The era of the mind

Current Science has frequently published many observations, editorial and otherwise, on the state-of-affairs of science and technology (R&D, education, and industry) in India and what needs to be done to improve it. Interestingly, some of these observations are attributable to those who have been or are responsible for formulating, and advising the government on, national S&T policies and the execution of such policies, the consequences of which we now bemoan.

What appears common in the suggested remedies is the simple-minded extrapolation of experiences gained in the past into the future. Surprisingly, none of the authors has shown any serious awareness of the fact that human civilization is already undergoing an epochal change, features of which are clearly discernible to some. The management guru Peter Drucker saw its coming (as an era dominated by knowledge workers) as well as its potential at least two decades ago. Global industries have begun grappling with the change out of stark necessity. Where all this lead to is difficult to predict but it is quite clear that we are already in the throes of a revolutionary transition, in the handling of which past experiences will count for little or nothing.

Today, the question is no longer one of rectifying past mistakes. Nor will the future be some variation and extension of the past, rather it will be a radically different one. Our past mistakes, and those who have been responsible for them, are fast becoming irrelevant. In the coming decades we are being offered an opportunity of starting with a new slate and only the clever and the talented will do well. The new era will definitely be an era of the mind. Working smart, not working hard will be the key to success. The command and control system of administration (which most societies borrowed from the military) within which we have spent most of our lifetime is changing to a more horizontal and consensual system. The ability to think globally and interact globally will be very important. The internet is going to change our lives beyond recognition, and the altruism of many top-notch knowledge workers (scientists, open source software developers, etc.) is going to completely redefine the dynamics of the world's social and economic activities. In another few years I fully expect computers to be able to do many of the mundane tasks of researchers, and therefore I expect to see the average researcher becoming irrelevant to society. Knowledge is becoming so freely available that only those who can use it innovatively or those who can create new knowledge will be respected and rewarded in a way, for example, as already happens to people knowledgeable in the literature and the arts. Mere possession of knowledge will be passé.

These views cannot bring comfort to those who in the old era have held an iron grip on the S&T R&D community promoting mediocrity and building fiefdoms, and now, shedding crocodile tears. With meritocracy on the rise, mafias and fiefdoms will fall into the dustbin of history, automatically. Our real problem is therefore: how to phase out the old educational system, what to replace it with, and how to bring meritocracy back so that our people can be adequately trained to meet not only the socio-economic demands of the future but also their personal ambitions of worth in life. The problem is compounded further by the fact that for a given set of skills, the employability span for a person is progressively becoming smaller, which in itself is frightening to many since most of us have serious limitations when it comes to adapting to the unknown and learning the unfamiliar. To have to do this several times in a lifetime, in a timely manner,
to remain just employable will be frightening.

On the positive side, the setting up of outstanding cyber-universities is not only a possibility but, I believe, within the reach of talented individuals. Which means that something in the nature of *gurukul* system, advantageously adapted to modern communications technology, can occur. I am not sure if many of the gurus will come from India in the near future but in the long run I am much more optimistic.

The new elite will be a very different breed both in talent and in attitude. To an unprecedented degree they will have global reach and influence over the minds of the people. This much is clear. In another few years many of us can expect to be working from home as productively, perhaps more, as from an office. The implication is that people will not have to abandon the comfort and culture of a place they like to make a global impact or even earn a global salary. These are going to be radical changes for our country which even today sees several centuries living side by side. But I hope we will cope because I believe the new elite will be far more generous, considerate, and helpful to the rest of mankind than history has ever witnessed before.

With every successive epochal change, people have identified and bound themselves to increasingly larger communities, and the future may well hold that global rather than national concerns will become the natural norm. For the scientific community it will not be something new since it has been a global community of distinction since the past few centuries. Only now the rest of mankind will emulate them in economic spheres by seeking quality products and services irrespective of their geographical origins. I think we will see, in the years to come, very interesting changes in our notions of nationality and government, of government and governance, and so on. I would hesitate to make predictions, except perhaps that some of these changes may occur suddenly and catch most of us unawares.

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Biology versus computers

Until some years ago, students desirous of studying science in the 11th and 12th classes in the Central Board of Secondary Education (CBSE) system, had to compulsorily study physics, chemistry, mathematics and biology. This I thought was a great improvement over the system that existed in my high school days, when biology and mathematics were made mutually exclusive immediately after the 8th class. However, some years ago the CBSE quietly introduced computer science as an alternative to biology at the 11th and 12th class levels. Thus students now have to choose physics, chemistry, mathematics and computer science or physics, chemistry, mathematics and biology. In effect, students interested in computers cannot study biology and those interested in biology cannot study computer science.

