated that the staff required for the scientific services in India and for industrial research will more and more be drawn from students trained in the Indian universities. It is thus imperative that the universities should be in a position not only to give a sound theoretical and practical instruction in the various branches of science but, what is more difficult, to select from the main body of scientific students those who are to be trained in the methods of research. It is from this relatively small group that we may expect to obtain the future leaders of research both for the universities and for general research organisation. This is a case where quality is more important than quantity, for experience has shown that the progress of science depends in no small degree on the emergence of men of outstanding originality of mind who are endowed with a natural capacity for scientific investigation and for stimulating and directing the work of others along fruitful lines. Leaders of this type are rare but essential for the success of any research organisation. With inefficient leadership, it is as fatally easy to waste money in research as in other branches of human activity.'

Training and Maintenance of the Research Worker.

'The selection of such potential investigators and leaders is not an easy task, for success in the examinations in science is no certain criterion that the student is fitted for a research career. A preliminary training in research methods for a year or two is required to select those who possess the requisite qualities of originality and aptitude for investigation. A system of grants-in-aid of scholarships to approved students may be required for such post-graduate training. In Great Britain the financial help given by the universities and other educational institutions for training in research is in many cases supplemented by maintenance grants to promising students, awarded by the Department of Scientific and Industrial Research. This system has proved of much value both in developing the research activities of the universities and in providing a supply of competent men both for research in pure science and in industry.'

You will admit that the whole of this quotation is an eloquent plea for the training of a large scientific personnel in the universities in the methods of pure science under persons

of outstanding originality by a large-scale system of grants-in-aid to approved students by the State with a view to their absorption later in industries and national scientific organisations. This maxim has been accepted as a basic one by the D.S.I.R.

Research in Pure Science.

The question of encouragement of pure research has unfortunately taken a controversial turn in our Indian organisations owing to the unfortunate large influx in our most important research bodies of industrialists and officials, the large majority of whom are unfortunately ignorant of science and incapable of appreciating its spirit. Let us again examine the British experience. It appears that in the earlier years of the inception of the D.S.I.R., the claims of pure research were in some danger of being swamped by those of applied research. The danger was so great that the Royal Society was compelled to send a deputation to the Lord President of the Council, the Earl of Balfour, under the leadership of the great physicist, Sir J. J. Thomson, then President of the Royal Society, who pleaded for the claims of pure research in the following memorable words:—

> 'Pure science is the seed of applied science and to neglect pure science in a thing of this kind would be like spending a very large amount on manuring and ploughing the land, and then to omit the sowing of any kind.'

Fortunately there was a Balfour at the head of affairs, and the Cabinet had no difficulty in adopting the principle whole-heartedly. The Lord President in the first report of the D.S.I.R. says:

> 'We accept the analogy and we trust that the absence of extended reference to pure science in this report will not be taken as indicating our lack of appreciation of its importance.'

According to a writer in *Science and Culture* (Vol. VIII, No. 10, 1943):

> 'If the records of investigations financed by the D.S.I.R. of England during the last twenty-five years are examined, it will be found that nearly three-fourths of the investigations are on "Pure Science". This is of course exclusive of investigations published by such specialised institutions under the D.S.I.R. as the National Physical Laboratory, the Fuel Research Laboratories, the Food Investigation Board, Central Glass Research Institute, most of whose publications are naturally of a practical nature, though even they have very frequently carried out "Pure Science Research".
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> 'The D.S.I.R. has financed schemes on various branches of atomic physics (e.g. Spectroscopy, X-rays), nuclear physics, investigations of the ionosphere, vitamin studies, photo-chemistry, organic synthesis and even sometimes purely mathematical researches.'

Planning of Programmes of Research.

Let us again quote passages from Lord Rutherford's address about the organisation and planning of research:

> 'In Great Britain, the responsibility for planning the programmes of research, even when the cost is borne directly by the Government, rests with research councils or committees who are not themselves State servants but distinguished representatives of pure science and industry. It is to be hoped that if any comparable organisation is developed in India, *there will be a proper representation of scientific men from the universities directly concerned.* It is of the highest importance that the detailed planning of research should be left entirely in the hands of those who have the requisite specialised knowledge of the problems which require attack. In the British organisations there is no political atmosphere but of course the responsibility for allocating the necessary funds ultimately rests with the Government.'

Lord Rutherford devoted a good deal of his address to the working of the National Research Institutes—e.g. the laboratories under the Fuel Research Board, Food Investiga-

tion Board, the National Physical Laboratory, the Radio Research Board. I am not aware whether the sponsors of these schemes had ever to answer the question which is often asked of us, 'Will these researches help us in making money?' or whether they had to waste half an hour in explaining to industrialists, legislators, and officials who are found in large numbers in many research bodies the difference between biochemistry and biology and such other elementary things as has been unfortunately frequently our experience.

