AN APPROACH FOR INDIA TO EXCEL IN FRONTIERS OF SCIENCE AND TECHNOLOGY RESEARCH

SYAMAL LAHIRI*

Recently many people have voiced concern about India’s inability to realize its full potential for scientific and technological (S&T) research that the nation expected from its large number of talented researchers in academic and research institutions. They publish and present many research papers each year. Nonetheless, the standing of India’s academia, as compared to many other countries, is gradually getting lower in recent years, particularly with respect to innovative or ground-breaking research. In recent rankings of global academic institutions, none from India was listed among the top 200.

No doubt this should be a matter of concern to the nation, particularly in view of the fact that modern knowledge-intensive high-science/hi-tech research and educational activities started in India many years ago—long before some of the higher ranked countries became involved in such activities. Even in the first five to six decades of the last century, the country had a number of world-renowned scientists, such as J. C. Bose, S. N. Bose, C. V. Raman, S. Ramanujan and M. N. Saha, whose pioneering and ground-breaking works opened up new frontiers of modern science, technology and mathematics. In recent decades, seminal works of similar calibre have been missing from India’s S&T contributions to the world. With the advent of electronic revolution, which started around six decades ago, the world’s S&T research frontiers advanced dramatically through many spectacular breakthroughs and achievements. However, practically all key ground-breaking ideas and innovations, which triggered this rapid advancement, originated outside of India. Clearly, both the nature of India’s S&T research and the ranking of its academia have changed over time.

There are several probable reasons for the recent decline in the ranking of India’s academic institutions. I will concentrate on one of them only—the quality of research output, which is a very important criterion to determine the standing of an academic or research institution. The quality may be defined in various ways. In general, greater is the originality of the idea or innovative or novelty component in the work, higher is the quality. If a work opens up new avenues of research and development worldwide, it is certainly a high quality work. Surely there are some individual scientists in India, who are doing good quality research. But their number is relatively small. However, most publications from India on emerging fields of S&T research seem to be deficient in innovative components, although many are publishable in peer reviewed journals. Shortcoming in this quality factor, I think, is a major cause for India’s recent slide in ranking. Even relatively new players and small countries like Japan, South Korea and Singapore are ranked higher than India in some of the evaluation categories. Clearly, something is not right in the planning or management of India’s R&D and education policies. We must introspect and review our approach and policies carefully and implement whatever course correction is needed in order to reclaim a leadership position in the S&T world.

In this article, I briefly present some of my views on what India’s strategy and approach should be for bringing fame and accolades to Indian universities and research institutions in the scientific and technological world. In doing so, and for the sake of brevity, I will cite the examples from medical research only to elucidate my

* Fellow of the American Physical Society.
points, as this emerging field has been undergoing very rapid development in recent years. Moreover, India has a strong base for pharmaceutical industry to facilitate and expedite such research activities. Consequently, chances of making key innovative or ground-breaking contributions in this area are high. However, the suggestions and conclusions of this article are not restricted at all to medical research only, but are generally applicable to all new or emerging areas of science and technology, such as non-conventional or green energy, nanoscience/technology, sensors, advanced materials, materials modelling, as well as ‘Internet of Things’, development of new software packages, ‘apps’ and algorithms for newer electronic system/device applications. There are still ample opportunities to make important innovations and contributions in these frontier areas of research, which are also critically important for augmenting the nation’s defence capabilities.

I will not discuss here what is sometimes called incremental innovation, an important approach that is helpful to existing companies to increase the performance, quality and reliability of their products for the same cost, and/or reduce the cost for similar performance, quality and reliability. In addition, we will exclude discussion on research institutions which are mainly involved in transforming new ideas or feasible technologies into manufacturing technologies, which are also important, but the objective and approach of such R&D work are not the same as those at the frontiers of research.

