JRD Tata - his influence on science in the first 4 decades of independent India

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I stand here in awe and humility delivering one of the lectures in this series in honor of Bharat Ratna J. R. D. Tata, who was amongst the greatest that India produced in the 20th century. I knew a great deal about his achievements, but I did not know him personally. However, I had the privilege of seeing him at close quarters on three occasions. So, you may ask me why I agreed to take on this task. I have my clear reasons to accept this task, beyond just being a prey to my ego of accepting this most honorable venture.

To hasten my defense, I would like to state that I owe my scientific career itself to the Tata Institute of Fundamental Research (TIFR), which I joined in 1949 when it was located at the Peddar Road, just two years after it was set up there.. At that time its total staff strength was the ballpark of a dozen. Today TIFR stands as an unique internationally recognized research institute, working in diverse fields such as astrophysics and biophysics. JRD Tata encouraged Homi Bhabha to build and grow this institute in a response to a letter by him dated 19th Aug. 1943, seeking to establish an Institute of Fundamental Research in India in the fields of mathematics and physics, including nuclear physics.

As a result of the unconditional support given to Homi Bhabha, the TIFR was established in June 1945 in the Indian Institute of Science at Bangalore. It was translocated later on to Bombay, and gained international recognition in the fields of mathematics, cosmic ray physics, theoretical physics and biophysics. The TIFR also served as a cradle to the highly successful program of Atomic Energy in India.

Today, science is wide spread in India. We have a large stock of highly trained scientists in all disciplines of science. We have several of distinguished Science Academies in India. It is well recognized that the biggest change in the scientific landscape of India occurred only after it gained independence. Prior to 1900, science was carried out in a few places: in Universities, in Surveys of Govt. of India, and in the Association for the Cultivation of Science. The unique scientific institution, the Indian Institute of Science at Bangalore was born on 27th May 1909, as a result of Jamshetji Tata's initiative to build an institution for scientific research. It remained as a teaching institution until Raman arrived in 1933. Homi Bhabha's arrival at the institute opened up research in novel fields: field theory and the nature of high-energy nuclear interactions produced by cosmic ray particles. With the help of grants from Sir Dorabji Tata trust, the TIFR was set up at the Indian Institute of Science. Homi Bhabha continued intensive studies in the field of cosmic rays with emphasis on production of mesons, and electron cascades. Experimental work in these areas was carried out with full force and emphasis on research in the field of cosmic radiation when the TIFR was set up at Bombay in 1947 at the Peddar Road.

It is my personal conviction that although a number of events spurred growth of science in India just after independence, for example the setting up of the National Laboratories, the Raman Research institute, the Saha Institute, by far the biggest impact on Indian Science came from the establishment of the TIFR, and the Atomic energy program in India. Central to setting up these organizations lay three main themes in the Homi Bhabha philosophy for spurring growth of science and technology in India: (i) growing a large group of trained scientists in the field of nuclear physics so that when atomic energy became a reality, India had the trained scientists at hand to avail of this energy source for power production, (ii) spreading sophisticated technology in the fields of electronics, high vacuum techniques and nuclear physics to colleges, institutes and to the common man, and finally, (ii) implanting and sharing highly trained scientists in universities as teachers. The first two ideas met with great success whereas the third idea met only lukewarm reception, but had this not be the case the universities would not have been in the position that they are in today.

The existence of the TIFR, and the sophisticated research it carried out in frontier areas of science, served to trigger a nation wide effort to simulate similar attempts in different institutions. An example generally serves better to raise the standards of human endeavor, especially in the intellectual sphere, and that is exactly what the TIFR did; it set an example of itself as a reference point for excellence in the country.

Therefore we must acknowledge the very significant contribution made by J. R. D.Tata, and for his fullest continuing support of the goals and ambition of Homi Bhabha, after the TIFR was established. J. R. D. Tata held Bhabha in very high esteem. In his own words, as he once commented: "*Bhabha was one of those who made me believe that some men in human history are born with the stamp of predestination on them which leads to accomplishments beyond human capability".* The contributions of J. R. D. Tata do not cease with the seeding of the TIFR and the Atomic energy. The many facets of J R D's interests and accomplishments in very diverse areas covering iron and steel, hydro- and thermal power, aviation, chemical industries, etc were discussed eloquently in the previous J. R. D. Tata memorial lecture delivered by Prof. M. G. K. Menon, entitled " JRD Tata's legacy: the development of India through science". He has extensively covered the many facets of JRD's achievements and the legacy he left behind. Also, a large volume of literature exists on JRD's accomplishments, including the most comprehensive biography "Beyond the last blue mountain: A life of JRD Tata (1904-1993), by R. M. Lala.

