Science in response to basic human needs*

M. S. Swaminathan

Despite the tremendous accomplishments in science and technology during this century, we go into the next century with nearly one fourth of the world population living in severe poverty and the gap between the rich and the poor widening. How can we alter this utterly indefensible situation? What changes in our development strategy can lead us to a more equitable society? The formidable power of science and technology can be harnessed to the benefit of the whole of humanity only if we know how to temper it with humanism.

The 20th century will soon end with an impressive array of accomplishments in nearly every field of science and technology. The last part of this century has been particularly rich in innovations in the fields of biotechnology and information and space technologies. Genomics and molecular genetics have conferred on human beings such levels of control over the very blueprints of life, that member nations of UNESCO have adopted a Universal Declaration on the Human Genome and Human Rights. The whole global population was only 940 million in 1798 when Thomas Malthus expressed his apprehensions about human capacity to achieve a balance between food production and population. Human numbers will reach the 6 billion mark in 1999. Yet, today the food security challenge is not one of availability of food in the market but one of economic access to it. Science-based technologies supported by appropriate public policies are responsible for food famines becoming rare. The famine of food at the household level today is mostly due to inadequate purchasing power arising from the famine of jobs or livelihood opportunities.

Progress in preventive and curative medicine leading to the control of many communicable diseases has been an important factor in determining demographic trends. From 1804, when the world population reached a billion, it took 123 years to reach 2 billion in 1927, 33 years to attain 3 billion in 1960, 14 years to reach 4 billion in 1974, 13 years to attain 5 billion in 1987 and 12 years to reach 6 billion in 1999. The medium fertility projection which is usually considered as ‘most likely’ by the Population Division of the United Nations indicates that world population will reach 8.9 billion in 2050. Most of the additional population will be in developing countries. India and China together now account for 38% of the world’s population.

Basic human needs: A 20th century balance sheet

Poverty and social and gender inequity are increasing globally and nationally. According to the World Bank, 1.2 billion people lived on less than $ 1 per day in 1987. This number increased to 1.3 billion in 1993. About 3 billion people worldwide lived on less than $ 2 per day in 1993. Nearly 1.5 billion of the world population of 6 billion will live in severe poverty at the dawn of the new millennium. The gap between the rich and the poor is increasing day by day, with disastrous consequences to achieving the UN goal of reducing poverty by half by 2015. Achieving FAO’s World Food Summit goal of reducing the number of children, women and men going to bed hungry by half from the present number of over 800 million by 2015 may also not be achieved, since hunger today is essentially poverty induced. In addition to energy–protein under- and malnutrition, over 2 billion suffer from micronutrient deficiencies.

Global per capita water supplies are declining and are now 30% lower than they were 25 years ago. By 2050, as much as 42% of the world’s population will live in countries with insufficient freshwater stocks to meet the combined needs of agriculture, industry and domestic use. In addition, water is needed for the maintenance of ecosystems. Water conflicts are likely to grow. Hence, a Committee, chaired by me has recommended the establishment of an International Centre for Cooperation in Water Management at Valencia in Spain, in order to initiate proactive action in resolving potential water conflicts.

Contaminated drinking water causes diseases that account for 10% of the total burden of disease in developing countries. Also in 1996, about 1.4 billion low-income and over 400 million middle-income people lacked access to sanitary facilities. At the present rate of progress, over 900 million persons will lack adequate sanitation in the year 2015. In one out of four major cities surveyed by UN Habitat, fewer than 10% of households had sewerage connections.

Gro Harlem Brundtland, Director General of the World

M. S. Swaminathan is at the M.S. Swaminathan Research Foundation, 3rd Cross Street, Taramani Institutional Area, Chennai 600 113, India.
*Keynote address delivered on 26 June 1999 at the World

Health Organization stressed in her address delivered at the 52nd World Health Assembly on 18 May 1999, that while the health gains of the 20th century count as one of the biggest social transformations of our times, more than a billion fellow human beings have been left behind in the health revolution. Whereas 90% of the disease burden is in the developing countries, these countries have only got access to 10% of the resources going to health. The following initiatives of WHO, if accorded the needed political, public and financial support will make a large difference to the health of the poor.

- Roll back malaria
- Tobacco free initiative
- Fight against HIV/AIDS and tuberculosis

The International Conference on Health Research for Development planned for the year 2000 should accord priority to developing an implementable strategy for reaching the unreached in the health sector.

Disparities are also growing in access to technology. For example, 97% of all Internet hosts are in developed nations, home to 16% of the world's population. The rapid expansion of proprietary science covered by intellectual property rights is leading to the emergence of 'technological apartheid' and to 'orphans remaining orphans' in relation to the choice of research areas for priority attention. Support from public funds for research aimed at public good is tending to decline.

The coming century is being referred to as a 'knowledge century', a century of innovation, enterprise, eco-entrepreneurship and genetic enhancement. Yet, UNESCO's goal of literacy for all is still a far cry in many developing nations. Enrolments by female students are catching up with those of boys in some regions but continue to lag in others. Intensive efforts have, however, significantly increased primary school enrollments during the nineties. In India, an *innovative Education Guarantee Scheme* was first introduced a few years ago in Madhya Pradesh. This approach is now being extended to the entire country in order to accelerate progress in achieving the goal of total literacy. However, in many countries of the Middle East, North Africa, South Asia and sub-Saharan Africa, girls' enrolments continue to lag behind boys' and illiteracy rates are still high.

It is not only in opportunities for education that children of many developing countries remain handicapped, *but even more alarmingly, in opportunities for the full expression of their innate genetic potential for physical and mental development*. For example, 25–50% of children born in several developing countries are characterized by low birth weight (LBW), caused by maternal and foetal under- and mal-nutrition. The UN Commission on Nutrition in its recent report[1] has warned about the serious consequences of LBW for both brain development in the child as well as to the health of the child in his/her later life (Figure 1).

The rich–poor economic and technological divide is not only causing inequity at the level of the present generation, *but is also enhancing inter-generational inequity*. For example, Panayotou *et al*.[2] point out that the affluent economies of the temperate zone are likely to impose severe net costs on the tropical regions because of their excessive consumption of fossil fuels leading to a large release of greenhouse gases. *Since the temperate-zone economies are rich and the tropical zone economies tend to be poor, global climate change represents a burden imposed on the poorer countries by the richer nations*.

Panayotou *et al*.[2] also point out that much of the damage caused by a continuous rise in CO_2 concentrations in the atmosphere will occur in tropical countries, especially Africa and India. India and countries in Africa are predicted to suffer adverse agricultural consequences, possibly severe vector-borne diseases, increased risks of severe tropical storms, vulnerability to rising ocean levels, and other stresses from an increase in temperature from already high levels. The temperate zone countries are either little affected in general or even benefited on an average by the prospects of global climate change. Agricultural productivity is predicted to rise in the high latitudes, through a combination of longer growing seasons plus CO_2 fertilization of crops.

Thus, the affluence as well as poverty-induced environmental damage leads to multiple forms of inequity, namely, *inequity at birth in mental capacity, inequity in opportunities for a productive and healthy adult life, and inter-generational inequity*.

Among the more serious dangers to sustainable human development is the increasing damage to our basic life support systems comprising land, water, flora, fauna, forests, the oceans and the atmosphere. The number of environmental refugees is increasing day by day due to

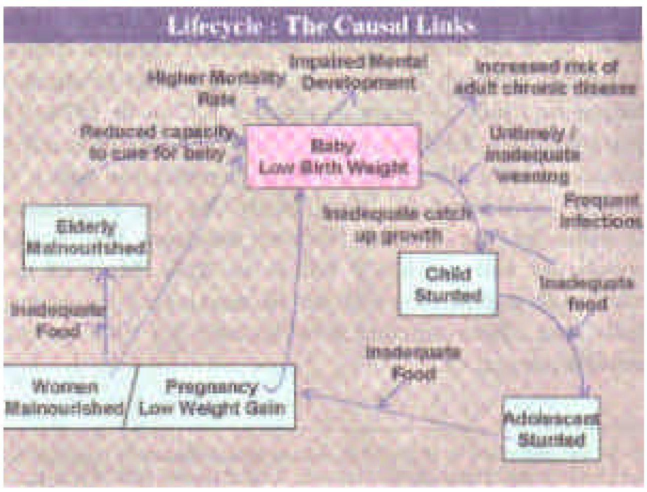


Figure 1. Consequences of low birth weight.

damage to environmental capital stocks resulting in the loss of rural livelihoods[3].

The decade of the nineties has highlighted our dismal record in the area of building sustainable food, health and livelihood security systems. Noteworthy among the recent UN Conferences in relation to basic human needs are:

- Child Summit, New York, 1990
- Earth Summit, Rio de Janeiro, 1992
- Human Rights, Vienna, 1993
- Population and Development, Cairo, 1994
- Poverty and Social Development, Copenhagen, 1995
- Gender Justice and Equity (the World Conference on Women), Beijing, 1995
- Food Summit, Rome, 1996
- Urban Quality of Life, Istanbul, 1997

These Conferences have led to global plans of action, which if implemented, could lead to a better life for all. The conventions on climate, biodiversity and desertification, the law of the Sea and Agenda 21 of UNCED provide a framework for the sustainable and equitable management of nature and natural resources.