**Examples from Emerging Medical Research Frontiers**

To further elucidate the above points, I will give just a few examples of recent ground-breaking or widely acclaimed innovating works in the field of medical science and technology, which were mostly carried out in universities and research institutes. These examples are cited not to propose research projects to India’s researchers, but just to illustrate the elegant aspects of some important works, which focus not on broadly described or diffused proposals, but on specific ideas. Such works have the potential to bring revolutionary changes in the approach towards management of diseases. These include:

- Creation of human red blood cells and platelets in-vitro from induced pluripotent stem cells obtained from the patient’s own skin or blood cells—a finding that could reduce need for blood donations.
- Application of stem cells derived from skin cells on amyloid formation in patients with dementia including Alzheimer’s and Parkinson’s diseases.
- Patient-specific treatment of cancer using cells, identified by genome sequencing of the patient’s immune system, that attack the specific mutation, with or without genetic engineering.
- Elucidation of the role of p53 protein in the self-destruction of cancer tumours by the natural process of apoptosis.
- Use of laser to measure neuron activities.
- Brain-machine interface for sharing thoughts and information or communicating with severely brain-injured patient.
- Use of genetic engineering to produce virus in order to prepare vaccines. The technique should be potentially very useful in India and many other microelectronics technology did a few decades ago. As a result, in spite of many talented researchers in India, as well as acclaimed capabilities of some of India’s premier institutes, eg IITs, in producing high quality B.Tech degree holders, it is very difficult for a relatively new player to catch up quickly with the front runner countries by chasing their work and following their footprints in such fast-moving fields that are emerging. A different strategy or approach is required to shorten the Research and Development (R&D) path that may allow India to leapfrog to a leadership position in the world within a reasonable time.

**Brief Background of Medical Research**

Currently a large number of scientists, technologists and engineers are working worldwide to develop an in-depth understanding of the causes of various diseases and their management. Most of the work is concentrated in several Western countries, such as the USA, which have spent many hundreds of billions dollars in the last few years alone. They have already developed very impressive research expertise to continue further development at a rapid pace. As a result of their work, a paradigm shift has occurred in recent decades in the general approach to understand the cause of many killer and debilitating diseases and their management. The root cause of many of these diseases appears to be related to genes or DNA. Accordingly, research on management of such diseases is increasingly directed to gene or cell-based therapy. Due to large infusion of funds, availability of trained and experienced manpower and infrastructure, as well as the prospect of very high return on investment, this research frontier is currently advancing at a phenomenal pace, as
countries to fight many infectious diseases, such as influenza, Rota virus and encephalitis.

- Effect of gut micro-organisms or microbes on diseases, such as blood pressure, and their control.
- Effect of small molecules, which are thought to be toxic, such as NO, CO, H$_2$S on apoptosis, repair of cell damage (eg during stent placement), hibernation (eg for transferring a severely injured soldier to hospital). Nitric oxide was also found to serve as a vasorelaxant and inhibitor of platelet aggregation. The 1998 Nobel Prize was awarded in recognition of a work in this field.

The list is very long. This kind of research is of great help in developing deep insight into the causes and management of various diseases, such as cancer, cardiovascular, neurological and endocrinological diseases. Many other interesting ideas are also being investigated, for which institutes like IIT or IISC certainly have capabilities to contribute, if they focus on some of these areas. These include: development of nano-generator powered by muscle movement, new contrast agent for image enhancement, anti-inflammatory coating for cardiac stents and brain electrodes, new blood tests for detecting heart attacks quickly (other than troponin test) etc, as well as research involving graphene, which is currently of immense interest for both medical and non-medical applications. Drug development and treatment based on India’s traditional medicines and treatment also offer an ocean of opportunities to researchers. Indian researchers will perhaps like to work more on such new ideas, which are often the products of ‘out of the box’ thinking.

Indians are very talented, a fact recognized all over the world. What are needed in India are a changed mindset, management with vision, right research topics and a conducive environment for nurturing talents that would help the scientists and engineers, particularly the young ones, to unlock their creative potential. It is not beyond our reach at all. We must try to be self-confident and ground-breaking trailblazers or pioneers in the frontiers of research and technology, and not just followers of the West’s footprints. If we succeed, at least some of our universities and R&D institutes will become world-renowned centres of excellence in a not-too-distant future.

