Homi Jehangir Bhabha and the Tata Institute of Fundamental Research

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This year is the 100th birth anniversary of Homi Bhabha, who was one of the founders of modern science in India. We sketch his scientific achievement and his visionary and historic contribution to institution and nation-building. Many of his insights and views, which seem lost in the march of time, are relevant even today. This note is a narrative with a view to introspect for a better future.

'Provided proper appreciation and financial support are forthcoming, it is the duty of people like us to stay in our own country and build up outstanding schools of research such as some other countries are fortunate to possess,' wrote Homi Jehangir Bhabha in 1944. It was a remarkable statement to make at the height of his scientific career. At the time, he was engaged in research at the Indian Institute of Science (IISc), Bangalore. He had been elected a Fellow of the Royal Society in 1941. Shortly thereafter, he had been awarded the Adams Prize at Cambridge for his thesis on 'The theory of the elementary particles and their interaction', and had become a full professor at IISc.

And yet, despite being highly accomplished, peer-recognized and deeply involved in the forefront of elementary particles and cosmic ray research, Bhabha decided to devote himself, increasingly, to the establishment of institutions and the service of the nation. For a working scientist at the height of his academic work, this is a considerable sacrifice. But true to his vision, Homi Bhabha built not one but two outstanding research institutions in India – the Tata Institute of Fundamental Research (TIFR), and the Atomic Energy Establishment, which was later renamed the Bhabha Atomic Research Centre (BARC) after his tragic and untimely death in 1966.

Since it is reasonable to assume that the influences and milieu of one's early childhood and teens have a strong bearing on one's later years, we begin with a brief biography of Bhabha's early years in India before he went to Cambridge. We then highlight the Cambridge years and his main scientific contribution to elementary particles and cosmic ray physics, which were brilliant and have a lasting value and upon which the edifice of his great achievement rests. His outstanding research earned him the respect and admiration of his peers. This period was followed by his return to India, the Bangalore period and the founding of the TIFR. We conclude with a brief outline of TIFR today.

Early years in Bombay and family background

Influences dating back to Bhabha's childhood in Bombay, in a cultured and wealthy environment where the threads of education, art, science, industry and nation-building were intermingled, played a key role in prompting him to chart this new course.

Homi was born in Bombay on 30 October 1909 (a hundred years ago) to Jehangir and Meherbai Bhabha. He was named after his grandfather, Hormusji Bhabha, who was the Inspector General of Education in the state of Mysore. Jehangir Bhabha had grown up in Bangalore and was educated at Oxford. After receiving his training as a lawyer in England, Jehangir started working in Mysore where he joined the judicial service of the state. He married Meherbai, the daughter of Bhikaji Framji Pandey and granddaughter of the renowned philanthropist Dinshaw Petit of Bombay. After marriage, the couple moved to Bombay, the first commercial city of British India. It was here that the young Bhabha spent his childhood.

Homi Bhabha with his mother Meherbai Bhabha, father Jehangir Bhabha and brother Jamshed Bhabha.

Homi's paternal aunt, also Meherbai, was married to Dorabji Tata, the elder son of the pioneer of Indian industry Jamshetji Nusserwanji Tata. Here, at the Tatas' ancestral home, the commercial world of his industrialist uncle revealed itself to the young Homi. But he also observed the deep bonds that the Tatas forged with institutions of learning: notably, following the death of Jamshetji Tata, Dorab had taken charge of IISc.

The young Homi had his schooling at the Cathedral and John Connon School which, he would write three decades later to the retired principal Hammond, did much to foster his love for science.

After passing the Senior Cambridge examination with honours at the age of 15, Bhabha joined Elphinstone College and later the Royal Institute of Science, both in Bombay, before his family decided to send the 19-year-old to England to the Gonville and Caius College in Cambridge in 1927. This was the institution where Homi's uncle Dorab had studied and to which he had made a handsome endowment.

As both his father and his uncle wanted him to become an engineer, with a plan to join the Tata Iron and Steel Company at Jamshedpur on his return to India, Homi enrolled for the Mechanical Sciences Tripos.

