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NEED FOR GLOBAL VIEW OF KNOWLEDGE

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What I wish to do in this presentation is to indicate what the expectations would be from the citizens of tomorrow in terms of knowledge that would allow an individual (a) to exercise one's rights and discharge one's obligations as a citizen, and (b) to play one's due role in the creation of a new world order that would be based on equality and respect for basic human rights, and that would not allow exploitation based on money, power or authority. I would then attempt to suggest the kind of institutional framework we would need to make this possible.

However, before I embark on this exercise, we must remind ourselves about the hierarchy between information, knowledge and wisdom. Information is what newspapers, magazines and textbooks provide. To convert information into knowledge, one needs to collate the information, put it in a larger perspective, and identify its relevant interrelationships. To convert knowledge into wisdom, one needs to bring to bear all of one's experiences and then put the knowledge within the framework of a value system conceived in reason so that it would lead to decisions that would stand the test of time and would be in the larger interests of mankind.

NEED FOR GLOBAL AND INTER-DISCIPLINARY APPROACH TO KNOWLEDGE

Let me straightaway present my main thesis. The point I wish to make is that, for the citizens of tomorrow to exercise their rights and discharge their obligations, their framework of knowledge would need to be global and inter-disciplinary. They would need to cease to think in terms of conventional disciplines of knowledge, and would need to know at least a little about virtually everything: be it science, computers, economics, history or sociology. I must hasten to add immediately that, concurrent with the growth of this need, there would also be an increasing demand for a high level of specialisation in one's chosen profession no matter what it is; every activity, from cleaning to laboratory or hospital management, would be highly professionalised. Therefore, the challenge would be to combine a high level of professionalisation in one's chosen area of activity or interest, with a global and inter-disciplinary approach towards knowledge.

Let us now look, in some detail, at the following four main reasons for the projected transformation in regard to the package of knowledge that the citizens of tomorrow would need:

(1) The historical imperatives
(2) Increasing role of science and technology in our daily life

(3) New linkages between diverse areas of knowledge
(4) Exploitation of ignorance

(1) The historical imperatives

Let us see how it has come to be so. We have, perhaps, had three stages in the evolution of knowledge. In the first stage, the ancient-medieval period, the view of knowledge was global. Thus, *Charaka Samhita* and *Susruta Samhita* are not treatises devoted to any of the large number of today's specialisations in medicine or surgery.

The second stage could be said to comprise the first phase of modern period (*ca* 1850-1975), when a plethora of new branches of knowledge came to be identified and the era of specialisation began. To take one example, towards the end of the ancient-medieval period mentioned above, science came to be divided into five distinct disciplines: physics, astronomy, chemistry, biology and mathematics; four of these were recognized as experimental sciences and the fifth, mathematics, as the abstraction of them all. Biology was, at most, broken up into botany, zoology, medicine and agriculture. In the last hundred and twentyfive years or so, we have had the emergence of a bewildering variety of disciplines in biology alone, such as biochemistry, biophysics, cell biology, genetics, immunology, virology, bacteriology, molecular biology, paleontology, entomology, parasitology, helminthology, agronomy, veterinary science, anatomy, medical jurisprudence, epidemiology, pharmacology, even pharmacokinetics and pharmacodynamics, to cite a few examples.

In the third stage of evolution of knowledge in which we are today and which represents the second phase of contemporary period, the different specialisations have again started rapidly converging and merging into each other. Thus today, we think of physics in terms of mathematics, chemistry in terms of physics, and biology in terms of physics, chemistry and mathematics. There is no getting away from the disappearance of borders of conventional and man-made compartments of knowledge: the process of dissolution of the walls of these compartments has already begun, and the age of globalisation is on us again but against the background of a much larger canvas of varied and highly specialised knowledge.

(2) Increasing role of science and technology in our daily life

Science and technology have become intimately intermeshed with the fabric of our very existence. Thus, technology has firmly established itself as a major determinant of our life styles today, and of the way we conduct ourselves in private or in public, in various areas of

human endeavour. The changes that have been brought about in our lifestyles through new space technologies, atomic energy, advances in chemical industry, new agricultural technologies, biotechnologies, advances in material science, computers and electronics, and the rapidity of communication and travel, would not have been predicted at the turn of the last century. It is becoming increasingly important to understand the bases underlying these advances, and to familiarise ourselves with certain elements of the technology concerned. It has thus become important to understand what electricity is, to ensure that when you build a house there is proper earthing provided, and that you do not need an electrician to fix a fuse. (I, of course assume that everyone in the audience can fix a bulb but how many, I wonder, can read a simple balance sheet!) A large number of avoidable deaths occur every year in our country - and new houses built without proper earthing - because of lack of understanding of electricity, the understanding of which could be imparted in less than an hour.

Inability to operate a PC or Fax, or to elicit reliable information from a data base, would be a serious handicap tomorrow. To assess consumer goods of tomorrow that are going to be products of high technology - even to make use of advice from consumer protection groups - you would need to know a little about the goods. (The success of Ralph Nader in the United States in the 1960s was precisely on this account: he made an American know what he ought to have known about his car.) Those who can use self-diagnostic kits tomorrow, would surely have an advantage over those who cannot. In fact, I can safely say that a large proportion of irresponsible and inaccurate statements made today by our leaders in various fields, that not only lead to confusion and disharmony but also to wastage of time and money, are a consequence of ignorance for which there is no excuse. Such ignorance causes enough problems even today but, tomorrow, it could lead to social, economic and political disasters of unimaginable magnitude.

