THIRD CONVOCATION ADDRESS

Borderless Science : The Need, The Challenge and The Way Ahead

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Hon'ble Minister of State for Health and Family Welfare, Government of India and Chancellor & President, NIMHAS, Shri Dalit Ezhilmalai, Dr. Shankar Naik, Hon'ble Minister of State for Medical Education, Government of Karnataka and Vice-President, NIMHAS, Mr. Vakshi, Secretary, Ministry of Health,Govt. of India, Dr. S. P. Agarwal, Director General Health Services, Govt. of India and Dr. Gourie Devi, Director of NIMHAS, the post graduates of the Year, their proud parents, distinguished guests, ladies and gentlemen.

Let me begin by extending my warm congratulations and also by offering my very best wishes to all of you, who received your degrees today. I wish to remind you all that you are graduating from an institute, which has an outstanding track record of performance. I have no doubt in my mind that all of you will bring honour and glory to this great institute through your dedicated work.

Let me say at the outset that I consider it to be a great honour and a special privilege to have been invited to NIMHANS to deliver the third convocation address. NIMHANS today is unquestionably the leader in the area of mental health and neurosciences in India. NIMHANS has been built assiduously by some of the most eminent men of India, which include Prof. M. V. Govindaswamy, Prof. R.M. Verma, G. N. Narain Reddy, Prof.S.M. Channabasavanna, among others. Let us all salute these institution builders. To build institutions is difficult but to sustain them is even more difficult. The rich traditions of scholarship and academic excellence of this institute have been sustained so well for the last few decades, and I want to congratulate all of you on this great achievement.

Science is galloping at a breath taking speed today. Ninety per cent of the scientists who ever lived are living today. The rate of new knowledge generation has increased manifolds; indeed Knowledge doubles up in less than ten years now. Scientific breakthroughs take place most frequently at the intersection of disciplines. NIMHANS has given the multi-disciplinary team effort a great thrust with the objective of promoting preventive and curative medicine. The founders of NIMHANS have brought together the modern biological, physical, scientific and sociological knowledge and the ancient wisdom under one roof. I am so impressed with this success of NIMHANS in promoting borderlessness, and indeed so convinced of the necessity of enlarging this approach to a whole range of endeavours in science, engineering and technology, that I have decided to make it the theme of my present convocation address. I would be speaking to you today on borderless science, the need for it, the challenges

that await us and also the way ahead. I will later on extend the context of borderlessness even further to other areas.

Borderless sciences & emergence of engineering science

We see that discrete boundaries no longer exist between various natural sciences such as physics, chemistry, biology, mathematics, etc. Explosive advances in adjacent sciences are shaping up the future of core disciplines. New paradigms of "seamless sciences" and even "seamless engineering" are emerging.

Take sub-disciplines such as inorganic chemistry, biological chemistry, organic chemistry and physical chemistry. The conceptual boundaries between these disciplines have already vanished. The 1987 Nobel Prize winning work of Lehn, Cram and Pedersen, led to the elucidation of molecular recognition. It lead to the whole new area of supramolecular science and engineering. Their work showed how subtle organisation of molecular, structural and dynamical features formed the basis of ***molecular information engineering***. The chemical, physical, and biological features of chemical species constituted the essence of this highly inter-disciplinary field. It involved the organic synthetic techniques of receptor construction, metal ion-ligand complexes involving physical chemistry and finally biological processes involving substrate binding and recognition. Its location at the intersection of chemistry, biology and physics made it a truly unique achievement.

It is not in scientific disciplines alone that the boundaries are breaking. They are vanishing between engineering and science also. A new breed of engineering scientists is emerging. I am myself an engineering scientist.

What is an engineering scientist? Let me give an analogy with the medical school. We have there basic scientists, who generate new knowledge, but it is knowledge for its own sake. Then we have the hard core practising clinicians, who use the established tools in their everyday practice. But in between these two communities, there are those academic clinicians. They are the ones who understand the language of the basic scientists and they are the ones who know the demands of the profession, as reflected by the clinicians. What these academic clinicians do is to use the methods of science to develop new tools and new paradigms that the practitioners would find helpful. They also communicate the needs of

these practitioners to the scientists. To my mind an engineering scientist is like an academic clinician, a facilitator. His task is to look at the continuous advances that take place in basic sciences such as chemistry, biology, physics, etc. He would harness this knowledge to develop new tools, which hard core engineers would put to use. Engineering scientists brings a rich variety of skills, tools into the profession from adjacent sciences.

It is obvious that in similar way, there will have to be others, who break barriers between say natural sciences and social sciences, and so on. I will come back to this issue later on during my address.