It is widely recognized that this is the age of biology. Any one even casually following the progress of biology cannot fail to recognize the pre-eminent role that computers are beginning to play in present day biological research, be it molecular biology or organismal and evolutionary biology. The advantage that Indian scientists have in undertaking computer-based research projects as opposed to projects dependent on sophisticated instruments is only too well known. The human genome project is expected to make available a mind boggling quantity of data within the next 2 or 3 years. Although Indian scientists did not participate in the sequencing of the human genome, it is widely expected that we can contribute significantly towards making sense of the more than 3 billion alphabets of the human genome. This of course will require great expertise with computers. What then can be a more retrograde step than to make biology and computer science as mutually exclusive subjects for our students?

An alarming decline in the numbers of students opting for science and the impending dearth of trained manpower to sustain S&T activities of such a large country, have emerged as serious challenges facing the Indian scientific community. A variety of organizations such as the Homi Bhabha Centre for Science Education, the Indian Academy of Sciences, the Jawaharlal Nehru Centre for Advanced Scientific Research and the Department of Science and Technology, Government of India, have launched massive programmes to encourage bright young students to opt for a career in science. Whether or not these programmes will yield the desired results is a moot point but seemingly trivial steps such as the one taken by the CBSE board in making computer science and biology mutually exclusive, will surely wash away any benefits that might accrue from these efforts.

I am very fond of watching so-called mud dauber wasps tirelessly build little earthen pots, fill them with caterpillars, lay an egg and seal the pot. If one makes a hole at the bottom of the pot, the caterpillars will fall out but the wasp will for ever keep attempting to fill the bottomless pot, not realizing that something is amiss. Evolutionary biologists explain this apparent 'stupidity' of the wasp by pointing out that during the course of its evolutionary history, the wasp never had to encounter mischievous scientists who make holes at the bottom of their earthen pots. Those of us who work towards making science an attractive career for young minds will, however, do well to watch out for agents such as the CBSE that can make holes in pots that we are attempting to fill!

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A clean certificate for transgenic plants

This is with reference to the correspondence by K. K. Narayanan entitled 'Are transgenic crops a threat to bio-diversity' (*Curr. Sci.*, 2000, **78**, 7). The author had given a clean chit to the transgenic plants in the beginning itself and wanted the readers to forget that he is working at the Monsanto Research Centre. The correspondence thus focused only on the advantages of transgenic plants.

We agree with the author's statement that as with time agriculture has begun to depend on fewer and better varieties. But the next statement that 'introduction of transgenic crop varieties does not add any new dimension to this scene in modern agriculture' can never be justified. The author is just trying to view the transgenic plants as one among thousands of our old varieties. This approach is not correct. As stated by the author, transgenic plants may be initially widely accepted by the farmers, but these may become a replica of plant protection chemicals which were the 'heroes' in green revolution. The author agrees that biodiversity is important for future crop improvement and anything against it will be a threat to human existence and should be resisted.

Transgenic plants will result in genetic pollution of traditional varieties by cross-pollinating them[1]. According to Green Peace, Novartis, genetically engineered maize has cross-pollinated an adjacent field of conventional maize in Germany[2]. Soon after the production of the first transgenic plant in the early 1980s, gene flow from genetically modified crop was recognized as a potential hazard. Thus, there is the possibility of the development of transgenic plant volunteers in nature and thus

endangering natural habitat[3,4]. Also, there is evidence of interspecific transfer of pollen from transgenic plants[5].

In the Codex Ailmentarius Commission, Ottawa, India and several other nations demanded more extensive labelling of the transgenic food. 'Genetically engineered herbicide-tolerant crops are laced with high level pesticide residues that may disrupt endocrine function, destroy immunologic defences against diseases, including cancer', according to Romeo Quijano, University of Philippines. 'Transgenic plant technology can create dangerous foods by generating mutation in the DNA of the food processing organism,' says John Fagan, USA. 'The fact is it is virtually impossible to even conceive of a testing procedure to assess the health effects of genetically engineered foods when introduced into the food chain nor is there any valid nutritional or public interest reason for their introduction', says Richard Lacey, University of UK[6]. Canada-based Rural Advancement Foundation International (RAFI) condemned this as a conspiracy for monopoly in the food market. M. S. Swaminathan opines that such technologies should be stopped from entering our country by strict import policies.

The '*Bt* genes' introduced may lead to a complete destruction of boll worm ecology leading to impaired biological equilibrium. Transgenic plants becoming weed is one which depends on the nature of the plant to be transformed and gene to be introduced[4]. Other hazards associated with transgenic plants are horizontal gene transfer, development of new viral strains and effect of toxin on non-target insects[7].