The Cambridge years

However, at Cambridge, Homi's interests soon shifted to theoretical physics and mathematics. In a letter to his father in 1928, he described his profound love for physics:

> 'I seriously say to you that business or job as an engineer is not the thing for me. It is totally foreign to my nature and radically opposed to my temperament and opinions. Physics is my line. I know I shall do great things here. For, each man can do best and excel in only that thing of which he is passionately fond, in which he believes, as I do, that he has the ability to do it, that he is in fact born and destined to do it . . . Besides India is not a land where science cannot be carried on. I am burning with a desire to do physics. I will and must do it sometime. It is my only ambition. I have no desire to be a "successful" man or the head of a big firm. There are intelligent people who like that and let them do it . . . It is no use saying to Beethoven "You must be a scientist for it is great thing" when he did not care two hoots for science; or to Socrates "Be an engineer; it is work of intelligent man." It is not in the nature of things. I therefore earnestly implore you to let me do physics.'

Homi's father agreed to his son's wish to take up the Mathematics Tripos – on the condition that he should first complete the Mechanical Tripos successfully. This Homi did; thereafter he passed the Mathematics Tripos again with first class. He was now free to take up his great passion, which was physics.

Homi Bhabha had thus crafted his journey away from iron and steel to academics. While on this journey, he worked with some of the great physicists of the times, including Paul Dirac, Wolfgang Pauli, Enrico Fermi, Neils Bohr and Gregor Wentzel.

The atmosphere in Cambridge during that time was extraordinary. In 1927, Dirac had made one of the greatest scientific discoveries of the 20th century, viz. the Dirac equation. A few years later he predicted the existence of the 'positron', which is identical in all respects to the electron but has an opposite electric charge, positive by convention. Anderson discovered this particle in 1932. In the same year, James Chadwick demonstrated the existence of the neutron; John Cockroft and Ernest Walton produced the transmutation of light elements by bombarding high-speed protons, and Blackett and Occhialini demonstrated with cloud-chamber photographs the production of electron pairs and showers by gamma radiations.

Main scientific contributions of Homi Bhabha

At Cambridge, Bhabha joined the Cavendish Laboratory, from where he obtained his Ph D with R. H. Fowler as his thesis supervisor.

Bhabha's important contributions during the Cambridge period include the explanation of relativistic exchange scattering (Bhabha scattering), the theory of production of electron and positron showers in cosmic rays (Bhabha-Heitler theory), speculation about the Yukawa particle related to which was his suggestion of the name meson, and prediction of relativistic time-dilatation effects in the decay of the meson.

Bhabha was the first to do a proper quantum theoretical calculation of the process of electron–positron annihilation and creation – one of the basic processes in quantum electro-dynamics using Dirac's theory. This process, known as the Bhabha scattering, is even today used as a luminosity monitor in electron–positron collider physics experiments.

Bhabha, jointly with the German scientist W. Heitler, then at Cambridge, explained the cosmic-ray shower formation in a paper published in 1937. It had been discovered by 1918, that there is a strong level of radiation in the upper atmosphere. Robert Millikan, who was the first to identify that the origin of the radiation was from outside the earth, called it cosmic radiation. During the 1930s, it was discovered that extensive but short-lived patches of high-intensity radiation develop in the sky, and then die out. No one understood how this kind of radiation could occur. Bhabha and Heitler developed a theory of this process by the cascade production of gamma rays and electron–positron pairs. A high-energy particle from the sun, or from some remote source like a star, a galaxy or a quasar, hits the atoms of the upper atmosphere. This causes the nuclei of these atoms to disintegrate, creating a number of high-energy fragments and new particles. These fragments fly-off with enough energy to hit neighbouring atoms and cause their nuclei in turn to disintegrate and fly-off. This process continues, spreading out over miles, with ever-diminishing energy, until the last fragments in the chain have no more energy to cause nuclear reactions. Thus, a shower of fast-moving charged particles is created, and this gets detected as cosmic radiation.

Not all the experimental facts about cosmic ray showers, however, were accounted for by the Bhabha–Heitler theory. To explain the penetrating component, Bhabha made the far-reaching hypothesis that there must exist a new particle with the same characteristics as the electron, but approximately 100 times heavier. Today, this particle is called the 'muon'. It is approximately 200 times heavier than the electron.

