To help its women fellows/associates, a period of absence up to 3 months on grounds of maternity with full stipend is given by CSIR. A relaxation in age limit up to 5 years for applying for these posts is also given to them. Also some travel concessions have been provided. It has also been generally agreed that in case of women scientists aspiring to return to science after fulfilling their family obligations, the condition of 'publication during the last five years' would not be insisted upon.

Despite changes in attitudes, society still places on the shoulders of women the major role in home building, and that combined with their biology means that the greatest domestic stress on women occurs in conjunction with the greatest scientific stress[4]. Child-bearing and rearing years coincide with the 'assistant professor' years. A special mention must be made of the emeritus scientists who have been the pioneers of the changing scenario and have successfully sailed through all these, and are still active.

It is heartening to note that with all this, women researchers are still coming forward to ask for grants in a supposedly male-dominated society, as evident from the Table 1.

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Planning for science and technology and its relevance to national security*

K. Subrahmanyam

India is one of the few countries which has been observing remarkable restraint on military expenditure. In spite of that, the planners and managers of our economy brought us to the verge of bankruptcy.

AS an observer I have been deeply disturbed by the lack of understanding on this area vital to our national security and my approach to this theme is essentially as a strategic analyst. Though we have been boasting about availability of a vast reservoir of scientific manpower and we have a few achievements to our credit in agricultural production, nuclear energy, space and missile technology, yet considering the potential this country has, our achievements in science and technology lag far behind our expectations and capabilities. I was recently in South Korea and visited the Hyundai automobile factory. They started licensed production in 1967 and today they ranked tenth in the whole world in automobile technology and talk of billions of dollars of R&D investment and prototype developments from their indigenous R&D on electric cars and other advanced type of automobiles. In steel, electronics, communication equipment and shipbuilding, they started a couple of decades after India in a country totally ravaged by war and yet today they are a global player. That set me thinking on this subject of relevance of science and technology to national security. When people talk of national security in India, especially those in the economic ministries, they think solely in terms of military security. Then they give a low priority to military security and argue that the country should focus on economic development since the real security is in economic development.

Today security has a much wider connotation than military security understood in the traditional sense. A nation must have economic security, food security, energy security, environmental security and political and social security. India is one of the few countries which has been observing remarkable restraint on military expenditure. In spite of that, the planners and managers of our economy brought us to the verge of bankruptcy in 1991. After four decades of economic planning, this country is still one of the poorest in the world in terms

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of per capita income, 40% of our population is still illiterate, the country still depends on foreign aid, licensed technology, heavy imports of energy source materials and lacks basic infrastructure in terms of power, transportation and communication. It is only in food production that we have managed satisfactorily. The country is worse off in terms of security with insurgencies, terrorism, inflow of small arms and narcotics. While what has been achieved – building up a state of some 500 millions above poverty level in a period of forty years – is not to be dismissed lightly, yet it is quite clear that our planners have a lot to introspect about their failures of the last four decades. In these circumstances, it is not surprising that the planning process in India has not led to this vast country with one fifth of world's population registering any global achievements and making it a global player in any major area of technology, except to a limited extent, computer software. Our performance is miserable even in an area like sports. If our Olympic team wins a single bronze medal, that is cause for great celebration. Sri Lanka which came into cricket only in the last two decades, is able to beat us hollow. Therefore our non-achievement is not something related to one particular field or the other. It spans the entire range of this country's activity. Therefore the lack of planning in the fields of science and technology should be viewed against the overall context of the country's lack of interest in achievement.

The first Prime Minister of India, Jawaharlal Nehru emphasized the need for developing science and technology and took personal interest in the scientific departments. Under his direct patronage the Council of Scientific and Industrial Research expanded and the Atomic Energy Commission was set up. The leading scientists had direct access to him. Unfortunately the Nehruvian tradition of scientific departments receiving the direct patronage of the Prime Minister later on turned out to be a disadvantage. Nehru's successors did not have his vision and were not prepared to devote as much time and interest to the advancement of science as he did. Perhaps it was not wholly their fault. The burden on the Prime Ministers has increased manifold. Logically they should have handed over the responsibility to a very senior cabinet minister who would have had adequate political weight and got things done. The Prime Minister continuing to be in charge of these departments and not being able to devote attention to them has led to their neglect. There have been occasions when the heads of scientific departments could not even meet the Prime Minister for months: The creation of the Prime Minister's Secretariat (now called the Prime Minister's office) raised one more barrier between the Prime Minister and the scientists.

