SYNTHESISING NEW INDIAN KNOWLEDGE AND INNOVATION SYSTEMS: FUTURE AGENDA

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I am beholden to *Academy of Grassroots Studies and Research of India and Rajiv Rural Development Foundation* for conferring the *Sixth Bharat Ratna Rajiv Gandhi Outstanding Leadership Award* for the year 2007 on me.

I am especially happy that last year's award winner was Dr. M.S. Swaminathan, whom, not only I, but the whole nation holds in the highest esteem. He is truly an iconic figure. He was not only the architect of our very own green revolution, but he has also provided a pioneering leadership to the world in promoting the idea of a sustainable global society.

Rajiv Gandhi's Legacy

I am particularly honoured and privileged that the award has been named after Shri Rajiv Gandhi, who was our youngest Prime Minister. He was a great leader and had a unique vision for the 21st century India. I was fortunate to serve as the Member of Rajiv Gandhi's Scientific Advisory Committee to the Prime Minister (SAC-PM) in mid 80's. I vividly remember my first meeting with him. His handsome profile and a charming affectionate smile made an immediate impression on me. He was a thorough gentleman and very courteous. On the other hand, he had a steely determination and a great vision for India's entry into the 21st century. Many initiatives that were taken during his time have made a lasting impact on Indian Science & Technology.

He blended beautifully three qualities of innovation, compassion and passion. He gave a great push to technological innovation. His passion for modern India of the twenty first century was unquestionable. His compassion showed up time and again. I remember his commenting in one of our earlier meetings of SAC to PM about the problem of drinking water in villages. He said "I have a dream equivalent to John Kennedy's dream to take a man on the moon and that equivalent dream is to take drinking water to 186,000 villages". This is how the water mission began, which was a forerunner for a number of other missions that followed. His commitment to S&T was total.

Indeed, one remembers the immortal words of Pandit Jawaharlal Nehru, who had once said "It is an inherent obligation of a great country like India with its traditions of scholarship and original thinking and its great cultural heritage to participate fully in the march of science, which is probably mankind's greatest enterprise today."

■ Text of the ***Sixth Bharat Ratna Rajiv Gandhi Memorial Lecture*** delivered by ***Dr. R.A. Mashelkar***, the then President, Indian National Science Academy, on 20thAugust 2007, under the aegis of Academy of Grassroots Studies and Research of India (AGRASRI), in Collaboration with Rajiv Rural Development Foundation at Hotel Bliss (Darbar Hall), Tirupati (A.P).

Rajiv Gandhi was fully committed to India's forward march of science. I still remember the last SAC-PM meeting that was held at his residence in late 1991. Little did we know that the following day the elections will be announced? With his usual enthusiasm he asked all of us as to what should be the goal for S&T in the next five years? What is that the Government should invest? When we were speaking about the investment in S&T as a percentage of GDP, it had stood at around 1% then. He said this must be raised to 2% in line with the advanced nations.

Someone from the Government was participating in the meeting. He pointed out the constraints on resources. Rajiv Gandhi smiled and in his own charming way he said, "we will keep aside 2% of GDP for S&T. We will then give the rest to the nation.. There is no future to India without S&T. It has to have a priority." I must say that it is India's fortune that successive Prime Ministers have repeated this pledge to raise the S&T expenditure to 2% of GDP. I remember Shri Atal Bihari Vajpayee announcing this in the Science Congress that was held in Pune in the year 2000. I also remember our current Prime Minister Dr. Man Mohan Singh reaffirming his commitment about raising the Indian S&T expenditure to 2% of GDP in the last Science Congress. For India to be globally competitive, we have to achieve this target and that too sooner rather than later.

India has changed dramatically after it opened up in 1991. The changes have been particularly spectacular in the last five years or so. I wish he was alive today. He would have loved to see the emergence of knowledge economy, which he championed, when he sowed the seeds of information and telecommunication revolution. After all C-DOT and C-DAC were his creations. He would have enjoyed India's march towards becoming a true knowledge society. In its true integrative culture, India has opportunity of creating new knowledge systems. It is this new emerging paradigm on which I am going to focus in this lecture.

