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FOREWORD

The ICTP Physics and Development Programme resulted from the recognition that the scientific, technical, economic and social progress of the developing nations are strongly interrelated and from the recognition that physical and mathematical sciences play an exceedingly important role in providing satisfactory solutions to problems of development in general.

Within the framework of this programme, renowned experts are usually invited to give lectures on science and technology, economics and planning, with particular reference to the needs of developing countries. The purpose is to improve the awareness of scientists visiting the Centre, of the current technical, economic and social aspects of development, thereby assisting them in better utilizing their talent in the development programme of their countries.

H.R. Dalafi

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Abdus Salam

Address at the Inaugural Session of the Roundtable Session on

"Development: the Human Dimension"

Istanbul, 2-4 September 1985

I wish to extend my appreciation to the United Nations Development Programme (UNDP) for asking me to participate in this Roundtable on the human dimension of the development process. I shall take as axiomatic the thesis that without highly-motivated and highly-trained manpower, no lasting development can take place. My purpose in coming today is to try to highlight the role of a much-neglected community, that of scientists - so highly neglected that they did not figure in the first draft of the programme. Technologists did, but scientists did not. I nearly declined the invitation before science for development was accepted as a legitimate subject to speak on.

My own experience of dealing with development-related Science derives from directing a United Nations run International Centre for High Level Physics located at Trieste. Since its inception in 1964, this Centre has had the privilege of welcoming of the order of 25,000 visits, of experimental and theoretical research physicists, nearly 13,000 of them working in developing country research institutes and universities.

Since I am speaking in Turkey, I wish to relate my remarks to the situation in Turkey, to that in nearby Egypt and to my own country - Pakistan. These three are not too small countries with population levels ranging between France and Japan and five to ten times larger than Sweden's. During the last 15 years, we at Trieste have welcomed 325 visits of physicists from Turkey, 375 from Pakistan and around 600 from Egypt.

I shall speak frankly; as a friend, I hope I shall not be misunderstood. Let me begin by recalling the year 1799: against the opposition of the Ulema - and surprisingly even of a section of the military establishment - Sultan Selim III introduced the subjects of algebra, trigonometry, mechanics, ballistics and metallurgy into Turkey. He imported French and Swedish teachers for teaching these disciplines. His purpose was to rival European advances in gun-founding. Since there was no corresponding emphasis on research in these subjects, Turkey could not keep up with the newer advances being made elsewhere. The result was predictable: Turkey did not succeed. Then, as now, technology, unsupported by science, will not flourish.

As my second example, take the situation in Egypt at the time of Muhammad Ali, thirty years after the episode with Selim III I have just recounted. Muhammad Ali in Egypt had his men trained in the arts of surveying and prospecting for coal and gold, in Egypt. This attempt was unsuccessful but it did not strike him, nor his successors, to train Egyptians on a long term basis in the basic sciences of geology or of related environmental sciences. Thus, till this day, there is not one high-level Desertification Research Institute in the entire sub-continents of North Africa or the Middle East (except in Israel). When we recently organised a course on the Physics and Mathematics of the desertification process, we had to import teachers from Denmark - with their experience with the wastes of Greenland!

My third example is again from Egypt, where, I am told, 30 million dollars was spent in setting up a factory for the manufacture of thermionic valves. The factory was built in the same year that transistors were perfected and began to invade the world markets. The recommendation to set up the thermionic valve factory was naturally made by foreign consultants.

It was, however, accepted by Egyptian officials who were not particularly perceptive of the way science was advancing, and who presumably never consulted the competent physicists in their own country.

Why do we neglect Science for development? First and foremost, there is the question of national ambition. Let me say it unambiguously. Countries of the size of Turkey, or Egypt, or Pakistan, have no science communities geared to development because we do not want such communities. We suffer from a lack of ambition towards acquiring science, a feeling of inferiority towards it, bordering sometimes even on hostility.