In my view, the World Food Programme (WFP), FAO, UNICEF, WHO and UNDP should immediately launch in collaboration with interested national governments a *global programme to fight maternal and foetal undernutrition, thereby helping to minimize the frequency of children with low birth weights*. *The programme may be titled 'Global Movement for Children for Happiness'*. *A similar programme involving horticultural and direct intervention approaches needs to be launched to eliminate hidden hunger caused by the deficiency of micronutrients in the diet*. Without these two steps, the foundation for achieving the goals of the UN Conferences listed above cannot be laid. Millions of children will continue to be born for mere existence and not for happiness if this area of nutrition continues to receive inadequate priority. This is why the proposed WFP–FAO–UNICEF–WHO–UNDP initiative for fighting the incidence of LBW children is urgently called for.

A stripe review of the recommendations of these international conferences reveals that apart from political, social and gender rights, the goal of poverty eradication should receive the highest priority from both national governments and bilateral and international organizations. Poverty is the root cause of hunger, lack of shelter and access to clean drinking water, illiteracy, ill health and other forms of human deprivation. *The pathway to meeting the basic needs of every human being is poverty eradication*.

Science, technology and economic and social inequity

The contributions of India, China and Greece to scientific discovery and knowledge since pre-historic times are now widely acknowledged. In contrast, modern science in the European tradition is only about 500 years old, dating from the time of Copernicus. Maddox[4] has urged that a clear distinction should be drawn between modern science and its precursors. The interplay between observation and explanation was formerly less important than it is now. A theory qualifies as an explanation only if it can be and has been tested by experiment or observation, employing when necessary measurements more sensitive than the human senses can yield. Similarly, a distinction should be drawn between science and technology. Science helps to advance the frontiers of knowledge, while science-based technologies help to advance the frontiers of economic wealth. Maddox has also emphasized that while we are right to marvel at what has been accomplished in the past 100 years, we should not forget that there would have been the same sense of achievement at the end of each of the preceding centuries. Thus, we should celebrate many different visions and technologies, both historical and contemporary.

Virginia Postrel[5] in her book *The Future and its Enemies* points out that knowledge, like experience, is in many ways cumulative. Dynamism and innovation are about creating the future. However, we should not ignore the past from which the future evolves. It is this concept which led Federico Mayor of UNESCO and the late Commandant Jacques Cousteau to propose the concept of ecotechnology. *Ecotechnology is a blend of the ecological prudence of the past and modern science*. It involves an inter-disciplinary approach and a proactive and continuous interaction among social scientists and technologists working in frontier areas like space and information technologies, biotechnology, nuclear science and renewable energy technologies (see Von Weizsacker *et al*.[6] for approaches to technology blending). Eco-technologies are more knowledge than capital intensive and provide opportunities for decentralized production supported by a few key centralized services.

Virginia Postrel[5] points out that 'loss of rural employment and migration from the countryside to the cities causes a fundamental and irreversible shift. It has contributed throughout the world to the destabilization of rural society and to the growth of vast urban concentrations. In the urban slums congregate uprooted individuals whose families have been splintered and whose cultural traditions have been extinguished'. The proliferation of urban slums as a result of the loss of rural livelihoods presents a grave threat to achieving the goal of ensuring every human being access to basic human needs like safe water, sanitation, balanced diets, health care and education.

To develop an effective strategy for poverty eradication, it is important to understand how poverty arose first and why it is affecting developing countries more. Jared Diamond[7] points out that until the end of the last Ice Age, around 11,000 BC, all peoples on all continents were hunter–gatherers. Different rates of development of different continents occurred between 11,000 BC and

AD 1500. While aboriginal Australians and many native Americans remained hunter-gatherers, most of Eurasia and much of the Americas and sub-Saharan Africa gradually developed agriculture, herding, metallurgy and complex political organization.

One of the interesting questions in comparative economic history is the gap in levels of real income between developed and developing countries. David Landes[8] pointed out that 'Western Europe was already rich before the industrial revolution because of substantial technological progress, not only in the production of material goods, but in the organization and financing of their exchange and distribution. The appropriation of extra-European resources and labour further increased the wealth of Western Europe'. Angus Maddison[9] generally supports this view. The industrial revolution in Europe led to a widening of the prosperity gap between industrialized and developing nations. The transition to the technological and industrialized age also marked the transition to a world with increasing economic inequity.

Roger Farmer[10] has stressed that although differences in rates of growth in the standard of living seem like small numbers, they can have a very big impact on real standard of living because of the increase each year getting compounded. Today, developing countries face additional handicaps including severe debt and debt servicing burdens, an unfair trade regime where trade is becoming free but not fair, and an expansion in social exclusion through patents and other forms of intellectual property rights.

Fortunately, there are no human differences in intelligence that parallel human differences in technology. *Hence, it should be possible to embark upon a dynamic programme for the technological empowerment of the poor*. Jared Diamond[7] points out that people who until recently were technologically primitive – such as aboriginal Australians – speedily master industrial technologies when given opportunities to do so. We have seen in India, especially in the Punjab and Haryana, barely literate farmers acquiring sophisticated electrical and mechanical engineering skills. Therefore, UNESCO, UNDP, WTO, ICSU and other interested multilateral and bilateral donors should develop a plan of action for mobilizing technology, training, techno-infrastructure and trade for poverty eradication. Trade policies should be formulated in such a manner that *they will strengthen and not erode the livelihood security of the women and men living in poverty*. *Developing countries should ensure that their import and export policies are based on a livelihood impact analysis*.

The pervasive poverty we witness today is the most serious indictment of contemporary developmental pathways. The poor are poor because they have no productive assets – no land, no education and no technical skill. They earn their livelihood largely through unskilled work. They have been bypassed by modern technological advances. They suffer from a sense of exclusion from the exciting scientific adventures we are witnessing today. Their sense of frustration is enhanced when they see on television the benefits of technological progress enjoyed by a section of humankind. *Reaching the unreached and including the excluded have to be important components of the science and technology policy and strategy for the new century, if the huge stock of scientific and technological knowledge and innovations with which we will be entering the next century is to become a blessing for humankind as a whole*. A priority task for the *Inter-Academy Center*, proposed by Bruce Alberts, President of the National Academy of Sciences, USA, should be the closing of the vast *knowledge and skill gap* prevailing between rich and poor nations on the one hand and between the rich and the poor within all nations. New information technologies provide a unique opportunity for the knowledge and skill empowerment of the poor. The women and men now living in poverty can be helped to experience a better quality of life only by increasing the economic value of their time and labour. *A transition from unskilled to skilled work resulting in value addition to labour and time will be needed for enabling the poor to experience a productive and healthy life. Opportunities exist today for achieving such a transition speedily*.

Gender dimensions of poverty: Women in science and technology and science and technology for women

UNDP's Human Development Report[11] states 'human development, if not engendered, is endangered'. The report further states that the revolution towards gender equality must be propelled by a concrete strategy for accelerating progress. The Beijing Platform for Action adopted by the Fourth World Conference on Women on 15 September 1995, says:

'In the past decade, the number of women living in poverty has increased disproportionately to the number of men, particularly in the developing countries. The feminization of poverty has also recently become a significant problem in the countries with economies in transition as a short-term consequence of the process of political, economic and social transformation. In addition to economic factors, the rigidity of socially ascribed gender roles and women's limited access to power, education, training and productive resources as well as other emerging factors that may lead to insecurity for families are also responsible. *The failure to adequately mainstream a gender perspective in all economic analysis and planning and to address the structural causes of poverty is also a contributing factor*'.

'*Science curricula in particular are biased*. Science textbooks do not relate to women's and girls' daily experience and fail to give recognition to women scientists. Girls are often deprived of basic education in mathematics and science and technical training, which provide knowledge they could apply to improve their daily lives and enhance their employment opportunities. Advanced study in science and technology prepares women to take an active role in the technological and industrial development of their countries, thus necessitating a diverse approach to vocational and technical training. Technology is rapidly changing the world and has also affected the developing countries. It is essential that women not only benefit from technology, but also participate in the process from the design to the application, monitoring and evaluation stages'.

The Beijing Conference recommendations concerning the technological empowerment of women were considered at a meeting of women scientists and technologists in Asia and the Pacific region at the M.S. Swaminathan Research Foundation (MSSRF), Chennai, in December 1996 under the auspices of UNDP and UNIFEM. The meeting recommended several institutional and policy devices to enlarge the role of women in science and technology development and dissemination. Recommendations were also made to mainstream gender considerations in ongoing S&T programmes. A major requirement for women entrepreneurs is flexi-time and flexi-duration of work. Also, women engaged in micro-enterprises supported by micro-credit will need institutional structures which will provide them with the power of scale particularly in marketing. An example of the kind of support needed is provided by the *Biotechnology Park for Women* coming up near Chennai in India. This Park will provide centralized services like information, training and electronic marketing facilities for many women entrepreneurs seeking to find avenues for remunerative self-employment. There is need for a global movement for the knowledge, skill and technological empowerment of women living in poverty. Because of the multiple burden on their time, they are over-worked and under-paid. Hence, the aim of scientific research designed for helping resource-poor women should be to add economic value to each hour of work and reduce the total number of hours of work. The Biovillage programme of MSSRF aims to achieve these twin goals. Successful examples of womens' technological empowerment need to be replicated worldwide. Opportunities for assured and remunerative marketing will determine the success of the micro-credit supported micro-enterprises now being advocated to end the feminization of poverty. It would be useful if UNIFEM, ILO, the World Womens' Banking and WTO undertake a careful study of the public policy support needed at the national and global levels to make womens' enterprises supported by micro-credit economically viable.