Synthesising a New Knowledge & Innovation System

While building the Indian knowledge society, we will have to worry about three different domains of knowledge. We as scientists have focused rather narrowly only on S&T based knowledge, which is established through the rigorous methodology of science. But there are two other domains of knowledge, which we have kept away from. One is the so called 'parallel', indigenous', 'traditional' or 'civilizational' knowledge system. These systems belong to societies in the developing world that have nurtured and refined systems of knowledge of their own, relating to such diverse domains as geology, ecology, agriculture, and health etc., our Ayurvedic medicinal systems being one such domain.

Indigenous knowledge systems must be sustained through active support to the societies that are keepers of this knowledge, be they villagers or tribes, their ways of life, their languages, their social organization and the environments in which they live. We need innovative ways of preventing the erosion of such knowledge, which usually vanishes with people. Equally importantly, we need an in-depth analysis of the parallelism of insights between the indigenous knowledge systems, on the one hand, and certain areas of modern science concerned with

fundamental aspects, on the other. Our university education and research needs to shift the search light on this important issue, which it has neglected so far.

The third is the knowledge systems of the spiritual world. Here again, the tools of modern science are giving us deep insights. For example, quantum physics is leading to inquiry into consciousness, computational advances are leading to inquiry into human intelligence, advances in neuro-sciences are leading to inquiry into the working of a human mind.

The new knowledge system will have to be a beautiful confluence of these three knowledge systems. I feel confident that India will lead in interpreting, creating, synergising and enhancing these knowledge systems. As a first step towards this journey, I will like to give you a perspective of how we can build bridges between the traditional and modern by illustrating what we can do with specific reference to Ayurveda, which follows from our ancient wisdom.

Leveraging India's Wisdom

I was attending a meeting of the Third World Academy of Sciences in Trieste a few years ago. Frederico Mayor, the then Director General of UNESCO made an interesting statement. He said "Knowledge flows from north to south and wisdom flows from south to north". I remember making a small correction: `knowledge' may flow from north to south but `usable knowledge' does not flow that easily from north to south, since usable knowledge has the potential to create wealth. No country, no corporation gives a competitive advantage to another, excepting at a price. India itself has realized this in the post liberalization era. However, the flow of wisdom from India to the rest of the world has been rather free. People are just realizing this value of our wisdom now. Let us take one specific example of India's great wisdom, the example of Ayurveda.

New Interest in Ayurveda

There are winds of change now. First and foremost, a number of our country's leading scientists and doctors are now getting persuaded about the real value of Ayurveda. This has stimulated a major support from the central government, in addition to the large patronage from our country's various states. Major organisations in world's health system all now recognize Ayurveda. These include organisations in developed and developing countries. US National Institute of Health's NCCAM, as well as the great international organisations like WHO, can be cited as examples. Following the lead of the Commonwealth, the UK and several European countries recognize Ayurveda as a form of complementary medicine.

In India, there are half a million registered practitioners of Ayurveda. Indian Government has created a department for AYUSH, which is actively promoting every aspect of its development. Ayush means life, and Ayurveda means "Science of Life". It is a beautiful terminology. Our educational system includes two dedicated Ayurveda universities with both undergraduate and post-graduate studies. There are also 200 Ayurvedic colleges training practitioners of all aspects of Ayurveda. Also, if you look at the way things are marketed today in many countries, be it diet, cosmetics, you will find they are marketed with Ayurvedic nuances.

Building the "Golden Triangle"

As I said earlier, Ayurveda literally means, "science of life". It dates long before the emergence of life sciences, which have now become so fashionable with the students, who now-a-days make a beeline towards courses in life sciences. But Ayurveda was the original science of life itself. It encompasses the total sweep of life sciences, pursuing its quest for understanding life in all its ramifications. It is truly holistic.

Ayurveda is possibly the earliest formal system of healthcare. It is not a mere compendium of therapeutic recipes as many other systems tend to be; nor was it the first one to use herbs. Herbs have been used from time immemorial. Ayurveda is one of the earliest frameworks which systematized knowledge of health and healthcare. Its framework is not only self-consistent, but also uses cause and effect arguments to correlate manifestations of sickness, its causes and its treatments. When this framework was developed in ancient India – and I am very proud of this – the notion of a molecule did not exist, nor was the cell and the role it plays in the life process known. The discoveries of DNA and functional genomics lay more the 3000 years in the future, yet in spite of all this Ayurveda offered effective treatments for many disorders, particularly those with multiple causes. For some degenerative diseases, most Indians consider it to be the treatment of last resort. There is a general belief that when all other treatments fail, Ayurveda may still succeed, and it often does! We should be proud of this.

