*We publish below an article on Homi Bhabha which is slightly a different point of view from the usual one. Bhabha came back to India in July 1939 at about the age of 30. Since the War had broken out in Europe, he decided to stay back. He rejected the offer of the Chair in the Allahabad University (vacated by M. N. Saha). It is also said that he did not accept an offer to work in the Calcutta University where Saha had started nuclear physics research. He came to Bangalore to see the Indian Institute of Science and to meet C. V. Raman. It was a love at first sight. Raman convinced him that he should work in Bangalore. He joined as Reader and began research in theoretical and experimental cosmic ray and particle physics. Raman immediately proposed his name to the Fellowship of the Indian Academy of Sciences and to that of the Royal Society. He wrote to Dirac requesting him to second the proposal which he did.*

*I saw and met Bhabha for the first time in 1941 in Nagpur at the Annual Meeting of the Indian Academy of Sciences (Raman's circus as it was called). Bhabha gave two lectures — an honour which Raman usually reserved for himself. In introducing Bhabha, Raman said, 'Bhabha is a great lover of music, a gifted artist, a brilliant engineer and an outstanding scientist.' 'He is the modern equivalent of Leonardo da Vinci.' It is indeed a great tribute especially when it comes from one as Raman. Almost similar sentiments are expressed by Greenstein: 'In thinking of this man, the image perpetually rises to my mind of one of those great larger-than-life figures of the Rennaissance....'*

*— Editor*

# A Gentleman of the Old School: Homi Bhabha and the development of science in India

*George Greenstein*

Homi Bhabha was not in the habit of travelling alone. When he drove out to the Bombay airport one day on one of his many trips overseas, he took along a retinue: aides, associates, secretaries. The day was Sunday, but a few last-minute instructions might have occurred to him before boarding the plane.

Trained as a physicist, Bhabha was an administrator of astonishing ability, capable of pushing to completion the most gigantic, visionary of projects. He was founder and director of one of India's most admired research institutes, creator of its atomic energy programme, secretary to the government of India, chairman of numerous international agencies. It can be argued that much of modern science and technology in India owes its origin to this one man. His research work, on the other hand, was deeply abstract. His knowledge of mathematics was extensive, even compared to that of other physicists. In style his work was formal, refined, elegant—almost Mozartean in tone. I know of no other instance in which two such radically differing skills—that of a high-level administrator and a superior scientist—were combined in the same person.

A man who dined with Bhabha overseas on one occasion has reported that Bhabha had brought along an aide whose sole function appeared to be to pay the bills. It would not have been seemly for a gentleman to be seen dipping his hand into his pocket, and, above all else, Bhabha was a gentleman. Born to a wealthy Parsi family in 1909, he was aristocratic, international in outlook, and a man of exquisite refinement and taste. In every major capital of the world, he had his favourite hotel. He knew who was singing at La Scala. He knew what was showing at the Tate.

Homi Bhabha's education was select and Western in style. His father was a barrister, one grandfather a government official and a Companion of the Order of the Indian Empire, another a well-known philanthropist. His family was related by marriage to the multi-millionaire Tata family of industrialists. In the Tata household across the street, Bhabha would hear as a boy discussions of giant, long-term projects relating to the industrial development of India. Back home in his father's panelled study was a remarkable collection of books and Western classical music recordings. To these records Bhabha and his friends would listen in hushed, reverent silence. A photograph of Bhabha in these days shows an adolescent dressed in a dark suit and tie, reclining in a formal pose inan over-stuffed armchair. In his lap is a book on El Greco.

It was inevitable that such a youth would be sent to England for his advanced studies. Bhabha went to Cambridge University (the college he attended there had not long before received a major endowment from an uncle). Although his father wanted him to go into mechanical engineering, Homi wanted to do mathematics. A compromise was reached in which the elder Bhabha agreed to finance Homi's mathematical studies if he started by getting a solid grounding in engineering. Homi got his First in engineering in 1930 and then went on to get a second First in mathematics one year later.

Through college he cut a wide swath. A fellow student who went on to a highly distinguished career at Cambridge has frankly confessed to me that he had felt positively overawed by his friend Homi in those days. Bhabha collected prize after prize for his mathematical abilities. An accomplished artist (his

paintings and drawings have since been published), he designed the stage sets for a Calderon play for a Mozart opera. He studied harmony and counterpoint, and he wrote a symphony in the classical style. He showed up at a department party dressed as a Spanish grandee. He wrote a skit:

Shakespeare Orders Lunch
SHAKESPEARE: What ho, without!
SERVANT: My lord.
SHAKESPEARE: Full twice or thrice
Have I, with lusty and barbated
speech
Sought to affront the portals of
thine ears.
SERVANT: Pardon, sweet lord.
SHAKESPEARE: Tis granted. Look you
now,
The time approaches when my corporal
frame
For lack of good grows incorroborate;
Fetch me my specs, that I may
make perusal
Of whatso'er of viandry is set
For our engorgement···.