Since a great deal of material exists on the wide-ranging contributions of JRD Tata, I would like to dwell in greater detail <u>only</u> into JRD's impact on science in India, and here too, by virtue of my familiarity with

TIFR and the Atomic Energy programs, I would limit myself to the impact made by the TIFR in the country. I would like to discuss with you both my appreciation of, and hopes in TIFR by sharing with you my personal experiences since the early days when I joined TIFR as a student. In the first lecture under this series, Prof. Yash Pal, another old-timer who roamed the early day corridors of TIFR, had presented his personal experiences

For me it is a great pleasure, privilege and honor to speak before you. TIFR is my alma mater. I feel I am qualified to present an account of the early and later days of TIFR, about its accomplishments, how it has changed with time, and what we expect in future from TIFR, still the only institution of its kind in India. I am going to freely express my personal opinions about TIFR. At this point, I would like to express my heartfelt thanks to Prof. Arun Grover who pressed me to give this talk, and who was also very generous by giving me full freedom to deviate by a large margin on the date of the talk, from the birth date of JRD Tata. I have tried my best to present before you a well thought out account of science in India in the post-independence era, but do recall what I said at the outset, I am apprehensive considering the nature of the task.

As mentioned earlier I joined TIFR within 4 years of its being established, and 2 years after India became independent. Between 1949 and 1972, I learnt science under extra-ordinary circumstances at the TIFR, which has very beneficially served me in all that I did in my entire life as a nuclear physicist. In 1972, I joined the Physical Research Laboratory at Ahmedabad. Since 1967, throughout my tenure at the TIFR and the PRL, I also served on the faculty of the Univ. of California at San Diego on a 25 % time basis. Thus, I consider myself most privileged since I was educated at and served the two major institutions of India, which were responsible for providing trained scientists for The Atomic Energy and the Space Research programs of India, respectively. At the same time I witnessed the growth of the two institutions in India, and creation of the Univ. of California at San Diego by the Scripps Institution of Oceanography (SIO) at La Jolla, which came into existence two years after I first visited the SIO in 1958. Undoubtedly, this exposure of a human being to all this science during a period of great patriotic fervor could only have two consequences: either build a scientist or make a historian out of him/her. Luckily I took the first path for which I owe everything to TIFR.

The first two decades of TIFR

During the first two decades, the TIFR was undertaking research in new frontier areas of science. Research in some of these areas also started in many institutions the world over. The temporary buildings where TIFR functioned initially, and later on the new buildings were bustling with visits by renowned scientists. Academic personnel were visibly seen busy thinking and working as if their life depended on it. The fervor of doing research was running high in TIFR, driven both by the environment created by

Bhabha, and one’s own patriotic spirit. Dr. Bhabha had close contacts with several great thinkers and visionaries, who often visited the TIFR. The list is huge. It included:

P. M. S. Blackett
J. D. Cockroft
George Gamow
Wolfgang Pauli
Jawaharlal Nehru
JRD Tata

just to give you some of the names. And we all had the possibility of seeing them at close range, and even talking to them if we had something to say to them.

One day I saw George Gamow jumping while walking through a TIFR corridor. He was walking away from me and therefore he was not aware that I was watching him. Gamow must have had an idea! Or may be he found a fata flaw in one of his many ideas! I have never forgotten that scene, for a few reasons. Of course for one, it was the pleasure of seeing George Gamow in that inspirational mood. But there was another reason that took the center stage in my mind. We all had to follow a strict code of behavior at the TIFR, and not jump around or make noise, a dictum handed down to us from the top. I was really afraid that if any of the administrators saw George Gamow, he might tell him to behave!

