RECENT DEVELOPMENTS IN THE ORGANIZATION OF SCIENCE IN INDIA

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Introduction

1. In the present article attention has been focussed on the institutional aspects of scientific work rather than on the scientific activities themselves. No attempt has been, therefore, made to review the progress of research as such; and only the broad lines of development have been indicated. It is worth recalling that significant advances had been made in ancient India in mathematics, astronomy, chemistry, medicine and certain branches of biology. From about the third century B.C. there were close contacts with Greeks and from the eighth or ninth centuries A.D. with the Arabs through which there was much exchange of scientific ideas and knowledge with the Middle East and Europe. The study of science and medicine continued with vigour during the period of Buddhist influence till the end of the 12th century. This was followed by a period of general stagnation relieved by some noteworthy investigations in chemistry and medicine during the Muslim period.

2. Scientific activities had, however, practically ceased at the time of the advent of the European nations in the 17th and 18th centuries. At this time there was a widespread system of education in the medium of the Sanskrit and the Persian languages, partly through schools of an institutional type but much more through instruction in private households which were open to children of other families. Surveys conducted in the 1830's in Bengal had indicated a literacy rate of the order of 5 or 6 per cent of the total population. The indigenous system of education was, however, highly scholastic in character with emphasis on grammatical and logical niceties; and was confined to a small section of the upper caste Hindus and upper class Muslims.

The nineteenth century

3. With the growing influence of the British, the teaching of English had started for purely practical purposes. A great impetus was given to the teaching of English from about 1813 through the activities of Christian missionaries who opened modern schools in large numbers in different parts of the country. Some of the Indian leaders of thought like Ram Mohun Roy, with the active cooperation of David Hare and some other British residents, took the initiative in starting the Hindu College in Calcutta in 1817 as the first institution of a modern type in which education was given in English, history, geography, mathematics, elementary science etc. The standard in the senior class was broadly of university level. This institution was maintained from private sources till 1854 when it was taken over by Government and began to be called the Presidency College.

4. There was sharp controversy regarding educational policy. There were three distinct schools of opinion, one in favour of continuing the traditional system of education through Sanskrit, Persian and Arabic; another group was in favour of using the vernacular as the medium of instruction; and the third in favour of English as the medium of instruction and the modern system. It is interesting to recall in this connexion the position taken by Ram Mohun Roy who is known as the "father of modern India". He was a great

scholar of Sanskrit, Persian and Arabic; and later learnt English, Latin, Greek and Hebrew to study Hindu, Muslim and Christian scriptures in the original which made him a pioneer in comparative religion and the founder of a society of monotheists called the Brahmo Samaj. He attached much importance to the proper study of the Vedas and the ancient philosophical writings of the Hindus and had maintained a school for this purpose in Calcutta at his own expense. He was also a great pioneer in Bengali language and literature and published translations of many important Sanskrit books in Bengali and also started one of the earliest Bengali newspapers in Calcutta. He was thus both a classicist and a vernacularist in practice; and yet he fully appreciated the importance of Western science. In a remarkable letter dated 11 December 1823, addressed to Lord Amherst, the Governor General of India, he urged Government to employ "European gentlemen of talents and education to instruct the natives of India in Mathematics, Natural Philosophy, Chemistry, Anatomy and other useful sciences, which the Nations of Europe have carried to a degree of perfection that has raised them above the inhabitants of other parts of the world." He referred to the state of science and literature in Europe before the time of Lord Bacon and said, "If it had been intended to keep the British nation in ignorance of real knowledge the Baconian philosophy would not have been allowed to displace the system of the schoolmen, which was the best calculated to perpetuate ignorance. In the same manner the Sanskrit system of education would be best calculated to keep this country in darkness." He therefore advocated the teaching of science and pleaded for the establishment of "a college furnished with the necessary books, instruments and other apparatus."[1] His proposal, however, was not approved.

5. In the meantime the controversy about education continued; and after much discussion a final decision was made in 1835 in favour of English and the modern system of education. Looking back after an interval of more than a century, one can appreciate the cultural advantages of studying the classics, and also of the need of using the vernacular as the medium of instruction without which the promotion of universal education would be impossible. There was however an urgent need of introducing the teaching of modern science in India; and this was facilitated by the decision in favour of English education.

6. Serious study of the ancient and mediaeval literature of India started towards the end of the 18th century under the leadership of Sir William Jones who was a judge of the Supreme Court. He was a great scholar of Sanskrit and founded the Asiatic Society of Bengal in 1784, and explained the objects of the enquiries to be "Man and Nature"; whatever is performed by the one, or produced by the other. This society during the first century of its existence provided a commodious house for meetings, library, collection of ancient coins and medals, and archaeological, technological, and geological collections and published 384 volumes of works of various kinds; and through its efforts the Indian Museum of Calcutta was founded in 1856. From about the middle of the nineteenth century the Asiatic Society started publishing papers on the positive sciences especially in zoology, botany and anthropometry with some papers on physics, meteorology, chemistry, geology and medical sciences and thus played a most important part in the advancement of science in India.

7. An Agricultural Society of India was established in Calcutta in 1820 and its name was changed to the Agricultural and Horticultural Society of India in 1823 which used to publish its transactions and journals for a long time. The Indian Association for

[1] The English Works of Raja Ram Mohun Roy, Part IV, pp. 106-108 (Sadharan Brahmo Samaj, Calcutta, 1947).

the Cultivation of Science was founded and endowed in Calcutta in 1876 by Dr. Mahendra Lal Sircar. The Bombay Natural History Society was founded in 1883 which published a long series of journals from 1886; and has fostered a great deal of work in its own field. Other societies were established and were active from time to time.

8. After it was decided to adopt English education, an integrated system of primary and secondary schools was gradually built up. In 1837 English replaced Persian as the official language in the law courts. After much discussion, three Universities of a modern type were established in Calcutta, Bombay and Madras in 1857; and the Universities of Punjab (at Lahore) and of Allahabad were established in 1882 and 1887 respectively. All five universities were of the examining and affiliating type on the model of the London University; and up to the end of the nineteenth century there was no provision for teaching in the universities themselves. Science laboratories were established in some of the affiliated colleges, and towards the end of the century, research work had also started on a very small scale by some individual scientists.