Advances in basic sciences in recent times have also influenced our thinking considerably. The theory of evolution has changed our ideas regarding our origins, and modern biology regarding reproduction and birth-related phenomena; and our understanding of the scientific basis of heredity has provided us with the most important argument against apartheid - that in all sufficiently large outbred populations, the distribution of genetic traits follows the same pattern. And science has, by providing testable and verifiable answers to many major questions, cut at the root of many dogmas that had the sanction of religion, custom, convention or tradition over centuries. Thus, we can say with confidence today that even if virgin birth took place in human beings (for which there is no proof yet), like parthenogenesis in frog, the progeny would always be a female, and that astrology or homeopathy have no scientific basis whatsoever.

It would be obvious in the light of what I have just said that basic knowledge of scientific concepts, ideas and possibilities, would be of great help in making an individual (a) exercise the right choice in regard to the use of available information and technology for determining lifestyles, and (b) participate intelligently in the process of moulding public opinion so that decisions are taken at various levels in wisdom and in long-term interests of the community and the humanity at large. I would present some specific examples in this regard in the latter part of my talk.

(3) Linkages between diverse areas of knowledge

New linkages have been established in recent years between various areas of knowledge. Consolidation of these linkages and development of new ones is going to characterise the global knowledge scene in the coming years - and for a long time to come. Let us take a few examples.

(a) Language and science

Language, today, is not the sole confine or domain of literateurs. It has come to be intimately and specifically linked with virtually every human activity. For example, one cannot be considered to be proficient in English today, if one's vocabulary, no matter how large, is totally confined to non-technical words. One may even predict that by the year 2,099, as many as half the words in use in the English language, would be technical words.

(b) History and science

History is becoming increasingly important in every sphere of activity. There is hardly an area of human endeavour in which history has not made meaningful inroads. For example, we are beginning to realise that there are many lessons to learn from the history of science in our country, from 5,000 years to 5 years ago! It is only through an in-depth understanding of history of our science and technology, from the ancient to the modern, that we would be able to frame strategies for the future that would ensure that we optimally utilise our assets and do not allow our historically inherent disadvantages to act as major impediments to progress. My colleague, Chandana Chakrabarti and I, recently did an analysis of the history of development of biology in India from the ancient times to the end of last century (1,2,3,4). The conclusions we arrived at are quoted below.

(i) Our forefathers in the ancient and the medieval period did all that was humanly possible at that time to acquire scientific knowledge. However, they tried to do more and in that

process gave us untruths which, in the social milieu in which they were generated and sustained, came to be stratified, amalgamated with truth on the one hand and with myth, legend, magic and religion on the other. If, today, we could separate the myth and dogma from truth, and reject what is not compatible with modern science, we would be in a position to not only have a better appreciation of what our ancestors were able to accomplish, but also lay the foundations of a systematic and rapid development of modern science in India by providing a new motivation. We have no doubt in our minds that one of the reasons for the lack of this development has been the hold of obscurantism and religious authority, partly derived from what has been said in our scriptures, on the minds of our people.

(ii) Even though Indian science reached remarkable and commendable peaks in certain areas, the scientific method and the scientific temper as a methodology, approach or way of life, appear to have been alien to us. This in itself, perhaps, could not be considered a major disadvantage to begin with. What we believe has been a disaster is that the scientific method and the scientific temper continued to remain alien to us even when they became a major force in Western thought, at least from the thirteenth century onwards, specially, with the beginning of the Renaissance in Europe with Leonardo da Vinci. And scientific temper and method continue to remain alien to us even today, more than a century after the introduction of Western science in the country - when other countries with equally strong local traditions in science, such as China, Japan and Vietnam, have recognised their validity.

One may ask why the scientific method did not develop and scientific temper did not take root in India in spite of the fact that India has had a five thousand-year-old tradition of science, unlike Europe with the exception of Greece. I give below some of the possible reasons:

- The above-mentioned tradition itself could have acted as a block to the development of the scientific temper and the acceptance of the scientific method on account of an in-built resistance to change, that has characterized all early societies.

- In a hierarchical society, specially one in which knowledge is considered as the confine of a select number of people identified by birth, knowledge becomes a tool for perpetuating vested interests. Under such circumstances, development of a culture of questioning which is an integral part of the scientific method, would pose a serious threat to the continuance of these vested interests.

- Finally, the tradition of experimentation was lacking in our ancient and medieval culture - even in Gautama's *Nyaya Shastra*. Experimentation to test a hypothesis based on observation or analysis of existing information, is the key to all modern scientific inquiry and progress, and an important step in the scientific method. Wherever we performed experiments, as in surgery, the knowledge gained has stood the test of time.

What we may now ask is: what has happened to this compulsive and acute power of observation that characterised our science in the past and was largely responsible for the glory that India was? When I was with the Centre for Cellular and Molecular Biology (CCMB) at Hyderabad, I used to often ask prospective Ph.D. students the following question in the interview: "What have you seen on your journey to the CCMB from wherever you started: stations, buildings, etc?" We repeatedly found that the bright ones had kept their eyes and ears open while coming to the CCMB during their train or road journey to or within the city, while those whose powers of observation in this regard seemed to be poor, did not fare well in other aspects of the test and interview. When and why did we lose this power of observation, and how may we develop it again? Its loss is surely not genetic, and its development is surely a requisite for a true scientific renaissance in the country that would have a mass base.