Bhabha was also the first to point out that cosmic rays, moving at a speed close to that of light, are the best place to verify the conclusions of Einstein's special theory of relativity. For example, mesons, which normally decay within a distance of half a kilometre, can travel more than 10 km down to the earth's surface because relativistic time dilation increases their decay lifetime.

Einstein, Yukawa, Wheeler and Bhabha at Princeton.

Bhabha proposed vector mesons as particles, in addition to Yukawa's scalar mesons, that would play a role in the nuclear interaction. These vector mesons were massive, had spin one and odd parity. In this way he explained the fact that the triplet state of the deuteron (a heavy isotope of hydrogen whose nucleus has one proton and one neutron) was the lowest stable state.

About the importance of Bhabha's research work, Cecil Powell, who was awarded the 1950 Nobel Prize for physics, wrote:

> 'Homi Bhabha made decisive contributions to our understanding of how they (the showers) developed in terms of electromagnetic processes. He was also well-known at this time for his attempts to account for those elementary particles then known to exist by a method using group theory. He was thus a very early exponent of those methods used many years later for a similar purpose by Gell-Mann and others.'

Homi Bhabha and Cecil F. Powell during the latter's visit to TIFR.

Bhabha returns to India

Yet destiny led Homi Bhabha in a different direction, where he would discover his calling as a builder of great institutions. In 1939, when the Second World War broke out, Bhabha was in India on a holiday. With the war changing his plans to return, Bhabha joined IISc, where a Readership in theoretical physics was specially created for him. C. V. Raman, who was then at IISc was deeply impressed by Bhabha. Introducing his younger colleague at the annual meeting of the Indian Academy of Sciences in 1941, Raman described the 32-year old Bhabha as 'the modern equivalent of Leonardo da Vinci'.

Homi Bhabha with C. V. Raman and others at IISc.

At IISc, Bhabha initiated and guided research on cosmic rays and organized a group of young researchers in experimental and theoretical aspects of cosmic-ray research. He also continued his work on relativistic equations of higher spin, known as the Bhabha–Corben equations. One of the main motivations to develop and generalize the Dirac equation was to treat the effect of a large number of soft-radiation quanta (photons, mesons, etc.) using a classical wave field. In modern parlance, the classical wave field is related to the coherent state of the radiation quanta. Bhabha's work on meson theory led him to predict isobar states of the meson–nucleon system. This work was a precursor to later developments in strong coupling theory of the meson–nucleon system.

The early forties were a period of scientific honours and recognitions for Bhabha. In 1941, he was elected Fellow of the Royal Society of London. He was awarded the Adams Prize for his thesis, and he also became full professor at IISc.

The genesis of TIFR

By now, after having spent a few years in India, Bhabha had realized that no institute in India had the necessary facilities for original work in nuclear physics, cosmic rays, high-energy physics, and other frontiers of knowledge in physics. He wrote to his friend J. R. D. Tata about this state of affairs: 'The lack of proper conditions and intelligent financial support hampers the development of science in India at the pace the talent in the country would warrant'. Tata replied suggesting that as the advancement of science was one of the fundamental objects with which most of the Tata Trusts were founded, Bhabha should write to the Sir Dorabji Tata Trust seeking help in setting up a new institute.

Homi Bhabha and J. R. D. Tata.

In March 1944, Bhabha sent a proposal to the Sir Dorabji Tata Trust describing his intention to establish 'a vigorous school of research in fundamental physics'. He wrote:

> 'I have for sometime past nurtured the idea of founding a first class school of research in the most advanced branches of physics in Bombay. . .the scheme I am now submitting to you is but an embryo from which I hope to build up in the course of time a school of physics comparable with the best anywhere.
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> 'There is at the moment in India no big school of research in the fundamental problems of physics, both theoretical and experimental. There are, however, scattered all over India competent workers who are not doing as good work as they would do if brought together in one place under proper direction. It is absolutely in the interest of India to have a vigorous school of research in fundamental physics, for such a school forms the spearhead of research not only in less advanced branches of physics but also in problems of immediate practical application in industry. If much of the applied research done in India today is disappointing or of very inferior quality it is entirely due to the absence of sufficient number of outstanding pure research workers who would set the standard of good research and act on the directing boards in an advisory capacity. . . .'