After getting his Ph D, Bhabha remained at Cambridge in a research position. He worked on cosmic rays. High-speed subatomic particles impinging upon the Earth from space, cosmic rays were the most energetic objects known in those days—and still are, their energies greatly exceeding even those produced in the largest particle accelerators. Their origin is poorly understood, although there is of course no lack of suggestions. But even in the 1930s it was clear that they must have been under way for thousands, possibly millions, of years before encountering the Earth.

Remarkably, cosmic rays appeared to arrive not singly as individual particles, but in sudden and exceedingly brief showers in which great numbers were detected at once, almost as if they had been produced and had travelled through space in groups. But this could not be, for the showers were known to consist of particles of differing velocity. In transit the more rapid particles would have outstripped the slower, elongating the hypothetical group and failing to produce the observed burst-like shower.

Things became clearer when a series of experiments actually succeeded in documenting the process. In perhaps the prettiest of the experiments, a horizontal metallic sheet was inserted into a cloud chamber, the chamber recording the passage of each ray as a track. A photograph would reveal an individual track impinging upon the sheet from above—but large numbers of tracks fanning outwards beneath in an inverted cone. Within the sheet each particle was multiplying into a spray. Presumably the same process was going on in the upper atmosphere, the individual cosmic rays spawning groups that arrived at the ground as showers.

It was as if a flying golf ball, upon striking the ground, spontaneously transformed into a collection of golf balls. Bhabha took the point of view that the cloud chamber photographs were providing explicit documentation of Einstein's famous relation between mass and energy, $E=MC^2$. The energy of motion of the impinging particle was turning into mass in the form of more particles. A proper treatment required a union of Einstein's theory with quantum mechanics, the theory of subatomic processes, that had recently been achieved by the Cambridge physicist P. A. M. Dirac. Bhabha and a colleague worked out a complete theory of the production of cosmic ray showers according to Dirac's theory.

The picture they evolved was that of a rapid and escalating back-and-forth interchange between matter and energy. The process began when a single cosmic ray collided high above the surface of the Earth with a molecule in the atmosphere. In the collision a photon would be produced—pure energy: a minute burst of light. The photon, now accompanying the deflected cosmic ray, soon itself interacted, transforming into a pair of particles. The single incident cosmic ray particle had become three. Each of these subsequently collided with another air molecule, producing its own photon, and the process continued in a snowballing cascade—thus, the shower.

Dirac's theory is aesthetically exquisite, but it is couched in a complex mathematical language, and the calculations it necessitates are daunting. Since the 1930s, various shortcuts have been discovered, smart tricks obviating the need for some of the more laborious slogging. But these were not available in those days. People used to lay out oversized sheets of wrapping paper on tables and fill them with their calculations.

The urbane, charming Bhabha could not have chosen a more unlike mentor than Dirac with whom to work. By all accounts Dirac was an austere, otherworldly individual. He was an uncommunicative soul and hardly ever told anybody what he was working on. His theory involved the mathematical symbol $<1\ 1>$ called a "braket," of which the two halves $<1$ and $1>$ also held significance. Dirac called them "bra" and "ket", respectively, and was apparently genuinely astonished to learn that the first of these terms also carried another meaning. (He was married at the time.) The story is told that a colleague once tried to give him a book with which to while away the hours on a long train journey, but Dirac refused the gift, explaining that reading "interfered with thought."

The cascade theory of cosmic ray showers was almost too successful. It accounted beautifully for their observed properties but failed to account for the fact that not all cosmic rays produced them. In reality, however, it was known that a second component of cosmic rays existed that could penetrate great distances, even through solid lead, without multiplying into a shower—entirely impossible according to Bhabha's calculations. For a time the possibility was even bruited about that Dirac's theory failed in some essential respect.

Bhabha took an alternative point of view and proposed instead that high in the atmosphere an elementary particle unknown to physics was being produced in cosmic ray collisions. He showed that, if this new particle possessed a particular mass, roughly midway between that of the electron and the proton, it would fail to produce a cascade. Subsequent efforts succeeded in confirming his guess by directly observing the hypothetical particle: it was named the muon.

It remained mysterious, however, how these muons could have been discovered in the first place. Muons were known to be unstable: laboratory experiments showed them to decay quite rapidly. So rapid was this decay that they would not travel far from their point of creation in the upper atmosphere before disintegrating. In particular, they could not possibly reach the ground. But they were reaching the ground: obstinately, muons persisted in showing up in

ground-level detectors.