In respect of ambition, let me illustrate what I mean by the example of Japan at the end of the last century, when the new Meiji constitution was promulgated. The Meiji Emperor took five oaths - one of these set out a national policy towards science - "Knowledge will be sought and acquired from any source with all means at our disposal, for the greatness and security of Japan". And what comprised "knowledge"? Listen to the Japanese physicist, Hantaro Nagaoka, specialising in magnetism - a discipline to which the Japanese have contributed importantly, both experimentally and theoretically

since. Writing in 1888 from Glasgow - where he had been sent by the Imperial Government - to his Professor, Tanakadate, he expressed himself thus: "We must work actively with an open eye, keen sense, and ready understanding, indefatigably and not a moment stopping. ... There is no reason why the Europeans shall be so supreme in everything. As you say, ... we shall ... beat those yattya bottya (pompous) people (in Science) in the course of 10 or 20 years".

Among the developing countries today, from our experience at Trieste, we can perceive just five which do value science, whatever else be their hang-ups against developing. These countries are, Argentina and Brazil in Latin America, and China, Korea and India in Asia. Barring these five, the Third World, despite its realisation that science and technology are the sustenance, and its major hope for economic betterment, has taken to science - as contrasted to technology - as only a marginal activity. This is, unfortunately, also true of the aid-giving agencies of the richer countries and also of the agencies of the United Nations, including UNDP.

Assuming that you agree with me that Science has a role for development, why am I insistent that science in developing countries has been treated as a marginal activity? Two reasons:

First: policy makers, prestigious commissions (even the Brandt Commission), as well as aid-givers, speak uniformly of problems of technology transfer to the developing countries as if that is all that is involved. It is hard to believe but true that the word "science" does not figure in the Brandt Commission report. Very few within the developing world appear to stress that for long term effectiveness, technology transfer must always be accompanied by science transfer; that the science of today is the technology of tomorrow and that when we speak of science it must be broad-based in order to be effective for applications. I would even go so far as to say; if one was being machiavellian, one might discern sinister motives among those who try to sell to us the idea of technology transfer without science transfer. There is nothing which has hurt us in the third world more than the recent slogan in the richer countries of "Relevant Science". Regretfully this slogan was parroted in our countries unthinkingly to justify stifling the growth of all science.

Second: science transfer is effected by and to communities of scientists. Such communities need building up to a critical size in their human resources and infrastructure. This building up calls for wise science policies with four cardinal ingredients - long-term commitment, generous patronage, self-governance of the scientific community and free international contacts. In addition, in our countries, the high-level scientist must be allowed to play a role in nation-building as an equal partner to the professional planner, the economist and the technologist. Few developing countries have promulgated such policies; few aid agencies have taken it as their mandate to encourage and help with the building up of the scientific infrastructure.

Why Science Transfer? What is the infrastructure of sciences I am speaking about and why? First and foremost, we need scientific literacy and science teaching at all levels, and particularly at the higher levels, - at least for the sake of the engineers and technologists. This calls for inspiring teachers, and no one can be an inspiring teacher of science, unless he has experienced and created at least some modicum of living science during some part of his career. This calls for well-equipped teaching laboratories and (in the present era of fast moving science), the provision of the newest journals and books. This is the minimum of scientific infrastructure any country of any size must provide for.

Next, should come demands on their own scientific communities from the developing country government agencies and their nascent industries, for discriminatory advice regarding which technologies should be acquired.

Still next, for a minority of the developing countries, there is the need for indigenous scientists to help with their applied colleagues' research work. For any society, the problems of its agriculture, of its local pests and diseases, of its local materials base, must be solved locally. One needs an underpinning from a first-class base in sciences to carry applied research in these areas through. The craft of applied science in a developing country is made harder, simply because one does not have available next door, or at the other end of the telephone line, men who can tell you what one needs to know of the basic principles, relevant to one's applied work.

I spoke earlier of indifference towards Science. When I was recently consulting my Turkish colleagues, I was told that this came sometimes even from the engineering community - a community which, in Turkey, enjoys reputation and status. I was surprised by this, for many reasons. Firstly, in Pakistan, my experience is that a lack of appreciation of the possible role of scientists stems from the shortsightedness of planners and economists and not engineers. (The same remark was made to me incidentally by Brazilian scientists).