Till today I can not believe that I have had close encounters with the scientist who was one of the chief proponents of the Big Bang origin of the Universe, and one who had made a large number of fundamental contributions to physical and biological sciences. Edward Teller once described Gamow: Quote “Gamow was fantastic in his ideas. He was right, he was wrong. More often wrong than right. …. When his idea was not wrong, it was not only right; it was new”.

Listening to Blackett was both a great experience and inspiration. Would you believe that I attended a physics lecture in the Yacht Club premises, sitting next to Wolfgang Pauli, who was often shaking his head vigorously during the lecture (which I learnt later on that it was his style)? And similarly it was a great thrill watching and listening to Jawaharlal Nehru and JRD Tata. Their faces were radiant; they glowed like incandescent lamps, infusing hope and inspiration in the audience.

The TIFR offered supreme facilities for the most sophisticated research. What excuse could one have for not doing good science at TIFR? We were all put under great moral and intellectual pressure to perform at our best of abilities.

Although Homi Bhabha had to spend a great deal of his time doing administration to give us the facilities at the TIFR, and towards building the Atomic Energy program, he spent a considerable amount of time doing research himself. In the late 40s and the 50s, he built Geiger Muller counter arrays, launched balloons for cosmic research, and carried out his theoretical research with reasonable intensity. He was up front with the way science was growing rapidly all over the world; post World War II. a period, which can be likened to freeing the global human population from bondage. The human spirit was seeking to discover the fundamental laws of Nature, and in India, Homi Bhabha made a major contribution to this effort by his own research, and by invigorating the Indian scientific community.

A very distinguished cosmic ray physicist, Bernard Peters, who had discovered the presence of multiply charged heavy nuclei in cosmic radiation, came to India in 1950 to conduct balloon flights for studying the composition of and nuclear interactions of energetic particles in the cosmic radiation. In 1951, Dr. Bhabha invited him to join the TIFR, which he did. The joining of Peters made a huge impact on the quality of research in the fields of cosmic radiation, high energy and elementary particle physics and geophysics, within a period of less than 8 years that he spent at the TIFR. *It would be fair to say that the contributions of the cosmic ray group during the fifties helped greatly in putting TIFR on the global science map.*

Peters' approach to science was simple but one that is difficult to practice! He asked himself if he could find answers to questions that were important: questions, which could immediately open further critical questions. The tremendous output of science in the short period that Peters spent at TIFR caused strong waves all over the TIFR, and in the country. Being privileged to be his student, I realized how hard it was to ask the right questions, the key to doing good science. I would often go to him asking his approval for carrying out certain experiments. Most of the time he quickly sent me home after asking a few simple questions such as what I expected to gain by doing the experiment. He said: assume a certain result of the experiment which you expect, and then ask yourself the question: what would I then learn?

What Bernard Peters did was to establish within a short span of time an important fact that we in India had all the capability to make discoveries and to do fundamental research, at par with the West, only if we had confidence in ourselves. And he assured us that we had the basic capability and that the confidence had to be built by asking good questions and doing well thought out science. What was considered good science? Again here the answer can be found in the fundamental approach of Peters: to ask critical questions and then to try to answer them. One does not have to leave one's room to get the answer to this fundamental question.

Peters demonstrated the power of his approach by his researches in the fields of cosmic ray physics, elementary particles, high energy physics and cosmic ray geophysics. During 1952-1958, a large number of discoveries were made in the fields related to cosmic rays:

(i) Composition of cosmic rays at the highest energies, from direct observations of cosmic rays, and also from phenomenology of extensive air showers.

(ii) Studies of properties of elementary particles. This was made possible by the development of a continuously sensitive block of nuclear emulsion pellicles, which allowed tracing tracks of secondary particles to their origin. Besides providing valuable data, this study established associated production of two different types of elementary particles in one nuclear interaction, and the nuclear capture of negative K-meson, as it was called at that time.

(iii) Discovery of ^{10}Be produced by cosmic rays, opening up the field of cosmic ray geophysics.

(iv) Discovery of more than a half a dozen cosmic ray produced radionuclides, further highlighting the role of cosmic radiation in studying terrestrial processes in diverse branches of earth sciences; meteorology, hydrology and oceanography. ^{10}Be and several cosmogenic nuclides were in fact discovered whilst the group was working in the naval barracks, a few years before they moved into the new TIFR buildings.