9. Scientific services and agencies had also began to develop under Government. The British Army in India required medical care; and medical services were established in 1763. It was very expensive to bring all the medical personnel from Great Britain; and training began to be given to Indians to serve as auxiliary medical personnel; and a school was established for this purpose in Calcutta in 1822. One view was strongly in favour of continuing the training only of low grade personnel but the more liberal views prevented. One British medical officer (I believe, Richardson by name) wrote in a despatch that "once a candle is lighted it is not possible to say to its rays that they may go thus far and no further; in the same way, once the teaching of science was started, it was not possible to restrict it." After much controversy and discussions it was decided to establish the Calcutta Medical College in 1835 as a completely modern institution with provision for training in physics, chemistry, and botany in addition to anatomy and clinical subjects. The Grant Medical College was established in Bombay in 1845 and other medical colleges were gradually started in different parts of the country. Medical research was organized in 1869; and much valuable work was done on clinical medicine and the study of tropical diseases, of which an outstanding example was the identification of the anopheles mosquito as the vector of malaria by Sir Donison Ross. There were early publications on medicine in the transactions of the Medical and Physical Society (1825-1845) and a number of other medical journals were started and continued publication from time to time during the century.

10. Practical needs had also led to the establishment of a school for surveying in Madras in 1793. The Trigonometrical Survey of the Peninsula of India was established in 1800 and was expanded as the Great Trigonometrical Survey in 1818. Topographical and Revenue Surveys were consolidated in 1817, and were later amalgamated with the Trigonometrical Survey in 1878 to form the Survey of India which continues to function under this name at present. Outstanding work has been done by this organization which includes the measurement of the height of Mount Everest.

11. Some geologists had been employed for survey work since 1818 and the Geological Survey of India was founded in 1851 and continues to function under the same name. It has done very valuable work in geology but, as a matter of deliberate Government policy, all minerals prospecting was left to the private sector; and it is only very recently that emphasis is being given on such work.

12. A meteorological observatory had been started in 1796 at Madras, and meteorological stations were established in Calcutta in 1824 and in Bombay in 1841; and a Meteorological Department was established for the whole of India in 1875. The scientific foundations of Indian meteorology were established through the researches of this department. The Calcutta Botanical Garden was established in 1781 and the Botanical Survey of India was founded in Calcutta in 1889. Zoological and anthropometrical research had started in the Museum of the Asiatic Society in 1841 and was gradually strengthened with the foundation of the Indian Museum in 1856; these two sections were converted into the Zoological Survey of India in 1916. Some hydrographical work and important investigations on fisheries were also conducted from time to time. The Archaeological Department was established in 1862 and has done valuable work in building up the knowledge of Indian history.

13. Instruction in elementary engineering began to be provided for purely practical purposes in Bombay from 1824. An industrial school was started in Madras in 1840. The first engineering college of the modern type was established at Roorkee in 1847 and has been recently converted into an engineering university. Engineering colleges were also gradually established in Calcutta and other places. A big system of railways began to be built up from the 1850's but India continued to depend on imported coaches and locomotives for nearly a century. Large schemes for irrigation also began to be developed in the second half of the nineteenth century; and Indian achievements in this field have been outstanding.

14. At the end of the nineteenth century a good deal of scientific work was being done in the surveys and departments of Government which were closely connected with their operational activities. Some pure or basic research was also being done on a small scale, mostly in the field of sciences, in some of the private societies. Five universities had been established, but there was practically no provision for research. Also, there were practically no scientific institutes. Towards the end of the century, a few pioneering Indian scientists (for example, J. C. Bose in physics, P. C. Ray in chemistry) had started publishing papers in pure science. In many ways the ground had been prepared for new developments..

THE TWENTIETH CENTURY

15. Rapid advances took place in three main directions in the first half of the twentieth century. Firstly, there was a reorientation of university education with increasing facilities for postgraduate teaching and research. Secondly, research institutes of a specialized type began to be established both on private initiative and by Government. Thirdly, scientific societies of both a specialist and a general type began to be established for meetings and conferences and usually with their own journals and publications. These developments stimulated a great deal of research activities.

16. After fifty years of university education, the pattern began to change and provision for postgraduate teaching was made in the Calcutta University in 1909. Under the leadership of Asutosh Mookerjee, well-organized postgraduate departments were established for the first time, and the University College of Science was founded in Calcutta in 1917 with large endowments from Taraknath Palit and Rashbihary Ghosh. This gave a great impetus to scientific research and led to the establishment of research laboratories in other universities.

17. The first three universities had been founded in 1857, and two more were established in 30 years by 1887. There was no further expansion for nearly 30 years; but 14 new universities were established between 1916 and 1947, bringing the total number

to 19. University education had thus become fairly widespread just before independence. Many of the new universities were of the unitary and residential type and had some facilities for scientific research. Expansion was much more rapid since independence, and 15 new universities were established and 3 higher scientific institutions were given powers to award degrees in 10 or 11 years, by the end of 1958.

18. Another significant development was the emergence of both private and Government research institutes. The Indian Association for the Cultivation of Science, which had been founded in 1876, became a most important centre for physical research under leadership of C. V. Raman during the first world war. K. S. Krishnan and M. N. Saha were associated with this institution for a long time, and S. N. Bose is working there at present. The Indian Institute of Science was established in Bangalore in 1911 with generous financial support from Sir J. N. Tata and was developed as the first important higher institute of engineering and technology. The Bose Institute was established in Calcutta by Jagadish Chandra Bose in 1917 and has a wide programme of biophysical research. The Indian Statistical Institute was established in Calcutta in 1931 and has research and professional training activities in statistical and allied subjects. The Indian Academy of Sciences was founded by C. V. Raman at Bangalore in 1934 which later became a strong centre for physical research. The Tata Institute of Fundamental Research was started in Bombay in 1945 under the leadership of H. J. Bhabha and is now closely associated with the Atomic Energy Commission. The Institute of Palaeobotany was established at Lucknow in 1946 and has been now renamed after its founder Birbal Sahni. The Physical Research Laboratory was established in Ahmedabad in 1948 with financial support from the Sarabhai family. The Institute of Radio Physics and Electronics was established in Calcutta on the initiative of S. K. Mitra in 1949; and the Institute of Nuclear Physics was started in Calcutta on the initiative of Meghnad Saha in 1951. Two Cancer Research Institutes were started in Calcutta and in Bombay at about this time. The Shri Ram Institute of Industrial Research was established in Delhi in 1947 with endowments by Lala Shri Ram and was the first private institute of its kind. The Ahmedabad Textile Industry's Research Association was set up after independence as a joint endeavour of textile factories; and some other associations are being formed in the same pattern. These research institutions, which were started on private initiative, began to make significant contributions to the progress of science.