The planning process in India, started with great hopes in the fifties, became a routine mechanical linear extrapolatory exercise after the third plan. Plans were put forward without any financial or political commitments. The Sarabhai plans on atomic energy or on space illustrate this kind of non-serious approach to planning on science and technology. The Planning Commission increasingly tended to get involved in implementation and there was less and less perspective planning especially in science and technology. As the planning process turned into permit license quota raj and the public sector became a milch cow for the ruling political party, the emphasis increased on import of technology. Product improvement in public sector production units was not generally encouraged. Successive imports of technology were preferred to indigenous R&D. When the country obtained licensed technology there was no attempt to establish R&D facilities associated with the technology. Neither our public sector nor our private sector thought in terms of being a global player and consequently there were no attempts at competing with global standards in quality and sophistication. There was no pressure on industry to have R&D to keep up with advances elsewhere in the globe. The protected domestic market meant there was no need for industry to exert itself. R&D did not become an engine for industrial innovation and competition. In turn the R&D had to rely exclusively on government funding. The indifference of the State to promote R&D from the seventies onwards was reflected in inadequate funding. This led to the phenomenon of brain drain when the brightest young minds started to emigrate to the US and find opportunities to exercise their talents in a congenial atmosphere there.

During this period there were also grave mistakes committed in R&D management in India which had an adverse impact on the credibility of indigenous R&D. Let me illustrate this with examples from defence with which I am more familiar. I have no doubt it applied to other fields as well. R&D projects were undertaken by understating costs and promising to reach a combination of performance characteristics totally unrealizable. This was done with the best of intentions to promote indigenous R&D. The result was initiation of R&D at inadequate levels of effort, upward revision of costs, prolongation of the R&D project much beyond the optimum period and failure to meet the promised performance characteristics. Because of long delays in R&D effort, imports were resorted to and indigenous R&D lost credibility in many instances. The major blame for this state of affairs must be laid at the door of generalist policy makers and users who are unfamiliar with R&D management and global R&D costs. But the scientific community must also share a part of the blame.

This is the overall situation in which India has decided to join the globalization process. There can be no two opinions that the globalization process had been unduly delayed. China, in spite of its Maoist past started its marketization and globalization some 12–13 years earlier and has gone about it in a massive way. The

question is not whether globalization and marketization is right or wrong. It is inevitable and therefore the issue facing the country is how to carry out globalization with the least destabilizing effect on our society. In this respect this country faces a major cultural hurdle. Devising a strategy to carry out globalization in a cost-effective way needs a careful assessment about the international political, economic, and technological present and future. The Indian establishment, political, bureaucratic and scientific ones are averse to disciplined structured decision making based on systematic assessments of present and future situations. Adhocist and personalized decision making is the normal one in India. Therefore, we face problems in formulating an optimum strategy for globalization of Indian economy and technology. For the same reasons the profound changes that have come about in the international system which make R&D as one of the dominant currencies of power have not been adequately appreciated.

The Clauswitzian era in which war was considered a viable instrument of politics is now over. It is recognized that there are no worthwhile political, economic and other objectives which would justify either a nuclear war or even a high intensity conventional war, though there will continue to be threats of use of force – both with sophisticated conventional weapons as well as nuclear weapons. Force will be resorted to only in extremely asymmetric situations where a dominant country can use it against a weak country without fear of retaliation or incurring significant casualties on one's own side. There can also be terrorist use of force when the perpetrators of terrorism can inflict spectacular damage without exposing themselves. The first development leads to more and more sophisticated weapons, weapon delivery systems and surveillance systems. The second development creates a sense of insecurity among the societies hit and tends to disrupt its effective functioning. Because war is no longer viable, states which want to damage a particular neighbour tend to resort to terrorism to hurt and damage the neighbour.

Therefore, even as India tries to globalize its economy and become a major market which would lead to its becoming a major economic player in the international system, those who are not well disposed towards this country are likely to attempt to ensure that India does not project an image of stability and security which would make it an area attractive for foreign investments. In this respect security and fast economic development are symbiotically related and the old adage of choice between guns and butter popular before the international system got globalized and when wars were considered viable instruments of policy among nations is now totally inapplicable. Without optimum security and stability, there can be no orderly economic development. Development promotes security and stability but the latter are also pre-requisites for development. If a number of cities of India were to be subjected to the experience of Mumbai on 12 March, 1993 we can forget about foreign investments in the country. All the industrialized nations of the world are under the protective umbrella of a hegemonic power and so are also most of the 'tiger' economies. The latter combine high growth rates with high defence expenditure exploding yet another myth. As China's economic growth speeds up, its defence expenditure also grows rapidly.