These were new areas of research. The field of cosmic ray geophysics was so ‘new’ that it was considered a very risky area to go into. I would like to narrate an interesting personal anecdote at this point. The year was 1954. Peters’ group was busy discovering elementary particles and studying high-energy nuclear interactions. In 1947, Willard Libby had discovered ^{14}C, produced as a product of nuclear interactions of cosmic ray produced thermal neutrons with nitrogen nuclei in the atmosphere. He subsequently applied it for dating archaeological samples. Peters then had the idea that we look for the radionuclide, ^{10}Be, expected to be produced by cosmic rays in the atmosphere, since it would prove an excellent radio-tracer for determining geochronology of sediments, which contained rich information about the past history of the Earth. I was then spending most of my time studying elementary particles and had discovered about 20 events in nuclear emulsions. The proposed ^{10}Be idea of Peters appealed to me greatly, and although it involved delving in new experimental areas, such as radiochemistry, I switched overnight and put all my efforts on discovering the cosmic ray produced ^{10}Be as a geophysics venture. Several of m*y close friends then discouraged me from switching to ^{10}Be, telling me frankly that I was stupid; that I was going from high-energy physics to zero-physics.*

The story of development of cosmic ray geophysics began in 1954. ^{10}Be was discovered in late 1955 in marine sediments. Peters’ group took up this field putting full force on (i) discovering new nuclides expected to be produced by cosmic rays, and (ii) determining accurately the expected rates of production of various radionuclides by cosmic radiation in the atmosphere, because it became clear to us that cosmic rays provided a natural source of a large number of radiotracers for studying earth sciences, whose source functions could be determined precisely. Fifty years later, it is still a very busy field, and ^{10}Be itself is one of the two most important tracers in geophysics (the other being ^{14}C); it is employed as an tracer in many branches of earth sciences including paleo-climatolgy. With the present sensitivity of measurement of isotopes, the cosmic ray produced ^{10}Be can be measured in about 1 milligram of soil from the surface of the Earth, and ^{14}C in about 0.1 milligram of carbon from any of the dynamic carbon cycle reservoirs.

The major strides made in the cosmic ray field, including studies of underground cosmic rays, fostered renewed excitement and intense research activity in other groups in TIFR. There was an excitement all over the TIFR, in other groups as well, in the fields of low temperature physics, nuclear physics and theoretical physics. After Prof. Peters left the TIFR in 1958, the newly formed geophysics group continued to exist. It broadened its outlook following the philosophy to look for new ideas, and soon was christened as the geo-cosmophysics group.

During the first 20 years of TIFR, which I term as its golden era, most of us worked day and night, 24/7. We were doing calculations and thinking all the time. Some of us could multiply numbers without using any tools. We could see the numbers graphically sliding smoothly on a slide rule in front of our eyes.

One of the reasons for this fervor was (as I mentioned earlier) that we were part of a global human excitement, just after World War II, when most nations began intensifying their scholastic activities to learn about the secrets of Nature, driven by a deep seated inner urge that comes after suddenly being released from bondage. As a result, science was growing by leaps and bounds all over the World. Throughout the history of science, there has never been a period of intense growth in our scientific knowledge as during the later half of the 20th century.

Quantum of science in India

Today we are a major producer of scientific publications in diverse fields. A survey of papers published in Current Science would immediately bring home the point that we are indeed very knowledgeable in most frontier areas of science. We are fully competent to discuss the current state in these fields. However, when one looks at the references in the articles, one generally discovers that the pioneering work in the field was done in the West.

There is no doubt that today India is intensely involved in research in many of the mainstream fields in the West. We have an enormous science and technology base to participate in most areas of science. The TIFR contributed enormously to development of this capability in India. Besides, it also created self-reliance in the masses by its transferring technical expertise in sophisticated areas, e.g. electronics, high vacuum and low temperature technology, nuclear physics etc.

Fundamental Research in India: an introspection

The TIFR was expressly designed to do fundamental research in mathematics and physics, including nuclear physics, and later on in the field of molecular biology. The question before us is where we stand today in context to fundamental research?