In response to this conundrum, Bhabha thought of the cosmic ray muon in a new and unusual way—not as a previously undiscovered elementary particle, but as a tiny, rapidly moving clock. Each tick of such a clock carried it closer to the moment of its decay. But, according to Einstein's theory of relativity, clocks in motion ticked more slowly than those at rest.

It had been an astonishing proposal when Einstein made it just after the turn of the century, and it remains so today. Einstein's argument—one of deep beauty, profound in its implications and breath-taking in scope—is perhaps the most perfect instance I have ever seen of the power of abstract reasoning. But no familiarity, no study has ever succeeded in accustoming me to such an apparently bizarre notion.

The slowing down of time is not great for clocks travelling at the relatively slight velocity of an automobile, or even of a spacecraft. But, according to Einstein, objects travelling at velocities close to that of light would exist in a kind of suspended animation: lugubriously ticking, each second requiring hours, each hour months ··· a curious combination of blazing speed and eerie stillness. Bhabha recognized that cosmic ray muons constituted just such high-speed "clocks" and that, if relativity was correct, their rate of ticking would be slowed in such a manner. In this way he accounted for their anomalous survival during their passage through the atmosphere down to the ground.

It was, indeed, a double triumph, for when Einstein formulated his elegant theory there had not been the slightest possibility of testing it experimentally. To do so would have necessitated accelerating some clock to impractical velocities. For decades, then, the notion of the slowing down of time remained in a kind of limbo; widely accepted, yet unproven. Bhabha's insight provided the first experimental test of Einstein's prediction.

In 1939 Bhabha returned to India on vacation. While he was there the Second World War broke out. After thirteen years at one of the world's centres of research, he suddenly found himself stranded in a relative backwater. He spent the war at an institute in Bangalore. There his work, in the assessment of his colleague and friend M. G. K. Menon, altered in character, becoming more abstract, less concerned with application to observed phenomena, and more taken up with questions of internal coherence and formal elegance. In later life Bhabha commented that this work, though it earned him less recognition, had, in the long run, given him the deepest satisfaction.

During this time a change also occurred in Bhabha himself, one which I find quite amazing. While at Cambridge he had given every indication of intending to remain there forever. Nothing I have learned of him gives the slightest hint of any desire in those days to return home. By the end of his exile during the war he had received a number of job offers from the West. But he rejected them all. For the rest of his life Bhabha never accepted a permanent position abroad.

By the end of the war Bhabha, formerly more British than the British, had become Bhabha the patriot, builder of indigenous science in India. His decision to remain in India went hand in hand with a decision to create a new scientific institution.He did not accept a job at some research centre—he built his own. In a letter to one of the Tata family's charitable trusts, he proposed the creation of an institute for fundamental research.

It is difficult for a Westerner to appreciate the context in which this decision took place. India at the time boasted of a number of superior scientists who had been honoured by the Nobel Prize or membership in the Royal Society, and the institute at which Bhabha spent the war years was a fine one. But these scarcely added up to a national environment conducive to the practice of science. Indeed, to an enormous degree, Indians regarded their country as inferior in matters pertaining to modern development and, as a matter of course, looked to the West for inspiration. Bhabha was not alone in having gone overseas to college. Endowed professorships at major universities often actually required the holders to have been educated abroad. So, too, with the Indian Civil Service, which insisted that its members be trained in England. Even after the independence of India, the presumption of European superiority remained. The first science adviser to the prime minister of India was British, and to this day Indian scientists prefer to publish in Western, not Indian, journals. In such a context, the decision to create a major research centre carried a particularly charged significance.

What can account for Bhabha's change of heart during the war years? In a letter to a relative he wrote of his duty to stay in India, but I find this explanation hard to credit. His actions do not strike me as those of a person acting from a grim sense of duty. Rather they strike me as the vigorous, contented acts of one who has suddenly found a sense of purpose for himself.

Perhaps when he returned home Bhabha found within himself an aptitude for institution building, for administration on a grand scale, that never could have fluorished in such a country as England, whose scientific institutions were already well in place, but which was free to flower in the relative vacuum of India. Perhaps, too, he found himself swept up in the exhilaration of a great moment. He had been too young when he left India to have taken part in the independence movement. But by the time he returned it was obvious that independence would not be long in coming. It must have been a heady time, a time in which everything seemed suddenly possible.

V. S. Naipaul, born in Trinadad and of Indian ancestry, has written of his childhood: "I felt [then] that the physical conditions of our life, often poor conditions, only told half the story: that the remnants of the old civilization we possessed gave the in-between colonial generations a second scheme of reverences and ambitions, and that this equipped us for the outside world better than might have seemed likely."