With his unique foresight, that the new school would also conduct research in nuclear energy:

> 'When nuclear energy has been successfully applied for power production in say a couple of decades from

now, India will not have to look abroad for its experts but will find them ready at hand. I do not think that anyone acquainted with scientific development in other countries would deny the need in India for such a school as I propose. The subjects on which research and advanced teaching would be done would be theoretical physics, especially on fundamental problems and with special reference to cosmic rays and nuclear physics, and experimental research on cosmic rays. It is neither possible nor desirable to separate nuclear physics from cosmic rays since the two are closely connected theoretically.'

This was over a year before the military use of nuclear energy in Hiroshima and Nagasaki. In 1955, when he presided over the first International Conference on the Peaceful Uses of Atomic Energy, Bhabha would again emphasize the need for atomic energy for development:

'For the full industrialization of the underdeveloped countries, for the continuation of our civilisation and its further development, atomic energy is not merely an aid, it is an absolute necessity. The acquisition by man of the knowledge of how to release and use atomic energy must be recognized as the third epoch of human history.'

Dag Hammerskjold, Homi Bhabha, Walter G. Whitman and others during the first International Conference on Atomic Energy for Peaceful Uses at Geneva in 1955.

Bhabha's vision was that India, too, should have its own expertise in the use of atomic energy. TIFR would thus become the birthplace of the nation's atomic energy programme, and Bhabha its visionary and meticulous architect.

What Bhabha had in mind, for the integrated development of the nation's research and industrial sectors, was a symbiotic relationship between fundamental science and its technological applications.

The trustees of the Sir Dorabji Tata Trust accepted Bhabha's proposal. With the Government of Bombay showing active interest in becoming a joint founder, Bombay was chosen as the location for the proposed institute. Thus TIFR started functioning in the IISc campus from 1 June 1945 and shifted to Bombay in December 1945. It was formally inaugurated in its Bombay premises on 19 December 1945 in a part of Kenilworth, a sprawling bungalow owned by Bhabha's aunt on Pedder Road and partly hired out to the new institute.

Kenilworth.

Inauguration of TIFR, December 1945.

When TIFR began to grow and could no longer be accommodated in Kenilworth, it moved again, this time to the more picturesque location of the Old Yacht Club near the Gateway of India.

Old Yacht Club.

In the 1950s, with the institute growing rapidly, it was again time to change residence. This time the move was planned as a permanent one. Bhabha selected a spacious plot in Colaba on the sea face that belonged to the Ministry of Defence. With Prime Minister Jawaharlal Nehru enabling his request, work at the new site was begun in 1954.

Homi Bhabha and Pandit Jawaharlal Nehru during the Stone Laying Ceremony of TIFR, 1954.

The choice of Colaba had to do with the proximity of the University of Bombay. Bhabha made this important point:

'After an extensive search, the site was located in this area because, among other factors, it was near the University. Contact with students is a revitalizing factor for the research worker and conversely we feel that the presence of the Institute here will be of some advantage to the University.'

However, efforts to partner with the university did not make much progress. B. M. Udgaonkar remembers Bhabha's unsuccessful attempts to modernize the university syllabus, after which he decided to start the Atomic Energy Training School to train bright, young people for induction into the atomic energy programme. Later, as the city grew, the university itself shifted a large part of its activities to its Kalina campus.

Bhabha believed that institutions first grew organically, around outstanding work and brilliant individuals – and that buildings could come later. Thus, TIFR's research work continued over the years even as the new campus was being planned and constructed. Work went on at a brisk pace. For example, Bernard Peters recalls early efforts at the collection of 'enormous quantities of rainwater' for Be^{10} extraction:

'Large plastic sheets were spread over roofs of huts which served as temporary chemical laboratories at Colaba where later the modern laboratories of TIFR would arise. We even collected water on the large terrace of our apartment on Peddar Road. From there we channeled the monsoon waters through ion-exchange columns to extract the very small number of interesting atoms.'

