SPEECH BY
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AT THE OPENING OF THE NEW BUILDINGS OF THE INSTITUTE
AT COLABA
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The Tata Institute of Fundamental Research started its work in June 1945. It is therefore the oldest of our post-war national laboratories. And yet it is only today, 16½ years later, that its own buildings are being inaugurated by the Prime Minister. This fact alone shows that the manner in which this Institute has been built up is different from that of the other national laboratories, where attention was first directed towards providing them with a building. There are, however, a number of other differences in approach also. I would therefore like to take a few minutes to recapitulate the history of this Institute and the manner in which it has grown.

While I was still working as a Professor at the Indian Institute of Science at Bangalore during the Second World War, I noted that there was no scientific institution in India devoted solely to fundamental research, especially in the newest branches of physics, namely, nuclear and high energy physics. By fundamental research I mean basic investigations into the behaviour and structure of the physical world without any consideration regarding their utility whether the knowledge so acquired would ever be of any practical value. Nevertheless, the support of such research and of an institution where such research can be carried out

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effectively is of great importance to society for two reasons. First of all, and paradoxically, it has an immediate use in that it helps to train and develop, in a manner in which no other mental discipline can, young men of the highest intellectual calibre in a society into people who can think about and analyse problems with a freshness of outlook and originality which is not generally found. Such men are of the greatest value to society, as experience in the last war showed, for many of the applications of science which were crucial to the outcome of war were developed by men who, before the war, were devoting their time to the pursuit of scientific knowledge for its own sake. Radar and atomic energy are two examples of two fields in which a vast body of known basic knowledge was developed into technology of immense practical importance, largely through the application in war time of the efforts of those who might be called 'pure' scientists.

Secondly, the history of science has shown that "there is no genuine knowledge of the universe that is not potentially useful for man, not merely in the sense that action may one day be taken on it, but also in the fact that every new knowledge necessarily affects the way in which we hold all the rest of our stock".

Accordingly, in a letter dated the 19th August 1943 to Mr. J.R.D. Tata, I pointed out that "the lack of proper conditions and intelligent financial support hampers the development of science in India at the pace which the talent in the country would warrant", and suggested that the Tata Trusts might consider taking the initiative in setting up an Institute for fundamental research. In his reply to me of 2nd September 1943, Mr. J.R.D. Tata wrote "from what you say in your letter it is evident that there is scope for rendering valuable service to the country and to the cause of scientific research in India .... After all, the advance of science is one of the fundamental objects for which most of the Tata Trusts were founded, ... If they are shown that they can give still more valuable help in a new way, I am quite sure that they will give it their most serious consideration". The Trustees of the Sir Dorabji Tata Trust decided to accept financial responsibility for supporting the Institute at a meeting held on the 14th April 1944. I think it should be recalled on this occasion that this decision was taken more than a year before the explosion of the first atomic bomb over Hiroshima and before nuclear physics had become what might be called "the band-wagon" of science.

The location of the Institute at Bombay was decided largely because of the interest of the Government of Bombay, which was anxious to build up a strong department of physics at the Institute of Science, and which had invited me to undertake this task. As I was already committed to starting an institute of fundamental research, I suggested that the Bombay Government might cooperate with the Tata Trust in the founding of this Institute. Thus it came about that the Institute was founded as a joint endeavour of the Sir Dorabji Tata Trust and the Government of Bombay in 1945.

Next year the Council of Scientific and Industrial Research of the Government of India under the Presidentship of Sir Ardeshir Dalal, and with the enthusiastic support of its Secretary, my distinguished colleague, the late Dr. S.S. Bhatnagar, decided to give a grant to the Institute for the year 1946-47. The subsequent development of the

Institute to its present proportions is due to the great interest and powerful support of the Government of India.

The Atomic Energy Commission of the Government of India was first established in 1948, and one of its immediate problems was the shortage of trained scientific personnel in its field. It was therefore natural that the Commission should turn to the Institute for training personnel for its work, and for carrying out some of its own major projects. These early projects were carried out by joint teams belonging to the Institute and to the Physics Division of the Atomic Energy Commission, which was then housed in the Institute's premises and looked after administratively by the Institute. The Commission on its part gave substantial help to the Institute by providing funds for increasing its activities and for specialised equipment for nuclear research.