The Tata Trust responded favourably to Bhabha's proposal for the creation of a new research centre, and in 1945 the Tata Institute of Fundamental Research was opened. In the early days it was housed in an elegant mansion owned by Bhabha's aunt. She remained in residence, occupying half the house, and she mothererd the scientists shamelessly, serving Homi tea in her best china, allowing the staff use of her kitchen and servants, and laying on a grand feast on Parsi New Year's Day. Bhabha's office there was the room in which he had been born. Within a few years the Institute outgrew these quarters, and it

moved to the former Royal Bombay Yacht Club, a fine old Victorian pile on the waterfront complete with turrets, porches, and gardens. In the days of British rule, no Indian had been allowed inside the building in other than a menial capacity: now the staff was housed in what had been the servants' quarters, and the library occupied what had been a formal ballroom. Funding for the Institute rose at an extraordinary rate, increasing by 30 per cent each year during the first ten years. By the mid-1960s it employed twelve hundred people and had moved yet again.

The Institute's money has come from a combination of private and public sources, but one potential donor has been conspicuous only by its absence: the University of Bombay. One might have thought that this university would have jumped at the chance to encourage a strong research presence on its doorstep. But throughout India the development of science and technology has taken place largely outside the university framework.

With rare exceptions, conditions at Indian universities are inimical to the practice of science. During my visit to India in preparation for this article, I visited a major, publicly funded state university and was shocked by the atmosphere of decay I found there. The physical plant can only be described as demoralizing: paint peeling from the walls, corridors filthy, office windows broken, an inner courtyard a mere weed-infested vacant lot. As for the faculty, most made not even the slightest pretense of keeping up with advances in their field, let alone participating in research, and were comfortably coasting downhill towards retirement. Those few who did engage actively in their professions did so in nearly complete isolation and with the most primitive equipment. Technical help was essentially nonexistent: one man with whom I spoke referred to the technicians as bureaucrats whose only function was to insure that work orders be accompanied by the proper paperwork, but who were utterly incapable of carrying out the most rudimentary tasks. The laboratory equipment would have made a Western high school science instructor recoil in horror. I was awed—and shamed—by the drive, the intensity of commitment, that enabled these people to turn out frontline research in the midst of such appalling conditions.

The Tata Institute of Fundamental Research, in sharp contrast, is internationally recognized as a centre of excellence. India's first computer was built there; its first nuclear reactor would never have been constructed without aid from the Institute scientists. People there work in conditions an Indian university professor would find positively sybaritic, and its research programme is competitive with that of any Western institution. The Institute occupies a sleek, modern complex of buildings set amid perfectly tended formal gardens. Paintings adorn the walls, sculpture the entrance foyer. From office windows the white towers of the Bombay skyline rise across the bay.

As I walked the corridors there one day, it occurred to me that Bhabha's choice of architectural style for his Institute might be significant. Not only in its research would the Tata Institute fit in well at, say, the Massachusetts Institute of Technology, but its buildings would look at home there, too. Why had he adopted so resolutely Western a tone and avoided the slightest reference in its construction to any Indian architectural motifs?

On the day I arrived in India, the newspaper carried an article describing an address given before a science congress by Prime Minister Chandrashekhar. In his speech, Mr Chandrashekhar pressed the delegates to cease pursuing what he termed Western-oriented science and return to a more Indian mode of research. Was he right? Is science an exclusively Western phenomenon? It is difficult to express in words the sense of cultural dislocation of an absolute and fundamental alienness, that I experienced throughout my stay in India. Much of the time I felt as if I had entered a different universe. But at the Tata Institute, I felt the ease and comfort of one who has returned home. For all his claims to be developing indigenous technological expertise, was Bhabha in reality merely attempting to impose foreign ideals onto an uncongenial environment?

Inside India today there exists a group of people who would agree with the prime minister. My guess is that these people are primarily motivated in their opinions by sentiments of nationalism—by the wish that the country would abandon modern technological and scientific development and return to its ancient glories. In America as well, one can point to people who would agree with Chandrashekhar—those who distinguish between the wisdom offered by science and the wisdom offered by Eastern meditative techniques, as well as those who regard science as nothing more than a form of political domination.

None of these people would take any comfort from those with whom I spoke in India. During my stay there, I raised the point of the prime minister's speech with every person I interviewed—a mixture of scientists and foundation executives. Without exception, each of them rejected his distinction utterly. There was no such thing as Western science or Eastern science, they argued—only science. "I never regarded myself as learning the methods of the West when I was a student," one scientist told me. "I was simple learning my trade."

The prime minister's speech may have amounted to nothing more than a concession to popular sentiment. But my guess is that his point may indeed have a certain validity, if not with regard to the nature of science then with regard to the role that science and scientists play in Indian society. The tourist who remains in its cities will return home with an utterly distorted image of this country. Three out of four Indians live not in these modern, industrialized centres but in tiny farming villages. In these villages, few homes possess either running water or electricity. The predominant means of transportation is the bullock cart, and farming techniques have altered but little in centuries. The gap between the inhabitants of such a village and an Indian scientist is overwhelmingly greater than that between this scientist and his Western counterparts. To these people, the activities of a scientist must appear as incomprehensible as those of a Martian.