Old Military Hutments on the Colaba site being used as laboratories during the construction of the buildings.

In fact, the institute was almost fully functional in its new 15-acre campus when Prime Minister Jawaharlal Nehru formally inaugurated the buildings on 15 January 1962. Bhabha had taken an

Rustom Choksi, J. R. D. Tata talking to Homi Bhabha and Pandit Nehru after the inauguration of the new buildings of TIFR in 1962.

active role in the design, architecture and high construction standards of the new buildings, especially insisting that the new campus be built almost entirely with indigenous materials.

In addition to his exacting standards, Bhabha's abiding passion for music, art and nature gave TIFR its aesthetically designed working environment. As an important patron of the Bombay-based Progressive Artists' Group, which produced artists like F. N. Souza, M. F. Husain, Tyeb Mehta, K. H. Ara and S. H. Raza, Bhabha selected some of their most powerful early works for the TIFR collection. Today the TIFR collection is one of the leading public collections of Indian contemporary art.

Bhabha also realized that scientific research institutions require the right kind of administrative support if they are to remain committed to excellence. In the last speech he gave before his death in 1966, Bhabha expressed his view of the kind of administration that is needed in an institution of fundamental research:

> 'The type of administration required for the growth of science and technology is quite different from the type of administration required for the operation of industrial enterprises, and both of these are again different from the type of administration required of such matters as the preservation of law and order, administration of justice, finance and so on.'

Clearly differentiating between government support and government control, he felt strongly that administrative practices should be aligned with the specific objectives of an institution. Bhabha had clearly given deep thought to the way to achieve his goal. The lesson for the present is that we must continuously strive to retain this administrative outlook, which is easy to lose as institutions grow.

Above all, Bhabha's focus was always on the work done at the institute. This was clearly stated in his speech during the inauguration of the new TIFR buildings on 15 January 1962:

> '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.'

True to this founding vision, TIFR continued to grow in the scope of its research activities during more than two decades of Bhabha's leadership. In 1955, the Government of India, due to its great interest and support of the institute, signed a new tripartite agreement with the Government of Bombay Presidency and the Sir Dorabji Tata Trust. As a result, the institute acquired its present official designation as the National Centre of the Government of India for Advanced Study and Fundamental Research in Nuclear Science and Mathematics.

It was the vision of a newly independent and modern India that compelled Bhabha to chart out this new course for Indian scientific research. The Silver Jubilee Commemoration Volume of the TIFR (1970) describes this early vision:

> 'In the rapidly developing frontier areas in which he had worked for almost a decade in Europe, Homi Bhabha was all by himself in Bangalore; and he knew that these areas of nuclear physics, elementary particle physics, cosmic ray physics and associated theoretical physics, had just opened up; and would flower with great possibilities for conceptual and fundamental breakthroughs as well in their applications. He further realized that it would be necessary to provide a fair amount of financial support in order to train and to provide opportunities for work for a sufficient number of scientists in these modern areas; and that it was only from such a base that one could hope to make real progress.
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> 'Homi Bhabha was an extrovert and a dynamic personality with a great deal of drive and energy. And he believed that he could, provided the right type of support and encouragement were forthcoming, develop new sophisticated areas of science and technology in the country, and equally important, harness these developments to achieve economic prosperity and social change. He had established an identity between himself and his country and wanted to remain in it and play a role in its development. In order to do this he felt it essential to set up a new institution, concerned with scientific development in the topical, sophisticated and frontier areas of science and technology, with modern concepts of research management, which had an atmosphere and environment condu-

cive to the growth of a scientific community and of self-confidence, and which would act as a pace-setter and be the base from which major ventures could be undertaken.'

Bhabha's dream was to 'build up in time an intellectual atmosphere approaching what we know in Cambridge and Paris', which would have 'an electrifying effect on the development of science in India'. It was this dream that led him to share his thoughts with J. R. D. Tata, whose suggestion then led Bhabha into a new direction as a builder of great institutions.