Science and food and water security

The 20th century began with the rediscovery of Mendel's laws of inheritance. It ends with moving specific genes across sexual barriers with the help of molecular mapping and recombinant DNA technology. The impact of science and technology in every field of crop and animal husbandry, inland and marine fisheries and forestry has been profound. Let me illustrate this, taking the improvement of wheat production in India as an example.

Wheat cultivation started in the Indian subcontinent over 4000 years ago. Wheat kernels have been found in the Mohenjodaro excavations dated 2000 BC. From that period up to August 1947, when the colonial rule ended, Indian farm men and women developed the capacity to produce 7 million tonnes of wheat per year. Between 1964 and 1968, when semi-dwarf strains containing the *Norin 10* genes for dwarfing were introduced in irrigated areas, wheat production rose from 10 to 17 million tonnes per year. In other words, 4000 years of progress was repeated in 4 years[12]. During 1998–1999, wheat production in India exceeded 70 million tonnes, i.e. a ten-fold increase in about 50 years.

Similar progress has been made in improving the production and productivity of rice, maize, soybean, potato and several other crops as well as in farm animals in many developing countries around the world. *New technologies supported by appropriate services and public policies have helped to prove doomsday predictions wrong and have led to the agricultural revolution (the green revolution) becoming one of the most significant of the scientific and socially meaningful revolutions of this century*. A world without hunger is now within our reach. A hunger-free world will be possible if every nation pays concurrent attention to improving food *availability* through ecologically sustainable methods of production, to enhancing economic *access* to food by promoting a job-led economic growth strategy, and to ensuring the biological *absorption* of food in the body through the availability of safe drinking water and environmental hygiene. Steps should also be taken to enlarge the base of the food security basket by revitalizing the earlier tradition of cultivating a wide range of food crops[13–15].

Emerging farming technologies will be based on precision farming methods leading to plant scale rather than field scale husbandry. Farming will be knowledge intensive, using information from remote sensing, Geographical Information System (GIS), Global Positioning Systems (GPS), and information and computer technologies. Farmers in industrialized countries are already using satellite imagery and GPS for early detection of diseases and pests, and to target the application of pesticides, fertilizers and water to those parts of their fields that need them urgently. Among other recent tools, the GIS methodology is an effective one for solving complex planning, management and priority setting problems. Similarly, remote sensing technology can be mobilized in programmes designed to ensure drinking water security. GIS can be applied for a variety of planning and management activities like:

- Environment and natural resources management
- Forestry and wild life protection
- Biodiversity conservation
- Groundwater assessment
- Landuse and thematic mapping
- Urban and town planning
- Health care
- Pollution management.

Let me cite two examples of their value from our recent work.

First, GIS was applied for determining priorities in a programme designed to launch a total attack on hunger in the Dharmapuri district in Tamil Nadu, India. Socio-economic data like the percentage of poor population, percentage of unemployment, literacy rate, and infant and maternal mortality rates were mapped in GIS. The layers were prepared for each factor and registered together. Different levels were given to classify each factor. They were overlaid to get a profile map showing the poorest villages which need to be accorded priority in the hunger-free area programme.

Second, GIS proved to be an invaluable tool in developing strategies for the conservation and sustainable and equitable use of biodiversity. The Gulf of Mannar region in South India (Figure 2) is a biological paradise. Unfortunately, anthropogenic pressures and the unsustainable use of coral reefs, sea grass beds and mangroves are causing serious damage to this priceless heritage. With financial support from the Global Environment Facility (GEF) a *Gulf of Mannar Biosphere Reserve Trust* is being created by the Government of Tamil Nadu. The aim is to make all stakeholders regard themselves as Trustees of this area. This evolution of the Gulf of Mannar Biosphere Reserve into a *Biosphere Trust* held in trust for posterity is an example of UNESCO's vision of Biosphere Reserves for the 21st century articulated at Seville becoming a reality.

'Rather than forming islands in a world increasingly affected by severe human impacts, biosphere reserves can become theatres for reconciling people and nature. They can bring the knowledge of the past to the needs of the future.'

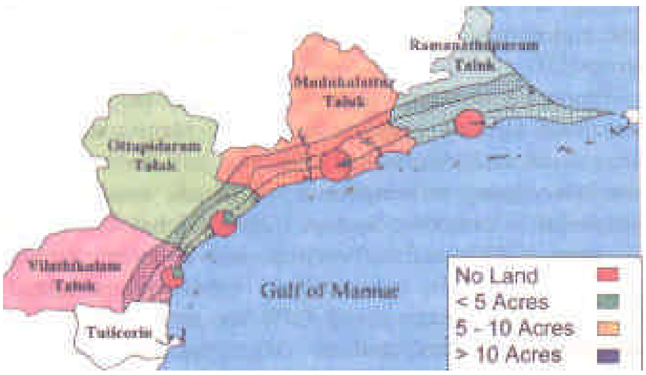


Figure 2. The Gulf of Mannar region in southern India, indicating the pressure of landless poor in the area.

Under a programme of the Government of India designed to provide drinking water to all, ground water surveys through satellite remote sensing data were used for hydrogeomorphological mapping. Based on a statistics of over 1,70,000 bore wells dug with these maps, it was found that the success rate of finding water was as high as 92%. Without such data becoming available, it would have been impossible to cover 445 districts of India, totalling to over 300 million ha with diverse terrain, diverse climate and diverse cultural conditions within a few years.

Biotechnology will play an increasingly important role in strengthening food, water and health security systems. Recent widespread public concern relating to genetically modified (GM) food stresses the need for more effective and transparent mechanisms for assessing the benefits and risks associated with transgenic plants and animals. An internationally agreed Biosafety Protocol on the lines recommended in Article 19 of the Convention on Biological Diversity is an urgent necessity. Biotechnology companies should agree to the labelling of GM foods in the market. All food safety and environmental concerns should be addressed with the seriousness they deserve. Broad-based *National Commissions on Genetic Modification for Sustainable Food and Health Security* should be set up, consisting of independent professionals, environmentalists, representatives of civil society, farmers' and womens' organizations, mass media and the concerned Government regulatory authorities. This will help to assure both farmers and consumers that the precautionary principle has been applied, while approving the release of GM crops. The Government of the United Kingdom has set an example by setting up two multi-stakeholder commissions to take a systems approach to all aspects of genetic engineering and GM foods (*Nature*, 1999, **339**, 287). These are:

- Human Genetics Commission, and
- Agricultural and Environment Biotechnology Commission.

The US Government has taken a similar step by setting up a Biotechnology Advisory Committee made up of scientists, farmers, industry groups, professionals, environmentalists, regulatory agencies and members of the public (*Nature*, 1999, **339**, 508). Such broad-based consultative and policy guidance bodies can help Governments to take decisions on issues like the application of 'Genetic Use Restriction Technologies' (GURTs) or what are popularly referred to as 'terminator' and 'verminator' technologies which cause the non-viability of seeds. The other aspect of biotechnology which is causing serious concern relates to the commercial exploitation of *biodiversity*. The commercial importance of biodiversity will be evident from the following data on the size of world markets in 1997 for a few important items of commerce[16].

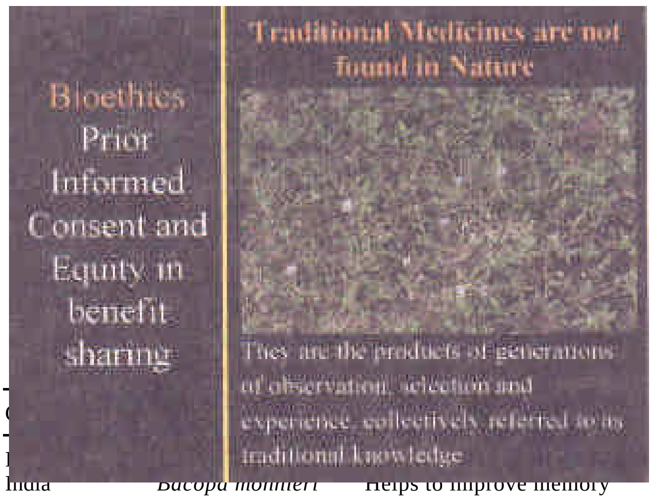
Genetic resources	:	$ 500–800 million
Petrochemicals	:	$ 500 million
Computer market	:	$ 800 million.