Bhabha argued for the funding of fundamental research in India by invoking the "trickle-down" theory of development: that the discoveries of research ultimately would emerge as benefits to the society as a whole. This happens in the West all the time—to-day's great

scientific discovery becomes tomorrow's gadget, obtainable for a pittance at Kmart. While these benefits also accrue to India's middle- and upper-class population, economically dominant but small in number, they never touch its villagers.

For these people, the fruits of technological advance are of a wholly different order, and they have nothing to do with advance-guard research. The most impressive example I know of is the Satellite Instruction Television Experiment. Under this so-called SITE programme, the government gave each village a television set, and educational programmes were beamed nationwide via a geosynchronous satellite. Care was taken that these programmes concerned themselves with technology appropriate to village life: crop rotation, water purification, and the like. Programmes we might watch on "Nova" were sedulously avoided. The antennas by which these satellite broadcasts were received themselves were a triumph of appropriate technology—a mere few wires suspended from poles stuck in the ground. The SITE experiment reached twenty thousand villages and went on for a year; its place has since been taken by a series of half-hour broadcasts each night. This modest, low-technology enterprise has done more to benefit the bulk of India's population than any amount of "Western- style" science.

In saying this, I am far from arguing that science should not be pursued in a country like India. I am saying that its justification must involve arguments of a different order, and I would argue that the real justification for science is the same in India as in the West: the benefits of learning something of the true scheme of nature and of our place in that scheme. These are enough for me. They are enough for most scientists: I have yet to meet a one who works for the good of humanity.

"Homi was a distant alp. One did not presume to climb it."

In conversation after conversation with those who knew him. I heard in people's voices appreciation and respect for Bhabha, but no friendship. He did not have personal friends at the Tata Institute. Throughout his career, there was always an element of social distance between him and the people with whom he directly worked. I think it is fair to say that, in some fundamental sense, Bhabha did not understand the life of the ordinary Indian. His wealth, his aristocratic upbringing set him apart. In designing the Institute, he took care to get an espresso machine for the cafeteria, but he allowed plans for staff housing to languish for years: this in Bombay, where real-estate prices are among the highest in the world. He was not one to hang around the corridors chatting—most people there hardly ever saw him. An air of fastidiousness about him, a formality, effectively forbade casual contact.

At one point Bhabha circulated a memo to the Institute staff dealing with its buildings and grounds. It makes for interesting reading:

> Each member of the staff should have a sense of personal pride in these buildings, which have been given for his use, and it is his duty to take personal interest in their proper maintenance and to see that he himself uses them in such a way as to maintain their quality and cleanliness.... A member, who sees another not using the buildings properly, should draw his attention to the proper conduct in such matters. If any person continues to misbehave, the matter should be reported to his superior.

This is not a memo to grown men and women: it is a memo from a father to his children.

The story is told that a group of scientists who had recently arrived in India for a conference found themselves transported about the country by bus while Bhabha himself travelled separately in his private limousine. One of the conferees is said to have been so disgusted that he left the next day. On another occasion, Bhabha escorted a visiting lecturer to the hall where the visitor was to deliver his talk. They found every seat taken. Bhabha gestured to the people sitting in the front row, each one of whom rose and vanished, leaving Bhabha to attend the lecture in solitary splendor in that row. The first of these stories has been disputed, and I cannot vouch for its accuracy. But Bhabha does seem to have been the sort of person about whom such tales accumulate.

With only one exception, every photograph I have ever seen shows Bhabha dressed in a Western suit (the exception is the inauguration of India's first nuclear reactor, for which he wore national dress). His outlook was international, not Indian. My guess is that most of the people he regarded as his equals lived not in India but in the West. Each was an acknowledged expert in his field, and Bhabha was continually travelling abroad to drop in on them. There he would learn of the latest advances and upon returning home would fill everyone in on the news.

By all accounts, Bhabha was an extraordinarily invigorating person to be around. Everything seemed possible in his presence. His ability to secure money was legendary. Roadblocks that would have defeated another were surmounted with ease through his personal connections. Some new and marvellous project was always in the offing. At one point he brought in a biologist to head a new effort in that direction (not bothering to tell anybody until after the position had been offered). Upon arriving, the biologist had a conference with Bhabha in which he was asked now much space the programme would require. "Oh, maybe five thousand square feet," the biologist replied. "Nonsense," Bhabha responded. "You'll run out of that much space in no time at all." So he built him a whole new building.