19. Specialized institutes had also began to be developed by Government especially in medicine and agriculture. The Haffkine Institute was established in Bombay in 1899, originally as a plague research laboratory, which gradually developed into an important centre of research of preventive medicine. The Central Research Institute for Medical Research was started at Kasauli in 1906 and one of its sections later developed into the Malaria Survey of India (1927). The Nutrition Research Institute at Coonoor was established in 1928 and the All-India Institute of Public Health and Hygiene in 1934. Other medical institutes were started by Provincial (now State) Governments, for example, King Institute of Preventive Medicine at Madras (1903), Pasteur Institute at Coonoor (1907), Medical Research Institute at Shillong (1917), the School of Tropical Medicine in Calcutta (1921).

20. In the field of agriculture, the Agricultural Research Institute was founded at Pusa in 1903 and was transferred to New Delhi after the severe earthquake in Bihar in 1934. Next came the Forest Research Institute at Dehra Dun (1906), the Tocklai Experimental Station in Assam for research on tea (1911), the Dairy Institute at Bangalore (1920), the Cotton Technological Institute in Bombay (1924), the Institute of Plant Industry at Indore

(1924), the Institute of Veterinary Research at Muktsar (1925), the Lac Research Institute at Ranchi (1925), Institute of Sugar Technology at Kanpur (1936), and the Jute Research Institute in Calcutta (1939). A number of research institutions also mostly in medicine and agriculture were established by the Provincial (now State) Governments.

21. Experimental work on river and irrigation problems had started after the first world war. Hydrological research laboratories were established in Sind, the Punjab, and the United Provinces by the Provincial Governments in the 1930's; and the Central Water and Power Research Station at Poona by the Central Government in 1937. Large developments in hydroelectric and irrigation projects had already started in India; and further progress was greatly helped by the research done in these laboratories.

22. Facilities for advanced studies and research in engineering (other than irrigation) however developed rather slowly. Departmental laboratories were set up by the Central Government for research on problems connected with railways, telegraphs, radio etc. The Indian Institute of Technology, the first higher institution with powers to award degrees, was established at Kharagpur in 1951, and similar institutes are being now started in different parts of the country.

23. With all these developments the need of co-ordination was increasing. A Board of Scientific Advice was established by the Central Government in 1902 which used to prepare annual reports on scientific progress; but it was not otherwise very effective and its activities were suspended in 1924. The Indian Research Fund Association was started in 1911 for the promotion of medical research and was later renamed the Indian Council of Medical Research (ICMR). The Indian Council of Agriculture Research was established in 1929, and has several associated committees for research in agricultural commodities (cotton, jute, sugarcane, oil seeds, tobacco, cocoanut, arecanut etc). The Council of Scientific and Industrial Research was started during the second world war; and, under the leadership of S. S. Bhatnagar, rapidly established a large number of National Laboratories and now has more than twenty institutions under its direct control.[1] All three Councils are, in legal form, non-Government corporations, but are under government audit and indirect government control. They function somewhat on the model of their three British counterparts in these fields, and give research grants to scientists.

24. Scientific societies mainly for meetings and conferences, and usually with journals and publications of their own, began to be formed about half a century ago. The Mining and Geological Institute of India was founded in 1906 and was followed by the Indian Mathematical Society (1907); Calcutta Mathematical Society (1908); Institution of Engineers, India (1920); Indian Botanical Society (1921); Indian Psycho-analytical Society (1922); Indian Chemical Society (1924); Geological, Mining and Metallurgical Society of India (1924); Indian Psychological Association (1925); Indian Statistical Institute (1931); Society of Biological Chemists (1931); Indian Physical Society (1934); Bio-chemical Society (1934); and the Indian Physiological Society (1935) before the second world war. Since then several other societies such as the Zoological Society, the Entomological Society, the Institute of Chemists, the Indian Council of Ecological Research, the Central Board of Geophysics and several

[1] The National Physical Laboratory (New Delhi); National Chemical Laboratory (Poona); National Metallurgical Laboratory (Jamshedpur); National Botanical Gardens (Lucknow); Central Research Institute for Fuel Research (Jealgora); Glass & Ceramics (Calcutta); Food Technology (Mysore); Drug (Lucknow); Road (New Delhi); Leather (Madras); Electro-chemical (Karaikudi); Electronics Engineering (Pilani); Building (Roorkee); Salt (Bhavnagar); Mining (Dhanbad); Biochemistry and Medicine (Calcutta); Coal Survey (Dhanbad); two Regional Research Laboratories at Hyderabad and Jammu; and the Birla Industrial Technical Museum in Calcutta; and other units are being established.

geographical societies have been established, some of which have active programmes of research. In addition to societies which had an all-India character, a number of regional societies had also been started in different parts of the country before the second world war.[1]

25. Among associations of a general type covering many fields, the earliest was the Asiatic Society of Bengal which was founded in 1784. After an interval of 130 years the Indian Science Congress Association was established in 1914 and has been organizing annual sessions since then on the model of its British counterpart. A special feature since 1947 has been the presence of a large number of distinguished foreign scientists at its annual session. The United Province Academy of Sciences was started in North India in 1930 and was renamed the National Academy of Sciences in 1936. The Indian Academy of Sciences was established in 1934 originally as a general academy and became an active centre of research later on. Finally, the National Institute of Sciences was established in 1935, broadly on the model of the Royal Society of London, but in actual practice it functions in a somewhat different way. All these institutions have their own publications.