**Proposed Objectives, Approach and Deliverables**

In view of the above, I think, a primary objective of India’s high science and high-tech researchers should initially be the development or enhancement of their research acumen and reputation in emerging multi-faceted and interdisciplinary fields of research as quickly as possible. The focus will be on the selection of *right topics*, such as technology *show-stoppers and bottlenecks*, and building up an intellectual reservoir of new ideas and knowledge-base by addressing these topics. This means that effort should be made first to identify, and then find solutions, of the *enabling or critical steps that act as a barrier to further advancement of knowledge and technology*. Even a few successes in this endeavour may open up new avenues of research that could bring name and fame not only to the individual researchers, but also to the Institutes. Accordingly, the primary research deliverables of the Institutes, at least at the beginning, should be *original or ground-breaking ideas, high quality intellectual properties (IP) with generic claims and associated publications, and the knowledge-base*. Key IP-s generated in the institutes could be very valuable to attract companies and facilitate their business activities later.

Initially, the primary focus should not necessarily be on the development of complete technologies, which are generally complex, expensive, and often require presence and support of existing industries in the field. This phase will come later as reputation, infrastructure and high-tech industrial situation improve.

The above approach has the added advantage of minimizing the delay in starting experimental work, as many of the instruments and equipment, as well as expertise, already available in many of the Indian universities and research Institutes, can be utilized for initial research activities. In general, *a university’s or research Institute’s main objective should be the development of new ideas and demonstration of their feasibility, which do not necessarily require large funding*. Further work related to issues, such as scale-up, reliability, reproducibility, yield, safety, clinical trials or manufacturing technology development etc are primarily the business of the industry, which is always on the lookout for new ideas or processes to license in highly lucrative and competitive fields. If the initially involved scientists wish, they may also contribute to this later development work by industry as consultant or adviser or partner. As in some US universities, he/she may also be allowed by the universities or R&D organizations to go on leave for a period of time to set up a start-up company, if he/she succeeds in obtaining funds from venture capitalists or government or other legitimate sources.
A Plan to Get Started

I do not know the details of all Indian scientists who are working in the frontier areas of research similar to the ones mentioned above. But I presume there are quite a few. They should be organized, encouraged and appropriately supported to provide initial manpower requirement for innovative research without any delay. However, this group’s effort should be augmented, at least initially, by inflow of reputed researchers, mainly NRIs from abroad, who are actively working in the emerging new frontiers of research. Their participation in our institutes’ research programmes should preferably be part-time (a total of about 4-6 weeks per year). Many NRIs would be delighted to visit for short periods to provide their services to India and share their frontline research experiences and knowledge with their counterparts in India, if they find appropriate opportunities and a sincere desire in the country. During each visit the NRIs will interact with India’s researchers and exchange information through well-planned seminars and discussion in a joint effort to identify directed and ‘undirected’ areas of research, as well as the challenging bottlenecks and potential show-stoppers along the pathway for advancement, without violating any confidential agreement they may have with their employers. India’s researchers may initially start their work on these jointly identified areas using the existing equipment and perhaps a few new ones, if needed. Information potentiates power and timely access to information regarding on-going and on-coming research areas is extremely important for realizing the scientific and technological potential, prowess and recognition. The involvement of the NRIs is likely to be helpful in expediting the dissemination of such information to a large number of researchers in India.

Involvement of well-recognized NRI visitors at the outset is also very important to leap-frog the initial development process. These visitors are likely to have much larger information base than their Indian counterparts about the future direction of ongoing research and potential roadblocks in frontier fields of research. This is mainly because of their direct involvement in advanced research activities in the frontier fields, and closer personal interaction with other pioneering researchers and high-tech industries in their countries of residence. Early access to appropriate information should provide India’s talented researchers a chance to make ground-breaking contributions to the advancement of science, as well as providing innovative solutions to the challenges in the frontier areas of R&D ahead of others. Under the prevailing circumstances, by the time the results of frontier research fields are published in the literature, pioneers and industry members in the field are already protected, and assured of ownership of their contributions and intellectual property (IP) rights regarding the key innovative aspects of their research results and applications.