One of the first activities undertaken by the Institute for the Commission was the setting up of a small electronics group to design and build the electronic instruments without which atomic energy work is impossible. This group was the nucleus from which grew the present Electronics Division of the Atomic Energy Establishment at Trombay with a staff of over 560 people, and which is now producing not only most of the electronics instrumentation used at Trombay, including the control systems of reactors, but also that which will be used all over the country in agricultural, biological, industrial, and medical work with radioactive materials. The Institute has given some 46 members of its scientific staff to man various divisions of the Atomic Energy Establishment at Trombay, to mention only two, Shri A.S. Rao,

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Head of the Electronics and Health Physics Group, and Dr. R. Ramanna, Head of the Physics Group. There was a time when no less than 175 members of the staff of the Trombay Establishment were looked after by the Institute. It is also appropriate to recall on this occasion that the control system of Apsara, the first reactor in Asia, was built under the auspices of this Institute in a war time hutment on this very site, and many parts of the Reactor in its workshop. It is not an exaggeration to say that this Institute was the cradle of our atomic energy programme, and if the Atomic Energy Establishment at Trombay has been able to develop so fast, it is due to the assisted take off which was given to it by the Institute in the early stages of its development. It is equally true to say that the Institute could not have developed to its present size and importance, but for the support it has received from the Government of India. By 1955 it had become clear that the Government of India's interest in the work of the Institute was of a permanent nature, and considering it "to be in the interests of the country to maintain a high level academic institution where study, search for knowledge and scientific research shall be pursued for the purpose of increasing man's knowledge of nature without considerations of practical utility", a new Tripartite Agreement between the Government of India, the Government of Bombay, and the Sir Dorabji Tata Trust was signed, as a result of which the Institute came to be recognised as the National Centre of the Government of India for advanced study and fundamental research in nuclear science and mathematics. Thanks to the steady support, which the Institute has always received from the Prime Minister at various important stages of its development, it has now become one of the largest

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and most important of our national laboratories.

The Institute started in a modest way during war time in half a house hired at 53 Pedder Road with a total floor space of 6,000 square feet. By the end of 1949 its activities had grown to such an extent that an area of some 35,000 square feet was leased in the premises formerly occupied by the Royal Bombay Yacht Club. This building has an area of some 256,000 square feet and the only elbow room left for future expansion is a little space on the top floor.

In planning the buildings of the Institute, the Council took the view that the latest and best ideas in laboratory design should be incorporated, and accordingly a noted American firm of architects with considerable experience of tropical building, namely, Messrs. Holabird & Root of Chicago, were commissioned to design these buildings. I would like to say on this occasion how happy we are with the result, and to express our appreciation of the personal interest taken in it by the principal architect, Mr. Helmuth Bartsch. They have done a truly fine piece of work, as you can judge for yourselves. A building of this complexity and quality is due to the combined effort of many people, and on behalf of the Institute I would like to thank all of them. I must, however, mention explicitly the principal contractor, Messrs. Shapoorji Pallonji & Co. Pvt. Ltd., who has done a magnificient job. I would also mention the Building Project Officer, Shri S.A. Kikkeri for the devoted and hard work he has put in.

The Foundation Stone of the building was laid by the Prime Minister on the 1st of January 1954, and a plaque at the entrance in the corner of the building commemorates the event. It is only appropriate that the building should be inaugurated by the Prime Minister today. For it is thanks to his personal interest and strong support of science in India, and of this Institute in particular, that we have such an ideal place to work in. This Institute has taken so long to construct because we had to do a lot of pioneering which has resulted in permanent benefit to the country. For example, the aluminium companies in India were induced to extrude special sections for windows and doors in a rustless alloy resistant to corrosion of the warm sea air. The well known firm, Messrs. Godrej & Boyce, imported a costly machine in order to weld and fabricate these windows. There is a whole list of other items now readily available in the Indian market which were produced for the first time.