While sophisticated military technology and nuclear weapons are still international currencies of power, their utility shows signs of reaching their limits. Unfortunately, as of today, the nuclear weapon powers attempt to project the nuclear weapons as the ultimate currency of power. In reality, the ultimate currency of power will be R&D capabilities of a nation. The Japanese boast that while the US may have conducted and won the high technology Gulf War, most of the equipment used in the war incorporated microchips made in Japan. There are ideas of using dominance over space and information technology as instruments of hegemonism over earth. Since it is expected that in the third or fourth decade of the 21st century China may catch up with the US as world's largest economy, the latter feels that the only way of asserting its pre-eminence in the global system is through its R&D. One of the papers prepared for the conference on 'The role of science and technology in promoting national security and global security' in the US by the White House Office of Science and Technology policy says: 'Since World War II, US military superiority has been based on our technological advantage, and technology will be even more important in the unpredictable security environment we now face. For technology to be an effective bulwark, however, we must abandon our reliance on separate and increasingly isolated defense industrial bases. We must recognize that commercial industry, not the military, is the driving force behind many advanced technologies today.' Unlike the US, India has no desire to be hegemonistic in military terms but promotion of R&D is essential for India in terms of its national security defined in the broadest possible terms.

India can envisage its future role in the globalized international system in two alternative ways. With its large market and a reservoir of relatively skilled labour available at low wages, India can be the base for a large number of foreign multinationals. It will grow economically, jobs will increase and it will be a major trader in the world. It will be better off compared to its present situation but will still not be a major player in the international system. Such an India living next door to a fast-growing China as a rival hegemon to the US will have to choose between the accommodation with one or the other. The other alternative is an India which not only grows economically as a market hospitable to foreign investments but applies its R&D skills and takes advan-

tage of its market size and its competitiveness to be a major actor with its own multinationals spreading out into the rest of the world. Such an India can aspire to be an independent actor not subject to the hegemony of either China or US.

Some assessments envisage that by 2020 AD the leading seven economic powers of the world could be US, China, Japan, Germany, India, Korea and Indonesia. If that kind of status is aspired to by India, it cannot be on the basis of our permitting large-scale foreign investments in our country and not generating new products out of our own R&D. It is to be noted that out of seven countries listed only US, China and India play an independent role in the international system and the others have accepted the US hegemony. To be free of hegemony of US and China in a globalized international system is very much of a security issue. Globalization is perhaps inevitable and on the whole beneficial to India. But the ranking in the international hierarchy and the role India is to play will very much depend on how this country proposes to manage the globalization process.

India has certain inherent advantages. It has a large reservoir of manpower with potential to acquire high skills. It is an English-speaking country in a globalized system where English will be the international communication medium. It is a large market starting with a middle class of above 200 millions with tremendous expansion potential.

As mentioned earlier, a comprehensive view of national security will have to cover food security, energy security, political, social and economic security besides other factors. Our food production will have to keep up with the growing population and their increasing demands. Further there will be world-wide need for more food and that will present challenges and opportunities for our food production and exports. We are today a large importer of energy source material – particularly oil. It is obvious that the demand for energy source materials will increase exponentially with rapid industrialization of the Asian countries. This raises two problems – first, availability of oil at economic prices and secondly the environmental consequences of the large Asian countries burning fossil fuel and adding to the greenhouse gases in the atmosphere. Alternative sources of energy will need to be developed and there are vast R&D projects both at international and various national levels for this purpose. Energy conservation too is gaining increased attention all over the world.

Information technology is revolutionizing our way of life and the US writings indicate that intense exploitation of this technology is expected to keep the US as foremost military and industrial power. Biotechnology too is today a vast frontline area of research and promises undreamt of potential and changes in human society. One can add to this list and all these technologies have dual uses both in civil applications as well as in destructive ones. Therefore global competitiveness in future will mean competitiveness in R&D and efficiency in converting the results flowing from the R&D into industrial production and services. US, China, Japan, Germany and Korea are likely to treat R&D as the new currency of international power. While the US has the advantage of having been a leader now for fifty years and is likely to do its utmost to keep the lead, China will attempt to catch up with the US and overtake it, because of its larger human resource potential. In all these countries there is considerable emphasis on quality education and production of highly skilled manpower base. In addition, the US also tries to tap the skills available world-wide through its multinationals.