What is basic or fundamental research? This is by no means easy to define. Webster's dictionary calls it as relating to the foundation or the base, and exploration of the laws of the universe. One way of defining it by examples of scientists who opened up new vistas for further research, to elucidate how Nature works. The examples of Newton and Galileo are too extreme because they set the stage for carrying out fundamental research in to Nature. These examples are hard to emulate. In India, we have superb examples of researches in the pre-independence era: J. C. Bose, S. N. Bose, Srinivas Ramanujan, Megnath Saha and C. V. Raman. The double helix structure of DNA was discovered exactly fifty years ago, for which Crick, Watson and Wilkins were awarded the Nobel Prize. Some of us here may not be aware that it was also exactly fifty years ago that G. N. Ramachandran and his colleague, Kartha discovered the triple helix structure of collagen fibers. This accomplishment did not receive much recognition partly because collagen is not as important a molecule as DNA.

Since independence, very large sums of money have been invested in science and education, and a large fraction of that was channeled into science. It is probably fair to ask the question whether in this time frame, about 55 years later, whether we can show examples of pioneering research work done as was done in the pre-independence era by J. C. Bose, Meghnad Saha, Srinivas Ramanujan and C. V. Raman. Their work is seminal in quality and will remain in the portals of science for a long long time. (We should of course realize that from the vantage of our pre-independence achievers, this is not a fair question considering that did not even have the minimal facilities and support for their research).

How many such names can we come up with today for the post-independent era? There is a serious problem here: can we come up even with a few names. Maybe it is too early to make an assessment, only ~ 5 decades after independence?

In my own opinion, if we were allowed to extrapolate the pace at the rate at which science was progressing in the TIFR during the first 20-25 years of its existence, we would have given you a big list of major contributions by Indian scientists. (I would hasten to state that any remarks which I make now, exclude the contributions made by TIFR in the fields of Molecular Biology and Mathematics, fields about which I know so little).

After the first 2 decades, a number of factors changed the very form of science and culture at the TIFR, and the world over. One of the important local reasons was that we lost our leader very early on. Dr. Bhabha passed away on 24th Jan. in an Air India accident. Other factors, some including the general environment in the country are:

(i) Within 2 decades of independence there occurred a general erosion of culture and increase of social imbalance and honesty.
(ii) Basic research, which was considered as a privilege for a few, became a salaried profession. The media often questioned the need to support basic research.
(iii) Scientific leadership was transformed into diffuse leadership at the hands of a large number of individuals.
(iv) The process of peer review that existed in the early days of TIFR has virtually totally disappeared today. Researchers receive guaranteed funds irrespective of their performance.
(v) Research topics were largely selected on the basis of research abroad.
(vi) Good scientists clamored for jobs at the Center.

The early exciting days of TIFR lasted until 1970 only. Distinguished visitors continue to visit India in large numbers but they did not make an impact on the Indian scientific community in the way it happened during Homi Bhabha's time. The boldness with which young scientists chose their fields of research has considerably weakened. As a result of lack of leadership, or fear, we choose today to work in the mainstream programs of the West. One must agree that it is necessary to work in the mainstream else we would be left behind and it may become too difficult to join those areas of research later on. But, manifestly, one has to use a strategy in dealing with the mainstream. One has to remain in it, and at the same time be independent of its domination. For example, if large particle accelerators or sophisticated spacecrafts were needed for the mainstream project, of course, we would always be lagging behind the West. In the fields of theoretical physics and mathematics, and experimental physics: nuclear physics, astronomy, astrophysics and geophysics, there are many unexplored areas in which we can make important contributions, not being limited by facilities. But to succeed, we have to choose to work on important questions. We can then continue to work in the mainstream, as well as remain aloof from the mainstream by defining our own thrust areas in science. Do recognize that we also have some advantages over the West. In West they are now increasingly pressurizing scientists to choose relevant projects. The performance of scientists in the West is based on their publications. In India we can be sufficiently relaxed on such considerations if a proper culture of science is established.

During the first 2 decades of TIFR, indeed we worked in this ideal fashion. We were deeply engaged in theoretical elementary particle physics, and cosmic ray physics in space and underground, areas where a great potential existed for fundamental discoveries. It was also quite apparent that there existed some areas of science which had not been touched, and where TIFR was capable of making a big dent. Let me give you an example here.