The interaction with the NRI visitors, who should be officially made part of the research team, may continue even during their absence, through the use of the electronic media such as Internet, Facetime or Skype. An appropriate budget should be allotted for the planned trips by the researchers. Involvement of an experienced Research Coordinator (or Director of Research) in every participating Indian institutes may be helpful in selecting and prioritizing the initial topics, because of the constraints of manpower and fund in the beginning.

Our research planners and managers will perhaps give serious consideration to start systematic utilization of the untapped and extremely valuable NRI resources without delay. I believe the involvement of this group of people would be far more effective in fulfilling the nation’s desire to come to the forefront of nations in science and technology than the involvement of many other foreign visitors or organizations from other countries. The driving forces of the two groups for visiting or interacting with India are not the same. Involvement of the latter group of visitors in the frontier areas of research is likely to create some complications for various reasons, such as their unavailability, cost and cultural mismatch. IP right is often a contentious issue. Researchers in India and associated workers are, in general, not well-versed yet as the scientists or engineers of the West in protecting their innovative ideas and Intellectual Property (IP) rights. They should be fully trained in this aspect, particularly what to say or what not to say to visitors or outsiders regarding their on-going work before the patent application is filed or results submitted for publication.

Concluding Remarks

I hope India’s policy-makers and leaders of academia and R&D institutions will find the views expressed in this article helpful in realizing the country’s desire to establish at least several centres of excellence with demonstrated capabilities to make pioneering contributions in the frontier fields of S&T research within a reasonable time. Of course, the strategy plan has to be worked out in detail without delay, as it needs to be followed up by appropriate staffing including different levels of management structure, necessary infrastructure development, setting up of control and monitoring processes, safety protocol, IP policy and personnel training. Team work is extremely important,
particularly for interdisciplinary areas of research. *Time is of essence in this race to excellence.* The plan should also include appropriate methods (e.g., PERT or bar chart) to monitor progress in a time-bound fashion. Any bottleneck or lack of timely action, in any link is likely to delay or stop the progress and realization of the goals. The delay will place India further behind the pioneers or front-line leaders, who continue to advance at a furious pace. Being first in the race for innovation and technology development in emerging fields has big advantages not only for receiving global recognition, but also for receiving big financial return from the R&D investment, which includes revenues from new lines of product and IP licensing fees.

The electronic revolution, which began about six decades ago, has brought revolutionary changes in the way we live and work, and do S&T research. Rapid advancement of microelectronics or integrated circuit technology, the vital parts of today's electronic components and systems, has been fuelling the revolution and opening up new frontiers of science and technology in quick succession. As a result, our knowledge-horizon has been expanding, and newer generations of devices, systems, equipment, and new applications are being introduced very rapidly, making it extremely difficult for new entrants in the fields to catch up. Unfortunately, India's academia and S&T planners missed the opportunities to meaningfully participate in this revolution at an early stage. As a consequence, Indians are primarily users of microelectronics-based components/systems/equipment at present, but not innovators or developers of newer electronic technologies and devices, which are not only of great strategic importance, but also key enablers for trillions of dollars worth of modern industrial, defence, data-processing and communication products and systems. The nation cannot afford to miss again such opportunities to participate in critically important S&T research at an early stage. It also needs to be proactive in deciding on its S&T research priorities, not just reactive. Accordingly, one of the important goals of India’s R&D planners, academia and researchers must be the generation and export of new ideas, technologies and associated scientific knowledge to the world. Achievement of this goal through a well-planned integrated strategy and team effort is essential to propel India towards a leadership position among nations not only in science and technology, but also in academic excellence and knowledge-intensive industrial development.

The journey towards excellence does not stop after the initial momentum. Perhaps it would be appropriate to often remind the nation’s S&T leaders and researchers an adage that the search for excellence never ends; if one stops or becomes complacent, he/she will surely find others soaring to the sky. This is the explicit and implicit motto of all aspiring centres of excellence in science and technology.