Research at TIFR

The first research areas to be taken up at the institute were theoretical physics, experimental work in cosmic rays and high-energy physics, and mathematics. It was clear to Bhabha that research in modern experimental areas was of utmost importance, not only for its own sake and to provide the right balance for the theoretical studies, but also because of the consequent confidence that it generated in the design, fabrication and use of equipment. Bhabha's own early training in engineering, thanks to his father's desire, shaped his vision of a research institute with strong foundations not only in theory, but also in experimental work.

For similar reasons, Bhabha understood the importance of growing mathematics at TIFR. In his speech on 1 January 1954 at the foundation stone-laying ceremony in Colaba, he described his reasons for emphasizing mathematics:

'. . . the scope of the Institute is not restricted to nuclear physics or physics. We have a strong school of pure mathematics which has built for itself an international reputation. The reason why we are so interested in pure mathematics is that it is only with the help of mathematics that one can understand today the complicated and subtle phenomena which nature reveals. On the other hand I feel equally that mathematicians must gain much from contact with physicists. What we call logic and mathematical thought are not reflexible things as the Greek philosophers imagined but they changed gradually with time, they changed and developed with the knowledge and understanding of the physical world. In this sense Karl Marx was righter than the Greek philosophers in that he pointed out that what we consider as logic and mathematical thought in its vigour developed with the knowledge and understanding of the physical world.'

This insight still remains valuable and it is important to maintain a dialogue between 'pure mathematics' and its applications not only to physics but also to biology, engineering, economics and other spheres of human activity.

Over the years, activities at TIFR steadily expanded to include fields such as nuclear physics, condensed matter physics, computer science, and later molecular biology and radio astronomy.

Bhabha's philosophy of institution-building had precedence in the Institute for Advanced Study at Princeton and the Kaiser Wilhem Institutes (now called the Max Planck Institutes) in Germany: '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'. Thus, the early team of eminent scientists at TIFR include K. Chandrasekharan (mathematics), R. R. Daniel, M. G. K. Menon, Bernard Peters, Devendra Lal (elementary particles and cosmic rays), R. Narasimhan (computer science), K. G. Ramanathan (mathematics), K. S. Singhvi (solid state physics), and B. M. Udgaonkar (nuclear and theoretical physics). One of the first people Bhabha had invited to join TIFR was S. Chandrasekhar of the University of Chicago. In spite of initial inclinations to accept the offer Chandrasekhar did not join TIFR.

In the early years the academic activity at TIFR was divided into two schools: The School of Physics and The School of Mathematics. In the School of Physics, bright young people were sent to various

K. Chandrashekaran, E. C. Allardice, Rustom Chowksi, Pandit Nehru and Homi Bhabha.

Raja Ramanna and Pandit Nehru.

From L to R: Bhabha and M. G. K. Menon during the visit of John Kenneth Galbraith; Bhabha and R. Narasimhan during the visit of John Cockcroft; Obaid Siddiqi.

From L to R: International Colloquium on Function Theory, 1960; Bhabha and Sarabhai with Cecil Powell and P. M. S. Blackett; Niels Bohr with Bhabha, J. R. D. Tata and Jamshed Bhabha.

western institutions like Berkeley, Caltech, Chicago, MIT, Rochester, Stanford for training and Ph Ds with eminent scientists. These included people like Yash Pal, S. S. Jha, Virendra Singh, E. C. George Sudarshan, G. Rajasekaran and others. Several of them returned to TIFR. Sudarshan who discovered the famous *V–A* law of beta decay, while still on leave from TIFR, unfortunately did not return after his degree at Rochester. K. Chandrasekharan trained the mathematicians M. S. Narasimhan and C. S. Seshadri who later went on to be the pillars of the School of Mathematics.

Obaid Siddiqui (Molecular Biology) and Govind Swarup (Radio Astronomy) joined in the early-sixties. Bhabha initiated these new areas when the right people came along.