It was quite obvious that the optical window was only one of the windows for peeping in to the Universe. The optical window provided color images of the Universe, but it had little information on the structure of matter. It was clear that one has to look at the universe in all wavelengths of the electromagnetic radiation, covering a range of 15 orders of magnitude in energy, to properly understand its physical and chemical structure of galaxies and stellar objects. TIFR was fully capable of opening new windows to the Universe, which were in fact opened one-by-one by the West, microwave, X-rays, infra-red and ultra-violet. Nobel Prizes were awarded in each of these windows. The only window in which the TIFR made pioneering efforts was the cosmic ray window, and here I hasten to add that the TIFR scientists did make pioneering contributions here, but primarily in the first 2 decades.

At this point of time, with your indulgence, I would like to tell our young colleagues what is really required for doing fundamental research. This is an entirely different beast from the mainstream research where one can get away by working 9 to 5. “Fundamental” is “subtle” which cannot be seen unless one probes very deep. There are two principal domains of fundamental research: microscopic and macroscopic. The two require very different approaches, but both require dedication and sweat. The basic approach is simple: conceive a model, and test it. Failures are a necessary part of success that is finally achieved in a dedicated onslaught on the problem. The efficiency has to be necessarily high at each step. Let us assume that we have to take 10 steps to reach the goal. Let us further assume that the efficiency at each step is 99%. Such a low efficiency fails because the final yield is only 90%. To succeed, we need better than four or five 9’s efficiency in each step; ten 9s would be excellent!

Hard work is necessary for fundamental research; it is a necessary but not a sufficient condition. The latter realization requires high-level collaboration with intellectuals. But one receives unparalleled rewards in carrying out fundamental research. It is an experience which the brain itself seeks for its fulfillment. *Voltaire once remarked that a lover dies only once but a scientist dies a thousand deaths.* Each model of Nature he makes seems at first to him to be the ultimate attainment of his goal!

Science is global. In as much as we can join the mainstream of the West, the west can also join in original research efforts in India. History tells us that the West indeed took active part in projects which could be executed in India with advantage. The simple conclusion is that once we undertake a research program we have to work on it with full support, dedication and haste. In other words we have to have a killer spirit so that we can compete with the West. This spirit existed in the first 2 decades, but it rapidly declined. *We often take on ambitious projects but execute them at a slow pace.* This has cost us quite a bit. We lost a great deal by way of scientific output in the past 3 decades. In an important sense, we are poorer today than we were earlier.

Lack of performance in basic research costs heavily. In the absence of excellence, the country does not have the authority to be proud of its scholars. Competence in basic research raises the intellectual property of a nation. Let me tell you a story to stress on this point. Robert Wilson, who proposed the first large Brookhaven accelerator, was asked at a senate hearing “What would the accelerator do to the defense of the country?” He replied” it will do nothing to the defense of the country but it would make the country worth defending”.

Let me now give you a hypothetical scenario and then ask you a question. Assume that Dr. Homi Bhabha appears before you today, and says that I have only ten minutes time at my disposal but I do want to know the highlights of your research after my Air India accident. What do you think you will say? Take it up as an exercise; find the answer in whatever time you want to take to make a 10 minutes presentation before Homi Bhabha. I am sure that we can all make a whole day presentation, but we would find it difficult to use the whole 10 minutes, if we were told to be selective.

The TIFR has always been a busy bee. It set up its own balloon facility to carry out experiments in cosmic rays, and optical and infra-red astronomies. It built the unique radio-astronomy telescope, the GMRT (Giant Meterwave Radio Telescope). It is engaged in several sophisticated fields: Theoretical physics, High energy physics, Astronomy and Astrophysics, Nuclear and Atomic physics, Condensed Matter physics and materials science, Chemical Sciences and Biological Sciences, at the cutting edge of science. There is no other institution in India like the TIFR. One would also not easily find a similar institution elsewhere.