(c) Molecular biology and music

New relationships have been discovered even for highly specialised activities such as music. It has thus been possible to convert the genetic language of DNA into the language of music, raising the possibility that wherever there is information in a sequence (in the case of music, in the sequence of notes, and in the case of DNA, in the sequence of its four chemical building blocks), Nature may be following similar laws. Surely, the recognition of such possibilities would open up new intellectual vistas for an individual that may help him exercise his rights and discharge his responsibilities more creatively, besides providing him immense pleasure and satisfaction.

(d) Science and law

Let us take some examples where we would need new legislation on account of advances in science (5).

- One can predict safely that vaccines would be available in the next two decades for a large number of diseases caused by microorganisms, parasites or viruses. Shall we make vaccination compulsory for all of them, or for some of them, or for none of them? What

would be the social criteria that the vaccine must satisfy? What epidemiological information would be considered to be a prerequisite for making vaccination for a particular disease compulsory? We have to remember that small pox would have never been wiped off the globe if there was no legal compulsion in regard to vaccination for this disease.

- I personally believe that through an investment of just a few hundred crore rupees over a ten-year period, it should be possible for our country to discover at least a hundred new drugs based on our indigenous systems of medicine - the Ayurveda and the Unani - that would have been tested using the most modern methods and whose efficacy would, therefore, not be in doubt. What laws would be needed to clear these drugs when we have today no laws for formulation or prescription of Ayurvedic or Unani drugs? It is strange that whereas a drug used in the modern system of medicine has to be approved by the Drug Controller, and its manufacture, marketing and use strictly regulated, a drug prescribed by an Ayurvedic or Unani physician (who, just as strangely, needs no license to practice) does not need to go through any of these stringent testing, marketing or prescription procedures, even though the efficacy of none of them has been tested anywhere nearly as stringently as in the case of drugs used in the modern system of medicine. Shouldn't this anomaly be removed through appropriate legislation?

  Then, today, there is no legal protection to the individual if an Ayurvedic, Unani or homeopathic prescription or medicine has in it a substance which is used in the modern system of medicine but only under careful medical supervision and which, while being a life saving drug under certain circumstances could, under other circumstances, on improper usage, lead to much damage. Further, if today a doctor trained in modern medicine and appropriately licensed is careless and a patient dies, he can be taken to task and rightly so; there have been several such cases even in our country where human life has little value. On the other hand, if a person dies at the hands of a homeopath, or a practitioner of Ayurvedic or Unani system of medicine, on account of total ignorance on the part of the doctor and inadequate or inappropriate medical attention, there is nothing one can do legally about such carelessness or inefficiency. Therefore, will there be need to establish protocols which practitioners of every system of medicine must follow?

- Genetic engineering - the acquisition of the ability to transfer genetic information from one organism to other, or to put in new genetic information in an organism that never had it during its entire evolutionary history - is destined to have a very substantial effect on medical and health care in the coming decades. By the year 2000, perhaps, a thousand

genetically-engineered products with a market value of over 50 billion dollars would be available. With the availability of such products, new problems in regard to quality control would have to be tackled. For example, contamination with extremely low levels of proteins of the organism in which the desired product was made, could lead to an immune response in the human being which could cause serious problems. How would one go about testing for such contamination? New standards for testing laboratories would need to be set up that will not only check such contamination but would ensure that the genetically engineered product is identical with the natural product in every respect, for the animal body has the most exquisite ways of responding differently to extremely subtle differences in structure; the altered response in some cases could be fatal.

- Nearly 5000 genetic or inherited diseases of man are known today. We are gradually learning to cure some of them, through extremely sophisticated procedures, slowly but surely. An important question that is going to arise is: whom to cure and whom not to cure because for a long time to come, the capacity of the system to take care of people suffering from such diseases, is going to be extremely small even in the most advanced countries. What criteria would be used for selection of the patient that may receive the cure? Who would decide, and what would be the arbitration procedure? We have to remember that all these decisions would need to be taken rapidly as such diseases are not like property suits that can drag on for 20 years!

- We have made steady progress in the technology of organ transplantation in human beings. It is widely known today that organs are in short supply - be they kidneys, eyes, or heart. As the technology becomes cheaper and more and more people begin to afford the cost of replacement of an organ, the limiting factor would be the availability of the organs. Would we then have a legislation requiring compulsory donation of certain organs at the time of the death of an individual?

- Today, it is possible to have a person whose brain is completely dead, to be maintained clinically alive with no chances of his ever recovering consciousness. It would be extremely expensive for the family or friends of the patient to maintain him in his condition. And, then, for what purpose?. The existing law in many countries (including India) does not normally allow a person to be taken off a life-support system once he has been put on it, unless he actually dies. Can the family or friends in the future, demand that the person be taken off the life-support system if it is certified by a "competent" doctor that there are no chances of the person ever regaining consciousness (for example, if the EEG is totally flat showing no activity in the brain)?

- Today, in many countries, the law prescribes the isolation of a person suffering from an infectious disease. However, there are generally no laws for compulsory testing for such a disease. Would we need such laws in the future? And what about compulsory testing for seropositivity for HIV (that is AIDS)? Wouldn't such testing be an invasion of the privacy of the human body which is today sanctified by law in many countries. On the other hand, we are well aware that such compulsory testing could be an important instrument for preventing the spread of disease. How would the law take care of these conflicting interests?