TIFR was itself a hub of activity in modern science. Many distinguished scientists visited the institute, including Paul Dirac, Niels Bohr, Laurent Schwartz, Murray Gell-Mann, T. D. Lee, Carl Ludwig Siegel, Henri Cartan, P. M. S. Blackett, Cecil Powell, John Cockcroft, George Gamov, Bruno Rossi, S. Chandrasekhar, Hargobind Khorana, Harish Chandra and others. Important international conferences and schools were initiated in mathematics and high-energy physics.

TIFR and the atomic energy programme

In his speech on 15 January 1962 during the inauguration of the new buildings at Colaba, Bhabha reiterated the idea of the symbiotic relationship between TIFR and the atomic energy programme:

> 'The Atomic Energy Commission of the Govt 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 major projects. The Commission, on its part, gave substantial help to the Institute by providing funds for increasing its activities and for specialized equipment for nuclear research.'

The first step towards organizing research in atomic energy was the creation of a Board of Research on Atomic Energy that was constituted as a part of CSIR with Bhabha as its Chairman. On 26 April 1948, Bhabha sent a note entitled 'Organization of atomic research in India' to the then Prime Minister of India, Jawaharlal Nehru. In this note Bhabha wrote:

> 'The development of atomic energy should be entrusted to a very small and high-powered body composed of say, three people with executive power, and answerable directly to the Prime Minister without any intervening link. For brevity, this body may be referred as the Atomic Energy Commission.'

Bhabha emphasized that the proposed Atomic Energy Commission should have 'its own secretariat independent of the secretariat of any other ministry or department of the government, including the envisaged Department of Scientific and Industrial Research'. He also suggested that once the Commission was appointed, the existing Board of Research on Atomic Energy should be abolished. The Government of India accepted Bhabha's proposal within a few months after its submission.

With the promulgation of the Indian Atomic Energy Act 1948, the Atomic Energy Commission was formed in August 1948 with the following charter:

> 'To take such steps as may be necessary from time to time to project the interests of the country in connection with atomic energy by exercise of the powers conferred on the Government of India by the provisions of the Atomic Energy Act;
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> To survey the territories of the Indian Dominion for the location of useful minerals in connection with Atomic Energy; and
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> To promote research in their own laboratories and to subsidise such research in existing institutions and universities. Special steps will be taken to increase teaching and research facilities in nuclear physics in the Indian universities.'

The first Atomic Energy Commission had three members, with Bhabha as its Chairman. The first three things that Bhabha felt necessary for putting India's nuclear programme on a sound footing were: the survey of natural resources, particularly materials of interest to atomic energy programme; the nurture of strong research schools in basic sciences, particularly physics, chemistry and biology by providing facilities to and training up high-quality research scientists; and the development of a programme for instrumentation, particularly in electronics.

Homi Bhabha discussing the construction of the APSARA reactor in 1955.

In the initial years, TIFR provided a great deal of support to the Atomic Energy Commission by setting up the Electronics Division of the Atomic Energy Establishment at Trombay near Bombay. Groups working in other emerging fields

such as accelerators, microwave communications, software technology, and semiconductor technology were also set up at the institute.

But when Bhabha realized that technology development for the atomic energy programme could no longer be carried out within TIFR, he decided to build a new laboratory entirely devoted to this purpose. About 1200 acres of land was acquired at Trombay for this purpose, which formed the campus of the centre now known as BARC.

Aerial View of the Trombay Campus, later renamed the Bhabha Atomic Research Centre.

In retrospect, one wonders whether TIFR and the Atomic Energy Establishment would have benefitted each other more by being geographically contiguous. TIFR had been the cradle of the country's atomic energy programme; but as the two institutions continued to grow, although a small overlap of activities continues, TIFR and BARC charted their independent scientific trajectories.

The establishment of both these institutions owed a great deal not only to Bhabha's sweeping vision, but also to his early engineering training, his attention to detail, and his willingness to wait for results. At the annual meeting of the National Institute of Sciences of India (later renamed the Indian National Science Academy) in October 1963, Bhabha spoke at length about the challenges of setting up a scientific institution:

> 'I feel that we in India are apt to believe that good scientific institutions can be established by Government decree or order. A scientific institution, be it a laboratory or an academy, has to be grown with great care like a tree. Its growth in terms of quality and achievement can only be accelerated to a very limited extent. This is a field in which a large number of mediocre or second rate workers cannot make up for a few outstanding ones, and the few outstanding ones always take at least 10–15 years to grow.'