Biodiversity-rich but biotechnology-poor countries are adversely affected by the prevailing non-adherence to the ethical and equity principles in benefit sharing contained in Articles 8 and 15 of CBD. The primary conservers, largely tribal and rural women and men, live in poverty, while those who use their knowledge and material for producing commercial products become prosperous[17]. The invaluable contributions of tribal and rural families to genetic resources conservation and enhancement have been recognized in the Convention on Biological Diversity (Figure 3). Yet, the political will to implement the equitable benefit-sharing provisions of CBD is lacking. We need urgent steps to recognize and reward their contributions to providing material of great importance to global food and health security. The following three validated findings (Table 1) will be adequate to stress the significance of traditional knowledge and conservation efforts to help mitigate handicaps caused by ageing in human beings.

Article 27(b) of the Trade Related Intellectual Property Rights (TRIPS) component of the World Trade Agreement will come up for review later this year. *All nations should agree to incorporate in this clause the ethics and equity principles enshrined in articles 8(j) and 15 of CBD.* The World Intellectual Property Rights Organization (WIPO) which has launched a study of the need to recognize the intellectual property rights of the holders of traditional knowledge, should complete this study soon and help to make the principles of ethics and equity the foundation of IPR.

UNESCO, FAO and WHO should formulate a *Universal Declaration* on the *Plant Genome and Farmers' Rights* on lines similar to the Declaration on the Human Genome and Human Rights. If such steps are taken, *biopiracy* will give way to symbiotic *biopartnerships*. Conservation and commercialization will then become mutually reinforcing. Such a step will not only help to strengthen biodiversity conservation but will make an important contribution to poverty alleviation. The life sciences industry based on the modification of living organisms to create new products and services will then have a sustainable future.

The biotechnology industry should lose no further time in giving a helping hand to evolve internationally agreed protocols for biosafety, bioethics and biosurveillance. If this is not done, biotechnology and other life science industries, which can be invaluable allies in a global *science and technology for basic human needs movement*, will remain clouded in controversies, suspicion and rich–poor conflicts.



India	*Bacopa monnieri*	Helps to improve memory
Tropical Africa	*Prunus africana*	Treatment for benign prostatic hyperplasis

Figure 3. Equity principle in the conservation of biological diversity; the plant in the picture is *Bacopa monnieri* (Brahmi).

Emerging scientific revolutions and an ecology of hope

Fortunately, as we approach the new century we are experiencing three major revolutions in science and technology, which will influence agriculture and industry in a fundamental manner. It will therefore be appropriate to make a brief reference to them.

(i) *The gene revolution* – which provides a molecular understanding of the genetic basis of living organisms, as well as the ability to use this understanding to develop new processes and products for agriculture, industry, the environment, and for human and animal health.

(ii) *The ecotechnology revolution* – which promotes the blending of the best in traditional knowledge and technology with frontier technologies such as biotechnology, space and information technologies, renewable energy and new materials.

(iii) *The information and communication revolution* – which allows a very rapid growth in the systematic assimilation and dissemination of relevant and timely information, as well as a dramatically improved ability to access the universe of knowledge and communicate through low cost electronic networks.

In principle, these three types of advances – when coupled with improvements in the management and governance – greatly increase the power of a scientific approach to genetic improvement, the integrated management of natural resources and ecosystems, and the management of local and regional development strategies. Eco-technologies enable the adoption of ISO 9000 and ISO 14000 standards of environmental management. These scientific revolutions seem to be proceeding at an ever increasing pace, with most of the action occurring in industrialized nations. Also, new discoveries of great relevance to sustainable food and health security are coming under the purview of proprietary science, since they are covered by Intellectual Property Rights. How then can we mobilize recent advances in science and technology for meeting the basic needs of the economically and socially underprivileged sections of the human family?

The gene revolution

The past ten years have seen dramatic advances in our understanding of how biological organisms function at the molecular level, as well as in our ability to analyse, understand, and manipulate DNA molecules, the biological material from which the genes in all organisms are made. The entire process has been accelerated by the Human Genome Project, which has poured substantial resources into the development of new technologies for working with human genes. The same technologies are directly applicable to all other organisms, including plants. Thus, a new scientific discipline of genomics has arisen. This discipline has contributed to powerful new approaches in agriculture and medicine and has helped to promote the biotechnology industry.

Several large corporations in Europe and the United States have made major investments in adapting these technologies to produce new plant varieties of agricultural importance for large-scale commercial agriculture. The same technologies have equally important potential applications for addressing food security in the developing world.

The key technological developments in this area are:

(a) Genomics: The molecular characterization of species;
(b) Bioinformatics: Data banks and data processing for genomic analysis;
(c) Transformation: Introduction of individual genes conferring potentially useful traits into plants, trees, livestock, and fish species;
(d) Molecular breeding: Identification and evaluation of useful traits by use of marker-assisted selection, which greatly speeds up traditional breeding processes;
(e) Diagnostics: Identification of pathogens by molecular characterization;
(f) Vaccine technology: Use of modern immunology to develop recombinant DNA vaccines for improved control against lethal diseases of animals and fish.

Let me cite one example from the work of MSSRF scientists to illustrate the value of the new tools. As a part of the anticipatory research programme to meet the consequences of sea level rise arising from global climate change, genes responsible for conferring the ability to withstand sea water intrusion were identified in a few mangrove species through molecular mapping. They have been transferred to annual economic plants through recombinant DNA technology.

The sequencing of the genome of rice (*Oryza sativa* L. cv. Nipponbare) by an international consortium supported by the Rockefeller Foundation and the International Rice Research Institute will permit allele mining for all genes of rice and possibly for other cereals. Thus, altogether unforeseen opportunities for creating novel genetic combinations have been opened up.

As mentioned earlier, there are widespread public concerns about the potential adverse impact of genetically modified organisms (GMOs) on human health, biodiversity and the environment. Several of these concerns are genuine. In order to take advantage of recombinant DNA technologies without associated harm to human or ecological health, it is important that every country has in place suitable institutional structures and regulations for biosafety, bioethics and biosurveillance. At the same time, there is need for greater investment of public funds for public good research, the results of which can reach the unreached. For example, in food and agriculture, there is need to strengthen both National Agricultural Research Systems and the International Agricultural Research Centres supported by the Consultative Group on International Agricultural Research (CGIAR).

The ecotechnology revolution

Knowledge is a continuum. There is much to learn from the past in terms of the ecological and social sustainability of technologies. At the same time, new developments have opened up new opportunities for developing technologies which can lead to higher productivity without adverse impact on the natural resources base. Blending traditional and frontier technologies leads to the birth of ecotechnologies with combined strengths in the following areas.

- Economics
- Ecology
- Equity
- Employment
- Energy

For example, in the area of water harvesting and sustainable use, there are many lessons to be learnt from the past. In the desert area of Rajasthan, India, drinking water is available even in areas with 100 mm annual rainfall, largely because women are continuing to harvest water in simple structures called *kunds*. In contrast, drinking water is scarce during summer months in some parts of North-east India with an annual rainfall of 15,000 mm. Thus, there is need to conserve traditional wisdom and practices, which are often tending to become extinct[18]. The decision of the WIPO to explore the intellectual property needs, rights and expectations of holders of traditional knowledge, innovations, and culture is hence an important step in widening the concept of intellectual property. FAO has been a pioneer in the recognition of the contributions of farm families in genetic resources conservation and enhancement by promoting the concept of ‘Farmers Rights’. Like WIPO, Union for the Protection of New Varieties of Crops (UPOV) should also undertake the task of preparing an integrated concept of breeders’ and farmers’ rights. UPOV itself should be restructured to become a *Union for the Protection of Farmers’ and Breeders’ Rights*.

The information technology revolution

New communication and computing technologies are already influencing life on our planet in a profound manner.

(a) Access to the Internet will soon be universal, and it can provide unrestricted low-cost access to information, as well as highly interactive distance learning. The Internet will not only facilitate interactions among researchers, but also greatly improve their ability to communicate effectively with the potential users of their research knowledge.
(b) Computing makes it possible to process large-capacity databases (libraries, remote sensing and GIS data, gene banks) and to construct simulation models with possible applications in ecosystem modelling, preparation of contingency plans to suit different weather probabilities and market variables.
(c) The software industry is continuously providing new tools that increase research productivity and create new opportunities for understanding complex agroeco systems.
(d) Remote sensing and other space satellite outputs are providing detailed geographic information useful for land and natural resources management.

The promotion of ecotechnology development and dissemination, the effective adoption of integrated systems of gene and natural resources management and the effective harnessing of information technologies should become essential elements of the ‘science and technology for basic human needs’ movement.

Launching a knowledge system for sustainable food and livelihood security

The explosive progress in science and communication has led to the christening of the communities who will live in our planet in the coming century as Knowledge Societies. Information technology is beginning to play a pivotal role in stimulating and sustaining such Knowledge Societies. Let me describe in some detail an innovative experiment we are carrying out at MSSRF with a view to using information technology for the benefit of the rural poor. The experiment aims to provide the information people need and can use in their daily lives. The whole programme is need-based and demand-driven. As we cannot hope to provide telephones, computers and other tools of technology to each household for a long time to come, we have chosen to reach the unreached through community access.