- To elaborate further on AIDS, what should be the responsibility of the employer when he discovers that one of his employees is seropositive for HIV? The chances are that the employee would go into the full-blown disease in 5-10 years but, on the other hand, he could lead a perfectly normal life until then and be productive and useful. Would the employer be justified in terminating the services of the individual as he knows that the chances are that 5-10 years from now, when he goes into the full-blown disease, the employer would need to bear all the medical expenses of the person, or will he be obliged by law to retain the person?

- It is surely going to be possible - may be by the turn of this century - for the human semen to be separated into male and female sperm (contrary to popular belief, it is the male who decides on the sex of the child and not the female who is wrongly blamed for it often). There might even be shops in small cities doing this where the husband or the man could give his semen in the evening and collect two tubes, one containing the male sperm and the other containing the female sperm, the next morning. He could then take the woman to a doctor where she could be inseminated either by the male or the female sperm of the man, thus ensuring a child of the desired sex with a virtually 100% certainty. What would the law have to say about it in a country like ours where a male child is at a premium?

- An experiment was done not long ago in China in which a female chimpanzee was inseminated with the sperm of a human male. The idea of the Chinese, perhaps, was to breed a slave race that would have the strength of a chimpanzee and the minimum intelligence of a human being. As it turned out, the pregnancy was established but, fortunately or unfortunately, it was terminated midterm during the cultural revolution. Such experiments designed to make inter-species hybrids are bound to be done. What should be the legal control - if any - over them? The entire disease pattern and pattern of susceptibility to disease of such inter-species hybrids would be very different. What about insurance laws for them?

- It has already been possible to grow a large mouse by insertion of additional copies of the growth hormone gene in its genetic makeup. If we can make a mouse grow to the size of a rabbit, the question of growing a man to the size of an elephant may only be a technological problem. Should the development of such technologies that are bound to spring new medical and health problems, be legally regulated?

- We have witnessed a continuous increase in the average life span of human beings in various parts of the world. It is now being debated amongst the scientists as to what the maximum life span of a human being could be. I personally believe that all of us - unless genetically unprivileged for one reason or another - are programmed to live for a hundred years if not more. Even today, the average life span in some parts of the world is close to a hundred. When this happens for the bulk of humanity, shall we still retain 58, 60 or 65 years as the retirement age? If we did so, the social security load on the State would become unbearable. Would we then have a flexible retirement age? We also have to remember that if we increase the retirement age, with the rapid advances in knowledge there would be need for retraining in the case of many categories of employees when they grow older.

- Somatic cell hybridization has already proven to be a powerful technique in biology. One can thus hybridize the cell of one species with the cell of another species and thus produce a cell which has genetic information from both the species. In the case of plants, we can already grow a whole plant from a single cell. Therefore, if we have a hybrid plant cell, we could grow a hybrid plant from it, which would have the characteristics of the two species. Suppose we are able to hybridize a tomato cell with the cell of a calf in such a way that the hybrid cell retains the ability to make collagen which is an animal protein. In all other ways, the cell would resemble that of the tomato plant. If this were so (this has, in fact, been actually claimed) the resultant plant would yield tomatoes which would have the animal protein, collagen, in them. Would we need to label them, by law, as non-vegetarian tomatoes?

- Today, it is possible to establish the identity of an individual, or his or her parentage, without any doubt, using the technique of DNA fingerprinting. Should we, some time in the future, think of making DNA fingerprinting compulsory at birth? Each one will then carry a small strip with him/her which could be computerised and coded at a central place in the country. The country would then have on its record material that would establish the identity of all its citizens irrevocably for all time to come. Thus, one could establish the identity of the person to whom an intact hairroot or a piece of skin or dried semen or blood found at a site, belonged to.

(e) Science and ethics

We are beginning to realise today, that there might be objective assays to determine whether a certain value system, a certain action, a certain behavioural pattern, is "right" or "wrong". The assays would probably emerge out of an increased understanding of biological evolution following Darwinian selection, and delineation of behavioural patterns that could have provided an evolutionary advantage. It is, for example, being recognised that altruism may have been an evolutionary imperative. Indeed, if altruism were not built into our genes, we would probably have been extinct! We are thus beginning to recognise a *scientific* basis for values which we have so far considered desirable axiomatically or on the basis of experience alone. In fact, the belief that all values are eternal has been a major source of today's social conflicts - for example, of the generation gap. We now know that this is simply not true and that no value is for all time or all occasions. A value which might be desirable today, may not be equally desirable a hundred years from now, when lifestyles change. Once we have a scientific assay for determining whether a particular value system is desirable or not, built in that assay would be the prescription for determining its validity at a given time or occasion. A "value system" that has emerged through such a scrutiny, may be more desirable than the concepts of morality and of what is right or wrong, that have come to us through word of mouth or through convention, custom, tradition, or religion, and that are considered immutable.

(f) Science and aesthetics

We regard aesthetics today as an entirely personal matter. It may turn out that this really is not so, and that there may be universal determinants of aesthetics which are built into one's genes. In a recent study, based on computer simulation and modification of facial structure of good-looking women from various ethnic groups, it was found that there are common elements of beauty that are recognised intuitively by both men and women, right across the ethnic groups. There is no evidence of aesthetic recognition in lower organisms and aesthetic satisfaction is likely to have provided an evolutionary advantage to the human species.