Ayurveda and Modern Science

The 20th century has revealed some of the greatest insights into our understanding of life at successively higher levels of organization: molecules, sub-cellular organelles, cells, tissues, organs, organisms, species, and ecosystems. A remarkable feature of modern medicine is its close integration with basic sciences, like physics, chemistry, and biology. For example, that new frontier of modern medicine, gene therapy, would not have been possible if the structure of DNA had not been known. That itself was made possible by structural elucidation achieved by x-ray diffraction, that means physics. The contribution of modern physics to the elucidation of the structure of DNA – and then gene Therapy is obvious.

This example illustrates how the connection between modern medicine and modern science has always been strong, whereas that between modern science and traditional medicine has been poor. This has resulted in a poor connection between modern medicine and traditional medicine. That is why India can benefit enormously if we can build a Golden Triangle between Modern Science, Modern Medicine and Traditional Medicine. I used the term, 'Golden Triangle', for the first time at a meeting in Chitrakut, where I gave the valedictory address. I am very happy the term has become so popular. Indeed, triangles are a popular concept in complementary medicine, but for AYUSH, the Golden Triangle project is not merely a triangle, but a 'Golden Triangle' because it presents a golden opportunity to bring these different systems together.

During the colonial period of world history, which was also a time of phenomenal growth in science and technology, science was projected and accepted as an essential feature of western civilization. An unfortunate, retrograde corollary was that modern scientific knowledge was seen as an adversary of traditional wisdom and traditional knowledge: the two were considered mutually exclusive. This was a regrettable syndrome, because it had the effect of belittling the intellect and wisdom of the vast proportion of the world's population, the heritage of the whole human race.

I believe we need to remind ourselves of a profound statement made by Mahatma Gandhi. He said "I do not want my house to be walled in on all sides and my windows to be stuffed, I want the cultures of all the lands to be blown about my house as freely as possible. Gandhiji implied that our minds should be open and uninhibited. We should be open to new ideas and new thinking. There should be no artificial boundaries, no walls or borders between different domains of knowledge or their practitioners. That is why I am so happy to see the present confluence of these different domains of knowledge, and their adherents.

Ayurvedic Research: Scientific Questions to Address

At the Science Congress that was at the Pune University Campus in 2000, I happened to be the President. Nobel Laureate Professor Richard Ernst lectured on his work using the latest advances and tools in high-resolution solid-state NMR. He gave indications on how an understanding of the Chinese system of acupuncture at the molecular level was being reached. He referred to papers in the Proceedings of the US National Academy of Science. You see, while western scientists are scientifically probing the ancient practices of the East, our own Indian research is invariably focused on the West's left-over problems. That is unfortunate. It is a great pity indeed. We need to change our ways.

As I have said, Ayurveda is the "Science of Life". The period 600 B.C. to 800 A.D. has been called the 'Ayurvedic period'. At that time, developments in Ayurveda led to fundamental advances in chemistry, and in our ancient forms of botany and zoology, as well as its own discipline of medicine. Today, however, Ayurveda gets equated only with herbal products. That is not only unfortunate, it is just plain wrong. It presents a vision of Ayurveda through the spectacles of molecular medicine and pharmacology, and excludes the greater proportion of its substantial scientific value. Dravyaguna, Ayurvedic knowledge of herbs, forms only a small part of the whole system.

Similar to the way that Nobel laureate Richard Ernst was looking at Acupuncture and the science behind it by probing with high resolution solid-state NMR, much of Ayurveda requires fundamental physical investigation. For example, Ayurvedic etiology is couched in terms of the concept of Dosha Prakriti, as are physician's strategies of treatment. It is scientifically very important to decide whether Prakriti has a genomic basis or if they are only phenotypes. We are only beginning to address this question, and future developments may be very important, since establishing a full scientific basis for Tridosha would be of utmost significance.

As Prof. Valiathan had so thoughtfully suggested, if we investigate Panchakarma, that powerful tool to detoxify the body, does it alter the patient's biological and immunological profiles? This has not yet been investigated. Then there are the Rasayanas. What do they do? Do they accelerate the repair of damaged DNA? Can any show improvements in mouse models of Alzheimer's, such as inhibition of beta-amyloid accumulation? These questions have not been addressed. There have not been any studies on them; they are virgin territories, where the Indian scientists can make major advances.