Opportunities for a learning revolution

Results from our work indicate that computer-aided knowledge dissemination mechanisms can help to reach the unreached and foster new voices and new leaders. For success, a user-controlled and demand-driven system is essential. Use of the local language as the medium of communication has ensured ease of access to the entire target population (Figure 4).

The MSSRF Knowledge System deals with the following three components of food security in an integrated manner.

Availability: The first requisite is the adequate availability of food for home consumption and for markets. In the coming century, more food and other agricultural commodities will have to be produced from less per capita arable land and irrigation water, first, to meet the needs of the growing population, second, to combat the undernutrition and malnutrition currently prevailing among 800 million children, women and men and, third, to meet the need for a larger volume of feed grains because of greater consumption of animal products in urban areas.

Access: Even if food grains, fruits, vegetables and animal products are available in abundance in the market, inadequate purchasing power inhibits access to balanced diets among the economically underprivileged sections of society. Women and children are particularly vulnerable. Economic access to food depends very much on opportunities for remunerative employment and on multiple livelihood sources in the case of the landless poor. An important aspect of food security thus relates to the creation of opportunities for sustainable livelihoods. Fortunately, ecological farming is both knowledge and skill intensive. There is need for spreading information on the opportunities for eco-jobs in the farm and non-farm sectors. Urban and peri-urban agriculture helps to link the producers, food processing industry and consumers in a symbiotic chain.

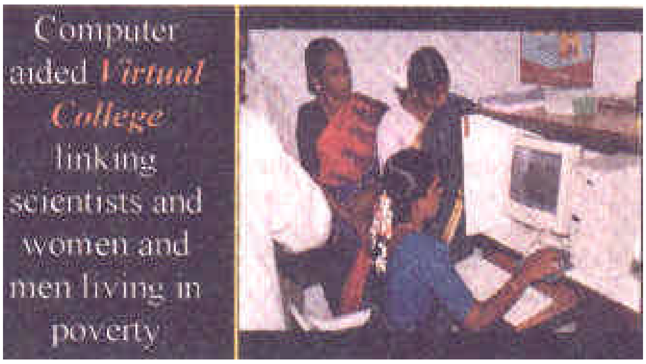


Figure 4. A typical scene at one of the village information centres near Pondicherry in southern India.

Absorption: Even if food is consumed in adequate quantities, the biological absorption and utilization of food in the body depends upon the availability of clean drinking water, environmental hygiene, sanitation and facilities for primary health care. Diarrhoeal diseases and liver ailments are common among infants and children living under insanitary conditions.

Thus, the Knowledge System for Sustainable Food Security has as its goal the empowerment of rural women, men and children with information relating to ecological agriculture, sustainable livelihoods and the biological absorption and utilization of food in the body. The Knowledge System is managed by local women at the Village Knowledge Centre, from where the computer- aided information system is operated. The Knowledge Centres can be coupled with training centres in order to create a cadre of eco-entrepreneurs.

Producing more but producing differently

The Knowledge System provides information on soil health care, water, pest and energy management, post harvest technology, farming systems design and marketing. Since the conservation of soil fertility is fundamental to sustained advances in productivity, farm families are trained to maintain Soil Health Cards. Similarly, those possessing livestock are helped to maintain Animal Health Cards. Since the system aims to convert generic information on meteorological, management and marketing factors into location-specific details, a high degree of interactive learning is built into the process.

The ecological farming database provides information on the environmentally sound management of pests as well as on eco-friendly methods of soil fertility and irrigation water management. The aim of the Knowledge System is to help in spreading an *evergreen revolution* in small farms rooted in the principles of ecology, economics, gender and social equity and employment generation. Precision farming methods help to lower the cost of production and enhance both income and ecological sustainability.

In the field of agriculture, knowledge dissemination and supply of the inputs essential for deriving benefit from new knowledge have to be synchronized in space and time. It will hence be desirable to link the Knowledge Centre not only with a Training Centre but also with a single window system of input supply.

Information empowerment and freedom from hunger

The Village Knowledge Centre enables farming families not only to produce more farm products without associated ecological harm, but helps everyone in the village to create a hunger-free area. The Action Plan for the elimination of hunger and malnutrition consists of the following seven steps.

First, the villagers themselves identify who the hungry amidst them are. They are generally very poor without land or livestock or fish pond or any other productive asset. They also tend to be illiterate.

Second, a *Household Entitlements Database* provides information on all the government, bilateral and international schemes available to rural families. The information is disaggregated according to age, gender and occupation. The families covered by the Knowledge Centre are given Household Entitlement Cards. They are encouraged to bring these cards to the Knowledge Centre and fill them up by themselves with the help of the lady operating the computer. This helps them to know what their entitlements are and how to access them.

Third, a database on elimination of undernutrition or calorie deprivation indicates the schemes available for overcoming protein–calorie under- and mal-nutrition. Information on projects run by civil society organizations is also provided.

Fourth, a *Hidden Hunger Elimination Database* deals with the micronutrient deficiencies prevailing in the village. Usually, a pediatric survey is conducted to identify the extent of prevalence of deficiencies of Vitamin A, iron, iodine and other micronutrients and information is provided on the programmes available for the total elimination of micronutrient deficiencies. The Knowledge Centre also organizes interactions between the affected families and those who provide remedies such as the use of iron and iodine fortified salt and *spirulina* and the cultivation of appropriate vegetables and fruits in home gardens.

Fifth, a *plugging the leaky pot* database provides information on schemes available for clean drinking water, environmental hygiene and sanitation, latrines, primary health care and other methods of improving the biological absorption and retention of food in the body. Information is also provided on oral dehydration and other methods of managing diarroheal diseases, particularly among children. These steps will help to ensure that food is used by the body for the purpose for which it is consumed.

Sixth, the *Eco-jobs Database* provides information on the opportunities for economically, socially and environmentally sustainable self-employment. The jobs suggested are chosen on the basis of credit and market availability. The Knowledge Centre thus performs the role of a *Rural Placement Centre for Remunerative self-employment*. A wide range of on-farm and off-farm employment opportunities are included in the database. Only those goods for which there is a reliable market, are recommended for production. The Knowledge Centre also becomes a place for interaction between credit and extension agencies and rural families, thereby triggering a *New Deal for the Self-employed*.

Finally, a *Women and Children Database* provides information on the projects available to preschool children, pregnant and nursing mothers and old and infirm persons. Special focus is on the nutritional health of pregnant women and on children in the 0 to 2 age group. Information on reproductive health care and on other special programmes for women is included in the database. Community managed support services, such as day-care centres, for working mothers are included in the database. This is essential because of the multiple burden shouldered by women, as a consequence of which they tend to remain over-worked but under paid or even unpaid.

Once a Knowledge Centre gets established, the subsequent development of databases can be done by the rural families themselves. Unless rural families have a sense of ownership and are willing to provide space and meet the salary of the computer operators, who are drawn from the village itself, the Knowledge Centre is likely to become a supply driven show piece. The Knowledge Centre is also designed to promote the monitoring of the impact of information empowerment. The following indicators are used: Infant mortality rate, maternal mortality rate, low-birth weight children, sex ratio, incidence of adult malnutrition, percentage of workers performing unskilled operations and incidence of micronutrient deficiency-induced ailments. Depending upon the interests of rural families, other criteria like the population supporting capacity of the ecosystem, per capita income and average life span can be included. The growth of the Knowledge Centre must be an evolutionary process, with information empowerment in areas relevant to meeting the basic human needs receiving over-riding priority.

Bruce Alberts, President of the US National Academy of Sciences, in his anniversary address delivered in Washington, DC on 26 April 1999 referred to the significance of the MSSRF Knowledge System for rural families in the following words:

‘Connecting scientists to each other is only the first step. Scientists everywhere must use these initial connections as a tool for spreading their knowledge, skills, and values throughout their own nations, including their local communities. By taking full advantage of new information technologies, the scientific community has an unprecedented opportunity to close the vast “knowledge gap” between all peoples. How might this be possible?’.

‘I want to highlight a wonderful example that points the way forward. The M.S. Swaminathan Research Foundation has established an experimental network in India that will soon connect more than 20 isolated rural villages to a wireless Internet service. About half of the population in most of these villages has a total family income of less than $ 25 per month. The project is designed to provide knowledge on demand to meet local needs using the World Wide Web, and *it does so through a bottom-up process*. The process starts with volunteer teams that help poll the villagers to find out what knowledge they want. Particularly popular thus far are women’s health information, advice on growing local crops and protecting them from diseases, the daily market prices for these crops, local weather forecasts, and clear information about the bewildering array of programmes that are provided by the Indian government to aid poor families. To participate, each village must provide a public room for the computer system, as well as the salaries for a set of trained operators. In return, the village receives the needed hardware and maintenance for the communication system, specially designed Web sites in the local language that convey the requested information, and training programmes for those villagers who have been selected to run their local knowledge system’.