In matters of research, Bhabha might leave his scientists alone, but when it came to the Institute's physical layout he snooped about endlessly. He pestered the firm of architects that designed it over the tiniest of details. He worried about the location of the tonets and would have half-completed walls knocked down if their location did not suit him. When he got word that a rare tree was scheduled to be cut down at a nearby botanical garden, he arranged for the thing to be dug up and transplanted to the Institute grounds.

A great patron of the arts, Bhabha through his wealth amassed a fine collection. Several well-known Indian artists had in fact been discovered by him. Universities collect art and hide it away in museums: Bhabha set his collection out for view in the corridors and offices of the Tata Institute. Upon purchasing a new painting, he would experiment with various locations, hanging it one place and another, asking the advice of friends. He did not merely want the Institute to be a world centre of research—he wanted it to be

a work of art, and he fussed over it endlessly as the proud father he was. Perhaps in this regard it is significant that he never married.

Bhabha took everything he did seriously. He was an artist of some talent. His interest in architecture was deeply informed, and he would discourse at length on the architectural principles expressed at Versailles, on the facade of a famous mosque, or on the Persian concept of the apotheosis of water that lies at the heart of Moghul garden design. He published an article on Leonardo da Vinci; he played the violin; he raised rare plants. Dinner parties at his penthouse apartment were elegant affairs of good food and fine wines. The guest list was carefully composed; the conversation, invariably scintillating, would range from an interesting new artist he had recently discovered to government plans for the construction of a giant hydroelectric plant, from the theories of Einstein to the ideas of Heidegger.

Both in his research and in his public policy work, Bhabha was fascinated all his life by energy. It is indeed a remarkable concept. At the time of the scientific revolution, energy was very poorly defined. Often confused with force or momentum, the term carried little more than a loose sense of "oomph." Newton's *Principia* pays little attention to it—Newton formulated his theory not in terms of energy but of force. Not until the nineteenth century and the development of thermodynamics did energy come into its own, achieving the status of an incorporeal, unseen, and yet objectively real attribute of the physical world.

The more time has passed, the more the concept has broadened far beyond the intentions of its creators. Nineteenth-century physics recognized three forms: the potential energy of a soaring hawk, the kinetic energy the hawk attains by folding its wings and diving, and the chemical energy of the food it seeks. Twentieth-century physics had added more forms. We now speak of the energy of light; of massless, chargeless neutrinos; and even of empty space. But throughout all its transformations and extensions, the term *energy* has retained the essential connotation of life, of vigor. Blake said it best: "Energy is eternal delight."

In his letter proposing the creation of the Tata Institute of Fundamental Research, Bhabha brought up an even newer form: that of the atomic nucleus. "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," he wrote. It was a prophetic statement, coming before the bombing of Hiroshima and the first public announcement of the existence of atomic power. It is significant that in his proposal Bhabha explicitly linked India's need for pure research with its need for energy.

Throughout Bhabha's career, he regarded the question of energy as central to the problem of national development. "No power is as expensive as no power" was how he liked to put it. In the mid-1950s he instituted a programme of development of nuclear power in India. At the 1955 United Nations Conference on the Peaceful Uses of Atomic Energy, of which he was president, he gave his reasons.

Bhabha's address before this conference is a remarkable document. It begins by dividing the range of history into three broad epochs, each distinguished by its pattern of energy use. The first, pre-industrial, epoch drew its energy from muscle power. He emphasized that

> A man in the course of heavy physical labour in an eight hour day can hardly turn out more than half a kilowatt-hour of useful work.... [T]his is to be compared with the rough figure of twenty kilowatt-hours or more of energy per person which is daily utilized in the industrially advanced countries today. It followed that a high level of physical comfort and culture could only be enjoyed by a small fraction of the population by making use of the collected surplus labour of the rest. It is sometimes forgotten that all the ancient civilizations were carried on the muscle power of slaves or of a particular class.

The second epoch was the industrial, which allowed a greatly increased level of power consumption—but only in certain nations. Bhabha argued that reliance on conventional technology would forever prevent the developing nations from attaining the level of energy use enjoyed in the West. India's percapita energy use amounted to a small fraction—the figure is one-sixtieth today—of our own. Were India to increase its level of consumption to match ours, the country would exhaust its coal reserves within a decade. Bhabha's point was quite general: if the developing nations were to reach the level of energy use enjoyed by the developed ones, the required increase in world power generation could not be provided by ordinary means—hence the need for nuclear power. "The acquisition by man of the knowledge of how to release and use atomic energy must be recognized as the third great epoch in human history."

I found it a sad and ironic experience to read over the proceedings of this conference. People were so optimistic that nuclear energy, having devastated two cities, might now become the godsend that would resolve at a stroke humanity's deepest problems. Everything seemed possible in those days: a dramatically increased standard of living for all, the banishment of hunger, a cure for cancer. So august a periodical as *The Old Farmer's Almanac*, ever the barometer of popular opinion, referred to 1951 as Atomic Year Six.