In a recent article (6) we have provided evidence in support of the following seven propositions.

- There is inherent beauty in whatever Nature generates or gives rise to following natural laws - from the lowest level of resolution as is obtained with the naked eye, to the highest as is obtained with electron microscopes, X-rays or telescopes.

- All that happens in Nature follows laws of mathematics, physics, chemistry and biology. Since these four sciences represent a hierarchy between themselves, with mathematics at the top and biology at the bottom, mathematics can be considered to be the 'vital force' in whatever Nature does and whatever is found in Nature.

- Certain mathematical relationships (such as the Fibonacci numbers and the golden ratio) are dominant in Nature over others so that they recur over and over again, often in apparently disparate fields. We are probably genetically programmed during evolution to recognise these relationships and respond to them through aesthetic experience. Appreciation of beauty is thus built in our genes and implies intuitive recognition of certain specific patterns and relationships that we then designate as beautiful.

- Not only is the appreciation of beauty probably built in our genes, but it must have also conferred an evolutionary advantage to the human species which alone seems to be capable of going through an aesthetic experience.

- When man creates, he is essentially generating beauty. His success depends on the extent to which his creation is analogous to what is found in Nature and is in consonance with certain natural laws. Consequently, in man's eternal search for beauty, he is also - sometimes consciously and sometimes subconsciously - seeking similies with Nature.

- Creativity and beauty are related in all areas of human endeavour, including science. This would predict that all creative activities must have common elements in terms of methodology (to the extent it can be formalised). This, indeed seems to be so.

- Another corollary of what is stated in the preceding paragraph would be that, given two theories, a good scientist would intuitively choose the one that is aesthetically more satisfying. History has repeatedly shown that a theory that is beautiful and elegant, is more likely to be proven right in the future than a theory that is not so aesthetically satisfying.

(g) Science and politics, economics and sociology

Today's politics of power depends primarily on the ability to use science and technology for warfare and defence. Perhaps for the first time in human history, man is in a position to totally destroy himself - in fact, not only himself but much of animal and plant life on our planet - through nuclear, chemical and biological weapons that he already has in his arsenal. This, however, is just one side of the story. On the other, we have the fact that if the vast amounts

of money and resources that have been spent on the use of science and technology for warfare and defence, were spent on constructive activities on a global scale, we may have been well on our way to a conflict-free world by raising the standards of living everywhere; this can, however, come about only when people around the world express their opinion in this regard, based on facts and accurate information, and demand that the resources which they have helped raise for their governments, be diverted from war-related activities to peace-related programmes. Many questions would be asked of them by those who gain from such conflicts; we would need to be prepared to answer them. Only more knowledge and wisdom can win over knowledge.

There seems to be evidence that compulsive gamblers have lower levels of brain chemicals that regulate arousal, thrill and excitement; therefore, they take recourse to other, high-risk activities such as gambling that give them the thrill that normal people derive from normal activities. Similarly, there seems to be a gene that regulates homosexuality. If these observations are confirmed, compulsive gambling and homosexuality would cease to be the moral or social aberrations they are generally considered to be in many societies today.

The availability of the technique of DNA fingerprinting - in our case, our own Indian technique developed by my colleague, Lalji Singh - is surely going to be a deterrent to certain kinds of crime. Let me give one poignant example of how knowledge in this regard can be a saviour of the otherwise unprivileged. A tribal woman was made pregnant by a building contractor (not an uncommon event in our country), who then refused to accept that the child that was born was his. By this refusal, he thought he could escape all responsibility in regard to the child. The woman had, however, heard of DNA fingerprinting and threatened that she would go to court and ask for the DNA fingerprinting of the child, of herself, and of the contractor to be done which would establish beyond doubt that he was his father. When the tribal woman said this to the contractor, he accepted the paternity! I personally believe that awareness of many new technologies on the part of the people around the world will, in the long run, reduce the number of cases that would have normally gone to court.

One can safely say that advances in material science, biotechnology, space science, computers, artificial intelligence, microelectronics and new energy sources, are going to be the major determinants of tomorrow's lifestyles. They would do so not only by providing facilities but also by raising new problems that would have immense social and economic implications. Let us look at some of them.

Traditionally, the Malagasy republic has been the main exporter of vanilla beans. This industry provides jobs to 70,000 small farmers and is responsible for 50 million dollars worth of export from this small island-republic. Now two American companies are in the process of producing natural vanilla through tissue culture which could very well throw the 70,000 farmers in Malagasy out of job.

A protein called thaumatin has been discovered that is 5,000 times sweeter than sugar. Indeed, it may not be impossible to genetically engineer it in such a way that it might become 50,000 times sweeter than sugar. Again, through genetic engineering, it can be produced in large amounts rather inexpensively. There is thus a real possibility that thaumatin - which would be surely preferable to ordinary cane sugar as it would have virtually no calories - could be produced at a cost which would not be more than that of sugar anywhere in the world. When this happens, 8 million workers in the Third World alone could be rendered jobless.

Europe, America and Japan, are developing biotechnologies for production of cacao butter in the laboratory. This would again be devastating for certain Third World countries.

Today, genetically engineered vegetables, such as potato, tomato, lettuce, sweet maize, onion, broccoli, carrot, celery, and cauliflower, are poised to enter the world market in a large way. For cauliflower, of which the sales in the United States a few years ago were 200 million dollars, the price would then become half, and for potato, for which the sales were 1575 million dollars, the price would become one-fourth. Who would bear this loss?