‘Drawing on this concept, I *envision a global electronic network that connects scientists to people at all levels* – farmers’ organizations and village women, for example. The network will allow them to easily access the scientific and technical knowledge that they need to solve local problems and enhance the quality of their lives, as well as to communicate their own insights and needs back to scientists’.

Thus, we now have an opportunity to develop a new form of computer-aided *Virtual College*, linking scientists and resource-poor women and men living at a per capita income of 1–2 dollars per day. Such a virtual college should be truly the product of partnership between the poor and those who have the requisite technological knowhow and do-how. *At the global level also there could be a similar Virtual College for basic human needs operated jointly by UNESCO and ICSU.*

Harnessing resources for a ‘Science for basic human needs’ movement

Since the onset of the Industrial Revolution in Europe, technology has been a major source of economic inequity among nations and among communities within nations. If technology has been a cause of economic and social inequity in the past, *today we have an opportunity for making technology an ally in the movement of social, gender and economic equity*. Modern information technology provides this opportunity. Knowledge and skill empowerment can now be achieved at a fast pace. However, the technological and skill empowerment of the poor cannot be achieved through programmes designed on the basis of a patronizing and a top-down approach. The information provided should be demand- and need-driven and the knowledge centres should preferably be managed by women belonging to the socially and economically underprivileged sections of the society. Our aim in the early part of the coming century should be the initiation and spread of a Knowledge Revolution for ending economic and gender inequity.

The accomplishment of the tasks I have outlined so far requires considerable technical, managerial and financial resources. Scientists of the International Peace Research Institute, Oslo, have studied the causes of armed conflicts during the last 10 years. They found that violent conflicts in most cases could be traced to economic rather than ideological differences[19]. They have hence suggested that investing in agriculture which helps to promote food and livelihood security in many nations is an effective strategy for preventing future wars, eradicating poverty, preventing environmental destruction and reducing violence. Unfortunately even now, far too high a proportion of national GDP is being spent on arms and military equipment as compared to programmes designed for poverty eradication and meeting the basic needs of the underprivileged sections of humankind.

The so-called peace dividend still remains only in the realm of possibility[20].

The year 2000 has been appropriately designated the *International Year for the Culture of Peace*. Without peace and human security, it will not be possible to ensure the basic human needs to every child, woman and man. It will be appropriate to recall on this occasion what Dwight D. Eisenhower, a great war leader who subsequently became the President of the United States, stated on 16 August 1953.

'Every gun that is made, every warship launched, every rocket signifies in the final sense a theft from those who are hungry and are not fed, from those who are cold and are not clothed.'

'This world in arms is not spending money alone. It is spending the sweat of its labourers, the genius of its scientists, the hopes of its children'[21].

Harnessing science and technology for fulfilling the basic minimum needs of every child, woman and man living on our planet will be possible only if this message becomes central to the ethos of human culture.

Conclusion

To sum up, we are ending this century with a huge stockpile of scientific discoveries and technological innovations. This stockpile is more than adequate to help all nations to provide every adult human being an opportunity for a healthy and productive life and every newborn child a happy future. It is therefore a sad commentary on our political, social and spiritual value systems that the number of children, women and men living in poverty today exceeds the entire human population of our planet at the beginning of this century. Unsustainable life styles and degrading poverty co-exist everywhere. This is the greatest failure of the developmental pathways and strategies adopted during this century. Can we lay the foundation at this Conference for the emergence of a new political, social and scientific commitment to end the irony of widespread human misery and deprivation prevailing in the midst of uncommon opportunities for a better common present and future for all? In my view we can, provided every one of the nearly 2 billion persons who are enjoying a healthy and productive life today will keep the following advice of Mahatma Gandhi as the guiding principle in his/her day to day life and work.

'Recall the face of the poorest and the weakest man whom you have seen, and ask yourself, if the steps you contemplate are going to be of any use to him. Will he gain anything by it? Will it restore to him control over his own life and destiny?'

In other words, the formidable power of science and technology can benefit mankind only if we know how to temper it with humanism. Let us hope the new millennium will throw up a new crop of leaders of science who will be able to usher in an era of humanistic science. It is the duty of scientific establishments and science academies to nurture and foster the growth of young men and women research leaders capable of initiating and managing change in goals and strategies in the coming century.

1. UN Commission on Nutrition, *Ending Malnutrition by 2020: An Agenda for Change in the Millennium*, 1999 (to be published).
2. Panayotou, Theodore, Jeffrey Sachs and Alix Peterson, *Developing Countries and the Control of Climate Change*: *Empirical Evidence*, Centre for International Development, Harvard University, Cambridge, MA, USA, 1999.
3. Myers, Norman and Jennifer Kent, *Environmental Exodus*: *An Emergent Crisis in the Global Arena*, Climate Institute, Washington, DC, USA, 1995.
4. Maddox, John, *What Remains to be Discovered*, Macmillan, London, 1998.
5. Postrel, Virginia, *The Future and its Enemies*: *The Growing Conflict Over Creativity*, *Enterprise and Progress*, The Free Press, New York, USA, 1998.
6. Von Weizsacker, Ernst, U., Swaminathan, M. S. and Aklilu Lemma, *New Frontiers in Technology Application*: *Integration of Emerging and Traditional Technologies*, Tycooly International Publishing Ltd, Dublin,1983.
7. Diamond, Jared, *Guns*, *Germs and Steel*: *The Fate of Human Societies*, W W Norton and Company, New York, 1997.
8. Landes, David, S., *Unbound Prometheus*, Cambridge University Press, Cambridge, UK, 1990, pp. 13–14.
9. Maddison, Angus, *J. Econ*. *Hist.*, 1983, **43**, 27–41.
10. Farmer, Roger, A., *Macroeconomics*, South-Western College Publishing Company, Cincinnati, OH, USA, 1998.
11. UNDP, Human Development Report, Oxford University Press, Delhi, 1995.
12. Swaminathan, M. S., *Wheat Revolution*: *A Dialogue*, Macmillan India Limited, Madras, 1993.
13. National Research Council, *Lost Crops of the Incas*, National Academy Press, Washington, DC, USA, 1989.
14. National Research Council, *Lost Crops of Africa*, National Academy Press, Washington, DC, USA, 1996.
15. M.S. Swaminathan Research Foundation, Proceedings of the International Consultation organized by the Genetic Resources Policy Committee of the CGIAR, 1999.
16. Kate, Kerry Ten and Sarah A. Laird, *The Commercial Use of Biodiversity*, Earthscan Publications Ltd, London, 1999 (in press).
17. Swaminathan, M. S., Farmers' Rights and Plant Genetic Resources, Biotechnology and Development Monitor No. 36, September–December, 1998, pp. 6–9.
18. Agarwal, Anil and Sunita Narain, *Dying Wisdom*: *Rise*, *Fall and Potential of India's Traditional Water Harvesting Systems*,

Thomson Press (India) Ltd, Faridabad, 1997.
19. de Soysa, Indra and Nils Petter Gleditsch, *To Cultivate Peace – Agriculture in a World of Conflict*, International Peace Research Institute (PRIO), Oslo, Norway, 1999.
20. Swaminathan, M. S., *Uncommon Opportunities: An Agenda for Peace and Equitable Development*, Report of the International Commission on Peace and Food, Zed Books, London and New Jersey, 1994.
21. Eisenhower, Dwight, D., Talk delivered before the American Society of Newspaper Editors, 16 April 1953.

Received 24 June 1999; accepted 5 July 1999

Young scientist award – Does it encourage scientific independence and advancement?

*Sukumar Mallick,Vinita Panchnadikar, Ruchira Tewari and Sushila Khilnani**

Many scientific organizations have instituted awards for recognizing and encouraging young scientists. CSIR Young Scientist Award aims at enabling the awardees in achieving scientific advancement independently at an early age. To see as to what extent these objectives have been fulfilled, a questionnaire was sent to 67 awardees. In this study their responses have been analysed, both qualitatively and quantitatively, and examined in the context of objectives of the award.

S&T personnel constitute one of the major input resources to Scientific and Technological (S&T) activities. The Technology Policy Statement[1] considers human resources to be our richest endowment and this urges for innovative measures to attract, motivate and utilize scientific and technological talents of young Indians. A declining trend in interest of fresh graduates for doctoral and postdoctoral training has been observed and lack of job opportunity has been shown as one of the reasons[2]. But what about encouraging young researchers who are already in R&D? There is tremendous enthusiasm in young people for S&T in India which needs to be harnessed properly. Many of the young scientists not only need and deserve research support but should also be empowered sufficiently, during their formative years, for achieving excellence in science. This leads to independence and courage to experiment with new ideas. To encourage talent and creativity and fulfill the ambitions of upcoming scientists and to fire up their genuine innovative ideas, scientific organizations like DST, INSA, CSIR and others should provide financial support in the form of research projects and awards. The CSIR had introduced its Young Scientist Awards (YSA) scheme in 1987 for promoting excellence in various fields of science and technology by recognizing meritorious work done by young scientists, below 35 years of age, in the CSIR system. These awardees are taken as sample for the present study.