At Trombay, a twelve-hundred-acre plot of land across the harbour from Bombay, Bhabha directed the construction of Asia's first nuclear reactor. It was an extraordinary effort, requiring the development of much technology new to the country—and all the more so in that, with the sole exception of the purchase of fuel elements from the United States, it was built entirely indigenously. While most European nations were purchasing their reactors from the United States, India built its own.

Throughout Bhabha's career, the technological expertise for which he pressed was a purely indigenous one. He used to say that if an item of equipment was imported from abroad, all one got was that particular instrument. But if one built it oneself, an all-important lesson in expertise was learned as well. In the long run, this policy contributed immeasurably to the creation of a technical base in India. But it drastically slowed things down.

The construction of the Trombay reactor, and indeed the entire development of science in India, represents a triumph of extraordinary magnitude. Steps that would have been trivial in the

West became time-consuming excursions into research and development. The most humdrum instruments—things one could buy off the shelf at Radio Shack—had to be built from scratch. But this required a network of supporting technology that was absent. A Western scientist who needs a particular piece of, say, laboratory glass will order it from the glassblower and can expect to have it within days. No such service was available to Bhabha's engineers: in the early years of the Tata Institute, he was forced to locate a promising glassblower and ship him all the way to England for training. The difficulty was that this man, lured by the superior facilities available in the West, might very well never have returned. In this instance he did, but a newspaper item during my stay in Bombay mentioned that every single graduate of the Indian Institute of Technology this year had chosen to emigrate.

India is a nation of chaos and of numbing, stifling bureaucracy. An item of foreign equipment imported from abroad, such as the Trombay fuel elements, can be held up for months at airport customs. The scientist who shows up at the airport, seeking to pry his stuff loose, will find himself caught up in a scene of unimaginable confusion. Hordes of people mill about aimlessly: others squat motionlessly in the middle of the room, gazing remotely into the distance and seemingly resigned to spending days there. Long lines queue up before sullen, uncommunicative officials: taking his place in one, the scientist will spend hours as it inches forward, only to learn upon reaching its head that he had chosen the wrong line or that his paperwork is not in order. Paint peels from the walls; illumination gleams weakly down from the occasional naked neon tube.

The engineers who built the reactor at Trombay worked at times around the clock. No late-night transportation was available to take them home, nor was food available at the construction site. Bhabha wished to provide these engineers with a car and food from a nearby restaurant. But both were forbidden by government regulations. He had to go all the way to the prime minister himself on this one.

So simple a matter as getting from here to there can be a daunting undertaking in India. Airplanes and trains are often booked to capacity for weeks in advance. As for travel by road, it is at best an adventure. Buses are jammed with hordes of people oozing out of windows and perched upon the roofs. They share the road with cars, trucks, motor scooters, bicyclists, bullock carts, camel carts, and pedestrians (the sidewalks are impassable). In one spot three men shove along a cart piled high with goods; in another a bullock lies motionlessly in the very middle of the road. A monkey darts across the street; drivers lean upon their horns.

Recently an Indian academic of my acquaintance spent a sabbatical leave in America. A friend took her driving on some errands. At one point the two found themselves whizzing smoothly along on a superhighway. After a period of uneventful silence, the visitor turned and addressed her friend. "Tell me," she asked, "when you drive in the States, what do you *think* about?"

There is not the slightest doubt in my mind that Bhabha would never have achieved what he achieved had it not been for his aristocratic background and personal connections. Coming as it did from a member of the family, his letter to the Tata Trust proposing a research institute must at the very least have received special attention. In leapfrogging over the bureaucracy, who he knew mattered far more than what he knew. When a group of Bhabha's people building a radio telescope encountered difficulties in acquiring an appropriate site, a personal call to a state minister of industries cleared up the problem. When Bhabha got wind one day of a plan to construct a naval dockyard in his Institute's front yard, he used his personal connections to defeat the project, salvaging the view of the harbour.

Bhabha's most important personal connection was Jawaharlal Nehru. The two had met as young men and personally liked each other. Both were of aristocratic families, had grown up in circumstances far removed from that of the average Indian, and both had spent long periods of time in the West. In later life they made every effort to meet regularly. Bhabha's correspondence with Nehru is courteous, formal, affectionate. He always addressed the prime minister in writing as "Bhai," a term that might be translated "elder brother".

My Dear Bhai,

I returned to India yesterday after a 12-day halt in London for the Tercentenary Celebrations of the Royal Society and a 2-day halt in Paris. I attended two [lectures] and found them most stimulating. It is remarkable how by dint of immense hard work by many outstanding people one has now been able largely to reconstruct the chemical structure of the biological molecules of which living substances are made...