26. Two scientific weeklies, one, the "Current Science" somewhat on the model of the "Nature" of London, and the other, "Science and Culture", with a wider scope, were started between the two wars. A number of other scientific journals of a general type are also being published.

The general pattern of development

27. The general pattern of development is fairly clear. In the nineteenth century the trigonometrical and topographic surveys were quickly developed and medical services were organized very early by the British authorities to meet urgent requirements. There was rapid progress in civil engineering and irrigation. Geology also was developed fairly early to supply basic information required for the economic exploitation of minerals which however was left entirely to private industry. English education was accepted after much controversy, and led to the building up of a new system of education from the primary school to the university stage by the middle of the century. In more basic research, the initiative came from the Asiatic Society; and botanical, zoological and anthropological surveys began to be made on a fairly large scale. It was only towards the end of the nineteenth century that research work had started in laboratories.

28. In the first half of the twentieth century there was a great deal of expansion in research facilities in the universities; and many research institutes of a specialized type were established both on private initiative and by Government. In the private institutes and universities the most significant contributions, on the whole, were made in mathematical and physico-chemical subjects. The mathematical genius of Ramanujan was *sui generis*, which required the environment of the Cambridge University to bring it to fruition. The work of the other scientists, however, became possible only with the development of research facilities and with increasing social appreciation of research.

29. In the Government institutions the emphasis, up to the second world war, was on medicine and agriculture. This can be easily understood as there was very little progress of basic industries. The production of steel had started in 1908, on the initiative of Jamsedji Tata, but remained practically at the level of one million tons for fifty years

[1] Specialist societies had also been established much earlier but they were mostly of a local character. For example, the Mysore Institute of Engineers was established in 1903 and the Anthropological Society of Bombay in 1886; and both still continue to function as local institutions. There were other such societies which were active from time to time.

although India has the biggest reserves of high quality iron ore in the whole world. Railways, textiles and some of the lighter industries were well developed but mostly with the help of imported machinery. It was only during the second world war, when imports were cut off, that attention began to be given to industrial production; and it was in response to urgent practical needs that the Council of Scientific and Industrial Research was established. At the time of independence, facilities for engineering and technological research were still extremely meagre; and research in biological subjects, on the whole, was not well developed.

PROGRESS SINCE INDEPENDENCE

30. India became independent in August 1947. And there was also partition which set up severe stresses and strains, both political and economic, some of which are still continuing. The former princely states were integrated; and state territories were reorganized more than once and the process has not yet been completed. Planning was accepted in 1951 as an indispensable tool for economic development; and socialism was accepted as the goal by the ruling Congress Party in 1954 and by the Indian Parliament in 1955. In the Second Five Year Plan, which began in 1956, great emphasis was given to industrialization. The production of steel is being increased from a level of one million tons to six million tons per year; and factories for heavy machineries, heavy electrical equipment, machine tools, oil, chemicals and many light industries are being established.

31. This has been a period of rapid changes in many directions. Fortunately, it has been also a period of steady expansion of education and scientific research. Between 1857 and 1947, that is, in ninety years before independence, 19 universities were established. During the first 11 or 12 years of independence, 15 new universities had been established and four higher educational institutions were empowered to award degrees. The University Grants Commission was established in 1956 on the British model; and has already made its influence felt in many ways for the promotion of science. There has also been a large increase in educational institutions of all types with a rapid increase, especially from the period of the Second Five Year Plan, in the number of scientific and technical personnel, and a great deal of expansion of facilities for research. A general statistical review is given below.

EDUCATIONAL INSTITUTIONS

32. The number of institutions of different types is shown in Table 1 in the Appendix for the three selected years, 1947-48 (the year of independence), 1951-52 (the beginning of the First Five Year Plan), and 1956-57 (the beginning of the Second Five Year Plan). The number of institutions, on the whole, had doubled in nine years between 1947-48 and 1956-57. That is, more educational institutions were established in these nine years than had been set up during the whole of the British period. The greatest increase had taken place in colleges for professional and technical education whose number increased three-fold.

33. There has been a rapid expansion of education at the stage of higher secondary schools, junior colleges, and universities. The number passing the "matriculation" examination (which qualifies for admission to universities and university-level institutions) was 116,080 in 1947-48; and increased to 429,494 in 1955-56, that is, was nearly four times higher in eight years. The number has been doubling in about four or five years since independence.

34. Enrolment and outturn at the intermediate and university levels are shown in Table 2 in the Appendix. Enrolment has, on the whole, nearly doubled in six years between

1950-51 and 1956-57. Outturn has increased by about 68 per cent; and the smaller increase is, of course, due to the lag between enrolment and passing an examination. By this time the outturn also must have doubled. There cannot be any doubt about the rapid expansion of education at college and university levels since independence.[1]

35. Out of the total enrolment, about 60 percent was at the intermediate level, 35 percent at the degree level, and a little over four per cent at the level of the master's degree. The proportions were roughly similar for the outturn. Science (including technology, medicine and agriculture) account for, out of all enrolments, only about a quarter at the intermediate level, an eighth at the degree level, and less than one and a half percent at the master's level. The share of science is thus only about 38 percent of all students at intermediate and university levels which is not satisfactory.

SCIENTIFIC AND TECHNICAL PERSONNEL

36. Progress of science may also be examined from the point of view of the increase in the number of scientific and technical personnel. We may first consider the case of "scientists". As the standard of science teaching at the degree level is believed to be somewhat low in India, it has been decided to define the term "scientist" as a person who possesses a master's degree in any of the branches of natural sciences (that is, mathematics or statistics, physics, chemistry, geology, botany and zoology) or a bachelor's degree in pharmaceutical or industrial chemistry or chemical technology.[2]

37. Data relating to the number of scientists turned out by Indian universities between 1910 and 1955 are given in Tables 3 and 4 in the Appendix. It would be seen that 31,880 scientists were turned out, as defined above, during a period of 47 years from 1910 to 1956. The average annual outturn of scientists was only 77 in the quinquennium 1910-1914 before the first world war, and had increased to 588 during 1933-39 just before the second world war. There was very little increase during the war, and progress was slow till 1949 or 1950. However, during the period of the First Five Year Plan, the number had more than doubled in five years from 1875 in 1951 to 3809 in 1956.