Scientific independence and advancement

Sukumar Mallick, Ruchira Tewari and Sushila Khilnani are with the Human Resource Development Group, Council of Scientific and Industrial Research, CSIR Complex, Dr K.S. Krishnan Marg, New Delhi 110 012, India; Vinita Panchnadikar is at National Chemical Laboratory, Pune 411 008, India.
*For correspondence. (e-mail: Sushila_Khilnani@hotmail.com)

In earlier studies[3], it was observed that the average age of a Principal Investigator (PI) receiving CSIR research scheme grant on an all-India basis was about 42 years and on a national platform PIs can compete and get an R&D project and guide research scholars independently. The research grants given through YSA scheme are to help the investigator to implement his original ideas independently at an age lower than the national average. The present study evaluates whether YS awards contribute to (a) scientific advancement in terms of publications and other scientific recognitions and research productivity, and (b) achieves scientific independence by attracting additional research projects and research fellows.

Methodology

CSIR has a vast network of 40 laboratories spread all over India. Scientists working in these laboratories are from different scientific disciplines. A recent CSIR study[4] showed that out of a total of 5528 scientists (as on July 1996) about 13% (i.e. 721) are less than 35 years of age, therefore, inter-lab as well as intra-lab competition is inherent in the system for getting YSA. Since its inception till 1997, CSIR YSA has been given to 65 young scientists in five different areas, viz. Biological Sciences, Chemical Sciences, Earth Sciences, Engineering Sciences and Physical Sciences.

To analyse the performance and perceptions of the awardees before and after winning the award, a questionnaire was framed and sent to all the 65 recipients. A total of 27 were completed and returned, thereby yielding a final response rate of 45.8%. High mobility has been observed among young engineers, as almost one-third of the total awardees in engineering sciences seems to have left the CSIR labs. This may be due to the applied nature of the field and related job prospects. The average age of 27 respondents is 40 years.

The responses to the pertinent questions of achieving scientific independence and advancement have been tabulated qualitatively without making an attempt to quantify it on a scale. Table 1 gives discipline-wise distribution of responses in the four categories of ‘yes’, ‘may be’, ‘may not be’ and ‘no’ against each question.

Results and analysis

Qualitative improvement

How far has YSA been effective in promoting and establishing a young scientist? An attempt has been made to analyse some of the attributes which would reflect on scientific independence and advancement of young scientists, through a set of ten questions (Table 1). The responses to these questions vary from an affirmative ‘yes’ to a strong ‘no’ with a few ‘may be’ or ‘may not be’. All the questions were framed in an affirmative mode, i.e. if the answer is ‘yes’ it indicates improvement in overall performance of the scientist *vis-à-vis* his/her pre-award phase. The responses to the set of ten questions (Table 1) have been arranged under five disciplines of the award. For

Table 1. Discipline-wise distribution of responses

	Biological Sciences	Chemical Sciences	Earth Sciences	Engineering Sciences	Physical Sciences	All disciplines	
						n = 27	(yes–no)
Is YSA a valued recognition?	5 0 1 0	5 0 1 0	6 0 0 0	4 0 0 0	5 0 0 0	25 0 2 0	25
Does YSA promote research activity and productivity of the awardees?	4 0 2 0	6 0 0 0	5 1 0 0	4 0 0 0	5 0 0 0	*24 1 2 0	24
Does YSA stimulate group activity and formation of a group around the awardee?	2 0 3 1	4 2 0 0	5 0 0 1	2 0 1 0@	4 0 0 1	17 2 4 3	14
Does YSA lead to further recognition?	0 1 2 3	2 0 2 2	5 1 0 0	1 2 0 0@	2 2 0 1	10 6 4 6	4
Does YSA provide opportunity for independent research?	4 0 0 2	4 2 0 0	5 1 0 0	3 0 0 1	3 0 0 2	19 3 0 5	14
Is YSA able to attract sponsored research programmes?	1 1 0 4	1 2 0 3	1 2 2 1	3 0 1 0	3 1 0 1	9 6 3 9	00
Is YS awardee invited to become member of many committees?	0 1 0 5	0 1 0 5	4 0 0 2	1 0 0 2@	3 0 1 1	8 2 1 15	– 7
Does YSA attract research fellows?	3 0 0 3	5 1 0 0	5 1 0 0	3 1 0 0	4 0 0 1	20 3 0 4	16
Does YSA facilitate social advancement	2 0 1 2@	1 2 0 3	3 0 2 1	3 0 1 0	2 1 0 2	11 3 4 8	3
Does YS awardee become popular among colleagues and press?	4 0 0 2	4 0 0 2	5 1 0 0	3 0 1 0	4 0 0 1	20 1 1 5	15
Total	25 3 9 22	32 10 3 15	44 7 4 5	27 3 4 3	35 4 1 10	163 27 21	55
(yes–no)	3	17	39	24	25		

*Note: Digit 24 1 2 0 means 24 ‘yes’, 1 ‘maybe’, 2 ‘may not be’ and zero ‘no’ and (yes–no) = 24–0 = 24.

Table 2. Value addition after the award in terms of increase in number of papers published per year, conferences attended per year, research project handled and other national awards

	Increase in no. of papers per year	Increase in no. of seminars/conferences attended per year	Increase in no. of research projects handled	No. of other prestigious awards (SSB)
Biological Sciences	6	– 2	1	7 (3)
Chemical Sciences	8	2	3	2 (0)
Earth Sciences	6	7	1	5 (0)
Engineering Sciences	5	2	4	3 (0)
Physical Sciences	1	3	1	5 (0)
Total	26	12	10	22 (3)

example, digit 5 0 1 0 indicates 5 'yes', zero 'may be', 1 'may not be' and zero 'no'. One biologist and three engineers did not attempt one of the questions.

Last column depicting 'yes' minus 'no' (yes–no) values give interesting trends. In a scale of + 25 to – 7, it shows the following:

- The higher values (like 25–24) indicate high degree of personalized advancement. It is a valued recognition and promotes research activities.
- The next higher values (16 to 14) reflect the degree of scientific independence. The awards seem to have helped in stimulating group activity around the scientist – a step towards independent research.
- The lower and negative values depict that the young scientist awardees do not get weightage and recognition outside the CSIR system. This may be due to the fact that that YSAs are selected only amongst CSIR scientists and not on the national level.

Discipline-wise, the last row of (yes–no) values show that earth science awardees, with a score of 39, feel YSA has helped them in all aspects of scientific advancement and independence. Whereas with low score of 3, biological science awardees seem to be most dissatisfied and feel YSA has been of no great help in advancement of their career, although they have received more number of prestigious awards as compared to other disciplines (Table 2).

Table 2 gives an overall picture of the incremental values of the measurable parameters which indicates scientific advancement/independence. It is highly encouraging to note that out of 27 YS awardees, 14 have received 22 other prestigious awards including three Bhatnagar (SSB) awards. Increase in the number of research projects handled and seminars attended is also significant.

Discussion

The reward and motivation system constitutes an important part of the R&D organizational feature. It is important that research of good quality be valued above work of mediocre quality. One of the aims of the YSA scheme is to motivate young scientists and encourage scientific advancement at an early age by providing them funds and recognition to continue their research. This seems to have been fulfilled to a large extent as is manifested by high scores of individual productivity. After receiving the YSA, their publications have also gone up by an average of 5 papers per year and with the exception of biological sciences, there has been an increase in the number of conferences attended, both national and international.

That YSA scheme has been able to instil scientific independence has been further substantiated by the increase in the number of research projects handled by the awardees. Also, they are able to attract research fellows, who influence the productivity of the scientists, to work in their projects.

Although the YSA scheme has been able to achieve its objectives, the fact that it does not carry much recognition outside the CSIR system, needs to be pondered.

1. Technology Policy Statement, January, 1983, Government of India, Department of Science and Technology, New Delhi.
2. Kumar, S., Khilnani, S. and Sahgal, Y. P., *Curr. Sci.*, 1998, **74,** 20–24.
3. Gupta, A., Panchanandikar, V., Bhati, V. and Mallick, S., *Curr. Sci.*, 1997, **72,** 607–608.
4. Srivastava, N. P. *et al.*, *Profile of CSIR Scientists*, HRD Group, CSIR, 1997.

ACKNOWLEDGEMENT. R.T. thanks CSIR for the fellowship provided.

Received 21 July 1998; revised accepted 21 April 1999

Multidimensional links in biodiversity research: An integrated exercise

T. N. Ananthakrishnan

The advent of viable techniques for phylogenetic estimates together with evidences on their relationships on the basis of molecular biology have kindled an increased interest in systematic and biodiversity studies. The coming together of systematists, ecologists, developmental and molecular biologists as well as the biotechnologists would give an impetus to the study of biodiversity. Thus, the integration of basic and applied sciences will result in an effective understanding of the dynamics of biodiversity and help in overcoming the deterioration of the biological systems as well as the diverse environmental problems plaguing society.

AN increased awareness of the impact of science and technology on society over the last two or three decades has led to an increased realization of deterioration of the biological systems, which has assumed global dimensions. Technology has resulted in ecological changes at a very fast pace, and with our limited understanding of the functioning of ecosystems, the intensity of the implications pertaining to the loss of biodiversity – i.e. the loss of species, genes and ecosystems – has not registered.