In the case of India, there is not even elementary awareness among our political leadership of the likely future strategic developments and their impact on our national security interpreted in the broadest possible sense. Since new sections of populations are getting successively empowered, their attention is solely focused on consolidating their power and very little attention is paid to overall national interests and security. In the longer term, such empowerment is a progressive development and helps to strengthen the nation and enrich the human resource development. In the interim period, however, the country is passing through a critical phase.

It is against this background that India has to consider long term planning for R&D to ensure that this country will play its due role consistent with its civilizational heritage and its population base. More than 25 years ago Vikram Sarabhai told me that in the latter half of 21st century the two foremost powers of the world would be China and India based on their human skills resources. I wonder whether there are people today who still cherish a similar dream. Since the political elite and bureaucracy tied to its chariot wheels are not likely to take the lead in this area, the responsibility will largely be on the scientific community and leaders of industry. If Samsung talks of a $200 billion turn-over and Hyundai dreams of reaching the top of automobile technology why should not our business aim high on similar lines. At present most of our business and scientific leaderships have not been conditioned to think strategically and relate our technological and industrial future to our national security and role in the world. While the scientific community is aware of the potential of certain areas of R&D and their roles in shaping the future and the business community is knowledgeable in assessing long term trends in international business transactions, there is at present no mechanism to develop a syncretic view of science and technology, globalized industrial and economic trends and strategic developments. This needs to be attempted and it would be appropriate if the scientific community would take the initiative in cooperation

with private and public sector industry. Our state planning process, represented by the Planning Commission cannot deal with the R&D planning against this background since their exercise is a limited one and over the years has been reduced to a largely mechanical linear extrapolatory exercise. With the liberalization process, there is need for a large-scale indicative planning since bulk of funding for R&D in future will have to come from private industry. In turn captains of our industry will have to be sensitized to the imperative of investments in R&D. The State should be persuaded to increase incentives for such R&D investments. Yet another important area is to organize efficiently the expeditious transfer of R&D to production. Efforts will have to be made to involve the universities in a much larger scale than have so far been done.

REVIEW ARTICLE

Laboratory studies of density-dependent selection: Adaptations to crowding in *Drosophila melanogaster*

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Over the last decade or so, studies on replicated sets of *Drosophila* populations, subjected to life-stage-specific density-dependent natural selection in the laboratory, have greatly enhanced and refined our understanding regarding how these organisms adapt to crowded conditions. Fundamental trade-offs constraining the evolution of life-histories under crowded conditions have been uncovered, such as the negative association between efficiency of food acquisition and its subsequent utilization. A large suite of traits adaptive under crowded culture conditions has been identified, and the behavioural and physiological mechanisms underlying adaptation to crowding are becoming understood. These studies have yielded results that are sometimes at odds with well-established theoretical principles and have, thus, also led to a refinement of our theoretical understanding of how density-dependent selection can shape the life-histories of organisms.

THE theory of density-dependent selection represents one of the early attempts to bring population genetics and population ecology together by explicitly considering the impact that population density may have on evolutionary trends. Although the impact of density on various components of fitness had long been documented in many species[1–10], it was only in the 1960s that the basic ideas about the possible specific effects of density on life-history evolution were explicitly laid out[11,12]. The following decade saw the development of the formal mathematical theory of density-dependent selection which rapidly became one of the major components of the theory of evolutionary ecology[2–20]. A major theoretical advance of relevance to empirical biologists during this phase was the development of *Drosophila*-specific mathematical models that explicitly incorporated important aspects of the laboratory ecology of *Drosophila*[19,20]. The theoretical work done during this period clearly suggested that many of the predictions from the verbal theory of density-dependent selection[21–23] were far from accurate, because in its oversimplified verbal version, the theory had been used to explain all kinds of differences among widely different species. This part of the historical development of density-dependent selection theory has been extensively discussed elsewhere[24–27], and I will, therefore, not spend further time on it. What is more important from the point of view of this article is that the refinement of the theory gave impetus to rigorous and systematic empirical studies of density-dependent natural selection, and it is to these that I shall now turn.

Several empirical studies of density-dependent selection in the 1970s and early 1980s sought evidence cor-