I have spoken so far only about the supporting frame work of the Institute's activities. The building itself is only a shell to make possible the work that is done inside it. It is by the quality and volume of its scientific work that an Institute like this must be judged, by the extent to which it has helped to explore and push back the frontiers of knowledge to open up new fields of knowledge, to provide the country with men highly trained in the newest fields of scientific endeavour and able to make their own contribution to the increase of scientific knowledge, and by its general impact on the scientific life of the country as a whole. I would like to devote the rest of my speech to the scientific work of the Institute.

From its very inception the work of the Institute has been in the fields of high energy physics, cosmic rays, and mathematics. Work since the war in many parts of the world has revealed that the ultimate structure of the physical world is not as simple as had once been thought.

While matter as we find it in normal conditions and at low energies may be built up of two or three types of building bricks known as the elementary particles, this is no longer so at higher energies. The simple picture had already been shown to be too simple just before the beginning of the war by the discovery of a new elementary particle, the meson. Since the war the process has gone much further and a number of new elementary particles have been discovered -- more than one type of meson and a number of other entities known as strange particles. It is to some extent a matter of taste as to what one calls a different type and what one considers as a different state of the same entity. The very concept of an elementary particle is something about which different views are held. There is no doubt that we have penetrated into a deeper level of nature, which is accessible to us only through the study of the interactions of matter at high energies. In cosmic radiation nature has given us a source of particles of the very highest energies we know extending certainly far beyond 10^{15} electron volts, i.e. a million billion volts and beyond. How high this energy is can be gauged from the fact that the largest accelerator at present in operation in the world, namely the one at Geneva belonging to the European Centre of Nuclear Research, provides particles of an energy of only 30 billion volts. Particles in cosmic ray, therefore, have energies of many thousands to many millions of times higher than those produced by the largest accelerator, and this is one of the primary reasons for the great interest in the study of cosmic rays. Indeed, most of the new elementary particles known today have been discovered through an analysis of cosmic ray phenomena, and in this line, the Institute has made significant contributions.

A method for studying phenomena at these high energies is by the use of special photographic emulsions. The technique of using stripped emulsions, i.e. emulsions without glass backing, was developed for the first time in the world in this Institute in 1951-52. The use of these stripped emulsions directly resulted in the discovery in 1953 by the Emulsion Group of this Institute under Professor Peters of the K - meson, a negatively charged particle of a mass approximately a thousand time that of the electron. It also yielded some of the first known examples of the associated production of K - mesons and hyperons. Since then large sandwich stacks consisting of alternative layers of emulsion and tungsten sheets have been used, and one of the largest stacks in the world, consisting of plates of 4 feet by 2 feet in size, was flown by the Institute last year in collaboration with the University of Bristol. We have in this building a facility for developing the largest nuclear emulsion stacks, and there is perhaps only one other comparable facility in the world today, namely, in the University of Chicago.

To fly these large stacks and other equipment at high altitudes special techniques had to be developed. The Institute's group which has concentrated on the development of plastic balloons, after a large amount of research and development spread over a period of several years, has now perfected the manufacture of plastic balloons of a million cubic feet in volume, which are capable of carrying loads of up to 250 lbs. to altitudes of some 110,000 feet and above. The radius of the largest balloons flown so far is about 60 feet and their length about 200 feet. Originally, these balloons were made of commercial polyethylene sheets, but these did not perform satisfactorily. It is generally known that the temperature of the air falls as we go up in the atmosphere. It is not so generally known however that the minimum temperatures reached in the tropocs at an altitude of some 55,000 feet is -85°C to -95°C, whereas the minimum temperatures at any point in the atmosphere in the temperate climates is in fact higher, being -60°C at a height of some 40,000 feet. The normal plastic from which our original balloons were made, while passing through these levels became brittle and splintered like glass. To meet this difficulty American balloon manufacturers have used special fabrics developed for the purpose, but till recently these were not sold outside the United States. We had therefore to tackle the problem ourselves and special plastic was extruded in Bombay with fine carbon powder mixed in it, so that the carbon would absorb the heat from the sun's rays and stop the plastic from freezing. At first too much carbon was mixed, and although the balloons did not freeze, they became too hot at the highest altitudes and the plastic began to melt. It is only after a lot of experimentation that the correct technique was developed, and we now have balloons which perform with a 100% success, and as well as, if not better than, some of the American balloons which were flown recently in a collaborative endeavour with us in this country. The credit for this considerable achievement goes to Professor M.G.K. Menon and the Balloon Flight Group under him, which is one of the two largest in the world engaged in flying high altitude equipment. Balloons made here were used last year in flights made from Italy by the Bristol University in a joint European programme of cosmic ray research financed by NATO.