Immense economic benefits accrue to man because of the prevailing biodiversity, therefore continued improvement of biodiversity, and hence the benefits will depend on new and enhanced resources from nature. At any given time, changes in biodiversity, i.e. the increase or reduction or maintenance of the diversity of genes, species or ecosystems will depend largely on human activities. Access to these resources will therefore depend on scientific knowledge of these resources through the studies of biodiversity to enable prediction of the most promising species, and choosing sites for prospective biological resources, which in turn will provide relevant information from the countless number of species.

The identification, recognition and emphasis related to this multifaceted discipline have assumed an increased relevance today, especially when such issues as environment, energy, global changes and sustainable development have become a part of basic education elsewhere in the world, aiming at an increased integration between basic and applied sciences. Furthermore, because of socio-economic changes, biological diversity has today come to occupy the central stage as it holds the 'key to the maintenance of the world'. It has emerged as a unifying discipline bringing together the ecologist, environmentalist, educationist and the economist, resulting in an interdisciplinary, multifunctional, problem-oriented education. Thus the essence of this education emphasizes relevance and quality to cope with issues like ecosystem dynamics, environment and climate changes, energy sources, biotechnology, global changes, and sustainable development at the local, national and global levels[1–3].

T. N. Ananthakrishnan lives at 18, Pushpa Nagar, I Street, Nungambakkam, Chennai 600 034, India.

Diversity of biotic interactions

Researches in biological diversity span through the themes of evolutionary biology, population and community ecology, as well as cover a continuum of pers-pectives of biodiversity from its genesis to its maintenance. On the basis of the understanding gained from the multidisciplinary interactions, a critical appreciation of the diverse issues involved, particularly of biological diversity existing at many different levels, will emerge. Many of the richest 'hot spots' in the tropical forests remain unprotected, so that meaningful conservation of the exploited areas has become imminent to enable maintenance of a high degree of biodiversity. The effects of climatic change on species and ecosystems with increased CO_2, changes in hydrological cycles, increased chemical loading of soils, changes in patterns of vegetation brought about by man and the like tend to have an added impact on the rate at which biodiversity is currently decreasing.

Species living in heterogeneous environments tend to show considerable phenotypic plasticity adding to the fitness of individuals in diverse environments. In heterogenous environments, there are adaptive advantages to the genomes that allow for environmentally induced expression of phenotypes[4]. Taxonomic diversity is critical because taxa are the units that contain genetic diversity and the units that make up ecological diversity, and therefore interest in the restructuring of evolutionary trees has resulted in cladistics. Phenotypic flexibility, genetic variation within populations, ecotypic variation, functional diversity, community diversity, gradient diversity, landscape diversity, besides species richness and diversity are the essential ingredients of biodiversity. Some species play a more significant role in the ecosystems than others as indicators of ecological processes or as keystone species influencing community structure[5], which are essential for ecosystem stability and diversity. Equally important are 'species guilds' which are taxonomically different but ecologically identical species[6]. Ecosystems flourishing at great heights in the forest canopy, often described as the 'undiscovered continent' or 'powerhouses of the forest'[7], harbour 'species guilds' in countless numbers which are best known for the ecological services they offer, specially in the form of pollinators and biocontrol agents. Incorporating species into ecosystem function results in functional groups. Synthesis of ecological, behavioural, and evolutionary aspects of populations go a long way for a better appreciation of community biodiversity studies. In this connection mention may be made of the 'biochemical cacophony' of rain forests which poses a problem to potential insects, and evolutionary innovations in plant defenses and in insect feeding habits seem to have spurred their adaptive radiation. Escalation of plant defenses has resulted in increased diversity, and plant feeding has stimulated insect diversification with changes in chemical profiles exerting different behavioural interactions. The role of constitutive and induced plant defenses, and the significance of plant volatiles, insect pheromones and kairomones in the behavioural diversity of insects and their natural enemies have come to be regarded as essential components in our understanding of biodiversity.

Of equal relevance are the taxonomical and functional aspects of community structure incorporated in food webs, which provide information on energy flow. Insect parasitoids and their hosts being an integral part of a complex web of multispecies interactions, such studies provide information on the mechanisms tending to promote the persistence of multispecies systems[8]. Long-term temporal aspects of biodiversity can be assessed only from phylogenesis, and evidence from phylogeny is available from molecular characterization. The potential of molecular phylogenies in revealing evolutionary radiation is immense in view of the rapid accumulation of molecular sequence data[9]. Tools of biotechnology have added to the pool of biodiversity through creating new genetic combinations not normally available in nature. Technological developments in the area of biodiversity have made possible the transfer of genes across species. This has revolutionized agriculture by opening up new opportunities that enable screening of a large number of plants and animals for their increased productivity and effectiveness against diseases, augmenting thereby opportunities for international trade in genetic resources[10].

Research priorities

The need for not only specialization in scientific knowledge and technological skills, but also on the legal and policy aspects has assumed importance in the studies of biodiversity, since, the new international legal framework on access to genetic resources provides countries with the opportunity to assert sovereignty over their genetic resources. The economic values of genetic resources are increasing owing to the fast changing field of biotechnology, thereby making it possible for bioprospectors to analyse the genetic make up of any material using very minute quantities. This has become a priority area of research, consultation, and action by the developing countries. Further basic researches in universities on the diversity of organisms, including microorganisms which form the basis for biotechnological exercises, would help in an in-depth understanding of genetic and cellular mechanisms. This in turn would enable application of biotechnological principles to the improvement of society.

Another area requiring attention is inventory and identification of animal and plant taxa, notably the teeming millions of insects. Lack of this taxonomic knowledge affects the ecological, biogeographical and evolutionary studies. Comparing the biological attributes of a species of one region with another is an uncertain exercise and doubts over their exact identification may lead to questionable conclusions. The study of the discipline of hard-core taxonomy and its sustenance is a must for a meaningful approach for understanding the issues of biodiversity.

The preparation of proper inventories of the various biodiversity resources, their adequate monitoring and inclusion of proper computer-based information systems for such resources, and evolving strategies for conservation of species, are priority aspects in biodiversity studies. Mapping of tropical forests through remote sensing to cover large areas has become an inevitable aspect to be able to identify natural vegetation formations and assess the extent of loss of vegetation.

Some of the basic issues in conservation education are: (i) promoting a concern for the wide and indiscriminate use of natural resources; (ii) promoting an understanding of integrity, stability and beauty of the community of life, and (iii) initiating integrated efforts at solving multifunctional, problem-oriented exercises, besides continued monitoring for sustained utilization of research. In many parts of the world, the emergence of National Institutes of Biodiversity has been responsible for the generation, storage and communication of information on biodiversity. Integration of diverse networks of information, so as to be able to tackle natural and local issues, is among the major concerns for the build-up of such capacity for the future. As technology is faced with the need to overcome diverse environmental problems, restoration in terms of ecological services and crop productivity is also important, with restoration biology or ecological engineering holding the key for conservation in the next century.

Worldwide concern for the conservation of biodiversity for the benefit of present and future generations has resulted in a global biodiversity strategy which offers guidelines for the sustainable utilization of biological wealth. In this connection, the convention on Biological diversity held in Rio De Janeiro in 1992 relates to the conservation of biodiversity, sustainable use of its components, and equitable sharing of benefits arising from the use of genetic resources. The convention also calls for strengthening of 'natural capabilities through human resource development and institution building, promotion and establishment of joint research ventures and programmes for the development of skills and technologies'.

1. Solbrig, O. T., van Emden, H. M. and Van Oordt, P. G. W. J., *Biodiversity and Global Change*, CAB Institute, London, 1992, p. 227.
2. Wilson, E. O., *Biodiversity*, Natural Academy Press, Washington, 1988, p. 521.
3. McNeely, J. A., *Biodiversity Conserv.*, 1992, **1**, 2–18.
4. Ananthakrishnan, T. N., in *Conservation and Economic Values* (eds Pushpangadan, P., Ravi, K. and Sathish, V.), Oxford and IBH, New Delhi, 1997, pp. 307–316.
5. Wilson, E. O., *The Diversity of Life*, W. W. Norton and Co., New York, 1992, p. 424.
6. Nadkarni, N. M., *Am. Zool.*, 1994, **34**, 70–78.
7. Silver, W. L., Brown, S. and Lugo, A. E., *Conserv. Biol.*, 1996, **10**, 17–24.
8. Hochberg, M. E., Clobert, J. and Barbault, R., *Aspects of Genesis and Maintenance of Biodiversity*, Oxford Zemraz Press, London, 1996, p. 316.
9. Realka–Kudla, Wilson, D. E. and Wilson, E. D., in *Biodiversity II*, Joseph Henry Press, Washington, 1995, p. 551.
10. Ananthakrishnan, T. N., *Dimensions of Insect–Plant Interactions*, Oxford and IBH, New Delhi, 1992, p. 184.

Received 22 December 1998; revised accepted 30 March 1999