My Dear Bhai,

I returned from Europe on Tuesday the 23rd June after a brief but very full trip.

I enjoyed the two days I spent in Cambridge in connection with the conferment of an honorary degree on me.... I stayed in Cambridge at the Master's Lodge in Trinity as the guest of Lord Adrian. This was evidently a particularly good year for roses. I have never seen such a profusion of beautiful roses, as was to be found in his garden at the back adjoining the river. The two days in Cambridge, although very hectic, were most refreshing.

And from Nehru:

My Dear Homi,

So you are back after collecting more honors! I liked your speech at the Cambridge Luncheon. I am glad you are staying at Bangalore to do some quiet work....

In 1959, at an address before an international Planned Parenthood conference, Bhabha proposed a solution to India's population problem. He called for a programme of research aimed at developing a substance that, when mixed with rice, would have the effect of reducing fertility by 30 per cent.

Bhabha was fully aware that his proposal would arouse opposition, but I think it is fair to say that he had little respect for that opposition. He understood perfectly well that people would suffer feelings of invasion under such a programme, yet he regarded those feelings as not particularly important—as no more than an unfortunate stumbling block standing in the way of his programme's implementation, rather than a basic flaw in its conception. It never seemed to have crossed his mind that children are the only form of social security that exists in rural India, that sons who will care for them in old age are all that stands between ageing villagers and starvation. It is characteristic that Bhabha's approach to the

problem of population — of any social problem — took little account of social realities.

Bhabha thought instead in terms of research. He had an unbounded faith in the power of science as an instrument of social change. The problem of national development was for him solely a problem of the development of modern technology. At the time of his death, he was working on a survey of India's electronics industry, ranging from the most inexpensive radio to the most sophisticated silicon chip. He formulated policies to protect its vast deposits of thorium, used in nuclear reactors and medical technology, and he inaugurated the Indian space programme.

Control of science in India is highly centralized, and its directors are largely answerable only to themselves. Toward the end of his life, Bhabha accumulated enormous powers. He was director of the Tata Institute of Fundamental Research, director of the nuclear reactor complex at Trombay (renamed the Bhabha Atomic Research Centre after his death), secretary to the government of India in the Department of Atomic Energy, and as such also ex officio chairman of India's Atomic Energy Commission, and chairman of the Scientific Advisory Committee to the Cabinet. In the year before his death, the budget under his direct control amounted to 115 million rupees — more than 6 million dollars at the present rate of exchange. On the international scene he was president of the first United Nations Conference on the Peaceful Uses of Atomic Energy, chairman of the Union of Pure and Applied Physics, and chairman of the International Atomic Energy Agency.

In thinking of this man, the image perpetually rises to my mind of one of those great, larger-than-life figures of the Renaissance: laying out plans for a new city one day, waging war on the next, writing a sonnet on the third. When the International Atomic Energy Agency was created and he was named its director, Bhabha established the headquarters in Vienna at least in part because of that city's cultural life. A visit to London for a meeting of the Royal Society would be combined with a meeting with a government minister; while in Chicago for a conference with the director of a giant hydroelectric plant, he might drop in on a well-known art collector.

Three quotations from Homi Bhabha's writings illustrate his range:

> Art, music, poetry, and everything else that I do have this one purpose — increasing the intensity of my consciousness and life.

> [The Canadian–Indian nuclear reactor] project will have to be handled by the Department of Atomic Energy, not only at the technical level but at the inter-governmental level, and the Agreement will have to be signed on behalf of India as the Secretary of this Department... unless this action is taken, all inter-governmental correspondence will have to be routed through the Department of Economic Affairs.

> The permanent things in nature are certain generalized concepts like energy, momentum, angular momentum and electric charge, which are always conserved, while the actual elementary particles themselves are but the transitory embodiments of their metamorphoses.

Bhabha died in 1966 in an airplane crash on a trip to Europe. The news reached India just as Indira Gandhi was being sworn in as prime minister. A postage stamp was issued in his honour. The first day cover shows him brooding mildly over Trombay, his nuclear city; beside him is an artist's palate, and beneath him the Ode to Joy theme from Beethoven's Ninth Symphony

Many thanks to Kannan Jagannathan for much assistance with this work. I am happy to thank S. Chandrasekhar for help and J. J. Bhabha, R. M. Lala, J. Maddox, D. K. Malegamvala, N. Mott, R. Narasimhan, D. Shoenberg, O. Siddiqi, V. Singh, B. V. Sreekantan, and B. M. Udgaonkar for having taken the time to grant me the interviews upon which this article is based. The travel that made this project possible was financed by a grant under the Amherst College Research Awards Program.

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