Social impacts may be a wider gap between the north and the south, and growing disparities in the distribution of income and wealth within societies[8]. Increased production will induce small farmers to grow transgenic plants and ultimately the MNCs will control the world food market leading to a complete disappearance of indigenous cultivars, and seed companies. Thus more than 1.4 million poor farmers in Africa, Asia and Latin America who depend on farm-saved seed as their primary seed source, will have to suffer.

While terminator technology is a threat to food security, agricultural biodiversity and future scientific research, traitor technology will be a tool for agroterrorism propagated by MNCs[9], in which seeds should be treated with their own chemicals to activate the disrupter genes, in the absence of which the cysteine protease promoter will activate the barnase enzyme to burn-off the germinating seedlings.

It is a matter of pity that even eminent scientists in this field do not consider the problems associated with the transgenic plants. In a seminar organized by UAS, Bangalore, some scientists and policy makers stated that 'every technology has got its own risk'[5], which they are reluctant to discuss.

Anything against nature's existence will be wiped off and so also terminator technology. An article which discusses only the positive aspects of any technology cannot be accepted.

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Transgenic crops and biodiversity

We found the article by K. K. Narayanan (*Curr. Sci.*, 2000, **78**, 7) very educative. We would like to present the following points for further consideration.

The author, while trying to alleviate the misconceptions on transgenics, seems to prescribe transgenics as the only alternative for the future and relates it to the needs of the exploding population. In supporting the cause the author also equates the natural selection process to **artificial selection** (transgenics). The cultivation of fewer traditional varieties selected from millions of species is based on human preference over the years; but this cannot be compared to the voluntary addition of any gene into a plant. A conscientious biotechnologist will not agree with the statement given in the article 'the addition of transgenic crops does not add any new dimensions to the existing scenario in modern agriculture'. Our view is different. Transgenics are a product of artificial selection and hence they cannot fall in line with the traditional varieties. No doubt, any scientific advancement needs to be received well, accepted and adopted in the modern system after a thorough scrutiny of impact on mankind. At the same time, the traditional varieties also have their own role to play.

The author further says that in future, the world community will have to rely upon only a few evolved varieties (transgenics) to feed the growing population. This would lead to disaster in countries like India where the per capita income is less and per area population is high. If every available and useful variety is converted into a transgenic variety, then, such a thing may be possible. A news item published in *Nature* (6 January 2000) discusses the pros and cons of transgenics related to patency. While the commercial companies hail the (patency of) transgen-

ics, an environmental group Green Peace criticizes this. Stefan Flothmann, Head of Genetic Engineering Department at Green peace, Germany, had said, 'This could lead to monopolies in the seed market. The production of transgenics if goes into the hands of few companies, the agricultural diversity in the farmers' field will be reduced to a few patented varieties and in the long term this is a threat to the world's food supplies.'

Hopefully, the collected genetic traits, maintained under storage or in germplasm centres or gene banks like NBPGR in India, will offer sustained free access to the farming community for use in the future. The government should also encourage the collection of such diversified genetic traits to help the farmers in case the transgenics fail in their task.

We do need transgenics and research on them has to be encouraged. While it is necessary to clear any doubts on transgenics among the consumer-public, it is also necessary to develop genetically modified crops devoid of gene protection (terminator) technology and selectable markers.

Ultimately one should aim not to leave the human community (i) rely upon one or two crops/varieties for cultivation in the future; (ii) lack self-sufficiency in the fields; (iii) rely upon monopolistic commercialization of essential crops.

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Herbal medicine – Some comments

While dealing with popularity of herbal medicines (HM) all over the world, Kamboj[1] has emphasized some widely used wrong concepts. The claims of safety and lesser side-effects of HM are in stark contrast with the reports published from time to time[2,3]. The belief that constituents of HM 'have better compatibility with the human body' due to their origin in living systems appears dangerous, as exemplified by an observer: 'I have considerable respect for the potential toxicity of plants. Some of the most poisonous substances known – curare, digitalis, ricin, and many others – are hidden in seemingly innocent greenery'[4]. Other problems associated with the use of HM stem from their heterogeneous nature[5,6] and admixing of synthetic drugs (like corticosteroids) to herbal formulations by the manufacturers[2]. Simultaneous use of western and herbal remedies may lead to dangerous interactions[7,8]. A recent systematic survey on some HM in Canada revealed that most of them were unsafe or ineffective. In some cases sufficient information was not available for their evaluation[9]. Such objective attitude towards HM is, by and large, absent in our country. Most of the reviewers either selectively highlight the promising aspects of these traditional medicines or express skepticism about their efficacy[10]. The vast potential of HM to complement western medicines can be hardly denied but problems associated with their use cannot be winked at. As a matter of fact, regulation of HM to ensure their safe use, is a global problem at present. Measures, suggested by Kamboj, for their standardization are useful but the cost involved in maintaining the required research infrastructure is a discouraging factor to the manufacturers.