Secondly, I was suprised because in the history of recent fundamental advances of Physics, a crucial role has been played by engineers. Thus, for example, Y. Nishina, the man who first brought high-level physics to Japan and who was the teacher of the two Japanese Nobel Laureates in Physics, H. Yukawa and S. Tomonaga, was an electrical engineer by profession. P.A.M. Dirac, the creator of quantum mechanics who, in my opinion, is the greatest figure in physics of the 20th century was trained as an electrical engineer. Eugene Wigner, who won a Nobel Prize for Physics, started life as a chemical engineer.

To reinforce my remarks, let me recall that in 1961, I attended the centennial celebrations of the founding of Massachusetts Institute of Technology, perhaps the most important technological school of the United States. To my surprise, it was the engineers at this school who wanted the modicum of science to be increased in their curricula.

But one aspect of neglect of Science, one can not gainsay; this is of neglect, as demonstrated by numbers. In the whole Arab world, there are around 1,500 scientists altogether, who are engaged in creating science. Of these, 55% come from one country, Egypt. Of these, one quarter are physicists - altogether some 150 individuals. On the normal averages, two percent of these will be very good. And during their youthful working life this two percent will wish to go where their work will flourish and be appreciated. Do you blame them? The same type of figures obtain in Turkey - the same for Pakistan. Extrapolating from international norms - which prevail in Japan or Israel - the numbers in Turkey should be of the order of 6,000. Believe me, Turkey or Egypt or Pakistan will not go bankrupt if they produced say, 1,000 physicists, and provisioned them, and kept them - for institutions which I shall presently mention.

But before I speak of these, I should perhaps speak of the situation in neighbouring Greece - till recently a developing country in the definition of UNDP, but now in the category of the developed. Greece has recently applied for and secured the membership of the Centre for Nuclear Research at Geneva - the largest and the most prestigious European organisation for Particle Physics Research, with an annual budget of a quarter of a million dollars. Greece displayed the ambition of joining the big league in Science and one can visibly see as a result the maturity which Greek Physics has acquired and its transformation year after year. How this maturity will reflect itself in the area of development, will, of course, depend on the policies which Greece will pursue in employing these men. But the physicists will be there, at any rate.

Let me come back to Turkey and the development of institutions which can be created and which will need Turkish Physics manpower. I know from personal experience of working with them, that Turkish physicists are some of the most imaginative physicists in the whole developing world. They undertake difficult problems in Physics consciously - and this is something I respect. I had the privilege of visiting this country a short while back when I was honoured to be received by President Kenan Evren. I suggested to him that, in my opinion, what Turkey needed in its national plans and priorities was something analogous to the Bell Telephone Laboratories in the United States in the field of communications. This Laboratory has produced six Nobel Laureates who have contributed to basic physics, besides including in their roster of inventions, transistors and their technology. I estimate that the Turkish or Egyptian or Pakistan analogue to the Bell Laboratories for Communications would cost 40 million dollars to build and around 4 million dollars yearly, to run. I believe it can be done with the highest level of quality, and that one can find those who could create it in Turkey. May I hope that this and similar Science projects will soon come to fruition in the developing world?

THE ALPHA AND THE BETA COUNTRIES

or

THE IMPACT ON THE WORLD OF EUROPEAN POLICIES

L.J. Emmerij
Institute of Social Studies,
The Hague, Netherlands

THE ALPHA AND THE BèTA COUNTRIES

The following letter was found among the papers of Prof. Louis Emmerij after his death early in 2035. Due to the sometimes poor handwriting it is not certain that we have always used the correct terms. Moreover, it is also not clear to whom the letter was addressed, but it may be assumed that it was to the recently appointed Minister of International Economic Relations. This assumption is based on the subjects that Prof. Emmerij discusses in his letter and on the fact that the Minister in question was also his grandson. In view of the deteriorating situation between Alpha and Bèta countries, we have asked Prof. Emmerij's relations for permission to publish this letter, a permission that was readily granted.

The Editor

North Sea Island No. 84, 25th December 2034

"Dear ....,

Now that I have reached the ripe old age of 100 on this Christmas Day and my days are numbered, I find myself reflecting on the discussion of some 50 years ago during the economic crisis of the 1970s and 1980s. My thoughts keep returning to that time not only because of my age (everything seems so far away that it is as if I were looking through the wrong end of the binoculars), but in particular because for the last few years it appears that we are sliding into another deep depression, although of a different sort.