38. It is of interest to note that out of 31,880 scientists turned out between 1910 and 1956, less than half or 15,668 had come out upto 1947; and this must also have been about the same as the total outturn upto 1947 since the master's degree was introduced

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[1] It should be, however, pointed out that the expansion at the bottom has not been fully satisfactory. I have already mentioned that enquiries conducted in Bengal during the period 1833–1838 had indicated a literacy rate of the order of 5 or 6 percent of the population. This was based entirely on the indigenous system of education. With the gradual building up of a modern system of organized schools, education became accessible to a wider circle; but progress was slow. According to the successive Censuses of India, the number of literates per hundred was 4.8 in 1881, 5.8 in 1891, 5.3 in 1901, 5.9 in 1911, 7.2 in 1921, and 8.0 in 1931 (inclusive of Burma and Pakistan). Census data for 1941 were only partially tabulated and no estimates are available for literacy. The rate was 16.6 per hundred according to the Census of India in 1951, after partition. In 1956 the estimated rate was about 20 per hundred persons in 1956; but some recent sample surveys show a higher rate of the order of 22 or 23 per cent in the same year. It is clear that there has been an appreciable increase in literacy in recent years. Opportunities for education, especially at the secondary and higher levels, are however still available only for a comparatively small fraction of the total population. Special efforts are intended to be made in the Third Five Year Plan to expand primary education.

[2] In some Indian universities there are three-year courses for honours B.A. and B.Sc. degrees; these have been also included. That is, either three or four years of college education after the intermediate examination, or five or six years after the final examination in secondary schools or after the entrance examination for admission to a university, has been accepted as the basis of the above definition.

only in 1900. The number 16,218 coming out after independence, in nine years from 1948 to 1956, was thus greater than the total outturn during the whole period before independence.

39. The distribution between different subjects has remained remarkably steady; and it can be seen from the two bottom lines of Table 3 that the pattern during the whole period from 1910 to 1955 was very similar to that in the year 1955. In India, chemists and chemical technologists form nearly a third of all scientists; mathematicians, including statisticians, nearly a fourth; physicists a fifth; and botanists and zoologists less than a tenth each; with geologists only a little over a twentieth. I may, however, add that since 1955, great emphasis is being given to training in geology and the number of qualified geologists is increasing rapidly. This has been the direct result of a decision to expand the prospecting of minerals and geological investigations to promote the exploitation of domestic resources of minerals.

40. The outturn of engineers with degrees at the university level and with diplomas from engineering institutions is shown for quinquennial periods from 1915 to 1949 in Table 5 in the Appendix. More detailed figures are given for both enrolment and outturn of engineers for the period 1951-52 to 1958-59 in the next Table 6. The outturn of engineers had increased to some extent in the 1920's but slowed down during the economic recession of the 1930's and was somewhat stimulated by the increasing production in the 1940's during the war. Conditions continued to be more or less stationary after independence and during the period of the First Five Year Plan (1951-56). This was only natural because there was very little progress in industrial production during the First Five Year Plan.

41. There was, however, a complete change in outlook in the Second Five Year Plan (1956-61) in which great emphasis was placed on industrial development. The need of a large increase in the number of engineers and technologists was clearly appreciated and steps were taken to expand facilities for technical training. The effect can be seen from the rapid expansion of enrolment; this had increased by only about 25 percent upto 1954-55, but rose from 15,334 in 1955-56 to 31,018 in 1958-59 or more than doubled in three years. Admissions to degree level courses in engineering and technology increased from about 6,000 per year in 1955-56 to 11,000 in 1958-59, and are expected to rise to 13,000 in 1960-61.

42. Medical personnel is also receiving attention. The total number available in 1956 was estimated at about 71,600 qualified persons, of whom 38,400 were licentiates (with four year training) and the rest university level graduates. The licentiate (or four year) course was abolished after independence and all qualified medical personnel now receive university level training. The average rate of attrition has been estimated at about 2.5 percent per year out of which about 2 percent may be attributed to death and 0.5 per cent to retirement on account of old age. If the growth of population is about 1.8 or 2 per cent then an increase of the order of 4.5 per cent per year or at least 3,000 per year would be required to maintain the present availability of 176 qualified doctors per million persons.[1] It may be noted, however, that the distribution of qualified medical personnel is extremely uneven; and possibly only about one-tenth or one-eighth of all qualified persons reside in rural areas although the rural areas have roughly five times the urban population. The availability also varies very widely between the different States of India. It is intended to provide greater facilities for medical training, and to expand the health services during the Third Five Year Plan.

[1] "Man-power Studies No. 15 : Doctors in India" (Perspective Planning Division, Planning Commission, New Delhi, August, 1959).

RECENT DEVELOPMENTS IN THE ORGANIZATION OF SCIENCE IN INDIA

Expansion of research activities

43. The expansion of research activities can be seen from the budget of the three quasi-government research councils, the Indian Council of Agricultural Research (ICAR), the Indian Council of Medical Research (ICMR), and the Council of Scientific and Industrial Research (CSIR) which were all started before independence, and the Atomic Energy Commission which was started after independence and is a government agency. From the budget of these four organizations, given in Table 7 in the Appendix, it would be noticed that the total expenditure has gone up from about Rs. 11 million[1] in 1948-49 to about Rs. 134 million in 1959-60 showing an increase of over twelve times in eleven years. The budget expansion has been the biggest (nearly fourteen times) in ICAR, but a good deal of this expenditure is of a developmental rather than a research type. The increase in expenditure in ICMR for medical research of about seven times, and in CSIR for scientific and industrial research of about ten times, give some idea of the greater emphasis on research.[2]

The present position

44. Since independence there has also been a good deal of expansion of the normal activities of the scientific departments and institutes of Government such as the Survey of India, the Geological Survey, the Meteorological Department, the Indian Forest Research Institute, the Indian Agricultural Research Institute, the Indian Veterinary Research Institute, the Central Water and Power Board, and various other institutes, departmental laboratories, and research units under the Central and State Governments. The total expenditure on research may have increased seven or eight times. Government grants to the Universities and the private (non-government) scientific institutions have also been appreciably increased; but these still form a very small part of the total expenditure on research. This is not satisfactory.