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Tropospheric ozone: An emerging problem in the urban environment

Chemistry of tropospheric ozone formation is a major complex and nonlinear problem of atmospheric research which is related to the public health, reduction in crop yield and climate change. This correspondence deals with the complex mechanisms of tropospheric ozone formation in the ambient environment, to identify the current challenges and strategies employed to control the vehicular emission at a national level.

Tropospheric ozone is a secondary air pollutant which is formed in the presence of sunlight by complex photochemical mechanisms through its precursors like

NO_x (oxides of nitrogen), VOC (volatile organic compounds), CO (carbon monoxide) and CH_4 (methane). NO_x and VOC are major precursors of ozone in the urban environment whereas CO and CH_4 are precursors of rural and oceanic environments. The sources of these precursors are vehicular exhaust, industrial emissions, change in land use patterns and a large number of biological processes. In this respect, in the urban environment vehicular exhaust (which consists of NO_x and VOC) is the main source of tropospheric ozone formation. Therefore to reduce the tropospheric ozone concentration in the urban environment, it is necessary to cut down its precursors concentrations, namely the vehicular exhaust.

The maximum tropospheric ozone will be produced at the ratio $VOC/NO_x \sim 6$; this condition is described as maximum incremental reactivity, here reactivity meaning the ozone-forming potential. Therefore maximum or peak tropospheric ozone formation is a function of VOC/NO_x ratios and not any individual precursor concentration. It is important to reduce the concentrations of both VOC and NO_x to curtail the ozone concentrations. Because of this complex and nonlinear nature of the chemical system, the environment is classified as NO_x -limited, if VOC/NO_x ratio is greater than 6 and it is VOC-limited, if VOC/NO_x ratio is less than 6, depending upon the VOC and NO_x concentrations.

Atmospheric chemistry of tropospheric ozone formation in the NO_x-limited environment is linear and simple. As long as the chemical system is NO_x-limited, tropospheric ozone formation is a function of NO_x concentration. Therefore it is easy to reduce the ozone concentrations in such an environment by reducing NO_x concentrations. This type of environment is found in the free troposphere (2 km to tropopause), (about 16 km altitude from the earth surface in tropics) level, remote and oceanic regions where NO_x concentration is low. If the chemical system becomes VOC-limited, then tropospheric ozone-forming mechanisms are more complex and nonlinear. This type of urban environment is characterized as highly polluted and is known as NO_x-saturated. Such high NO_x concentrations are experienced in the atmospheric boundary layer (from the surface of the earth to 2 km height) of the urban atmosphere. In such a situation the abatement policies of ozone become more complex, less effective and less economically viable. For example, after reducing 50% of VOC and NO_x, ozone reduces by 12% only. This indicates that ozone reduction is a highly nonlinear function of its precursor concentrations. Furthermore, because of nonlinearity in ozone-producing mechanisms in the NO_x-saturated environment, if the NO_x concentration is reduced, then ozone concentration will increase instead of decreasing. The VOC reduction is required first in such a type of environment and then NO_x. It is not an easy task to reduce VOC, because of a very large number of anthropogenic as well as natural sources. Because of this, cities like Los Angeles, London and Tokyo are experiencing ozone concentrations more than the prescribed permissible limit of 80 ppbv (parts per billion by volume) set by WHO. In fact, after spending billions of dollars, these countries have failed to attain ozone concentration less than 80 ppbv in their environment because of the nonlinear and complex nature of chemical systems in the VOC-limited environment. At present, Asian and other developing countries are experiencing NO_x-limited environment and hence ozone abatement is easier in these regions than in developed countries. The concern is that major cities like New Delhi, Mumbai, Calcutta, Chennai and Hong Kong are approaching the VOC-limited environment. Therefore, at this stage, there is an urgent need to reduce the NO_x concentration by reducing the vehicular exhaust through stern legal action. Ozone abatement is easier as long as there is a NO_x-limited environment, but once the urban environment becomes VOC-limited, it is very difficult to reduce ozone concentrations.

The present research shows that ozone concentration is increasing at a rate of about 2% per year in the Asian region which is higher than that in developed countries (about 1 to 1.5%) because of ineffective pollution control policies. Effective pollution control policies, enforcement, effective combustion technologies and public awareness about the environment are needed to be undertaken at the earliest.

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