An instrument which has been of great importance in studying cosmic ray phenomena is the cloud chamber, and we have designed and have under construction a cloud chamber, which will be 2 metres wide, 1.5 metres high, and a meter in depth. This cloud chamber, weighing some 4½ tons, will be the largest in the world. It will be operated with a device called a total absorption spectrometer, which will measure the energy of particles upto 10^{14} (hundred thousand billion) electron volts with an accuracy of about 10%. This device, the only one of its kind in the world, has already given some important results. It has permitted the correlation of the multiplicity of very high energy collisions with the effective target mass in the collision.

A group at the Institute is engaged in the study of extensive air showers which are produced by extremely high energy cosmic rays. The equipment for measuring these events has been built by the Institute at Ootacamund in the grounds of Government House through the courtesy of the then Governor of Madras who is happily with us today as the Governor of Maharashtra. In this equipment scintillation counters, each 1 square metre in area, are spread over an area of 100 metres square for sampling the electronic densities over the area. There are three mu-meson detectors, nine units for detecting nuclear interacting particles, a total absorption spectrometer of the type I have just mentioned, fifteen units for studying the cores of local showers, and finally electronic circuitry which can measure the difference in the time of arrival of different parts of the shower within time intervals of the order of a thousand millionth part of a second. This impressive piece of equipment was built by Dr. Sreekantan and his group and has recently yielded a result which may have far reaching consequences for cosmology. There is a north-south asymmetry in the arrival of primary cosmic rays with energies greater than 10^{15}

(million billion electron volts), two to four times as many of these high energy cosmic rays entering the earth's atmosphere from the northern than from the southern hemisphere.

Our work in cosmic rays has led us into the field of geophysics, High energy cosmic rays entering the top of the atmosphere collide with atoms there and produce radioactive forms or isotopes of known chemical elements in very small quantities. Thus, while natural carbon is not radioactive, a variety of it, called Carbon 14, is produced by cosmic rays, which is radioactive and decays with a half-life of 5,600 years. In this way are produced about a dozen radioactive isotopes of known elements. In 1954, when the Geophysics Research Group at the Institute was formed, only three isotopes produced by cosmic rays in the atmosphere were known. In the following five years eight other isotopes were detected, and out of them five were discovered as a result of investigations carried out by members of the Institute, and especially Professor Lal.

The life times of these cosmic ray produced isotopes vary from a few minutes to several million years. Phosphorus 33, for example has a half-life of 25 days, Sulphur 35 a half-life of 87 days, Silicon 32 a half-life of 700 years, and Beryllium 10 a half-life of 2.7 million years. These different isotopes can therefore be used to study geophysical phenomena, such as the nature and amount of atmospheric circulation and circulation of water in the oceans, in studies of sediments from the ocean floor and of certain regions on the ocean floor where their deposition continues undisturbed, providing a record of the occurrence of a variety of geological and oceanic phenomena in the past, such as volcanic activity, climatic conditions, ocean's biological activity and the influx of extra-terrestrial material. Since the amount of these cosmic ray produced isotopes is extremely small, and practically all material contains some radioactive atoms, extremely fine techniques have to be developed in order to exclude spurious effects due to the surrounding matter. The techniques developed at the Institute now permit the counting of one atom in 10^{24} atoms, i.e. one in a million billion billion. Chemical techniques had also to be developed capable of removing quantities of a particular element as small as a millionth part of a gram to a thousand-millionth part of a gram. It is a matter of some satisfaction that the Geophysics Group at the Institute has made some pioneering contributions at the frontiers of knowledge.