45. In recent years systematic attention is being given to scientific and technical man-power for which separate agencies have been created in Government; and a Standing Committee of the Central Cabinet has been set up for Man-power. The world shortage of scientific and technical personnel has, however, created a special difficulty. A considerable number of able Indian scientists are now working abroad, mostly in the USA, usually because of the more attractive terms and conditions of service. This has led to a very curious situation. An advanced country like the USA, for example, have taken away some of the able Indian specialists and are sending American specialists in the same subject field to work in India under various schemes of technical aid. This is far more expensive and less effective. A more rational approach would be to help India to retain and make the best use of her own scientists.

Need of structural changes

46. The organization of scientific and technical research took general shape in India during the British period. On the surface, the pattern of development was broadly the same as in the Western countries. There was a threefold structure: firstly, government agencies and institutes; secondly, universities and private scientific institutions; and, thirdly, private societies and associations primarily for meetings, conferences, and publications. In the highly industrialized countries of West Europe and America, the development of research

[1] One Indian rupee = 0.21 U.S. cents approximately.

[2] The index number of wholesale prices with 1948 = 100, did not increase very much, and was about 110 or 115 in 1958 or 1959. As the salary of scientists had not increased, there was not much change in the cost structure; and expenditures in 1948-49 and in 1959-60 are broadly comparable.

had taken place mostly outside Government until the first world war in UK, and the second world war in other countries. In consequence, a durable structure of research had come into existence in the universities, scientific institutions, and industrial laboratories which were mostly financed from private sources. Sound scientific traditions with standards of criticism and evaluation were thus built up and were being maintained independently of Government.

47. In the socialist countries in Europe, before revolution, there was an older fabric of science broadly on the pattern of the countries of Western Europe. After revolution, all funds for research began to come from Government; and a very wise policy was adopted to establish autonomous Academies of Science and to make research agencies in universities and scientific institutions as free as possible from official control. This is also true of China. In the countries of both the Eastern and the Western blocks, scientists enjoy a great deal of autonomy.

48. The position in India is somewhat different. Most of the research expenditure is incurred in Government or quasi-government agencies. Very little or practically no research funds are available from private sources. The universities and private scientific institutions thus have to depend almost entirely on Government grants. There has not been enough time to build up a strong and independent tradition of scientific criticism and evaluation. The administrative machinery of Government continues to be highly centralized with a great deal of secretariat control in details, partly because the system was taken over from an alien Government and partly because of the lack of economic development. In this situation there are serious dangers of scientific progress being hampered by the pervasive pattern of hierarchical authorities. There is no difference of opinion about the urgent need of decentralization, but, in practice, progress has been very slow. It is possible that effective decentralization and lessening of bureaucratic control would come only with increasing economic maturity. But administrative rigidities may continue to hamper economic progress, while the lack (or a slow rate) of economic growth would tend to preserve such rigidities. This is one of the peculiar antinomies of the Indian situation.

49. It is not clear whether the Western structure of science is really suitable for Indian conditions. As in a political democracy, the form alone is not enough; without the proper content, the form itself may crumble. On the other hand, it is also not clear whether it is possible to establish in an effective way the structure of science which has been adopted in the socialist countries. A most urgent problem is to develop an organization of science suited to Indian needs.

HOPEFUL FEATURES

50. In India there is growing appreciation of the need of scientific progress. Expansion of scientific work has become more rapid from the period of the Second Five Year Plan when the intimate connexion between scientific progress and economic development began to be properly appreciated. In principle, it is now generally accepted that the programme of applied and developmental research should be directed towards the needs of national planning. It is also being appreciated that applied and developmental research must be based on fundamental research in which a great deal of freedom of choice of subjects and methods must be given to scientists to enable them to do their most fruitful work. Prime Minister Nehru has given a great lead by his personal association with scientific meetings and associations. Conditions are in many ways favourable for the progress of science but there are also internal weaknesses and dangers which can be overcome only through seriousness of purpose and integrity of thought and action on the part of the scientists themselves.

Appendix

TABLE 1. NUMBER OF EDUCATIONAL INSTITUTIONS IN INDIA BY TYPE WITH INDEX NUMBER OF INCREASE BETWEEN 1947-48 AND 1956-57

type of institution	number of institutions			index based on 1947-48 = 100		index based on 1951-52 = 100
	1947-48	1951-52	1956-57	1951-52	1956-57	1956-57
(1)	(2)	(3)	(4)	(5)	(6)	(7)
higher institutions						
1. universities	16	29	33	181	206	114
2. boards of education	5	9	12	180	240	133
3. research institutions	n.a.	20	41	—	—	205
4. arts & science colleges	459	552	773	120	168	140
5. sub-total (1)	480	610	859	127	179	141
colleges for professional and technical education						
6. agriculture	12	16	25	133	208	156
7. forestry	3	4	3	133	100	75
8. engineering	11	31	47	282	427	152
9. technology	6	4	7	67	117	175
10. medicine	24	42	99	175	413	236
11. veterinary science	5	10	14	20	280	140
12. education : training	38	55	133	145	350	242
13. physical education	—	7	10	—	—	143
14. commerce	18	22	28	122	156	127
15. law	15	22	29	147	193	132
16. others	—	1	4	—	—	400
17. sub-total (2)	132	214	399	162	302	186
colleges for special education						
18. music, dancing & fine arts	—	14	27	—	—	193
19. home science	—	3	—	—	—	—
20. oriental studies	—	49	79	—	—	161
21. sociology	—	3	6	—	—	200
22. others	—	—	10	—	—	—
23. sub-total (3)	—	68	122	—	—	179
24. total : higher education (4)	612	892	1,380	—	—	155