The new genetic engineering, tissue culture, and somatic cell hybridisation technologies are already poised to give us, on a large scale, plants that would make their own pesticides and fertilizers, and plants that would grow in a variety of soil and climatic conditions. The socio-economic implications of these dramatic advances in agriculture are yet to be assessed.

And we have unfortunately not realised that no country in which the total income of over 70 percent of its population comes from agriculture or related activities, can ever be affluent, with the fruits of affluence reasonably distributed. In such countries, like ours, the 70 percent or so employed in agriculture produce food for themselves and the remaining 30 percent of the population, implying that for every Rs. 100 worth they produce, they are spending Rs. 70 on their own food, thus leaving only 30 percent of their real income available for everything else. Today, in every affluent country and in every affluent section of our own society, less than 10 percent of one's income is spent on basic food necessities - in contrast to some 70 percent in the case of our agriculture sector. In fact, affluence in the West (or in a small proportion of the population in our country) is a consequence of 90 percent or so of the income

being available for buying other consumer goods or services such as a scooter or a telephone. It is well within our means to produce all of our food requirements by employing less than the full-time equivalent of 10 percent of our population on agriculture (in many of the Western countries, for example in the United States, this figure is much less than 10 percent). For increasing the level of affluence in our society, this may be inevitable. Have we ever thought as to what we would do with the remaining 90 percent? Should we think of providing them with *alternative* employment which may make them migrate out of the village sector, or should we still retain their interest in agriculture and give them *additional* employment wherever they are? There are technologies such as biotechnology that are labour-intensive and can be operated in villages, that could provide this additional (part-time) employment. Shouldn't all this be known to everyone in the country so that adequate pressures can be exercised on the decision-making authorities to make this a reality?

If the scientific decision-makers in our country were truly knowledgeable and concerned, India would have invested over a period of 15 years beginning 7 years ago, Rs. 300 crores on the human genome sequencing project. I dread the penalty that we would now have to pay for not having done so because the information that the rest of the world - the developed world - would have when the human genome is sequenced would not be available to us in its entirety as we would have nothing to give back in return. Tomorrow's strategies in regard to medical and health care are going to draw very heavily on information gathered through sequencing of the human genome. And, take the case of the much-debated Dunkel proposals and GATT. The situation in the country today in this regard would have been very different if the people of the country at large understood them and their implications. For example, those developed countries that today allow product patent and have forced India to do so too, did not allow product patent until recently, until they had reached a stage of development when they had new products which the rest of the world would want. Why should then India be forced to allow product patenting unless it has reached the same stage of development?

I have mentioned other examples of the dilemmas we would have to face, in the discussion on the relationship between science and law. Knowledge in regard to such issues must be widely disseminated if we were to take decisions conceived in reason that would stand the test of time and would be in the larger interest of our people.

(4) Exploitation of ignorance

Ignorance is fast becoming the main basis, and knowledge the main tool, of exploitation or neocolonialism. Not only has science and technology begun to mould our lives in ways more

than one, ignorance of science and technology and a lower level of scientific and technological development is being exploited today by nations and multinationals for their own gain. It has, therefore, become imperative for the political machinery of countries susceptible to such exploitation, to be aware of the advances in science and technology and their implication, in real time. Unfortunately, higher the position in the political hierarchy in such countries, lesser is today, generally, the knowledge and understanding of science and technology though greater is the need. New mechanisms clearly need to be worked out to take care of these lacunae.

Within our country itself, the two classes that have emerged - of the exploiters and the exploited (the former representing less than five percent and the latter more than 95 percent of our population) - are based on ignorance, lack of information, lack of the ability to convert information into knowledge, and the inability to take a global view of things and establish connections between apparently disparate bits of information, on the part of the exploited 95 percent.

I now wish to give an example of an area of our ignorance today where knowledge acquired in the future would generate new, as yet, unthought of possibilities. Ignorance of these possibilities could lead to our exploitation and domination, while leadership in this area through research and development could give us an advantage in the community of nations of tomorrow. This area concerns an everyday experience: "smell" (7).

A dog can distinguish between any two individuals on our planet, entirely on the basis of their smell - excepting identical twins! These observations mean that all of us are constantly producing individual-specific smell signals that are genetically determined. The probability of such smell signals generated by any two randomly chosen individuals being identical, is extremely small - perhaps, just as small (or as large!) as the probability of two individuals in the world, besides identical twins, being indistinguishable in looks.

A human body, even when two days old, has already learnt to recognise the specific odour of the breast of the mother given off, probably, by the areola of the breast. Thus, if two wads of cloth - one infiltrated with the odour of the mother's breast, and the other with the odour of the breast of another woman - are placed on either side of an infant's head, the child instinctively turns towards the wad with the odour of its mother's breast.