Carbon 14, the radioactive isotope of carbon produced by cosmic rays, is found in all living matter. It decays with a half-life of 5,600 years, and the amount of it contained in any remains of any living matter allows one to date the day when the organism ceased to live in time periods extending from 500 to 40,000 years. Due to the existence of an outstanding Geophysical Group, the Institute has set up a Carbon Dating Laboratory, which will be available to the whole country to assist in the scientific dating of archaeological specimens and human antiquity.

Another radioisotope produced by cosmic rays is tritium, the radioactive equivalent of hydrogen, with a half-life of 12.3 years. This isotope finds its way into all hydrogen containing material, like water. It can be used as a tracer in studying the circulation of water and in obtaining information about underground water, such as the sources of water, the size of the underground reservoirs, and the rate of its charging from water deposited on the surface. A Tritium Laboratory has also been set up recently at the Institute as a general facility for the country, and the Department of Atomic Energy has appointed a Tritium Committee to build up a library of water samples from all over the country and to select those samples which should be analysed for their water content.

Lastly, I would like to mention one other activity, because of its pioneering nature in this country. Electronic digital computers are becoming more and more important in modern scientific research and there are many fields today in which progress would be impossible without their help. Work was started in the Institute in December 1954 towards building a pilot machine. The pilot model was completed two years later, and based on this experience the design features of the main computer were worked out early in 1957. In a period of two years thereafter, i.e. by early 1959, the main computer had been built. The instrument uses about 3,000 radio valves and consumes about 20 kilowatts of power. Since February 1960, this computer has been in regular operation, and the demands on it had become so great that it was put on to two-shift operation a year ago. It has been used for solving problems in the field of extensive air showers, high energy nuclear interactions, cascade theory, magnetic resonance, X-rays and crystal physics, and reactor physics. It has handled computational problems for the Atomic Energy Establishment at Trombay, for the Indian Institute of Science at Bangalore, and for the Physical Research Laboratory at Ahmedabad. It is now available as a national facility for the whole country. It is now proposed to develop this computer work at the Institute along two parallel lines. In order to develop the art of designing and building computers in this country to the level it has reached elsewhere, the group which built the present computer proposes to take up the design and development of a computer which will be comparable with the most powerful and versatile computer available some 4 or 5 years hence. On the other hand, as the practical demand for a computer in the next five years is going to be very great, and the Institute's projected computer will not be ready for another four or five years, it is proposed to acquire one of the latest and most powerful standard computers available today and to operate this as a service not only for the Institute, but for the Atomic Energy Establishment and other scientific institutions throughout the country.

There are several other fields of physics in which good work is being done in the Institute, but which lack of time does not permit me to touch on.

My talk would however be incomplete, if I did not refer to the School of Mathematics of this Institute, which has established an international reputation for itself for the outstanding contributions, which its members have made to various branches of modern mathematics. Credit for this must go to Professor K. Chandrasekharan who has carefully and painstakingly built up an exceptionally fine group of young mathematicians over the years. The Government of India has reason to be satisfied that this is its National Centre for mathematics.

The completion of a building of this size and the organisation of a function such as this needs a great deal of attention to detail and effort from all concerned. Members of the administrative and workshop staff have worked very hard and for long hours into the night, and I wish to thank them all most sincerely for their devotion to duty and their whole-hearted cooperation.

Now that the building has been completed and the myriads of chores connected with moving to a new place of work, organising new laboratories and making new arrangements have been more or less dealt with, I hope the academic staff of the Institute will be able to concentrate without distraction on the aims for which this Institute was established, namely, the furthering of scientific knowledge. I trust that the scientific achievements in the years ahead will justify the confidence which the Prime Minister and the Government have placed in us.

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