TABLE 1. NUMBER OF EDUCATIONAL INSTITUTIONS IN INDIA BY TYPE WITH INDEX NUMBER OF INCREASE BETWEEN 1947-48 AND 1956-57—*Continued*

type of institutions	number of institutions			index based on 1947-48 = 100		index based on 1951-52 = 100
	1947-48	1951-52	1956-57	1951-52	1956-57	1956-57
(1)	(2)	(3)	(4)	(5)	(6)	7
schools for general education						
25. high/higher secondary	4,076	8,003	11,805	196	290	148
26. middle	8,823	14,576	24,486	165	278	168
27. primary	140,794	215,036	287,298	160	204	134
28. pre-primary	—	330	769	—	—	233
29. sub-total (4)	153,693	238,005	324,358	155	211	136
schools for vocational and technical education						
30. agriculture	15	37	94	247	627	254
31. forestry	—	1	4	—	—	400
32. engineering	5	27	68	540	1,360	252
33. technical & industrial	504	427	644	85	128	151
34. medicine & vet. science	20	45	116	225	580	258
35. teacher's training	529	802	916	152	173	114
36. physical education	—	188	36	—	—	19
37. arts & crafts	15	352	304	2,347	2,027	86
38. commerce	302	583	829	193	274	142
39. others	—	1	11	—	—	1,100
40. sub-total (5)	1,390	2,463	3,022	177	217	123
schools for special education						
41. handicrafts	48	84	98	175	204	117
42. social work	—	14	44	—	—	314
43. music, dancing & fine arts	—	131	184	—	—	140
44. oriental studies	—	3,358	3,322	—	—	99
45. reformatory	13	21	37	162	285	176
46. social (adult education)	6,536	43,403	44,058	665	674	101
47. others	2,261	923	1,327	41	59	144
48. sub-total (6)	8,858	47,904	49,070	542	554	102
49. total : schools (7)	163,941	288,462	376,450	176	230	131
50. total recognised institutions	164,553	289,354	377,830	176	230	131
51. total un-recognised institutions	6,508	7,164	4,806	110	74	67
52. grand total (8)	171,061	296,518	382,636	173	224	129

Source : Ministry of Education, and Perspective Planning Division, Planning Commission.

TABLE 2. ENROLMENT AND OUTTURN OF TRAINEES IN INDIA BY SUBJECTS

	number enrolled (000)		1956-57	index number 1950-51 = 100	number passed		1955-56	index number 1950-51 = 100
	1950-51	1956-57	percentage		1950-51	1955-56	percentage	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
intermediate & diploma								
1. science	90.9	156.2	20.06	172	27,343	41,341	15.98	151
2. agriculture	1.6	6.1	0.78	381	673	1,245	0.48	185
3. engineering & technology	8.2	26.8	3.45	327	2,027	4,977	1.92	246
4. sub-total	100.7	189.1	24.29	188	30,043	47,563	18.38	158
5. arts & commerce	132.1	278.4	35.76	211	85,186	111,155	42.94	171
6. total intermediate & diploma	232.8	467.5	60.05	201	96,229	158,718	61.32	167
degree level								
7. science (pass)	31.5	54.4	6.99	173	10,407	14,047	5.78	144
8. science (honours)					786	1,209	0.57	154
9. engineering & technology	10.1	17.7	2.27	175	1,773	3,816	1.47	215
10. medicine & veterinary	15.3	24.0	3.08	157	1,923	3,074	1.19	160
11. agriculture	2.7	3.7	0.48	137	1,041	893	0.34	86
12. sub-total	59.6	99.8	12.82	167	15,930	23,939	9.25	150
13. arts & commerce	85.8	175.3	22.51	204	34,543	62,100	23.99	180
14. total degree level	145.4	275.1	35.33	189	50,473	86,039	33.24	170
master's degree								
15. science	4.7	8.2	1.05	174	1,308	2,539	0.98	182
16. engineering	0.2	0.6	0.08	300	88	148	0.06	168
17. medicine & veterinary	0.3	1.2	0.15	400	117	202	0.08	173
18. agriculture	0.4	0.6	0.08	150	143	152	0.06	106
19. sub-total	5.6	10.6	1.36	189	1,746	3,041	1.18	174
20. education	3.6	11.7	1.50	334	3,193	9,071	3.50	284
21. arts, commerce, law	12.2	13.7	1.76	112	3,584	1,974	0.76	55
22. total master's degree	31.3	36.0	4.62	169	8,523	14,086	5.44	165
23. grand total	399.5	778.6	100.00	195	154,225	258,843	100.00	168

Source : Perspective Planning Division, Planning Commission.

TABLE 3. NUMBER OF SCIENTISTS TURNED OUT BY INDIAN UNIVERSITIES : 1910- 955

	year	all subjects	number of degrees awarded in					
			mathe-matics	physics	geology	chemistry	botany	zoology
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1.	1910–1955	28,947	7,533	5,897	,552	8,669	2,497	2,799
2.	1910–1914	385	133	89	26	97	21	19
3.	1915–1919	832	391	220	25	112	48	36
4.	1920–1924	917	269	181	30	328	60	49
5.	1925–1929	1,923	516	399	47	449	243	267
6.	1930–1934	2,784	840	630	179	653	280	302
7.	1935–1939	2,938	819	647	183	739	264	286
8.	1940–1944	3,378	882	730	200	980	282	304
9.	1945–1949	4,375	1,074	800	294	1,588	294	225
10.	1950–1954	8,756	1,976	1,668	413	2,966	781	952
11.	1948	925	234	162	63	345	61	60
12.	1949	939	227	176	78	333	58	67
13.	1950	1,083	240	192	74	395	81	101
14.	1951	1,444	292	221	71	598	105	157
15.	1952	1,693	373	346	72	551	152	199
16.	1953	2,104	465	411	88	711	188	241
17.	1954	2,432	606	498	108	711	235	254
18.	1955	2,659	633	533	156	857	222	259
19.	percentage 1910–1955 = 100	100.0	26.0	20.4	5.4	29.9	8.6	9.7
20.	1955 = 100	100.0	23.9	20.0	5.8	32.2	8.4	9.7