Some of these laboratories dated before the first World War, but most had sprung during the War or just after the War. They were established with a view to serve national as against private industrial interests for which a separate set of bodies known as Research Associations were brought into existence. Though the purposes for which these national laboratories were ushered into existence were specific, the planning of research was left entirely in the hands of expert scientists as mentioned by Lord Rutherford, and they were free to carry out any researches on pure sciences if they thought that these would be helpful to their subject. As a matter of fact, most of the methods evolved, say in a subject like food technology, like the low temperature gas storage of preserving perishable fruit, vegetables, and meat, the large-scale use of vitamins in national foods had their roots in pure researches carried out under the auspices of the Food Investigation Board by professors in their laboratories. It is probably no exaggeration to say that but for these researches, and the methods evolved out of them, and prompt measures taken by the State to implement them, England would have had to beg for peace (with the bread-basket hanging before her like a Tantalus's cup, as Paul Banse had wishfully expected).

Let me place before you the work of another of these national research boards, viz. the Radio Research Board which had financed liberally the researches of Appleton on the Ionosphere, that of Watson-Watt on reflections of wireless waves from the lower regions, and other professors whose schemes were on pure research.

But it is these experiments on pure research, particularly those of Watson-Watt, on the low level reflections of e.m. waves which led to the invention of the Radio-locator, and according to the testimony of Lord Beaverbrook, the then Air Minister, this invention has helped substantially in defeating the air onslaught of the *Luftwaffe* on England during the terrible days of 1940-1941.

The National Research Councils.

The audience will probably observe that in spite of the wide difference in the conditions between Germany and England, the basic principles of organisation of scientific research evolved in the two countries at wide intervals of time have been identical. Our President has referred to the organisations known as the National Research Councils in the U.S.A., Canada, and Japan. Of these bodies, the N.R.C. for the U.S.A. appears to have been the model for the remaining bodies though there are important differences. It will suffice therefore to examine the N.R.C. of the U.S.A. It must be remembered, however, that conditions in the U.S.A. are widely different from those in any European country. The U.S.A. is pre-eminently the country of private enterprise, of enormous surplus wealth in the hands of private citizens, a large part of which goes to private benefactions. Scientific organisations have grown there largely out of private benefactions of which the Rockefeller and Carnegie foundations, the research laboratories of huge industrial trusts, are the most well-known examples. The State was mostly content to watch the growth with benevolent indifference or forgetfulness. But the attitude had to be abandoned, as a result of the impact of the World War of 1914, and the present War, and now the State is taking as much interest in the control of organisations of scientific research as England or Germany, though of course without much interference with private bodies. It will be interesting to note how in spite of wide variations in conditions the same basic principles for organisation of scientific research have been evolved as in England and Germany. Let me give a brief account.

In the U.S.A., the National Academy of Sciences under its congressional charter is the supreme body of scientists recognised by the State.

The Charter of the National Academy of Sciences, passed by Congress and approved by President Lincoln in 1863, provides that

> '. . . the Academy shall, whenever called upon by any department of the Government, investigate, examine, experiment, and report upon any subject of science or art, the actual expense of such investigations, examinations, experiments, and reports to be paid from appropriations which may be made for the purpose, but the Academy shall receive no compensation whatever for any services to the Government of the United States.'

The National Academy of Sciences has a maximum membership of 450, but the actual maximum has never exceeded 350. Most of the members are senior scientists and the seat of the Academy is in Washington D.C. The use of the Academy by the State, in the words of President Compton, was 'Spotty' up to the outbreak of the first World War.

The National Research Council was created during the first World War (1916) by the National Academy of Sciences, at the request of President Wilson, as the active agent of the Academy to assist the Government in organising the scientific resources of the country. After the War, it was perpetuated under the following terms:—

> '1. In general, they stimulate research in the mathematical, physical and biological sciences, and in the application of these sciences to engineering, agriculture, medicine and other useful arts, with the object of increasing knowledge, of strengthening the national defence, and of contributing in other ways to the public welfare.
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> 2. To survey the larger possibilities of science, to formulate comprehensive projects of research, and to develop effective means of utilising the scientific and technical resources of the country for dealing with these projects.
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> 3. To promote co-operation in research, at home and abroad, in order to secure concentration of effort, minimise duplication, and stimulate progress; but in all co-operative undertakings to give encouragement to individual initiative, as fundamentally important to the advancement of science.
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> 4. To serve as a means of bringing American and foreign investigators into active co-operation with the scientific and technical services of the War and Navy Departments and with those of the civil branches of the Government.
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> 5. To direct the attention of scientific and technical investigators to the present importance of military and industrial problems in connection with the War, and to aid in the solution of these problems by organising specific researches.
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> 6. To gather and collate scientific and technical information, at home and abroad, in co-operation with governmental and other agencies, and to render such information available to duly accredited persons.
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> Effective prosecution of the Council's work requires the cordial collaboration of the scientific and technical branches of the Government, both military and civil. To this end representatives of the Government, upon the nomination of the National Academy of Sciences, will be designated by the President as members of the Council, as heretofore, and the heads of the departments immediately concerned will continue to co-operate in every way that may be required.
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> The White House, (Signed) WOODROW WILSON.'
> 11th May, 1918.