TIFR is my alma mater. The electrifying atmosphere in the first 20 years, intense guidance from my Professor, B. Peters, and the inspiration from Homi Bhabha and the visiting dignitaries, coupled with the patriotic fervor, prepared me to do research which I practice till today. I owe my career to TIFR. (Also as some of you may know, my studies at TIFR also led to my finding my wife amongst the TIFR staff, Aruna Lal.). In view of my heavy debt to TIFR, I would never say anything out of color for TIFR. But I do believe firmly that the pot of human imagination and creativity that was boiling in the first 2 decades has cooled substantially since. The universal Arrhenius equation tells us that when the pot’s temperature is lowered, the reaction rate drops in an exponential manner. At the lower temperature, given enough time, we would succeed in the long run, but others would certainly reach the goal long before we do! Today we tread carefully so that we are not wrong. We have to be bold and take risks. Remember what Teller said about George Gamow. “He was right, he was wrong. More often wrong than right.”

Realizing that by and large, we are not currently engaged in research chosen entirely by us, it is not difficult to see why we have not made fundamental contributions in the past 2-3 decades.

We can in fact justify why it has been the case. An important fact which we must recognize is that many fundamental discoveries about the structure of matter and its behavior in different impressed states, were made in the 50's thru 70's, so that it became difficult to ask real questions. But the blame for the lack of continuing to ask fundamental questions lies in many factors, e.g. change of scientific culture and environment in India, the disadvantages of following the mainstream, in contrast to being original, not taking risks by opening up new windows of research, etc., all which we did not fight. Our lukewarm successes in the past 3 decades in spite of very active involvement in a number of frontier sciences only means that we were not adventurous; we did not choose to take risks, or we failed to intensify our researches at the right time. But, in hindsight we all do acknowledge clearly that the TIFR indeed selected research areas at the cutting edge, such as elementary particle physics and neutrino physics, areas in which Nobel Prizes were awarded. We could have put much greater thrust in these areas, and selected areas where we had the expertise, such as new windows to the universe, in which Nobel Prizes were also given.

<u>To sum up:</u> We all recognize that both Jamshetji Tata and JRD Tata made very significant contributions to science and education in India. JRD Tata recognized talent and leadership, and gave complete support of Homi Bhabha to build the TIFR and the Atomic Energy program. J. R. D. Tata held Bhabha in very high esteem. On his part, during his lifetime, within about 2 decades of setting up of the TIFR, Homi Bhabha demonstrated the great merit as well as national relevance of his ideas and ambitions. During his time, the TIFR jumped into new areas of science, and made important discoveries. In the post-Bhabha period, science continued at a high level at TIFR. It created massive self-reliance in the masses by its transferring technical expertise in many sophisticated areas of electronics, nuclear and solid state physics, using TIFR and the Atomic Energy laboratories as the base.

But during the past 3 decades, the TIFR did not make any significant impact in the area of fundamental research in physics centered fields of research because the choice of questions in the chosen areas did not show much imagination, and/ or any quantum of risk. We expected much more from TIFR in the area of fundamental research in the past decades. I do not think this is an unfair criticism. I have earlier given some reasons why all over the world the growth of fundamental concepts has been on the decline the world over, which included (i) major discoveries about the structure of matter during the 50's thru 70's, and the subsequent (ii) winds of change in human appreciation of the necessity to engage in pure philosophy for its own sake. The latter is necessary to both appreciate the beauty of Nature, and also to raise Man's own place in the Universe.

The present health of TIFR is superb, and it is uniquely suited to perform at a very high level in the field of basic research. Good health is a necessary but not a sufficient condition to carry out fundamental research. Are we prepared to ask important questions, and then try to get at them, even if it means that the task involves taking high risks? JRD Tata was born with a silver spoon. He did not have to take any risks. He was an adventurer and loved action. He took chances whenever he thought it was necessary, including his foray into aviation. He faced many ups and downs but he faced them all with integrity, always succeeding in the end. JRD Tata was not a scientist, but had he been a scientist he would have been very successful.

We are a very unique country whose gene pool is very rich, deriving our superior intellectual heritage from our ancestors who were great philosophers and pioneers in many fields including medicine. By this fact, we should feel confident that we can rise to greater heights in fundamental research should we chose to so dedicate ourselves.

In closing, I am fully aware that I do not know all that is going on today at the TIFR. I won’t be surprised if TIFR scientists have already, or are just about ready to make groundbreaking discoveries soon. This is what is expected of TIFR, and it is indeed my sincere hope that this will happen soon.