TABLE 4. NUMBER AND ACCUMULATED TOTALS OF OUTTURN OF SCIENTISTS FROM INDIAN UNIVERSITIES : 1910–1956

	year	number of degrees awarded		index number 1910-14 = 100	accumulated total number col. (2)	percentage col. (5)
		total	average per year			
	(1)	(2)	(3)	(4)	(5)	(6)
1.	1910–1914	385	77	100	385	1.2
2.	1915–1919	832	166	216	1,217	3.8
3.	1920–1924	917	183	238	2,134	6.7
4.	1925–1929	1,923	385	500	4,057	12.7
5.	1930–1934	2,784	557	723	6,841	21.5
6.	1935–1939	2,938	588	764	9,779	30.7
7.	1940–1944	3,378	676	878	13,157	41.3
8.	1945	786	786	1,021	13,943	43.7
9.	1946	824	824	1,070	14,767	46.3
10.	1947	901	901	1,170	15,668	49.2
11.	1948	925	925	1,200	16,593	52.0
12.	1949	939	939	1,219	17,532	55.0
13.	1950	1,083	1,083	9,406	18,615	58.4
14.	1951	1,444	1,444	1,875	20,059	62.9
15.	1952	1,693	1,693	2,199	21,752	68.2
16.	1953	2,104	2,104	2,732	23,856	74.8
17.	1954	2,432	2,432	3,158	26,288	82.5
18.	1955	2,659	2,659	3,453	28,947	90.8
19.	1956	2,933	2,933	3,809	31,880	100.0

Source : "Man-power Studies No. 16 : Scientists in India" (Perspective Planning Division, Planning Commission, July 1959).

TABLE 5. OUTTURN OF DEGREE AND DIPLOMA HOLDERS IN ENGINEERING AND TECHNOLOGY IN INDIA : 1915–1951

year	number		total	average annual outturn	index number 1915-19 = 100
	degree	diploma			
(1)	(2)	(3)	(4)	(5)	(6)
1. 1915–1919	568	1,703	2,271	454	100
2. 1920–1924	771	1,902	2,673	535	118
3. 1925–1929	1,619	4,322	5,941	1,188	262
4. 1930–1934	2,190	5,397	7,587	1,517	334
5. 1935–1939	2,901	5,331	8,232	1,646	362
6. 1940–1944	3,765	6,280	10,045	2,009	442
7. 1945–1949	5,965	7,404	13,369	2,674	589
8. 1947–1948	1,251	1,393	2,644	2,644	582
9. 1948–1949	1,644	1,473	3,017	3,017	664
10. 1949–1950	1,896	1,757	3,653	3,653	804
11. 1950–1951	2,301	1,700	4,001	4,011	883

Source : Man-power Studies No. 5 : Engineers in India 1955 (Perspective Planning Division, Planning Commission, October 1957).

TABLE 6. NUMBER OF ENROLMENT AND OUTTURN OF DEGREE AND DIPLOMA HOLDERS IN ENGINEERING AND TECHNOLOGY IN INDIA : 1951–1959

year	degree		diploma		total		index number 1951–52 = 100	
	intake	outturn	intake	outturn	intake	outturn	intake	outturn
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1. 1951–1952	4,788	2,603	6,216	2,626	11,004	5,319	100	100
2. 1952–1953	5,184	2,956	6,499	2,654	11,683	5,610	106	105
3. 1953–1954	5,450	2,880	7,213	2,747	12,663	5,627	115	106
4. 1954–1955	5,488	3,207	8,313	3,397	13,781	6,604	125	124
5. 1955–1956	5,037	4,017	9,397	4,072	15,334	8,089	139	152
6. 1956–1957	6,367	4,293	9,899	4,075	16,266	8,388	148	157
7. 1957–1958	9,778	4,290	15,995	5,034	25,773	9,324	234	175
8. 1958–1959	11,086	4,571	10,932	6,021	31,018	10,592	282	199

Source : Answer to question in the Parliament : Lok Sabha No. Education 21.7 on 10 August 1959.

TABLE 7. EXPENDITURE ON RESEARCH IN MILLION OF RUPEES AND INDEX NUMBER WITH 1948–49 = 100

year	ICMR	ICAR	CSIR	sub-total (2)+(3)+(4)	AEC current	total (5)+(6)	ICMR	ICAR	CSIR	sub-total col. (5)	total col. (7)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	expenditure on research (in million rupees)						index number based on 1948-49 = 100				
1948–49	1.0	2.6	7.2	10.8	—	10.8	100	100	100	100	100
1949–50	1.2	2.3	11.2	14.7	—	14.7	120	888	156	136	136
1950–51	1.5	2.4	16.0	19.9	—	19.9	150	92	222	184	184
1951–52	1.3	3.9	17.8	23.0	—	23.0	130	150	247	213	214
1952–53	1.7	3.2	20.9	25.8	—	25.8	170	123	290	239	238
1953–54	1.5	5.1	19.8	26.4	—	26.4	150	196	275	244	244
1954–55	1.9	6.8	18.7	27.4	8.2	35.6	190	262	260	254	330
1955–56	2.9	6.5	22.7	32.1	15.2	47.3	290	250	315	297	439
1956–57	3.3	17.9	28.0	49.2	17.8	67.0	330	688	389	456	620
1957–58	5.7	23.7	35.5	64.9	23.8	88.7	570	912	493	601	821
1958–59	5.2	29.2	50.7	85.1	28.5	113.6	520	1123	704	788	1052
1959–60	7.2	35.0	61.5	103.7	30.0	133.7	720	1346	854	960	1238
total	34.4	138.6	310.0	483.0	123.5	606.5					

ICMR = Indian Council of Medical Research CSIR = Council of Scientific & Industrial Research
ICAR = Indian Council of Agricultural Research AEC = Atomic Energy Commission, current expenditure
Source : Central Statistical Office, Government of India.

BIBLIOGRAPHICAL NOTE

I have used a number of standard publications and may mention two books which give a good deal of information, namely, *The Progress of Science in India during the Past Twenty-five years* (Indian Science Congress Association, Calcutta, 1939); and *A History of Education in India* by Syed Nurullah and J. P. Naik (Macmillan & Co., second edition, 1957). I am grateful to the Central Statistical Organization, the Perspective Planning Division of the Planning Commission, and the Indian Statistical Institute for collecting and processing some of the statistical data.

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