Borderless approach to problem solving

Today, more than ever before, we not only need "borderless science" but also need "borderless thinking" for problem solving. Yet we find that we work and think in isolation. Let me illustrate this by taking up a problem that we encounter in our everyday life, namely mixing. Mixing is a challenge in diverse disciplines. In the case of astrophysics, one is concerned about the mixing of the interior of stars. In mechanical engineering, it is combustion. In environmental sciences, we are concerned with mixing and dispersion in the atmosphere. Oceanography deals with mixing and dispersion in oceans. Chemical engineers are concerned with mixing in chemical reactors. Physiologists look at mixing in blood vessels. Bioengineers are interested in mixing & aeration in bioreactors. Geologists deal with mixing in the mantle of the earth. All these diverse mixing phenomena occur on diverse time and length scales, differing by several orders of magnitude. However, these disciplines rarely benefit from each other, and discovery & rediscovery of concepts and ideas is a common place.

Let me take this point further and show that blending of traditional engineering with developments in modern day physics, such as dynamical chaos, can open up new vistas in mixing. Indeed dynamical chaos can provide a new paradigm for analysing mixing from a universal view point. Whenever one wants to mix a fluid in a vessel, chemical engineers use a mechanical stirrer. They always operate it at a fixed speed of rotation. One never thought of subjecting the stirrer to a periodically changing speed. The Japanese showed a few months ago that by using unsteady and time periodical speed, one could improve the mixing efficiency by as

much as 100 times! They demonstrated that by this strategy one could induce chaotic mixing and destroy islands of unmixed regions in the chaotic mixing regions. The message is that even the mundane can become sublime by continuous blending of new knowledge in other disciplines.

Borderlessness leads to new insights & new business

Let me give you another example, which may be closer to your heart, as it is linked to the issue of recognition of taste by the brain. Breathtaking synergistic efforts from diverse disciplines interpreted by using the theory of dynamical chaos, are leading to new ways of taste detection.

Let us consider membranes with biological activity. Properties such as the action potential, spontaneous firing and chaotic behaviour can be viewed now from a system dynamical viewpoint. The simple philosophy followed here is that the substances as received by biological membranes change the membrane potential leading to sustained oscillation and spatio-temporal firing patterns of the neurons, which when transmitted to the cortex and the brain, recognizes the taste. It is thus possible to use an artificial lipid membrane to convert chemical information to electric currents and construct sensors that identify the taste. The prowess of the borderlessness in advancing the knowledge is at once obvious here.

It is not in improving our knowledge and insights alone but also in making economic sense of science that the strategy of borderlessness is helping. Take the issue of new drug discovery. The new ways of drug discovery have been aided considerably by fusion of disciplines. Take combinatorial chemistry. It involves light directed chemical synthesis which combines semiconductor based photolithographic techniques with solid phase organic chemistry to produce arrays of molecules with potential biological activity. The fast development of genome analysis of pathogens and also of plants, animals and humans has provided a rich source of new targets. Cell biology and structural biology and new technologies viz. bioinformatics and combinatorial chemistry are being brought together to set up the dream of "2000 by 2000" – i.e. moving from mind to market place in the case of a drug within 2000 days by the year 2000. This means reducing the new drug development time by half ! You can see again the prowess of borderlessness & fusion.

Borderlessness in the wider context

As I remarked earlier, we need to fuse borders between several disciplines, including those in natural sciences & social sciences. For this, we need to change our culture. We need to ensure that our mind moves through diverse disciplines in a seamless way. The ability to correlate and link the non-obvious can lead to major breakthroughs. Consider the issue of self-organisation in molecular systems by using molecular recognition. The organisation of molecules finally determines the properties and functions. But is this not what we want in creating modern management structures to derive a specific end objective, or an organisational goal, or a function? Innovative efforts have been made recently to create flexible management structures by using the concepts of self-organisation in chemical and biological systems. It is indeed fascinating that the chemistry of the non-covalent band, or supramolecular chemistry, is being used to create modern management systems. This is a splendid example of borderless thinking. We need more of it.

We need to take this concept of borderlessness further in India. For instance, we need to become borderless by creating knowledge networks between the formal systems of innovation, such as in our universities and national laboratories and also the informal systems of innovation, which are represented by our traditional knowledge, community knowledge etc. which has been built in India for centuries. Again, for freeing these borders, we will also require an attitude of mind and also understanding the language of non-formal innovators. This again is as difficult a language barrier, as between a physicist and the biologist that I referred to earlier. I find that opportunities for India are enormous.