Many other higher organisms are also known to give off individual-specific smell signals. The memory of such individual-specific signals plays an important role in determining subsequent behaviour and response. Thus, ants, bees and many other animals recognise relatives through smell signals. Some mammals, such as dogs, use individual-specific

pheromones to regulate their movement in home ranges. In the case of the rabbit and the lamb, the new born locate their mother's nipples or udder immediately after birth by the mother's smell signal which is concentrated in the area of these organs. In rabbit and sheep, mothers recognise the new born by its specific odour. Thus, if a sheep that has just given birth to a kid, is allowed to smell the kid (as is normally the case), she would recognise the little one all through her life, without any mix-up with any other sheep in the flock. If, on the other hand, the mother was not allowed to sniff the little one that she gave birth to, but was made to smell a kid born at about the same time to another sheep, the mother would recognise the foster-kid as its own for the rest of its life. Similarly, rat littermates recognise the mother only by its smell. Experiments have also shown that such infantile olfactory experiences play a role in determining the sexual behaviour of adult animals.

In certain rodents, if a female that has just mated with the male is exposed to the odour of another male of a different strain, it may not give birth. It appears that some olfactory signal from the male, blocks implantation of the fertilised egg (the Bruce effect). It is well-known that in humans a much smaller percentage of women become pregnant than would be expected by the normal laws of reproductive physiology - that is, when the female was ready and the male was normal. Could it be because of the Bruce effect? Could we increase the success rate by preventing the exposure of the female to other male odours until the time the fertilised egg has implanted?

The olfactory signals also seem to get imprinted in the memory. Birds such as pigeons, seem to use for navigation, their olfactory memory of the environment around which they are flying. Fawns of black-tailed stags recognise the odour of other species as their own if exposed to it early after separation from their mother. Young monkeys and squirrels will respond to a dummy coated with their own odour but not to the one which has no odour or has the odour of another species. Even the new-born human babies learn to distinguish between asafoetida and aniseed very soon; a one-day old human child can remember for life, odours to which it has been exposed for 24 hours. This response, which seems to be stronger in girls than in boys, decreases very rapidly in the first four days. And there is evidence - at least in the case of rats - of in utero familiarisation with olfactory signals. Thus, a litter born to a rat that had been fed garlic, would recognise the garlic odour as familiar even when exposed to it the first time after birth. Could it be that the similarities between the food preferences of a child and the mother are a result of such in utero familiarisation through odours?

Smell signals may not only be individual-specific but also species-specific. Species-specific olfactory signals have a role in attracting the opposite sex, for example, in insects and

snakes. In fact, the first smell signals to be chemically identified were sex attractants in insects. Following an earlier lead by P Carlson, Adolf Butenandt of Germany purified in the early 1960's, the smell signal given out by the female silkworm moth; from half a million glands of the silkworm moth *Bombyx mori*, Butenandt and his coworkers obtained 12 milligrams of a crystalline material (in chemical jargon, a primary unsaturated fatty alcohol) - the first "pheromone" as such signals have been since then called. As little as a millionth of a millionth of a millionth of a gram per millilitre of this substance placed in the vicinity of the male silk moth, induced flutter, dancing movements and other symptoms of sexual excitation. The signal could be detected one mile away by the male silk moth. Later on, it was found that the female responded to just one molecule of the substance coming into contact with its antennae. In fact, it was this pioneering work which opened up the whole new field of pheromones - sex attractants and all.

Olfactory signals are known to be used widely in the animal world to convey various other messages as well, such as individual, group and species identity; sex and age; social and reproductive status; predator or prey status; health or disease status; trail and territory; emotional status such as of alarm, need for attention, distress, frustration, desire to be approached, pain and desire to submit; and greeting or warning by olfactory signals deposited in the soil by other animals of the same species. It is thus clear that our environment is full of a vast variety of olfactory signals. The air we breathe not only gives us vital oxygen but also keeps our olfactory system busy.

The advantages of olfactory signaling we already know of, are many: an olfactory signal given off by a few can be received by thousands and very quickly: further it can disappear quickly to make way for a new signal.

If it turns out that we are capable of responding subconsciously to olfactory signals, it would become very likely that a part of our behavioural response to others is determined by the olfactory signals to which we are exposed all the time. In other words, a part of our intuitive response to another individual could be due to a match or mismatch of our individual-specific olfactory signal - and "love at first sight" could be a consequence of more than just a visual response. Some day, then, it should be possible to determine what kind of olfactory signal elicits a particular kind of behavioural response amongst human beings.

How is the olfactory uniqueness generated? What is the chemical nature of these signals and what makes the chemistry of the olfactory signals from one individual different from that

of *any other* individual? What are the genetic determinants of these signals? Where are they located in our genetic material - that is, on which chromosome, which gene and where in the DNA of the gene? And how do they eventually determine the olfactory uniqueness of the individual? In other words, how, in one individual, only those set of genes are expressed that are involved in determining the unique chemistry of the olfactory signals of the individual? And finally, what are the functions of these signals in the human species? Surely, such a complex and sophisticated system would have never survived the rigours of evolution through time, unless it performed an important function? We do not have answers to any of these questions today. The answers, when found, would have far-reaching implications both for the individual and for the society. If it is confirmed that odours regulate human behaviour, perfumerycould even acquire strategic importance. Knowledge of the answers to the questions mentioned above could make the individual's life richer. On the other hand, ignorance of these answers and of the facts such as those I have mentioned earlier, could lead to exploitation. Let me give an example.