I would go as far as saying that just as we have cellular biology, molecular biology, and structural biology, there must be an "Ayurvedic biology" that we should start talking about. I must give credit to Dr. Valiathan for coining out with this phrase. The more I think about it, the more I believe in it. What has India given to the rest of the world? Did we give cellular biology, molecular biology, or structural biology? Did we give structural genomics, functional genomics, or pharmacogenomics? No, but we can give 'Ayurvedic biology' and 'Ayugenomics' to the world.

CSIR Involvement: The New Initiatives

It makes me very happy to see that formal scientific systems that used to be averse to traditional medicine are getting integrated nicely with it. When I was the Director General of CSIR, I was very happy that we had instigated major programmes of research, which partner traditional medicine, modern medicine and modern science. Getting the programme going was very tough.

I still remember my visit to Arya Vaidya Shala, Kottakal, where I went with Dr. Warrier to sign our Memorandum of Understanding with CSIR, of which I was then the Director General. It took us almost an year to get together. Dr. Warrier is a very great visionary and Dr. Valiathan managed to bring us together. I well remember how, when we had signed the memorandum, Dr Valiathan said, "This is a holy place for me, because there are two rivers meeting here. One is the river of traditional knowledge, Arya Vaidya Shala, and the other is the river of modern knowledge represented by CSIR." "Sangam" is the word he used. I only wondered why it had taken so long for this "Sangam" to take place, but now that it has done so, an unbelievable programme has developed.

There are 19 CSIR laboratories, 21 universities, Arya Vaidya Shala and a whole range of people working together. It has evolved into a great programme. Prof. R. Kumar, a legendary scholar and leader from Indian Institute of Science is providing a leadership for this 'Team India' effort. The CSIR programmes include identification of target therapeutic areas, discovery of active fractions, molecular description of active fractions, understanding mechanisms of action, toxicological studies, clinical trials, etc. A whole range of promising leads for new therapeutics are beginning to emerge.

Science Based Ayurveda Products

We now have an opportunity to create new products that are science-based Ayurvedic products, see four different types of use. First, those to be used for minor ailments like dysphagia,

unpleasant taste, anorexia, etc. Secondly, the other ones that is more specific products like detoxifiers, toners, resistance builders, and rejuvenators for longevity. Both these sets of preparations are likely to be available over-the-counter, OTC.

Thirdly, those for support therapy where the therapeutics may be administered together with allopathic preparations. Traditional medicines may even partially replace allopathic ones.

These will most probably be prescribed by existing medical practitioners, who will be using combo-therapy to take advantage of the synergy between the two sets of preparations for patients' overall benefit. In combo-therapy, use can be made of bio-enhancers, detoxifiers, toners, and specific therapeutic agents to accelerate recovery. Similar use may also be made of them at hospitals based on the existing systems. With time, such combo-therapy may become acceptable not just in India, but universally.

Questions of Toxicity and Mechanism

In addition to molecularly defined, and mechanistically understood, non-toxic herbal fractions containing only a few molecules, there are other important preparations, which are unique to Ayurveda: the bhasmas, which are made from mixtures of metals or minerals. Most are traditionally calcined in sealed earthen containers by burning cow dung cakes, or else in furnaces. The final products are fine powders about 50 microns, or less in diameter. They use elements like lead, tin, iron, arsenic etc. Nearly 10% of Ayurvedic products are bhasmas, I understand.

Most of the elements used in these preparations have been classified in standard scientific textbooks as toxic. For example, lead in any concentration is described as toxic; not only that, it is known to accumulate in various tissues. Bhasmas, however, are considered fast acting healing agents and are used quite freely, particularly Siddha preparations. No toxic effects have apparently been reported from them; but to make them internationally acceptable, it will not only be necessary to show that they are efficacious and non-toxic, but also to define their physicochemical characteristics by accurate scientific measures. In this regard, the work being done at the National Chemical Laboratory by Dr. Rajiv Kumar is pioneering. He is looking at what is happening in bhasmas at the atomic and molecular levels. Very interesting findings are coming out.