The National Research Council is a co-operative organisation of the scientific men of America. Its members include, however, not only scientific and technical men, but also businessmen interested in engineering and industry, and lately Government servants have also been included. The total personnel is 250, and the members are appointed for three years. But if the personnel of the committees appointed by the N.R.C. be included, the number is well over a thousand. But the supreme direction is in the hands of the senior scientists constituting the National Academy of Sciences. It will probably shock Delhi to hear how Government members are nominated:

'The representatives of the Government shall be nominated by the president of the National Academy of Sciences, after conference with the secretaries of the departments concerned, and the names of those nominated shall be presented to the President of the United States for designation by him for service with the National Research Council. Each Government representative shall serve during the pleasure of the President of the United States, not to exceed a term of 3 years, and a vacancy from any cause shall be filled for the remainder of the term in the same manner as in the case of the original designation.'

During the year 1932-33 the National Research Council was reorganised for the purpose of making its structure simpler and more compact than its former organisation had been, but with the retention of the two major features of its earlier plan of organisation. These are: (1) the democratic character of the Council, representative of the great body of scientific men of the United States through affiliation with their national scientific societies; and (2) the maintenance of Chairman of the several divisions of the Council charged with the scrutiny of their respective fields with a view to the timely encouragement of research in these fields.

Under its present organisation the work of administration of the Research Council is carried on by a small group of officers and an Executive Board, with an Administrative Committee which acts for the Board between its annual meetings. The Council itself is composed of nine major divisions arranged in two groups. One group comprises seven divisions of science and technology representing, respectively, physics, mathematics, and astronomy; engineering and industrial research; chemistry and chemical technology; geology and geography; the medical sciences; biology and agriculture; and anthropology and psychology. The other group comprises two divisions of general relations, representing foreign relations and educational relations. With these divisions are associated various technical committees, appointed to take charge of projects undertaken by the Council. There are certain other committees, administrative and technical, which affiliate directly with the Executive Board of the Council. The Library of the Council, a limited collection of directories and source books in science, is available for reference services in so far as its facilities extend.

But neither the National Academy of Sciences nor the National Research Council receive grants from the State, but are advisory bodies. But the Global War has changed all that. We quote from an article by H. Grundfest in *Science and Society*:

'All forms of scientific and technological research have expanded greatly since the first World War, particularly in the government and industrial laboratories. Much of the research being done in the present war is being carried on in these laboratories and directly by the army and navy. To co-ordinate all this and to utilise the facilities of the university laboratories there has now been created a new organisation which works through the National Academy and National Research Council, but which has money to initiate research and to promote that going on. The top structure is the Office of Scientific Research and Development (O.S.R.D.); under it are the National Defence Research Committee (N.D.R.C.) supervising physical and chemical research and the Committee on Medical Research (C.M.R.). About 1,200 scientists are serving on some 100 advisory committees of these bodies. O.S.R.D. has placed over 1,000 contracts with university and industrial laboratories, and has spent about 40 million dollars. In 1943 alone its budget will be 73 million dollars.'

Summary of the Basic Principles of Organisation of Scientific Research.

Let me now therefore summarise the basic principles of organisation of scientific research which have been evolved and are followed in all advanced countries of the world. Science is the same all over the world and the really efficient methods of promoting science, of harnessing science to the needs of national work, of industry and general economy, cannot be a function of the latitude and longitude of the place, or a function of the psychological make-up of the individuals who happen to possess the requisite power. The basic

principles must be the same, though they may require some modifications in actual application.

(1) The planning of programmes of research, even when the cost is borne by the Government, should be in the hands of research committees or councils composed of members who may not be State servants, but the majority should be distinguished representatives of pure and applied science, likely to be of use in the subject under investigation and a smaller number of scientific men connected with corresponding industries.

(2) A very large scientific personnel is required for national scientific work, and for manning modern industries; for this purpose, a large-scale system of grants-in-aid should be given by the State to approved students, to be trained in the methods of pure science in the universities and research institutes under persons of outstanding originality.

(3) There should be no restrictions whatsoever on researches in pure science if the research committees consider them desirable for the fulfilment of their objective; on the other hand, it is in the interests of the country to develop schools of pure research under persons who have made outstanding contributions to science.

(4) The administration of all organised research institutions should be in the hands of scientists—as dissociation of power from responsibility, as is unfortunately followed in this country, leads to frustration and failure.

(5) Co-operation of all existing scientific institutions in India—e.g. universities, academies and scientific societies, technical institutions, industrial research laboratories—should be secured in all schemes of organisations of scientific research in this country.