Since the discovery of the sex pheromones,there has been much speculation about the existence of similar sex attractants in the human species where the question is still open. Nevertheless, unscrupulous business organisations have already begun to exploit the idea. So an Australian magazine advertises a sex attractant (Attractant-8) for 35 Australian dollars a bottle that contains androstenone which is known to be produced by the human species. The advertisement states that only one out of ten men produce the right amount of this chemical substance which women cannot resist; the other nine need to supplement the little they produce, by Attractant-8 if they wish to succeed with the fairer sex. Although there is no hard evidence that would support this contention, the possibility cannot be ruled out. Generally speaking, in the living world, what is true of the lowly E.coli (the bacteria that cause the discomforting intestinal disorder, colitis) is also true of the mighty elephant! Even if the main contention of the ad was, in principle, right, we would have to reckon with the probability that the sense of smell between individuals is not the same. For instance, about a third of us cannot smell androstenone at all; to another third, it smells like urine and to the remaining third it has a musky, sandalwood or perfume-like odour. Therefore, the physiological responses to it, if any, may be different for different individuals.

WHAT KIND OF INSTITUTIONAL BASE WOULD WE NEED?

New institutions have, through history, provided a platform for consolidating and accelerating the pace of change in a specific, desired direction. In our own country, since World War II,

we have set up a large variety of new institutions - the agricultural universities, the Indian institutes of technology, the Indian institutes of management, a large number of new science agencies and departments of the Government of India, and new institutions that have dealt with economics, money matters, law, sociology, culture and education, to mention a few. I have in another publication (8), given reasons as to why it has been necessary to set up major scientific institutions outside of the universities in our country and elsewhere in the world, in this century. I hope I have in this presentation, given enough reasons for new institutions - formal and informal, official and non-official, private and public, educational and social, political and economic, cultural and legal - to meet the challenges that I have outlined. I hope there would be discussion on this question during the Congress; I would, therefore, not comment on it here in any detail. However, I would venture to make some observations in this regard that, I believe, would be relevant:

(a) The existing institutional infrastructure is inadequate to meet the challenges that I have outlined above.

(b) There is need to restructure our formal education system from the beginning (from Class I) to the University stage, to meet the above challenges. No formal educational system, however, would be able to take care of all the requirements that I have outlined above.

(c) Consequently, we would need to complement the formal education system with, perhaps, loosely structured non-formal education through television, radio, films, newspapers, magazines and other periodicals, and through special material written and brought out in a way that would attract readers. This would mean a wide-base of responsibility-sharing in this regard. For this to happen expeditiously, the initiative would need to come from the privileged, such as those who are present here at this Congress.

(d) There would be need to have a mechanism through which any member of the public could obtain any available information at any time, say through a computer, telephone or letter. The information sought could be in regard to simple problems of electricity or a complex issue such as the Dunkel Draft. Perhaps, we would need both Government-run and voluntary organizations which would have, over a period of time, learnt to anticipate questions, the answers to which could then be put in a computer which could be accessed by anyone desirous of obtaining such information. Perhaps, there could be a multimedia channel running virtually round the clock to answer such questions. This would mean good communicators, whose training would need to be planned.

(e) Our future system of education may need to represent concentric circles as we move up, rather than a straight line, so that at each stage one receives a rounded-off education; at subsequent stages, each subject is then discussed in greater detail.

(f) The emphasis during school education would need to be on concepts rather than on facts, just as the emphasis during higher education, specially technical education, would have to be on facts in addition to concepts. Similarly, the emphasis would have to be on understanding and not memorising, and on knowing where to get factual information rather than carrying it all in one's head all the time. Perhaps, in the twentyfirst century, say towards the end, we would have obtained enough information about the functioning of our brain that would allow us to utilise its capacity maximally.

(g) It would be important to be able to make changes in a system - legal, social, political, economic or educational - in real time as the need arises. Today, in our country, we very often do the right thing but far too late. In the future, to make what I have said earlier possible, we would have to learn to count seconds instead of knowing how to count just years, months or days. New standards of efficiency would have to be set up.

(h) Employers would need to set up human resource development centres for their employees, that would help update and widen their knowledge-base in real time.

(i) Just as there is, at a given point in human history, need to set up new institutions, there is also need to close existing institutions. One of the major criticisms that has been levelled against us is that we have hardly ever closed an institution. The reasons have been clear. We easily succumb to vested interests, for those in power themselves have vested interests. This situation can be remedied only by pressure from below through a sound and global knowledge-base amongst the citizens.

CONCLUSIONS

There is just one major conclusion. In the world of tomorrow, ignorance shall not be bliss while knowledge shall be power. More knowledge would be more power and global knowledge would be global power. We have already paid heavily for ignorance, for example, of the following:

- Hinduism did not evolve as a religion.

- The term 'Hindu" was used till a few centuries ago to indicate residents of the sub-continent and not to refer to any particular religion.
- The term 'religion' is foreign to Indian tradition.
- 'Dharma' is not religion.
- Division of our people on the basis of caste and sub-caste, religion and similar considerations, is a consequence of ignorance of both our history and contemporary knowledge.
- Many of our leaders in all areas, from science to religion, from politics to bureaucracy, do not hesitate to make statements that are inaccurate or invalid. An example is a recent statement made by a Shankaracharya that reading or reciting of the Vedas by women would harm their reproductive abilities (8).

The choices for us are clear. They are only two. Either we perpetuate ignorance, quarrel amongst ourselves and be victimised, neocolonialised and exploited by the wiser nations and communities around the world who are more knowledgeable; or we make our people - all people - more knowledgeable (not just literate or educated). The future of our country is surely going to depend on which of these choices we exercise.

If we wish to make history we must work with it, and not against it.

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