TIFR today

TIFR today is an autonomous institution funded mainly by the Department of Atomic Energy, Government of India. It is a deemed university and awards its own degrees. Its scientists conduct research in most areas of the basic sciences: astronomy, biology, chemistry, computer science, mathematics and physics. TIFR scientists are also involved in experiments across the world.

Over the years since its inception, TIFR facilities have been located in various parts of India: the Radio Astronomy Centre and the Cosmic Ray Laboratory at Ooty, the Giant Metre-wave Radio Telescope at Khodad near Pune, the High Energy Gamma-ray Observatory at Pachmarhi in Madhya Pradesh, the National Balloon Facility in Hyderabad, and the Gravitation Laboratory at Gauribidanur.

Besides these facilities, TIFR has specialized centres devoted to various subjects. The Homi Bhabha Centre for Science Education is located in Mumbai. The National Centre for Radio Astrophysics is located in Pune. The National Centre for Biological Sciences and the Centre for Applicable Mathematics are located in Bangalore.

Radio Astronomy Centre, Ooty.

Balloon Flight.

It is a tribute to the enduring foundations laid by Homi Bhabha at the institute that, in the year of the Bhabha birth centenary, TIFR is now planning to set up its second campus in Hyderabad. Another new initiative is the International Centre for Theoretical Sciences which will be set up in Bangalore.

A life cut short

Tragically, on 24 January 1966, while on his way to Vienna to attend a meeting of the Scientific Advisory Committee of the International Atomic Energy Agency, Homi Bhabha was killed in an air crash on Mont Blanc in the Alps.

His life, though brief, had been a full and accomplished one. He had once, in a letter to a friend, described the kind of life he wanted to live:

> 'I know quite clearly what I want out of life. Life and my emotions are the only things I am conscious of. I love the consciousness of life and I want as much of it as I can get. But the span of one's life is limited. What comes after death no one knows. Nor do I care. Since, therefore, I cannot increase the content of life by increasing its duration, I will increase it by increasing its intensity. Art, music, poetry and everything else that I do have this one purpose – increasing the intensity of my consciousness of life.'

Until his untimely death, Bhabha had lived exactly such a life. It was a life that symbolized achievement and leadership. Both scientist and artist, deeply interested and involved in art, music and architecture, with deep roots in India, he had

served his country like few others. As Indira Gandhi remarked in her tribute:

> 'The flower beds, the landscaping, the architecture of the buildings in Trombay, all bear witness to the keenness of Homi Bhabha's perception of colour, form and design. India will long cherish Homi Bhabha's memory, for he was deeply involved in her destiny and in the process of changing the texture and quality of her society.'

Above all, Bhabha's contributions were made on the strength of his scientific achievement. At the time of his death, he was Director and professor of theoretical physics at TIFR, Secretary to the Government of India in the Department of Atomic Energy, ex-officio Chairman of the Indian Atomic Energy Commission, and Director of the Atomic Energy Establishment at Trombay. He had founded two great research institutions and launched the country's atomic energy programme. In the words of J. R. D. Tata, Bhabha's 'wide-ranging vision, drive and genius (had) achieved in twenty years a lifetime's work'.

In his speech during the inaugural function of TIFR on 19 December 1945, Bhabha had described the role that he saw for science in our time:

> 'The pursuit of science and its practical application are no longer subsidiary social activities today. Science forms the basis of our whole social structure without which life as we know it would be inconceivable. As Marx said "Man's power of nature is at the root of history" and we have in our own time seen the history of the world shaped by those countries which have made the greatest scientific progress. Science has at last opened up the possibility of freedom for all from long hours of manual drudgery and today we stand at the beginning of an age when every person will have the opportunity to develop himself spiritually to his fullest stature.'

In the year of Bhabha's birth centenary, it is worthwhile to remember his vision of science in the modern age, as a way to true freedom.

In preparing this article I have generously drawn from the following sources:

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