My last question is: How do we get more and more outstanding scientists such as Dr. Rajiv Kumar interested in this? Let me remind you that Dr. Rajiv Kumar, till the other day, was busy developing catalysts for Indian and international companies. Today, his mind is engaged in these issues that interface the tradition and the modernity. Therefore, the first need is to expose our best minds and our best scientists to the accumulated wisdom of Indian systems of medicine, including Ayurveda. There is no doubt that there are enormous opportunities for doing focussed, basic-cum-applied research. Mechanisms need to be elucidated in such areas as actions of bhasmas, detoxification, reversal of ageing and bio-enhancers and how molecular synergism occurs. All these offer great scientific challenges. All are going to be very valuable.

Traditional Knowledge Digital Library

It is also important to protect our traditional knowledge. I remember fighting the turmeric battle and Basmati battle. Wrong patents were given by the patent office in United States. We fought these battles and won them. But we do not have to fight them again and again, if we use modern technology to digitise traditional knowledge. This is the effort that CSIR has launched in partnership with the Department of Ayush in Central Ministry of Health & Family Welfare. We have created a Traditional Knowledge Digital Library. This is a knowledge repository of the traditional knowledge. The objective of this library is to protect the ancient and traditional knowledge of the country. The idea is to avoid bio-piracy and unethical patents.

Data on 65,000 formulations in Ayurveda, 70,000 in Unani and 3,000 Siddha have been put in the TKDL. TKDL is available in five languages – English, German, French, Spanish and Japanese. Some more Unani and Sidha formulations and 1,500 postures in yoga remain to be included. The entire process is expected to be completed by December, 2008.

Conditional access to international patent offices of TKDL will ensure that they become aware of our knowledge base, realise that this is prior art, and not grant wrong patents anymore. We do not have to fight turmeric and Basmati type of battles anymore.

Future Agenda

Great visionaries such as Dr. Valiathan and Prof. Kumar, who really represented modern medicine and modern science, are helping us to build a bridge of these with traditional medicine. They are laying an ambitious agenda.

What should be the new agenda? First, encourage clinical research in Ayurvedic institutions. Second, create a complete Ayurvedic pharmacopoeia thousands of products. Third, create an effective surveillance system like the post market surveillance systems. This would include providing support from modern laboratories spread all over India. Fourth, we must carry out multi-centric trials of Ayurvedic biology. Fifth and the last, we must establish a presence in international scientific journals. We must have a very strong presence in the world's scientific journals.

Then there is another challenge linked with new Institution building. We first built IIT's i.e. Indian Institutes of Technology. We already have IIM's i.e. Indian Institutes of Management. Then we built IIIT's i.e. International Institutes of Information Technology. We have heard recently about building several more IITs, IIMs and IIITs. What else should we be building? What we should now focus on is IIIM's. What is an IIIM? An International Institute of Integrative Medicine: that is where our great strength is. We should create and demonstrate to the rest of the world our own power, what it is, and where it lies.

Final Challenge

The bigger battles of integrating knowledge and innovation systems must be continuously fought. Prof. Anil Gupta is leading a great movement of National Innovation Foundation to give a voice to the grassroots innovators such as local artisans, craftsmen, farmers, etc. His Honeybee

network experiment is a great movement today. The problem is that their technologies and innovations are never included in the fabric of modern technology. Again a change of mindset and value systems is required. I tried an experiment in Pune during the Indian Science Congress in January 2000. As President of the Science Congress, I said let this Science Congress be 'knowledge congress'. Let it be 'people's congress'. We will show that we value people's knowledge.

We had several grassroots innovators participate in our science exhibition. They demonstrated their technologies. None of them spoke English. We had a session, where they made a presentation on their technologies in local languages to around 2000 scientists. They stood on the same platform from which the Nobel Laureates spoke. I must say that they got a bigger applause than even the Nobel Laureates. I believe the scientists, for the first time, realised the power of innovation that takes place in the field. They also saw the innovative and creative abilities of those, who were unadulterated by the modern day educational system.

Can this realisation now turn to respect and then to meaningful partnership? I believe it can. India has to show the way to synthesise a new Indian Knowledge and Innovation Systems, which has the confluence of the old and the new, the traditional and the modern and those who work in modern laboratories and those, who work in laboratories of life.

Padma Vibhushan Dr. R.A. Mashelkar, Former Director-General of CSIR, delivering the ***Sixth Bharat Ratna Rajiv Gandhi Memorial Lecture*** on 20 August, 2007 at Hotel Bliss (Darbar Hall), Tirupati, under the aegis of AGRASRI.