Let us take the case of traditional medicine and our practice of Ayurveda. CSIR & Arya Vaidyashala in Kottakal signed a memorandum of understanding. Someone described this as a unique event, since it was an attempt to create the fusion of modern science & traditional knowledge & wisdom. But this is only a small beginning in a much larger movement of creating a borderless world. We need to multiply such efforts.

Creating borderless communities: some problems

Forging partnerships between practitioners of different disciplines is not easy. We all live in a world of very high specialization.

This automatically implies that we are continuously erecting our own new boundaries, creating our own small clubs and generating our own special language and jargon all the time. On the other hand, borderlessness implies interconnectedness. There itself lies the contradiction! Taking care of these contradictions is the biggest challenge we face in creating borderless science.

The essence of the issue can be highlighted by looking at the partnership between physics and biology. Frauenfelder and Berg edited a special issue of ***Physics Today*** in 1994 that dealt exclusively with the emerging new relations between physics and biology. They said "interface between physics and biology...is a cross field endeavour to which physicists can make major contributions. But to do so, they need to learn enough biology to be able to talk with biologists and to distinguish problems that are central from those that are peripheral. Since much of biology is descriptive, the physicist has a strong advantage: It is much easier for a physicist to learn biology than for a biologist to learn physics". May be my biologist friends present here will not agree with me but you can see the essence of the underlying problem in forging these partnerships, anyway!

The problem of the language and the cultural barriers between different disciplines is a serious one. Learning the language from another discipline and also teaching the language to practitioners of another discipline is not easy. Only those scientists, who have dared to learn other skills and languages from adjacent disciplines will eventually make a mark. Interdisciplinary scientists need to be great communicators. They will have to constantly exchange information in a "jargonless" way and also pass on their infectious enthusiasm by communicating skillfully.

There are many barriers to becoming borderless. There is a serious problem about the peer recognition for those who work in interdisciplinary areas. For instance, when it comes to the selection of Fellows of learned academies of sciences & engineering, it is seen that engineers and scientists, who are working on borders have difficulty in getting recognition. Invariably, they fall between stools. Thus somebody working in biomedical electronics gets considered seriously neither in medical sciences nor in engineering sciences committees. Thus they fall between stools. This is truly demotivating. I am afraid our academies have still not solved this problem.

An innovator is defined as one, who does not know that it cannot be done. Invariably, individuals who are unfamiliar with the discipline are also ones, who do not know that things cannot be done. Probably it is these individuals who will be able to give us conceptual breakthroughs through their unconventional thinking. Should we not, therefore, organise unconventional fora, where only club members belonging to a single discipline do not meet but those in seemingly unrelated disciplines meet?

I was recently attending the meeting of a science academy, where a number of researchers were presenting their research findings. Many of them took up problems that could be solved but not those that needed to be solved. I do believe that that we need to organise major discussion groups, which would deal with unresolved problems in different branches of science. We should invite here people from diverse disciplines. I am sure breakthrough suggestions will come from those, whose minds are uninhibited, namely the participants from the adjacent disciplines.

Modern information technology can play a crucial role in creating a borderless world. Intranet provides connectivity of minds within organisations. Brainstorming to generate new ideas used to take place in confines of time & space with a narrow range of specialists. Now intranet connectivity within an organisation allows borderless thinking, since people from the entire organisation, irrespective of their narrow specialisation, can participate in brainstorming, removing the constraints of time, space & specialisation.

We, in India need to seriously address several issues that hinder borderlessness. They include rigid academic curricula, hierarchical structures in management, etc. Our systems which promote inhibition and imitation rather than innovation. It is only in an environment, which fosters innovation, that borderless thinking can flourish. Using information technology to promote Indian knowledge networks will help hugely in promoting borderlessness.

The final challenge

The leadership in science tomorrow will rest with those who are daring to travel the intellectual path by recognising the key role of cross-disciplinary partnership between scientists and engineers from different disciplines. Advances will be the sum total of numerous creative ideas and interdisciplinary cooperation. In industry, individuals with

diverse scientific and technical backgrounds tend to work together in a mission mode. The driving force for industry is continuous innovation to displace one's own product by oneself – with the well known fear of someone else displacing it otherwise for them. Unfortunately, the concept of interdisciplinary research and development has not gained as much ground in academia, especially in India, as one would have wished. And this is really sad because innovation is not a undimensional process. It is comparable to the intermeshing gears of a clock. The challenge before us is to make this intermeshing happen. This is really the core issue in building up the new India of our dreams.

Let borderlessness be the new Indian spirit in the next millennium in the broadest sense possible extending finally to the "Team India" spirit. It is then and then alone that India will occupy its rightful place in the community of nations.