One of the advantages of old age, at least as long as your memory doesn't let you down, is that most things seem to have happened before. In a way this gives you an historical point of view.
I was born during the crisis of the 1930s. Some 45 to 50 years later I played a part during the second major economic crisis of the 20th century. Even then I was struck by the fact that people seem to learn little from the lessons of history. The discussions held then on employment and unemployment were almost the same as those held on that same subject during the 1930s, and even during the last two decades of the 19th century.

Socio-economic history has never really been popular, not even in the present day. Perhaps this is why the people have so little "socio-economic memory". What is worse, however, is that the policy makers and the civil service suffer from a lack of socio-economic memory. And the same applies, particularly in the present day, with regard to the cultural aspects of our world history.

As you know, the crisis that made itself felt around 2030 was due mainly to the growing and still increasing differences in income and particularly in lifestyles between the Alpha and the Bèta worlds. The Alpha world consists of those countries which some 50 years earlier had belonged to the OECD. During the 1980s and in the aftermatch of the great depression, the Alpha countries made a clear choice to intensify an already highly technological society and to drastically reduce the working week. All this was done behind protectionist walls which, during the 1980s and 1990s enabled these countries to adapt their economic and technological systems. When these protectionist walls were torn down early in the 21st century, the world was confronted with an awe-inspring economic machine. A number of countries from what used to be called the Third World were able to align themselves with the Alpha countries and adopt a similar lifestyle. The Bèta countries, i.e. those that used to belong to the Third World with the exception of the few that managed to link-up with the Alpha countries, had enormous difficulties in getting out of the great depression of the 20th century; for the majority, in fact, it proved impossible. These were then forced to aim at a variation of what used to be called the "basic needs model", putting emphasis on appropriately adapted technologies which would enable them to create employment opportunities for the larger part of their populations. The jobs created in this way were not very productive, however, incomes were low and the goods produced were monotonous and lacking in fantasy and creativity, although of acceptable quality.

Strange as it may seem now, we were well into the 21st century before people became aware that this could give rise to a dangerous and unexpected gap. Although in the 1950s and 1960s many economists had warned against the so-called income-gap, it now became clear that an entirely new gap was appearing, namely, between lifestyles. What had happened? In the Apha world, the enormous increase in labour productivity caused by the huge wave of technological innovations introduced on a large scale as of the second half of the 1980s meant that people had to spend less time on the labour market to earn a living. As a result, most individuals in the Alpha countries had far more leisure time, the organisation of which actually became a branch of industry. The contrast as regards the situation in the Bèta world grew greater: people had to work longer and harder to earn a bare living in the Bèta world which could only offer the prospect of a miserable existence, at least when compared to that of the Alpha countries. Everything has always been a matter of relativity, of course.

The crisis of the 2030s is a direct consequence of this contrast which has become ever more glaring: in fact, it is the first world crisis to be neither purely economic nor militarist in nature. It has been caused rather by a collision between different social systems: a contrast which became intolerable. In other words, although our present crisis naturally has an economic background, it is due principally to the fact that in our world a relatively small group of people can indulge in a luxurious, colourful and almost exhibitionist lifestyle, while in the rapidly growing (in terms of population) Bèta world, people can hardly keep their heads above water.

During the last few months I have re-read a number of papers, including my own, which were written in the 1970s and 1980s. It was amazing to realise that even then a few of us attempted to show the fundamental choices which confronted the world, choices that are now nearing their explosive peak.

At least two fundamental choices faced the world during the depression of the 1970s and 1980s. First, the choice between continuing with the global international division of labour with considerable mutual dependence among the various regions on the one hand, and on the other hand, the relative disintegration of the world economy into a number of regional units which would reduce the mutual dependence of the various regions.
The second choice that faced us some 50 to 55 years ago had to do with the way in which we wished to overcome the world economic crisis. Should we opt for economic recovery starting in what were then the OECD countries, or should the aim be a simultaneous world economic recovery ?

There was a third basic choice, however, which had to do with the then current unemployment problem. Should we try to get back to old-style full employment, i.e. the eight-hour workday, five days a week, 48 weeks per year, and so on and so forth, or should we switch to a new style of full employment based on more or less drastic forms of reduced working hours and job-sharing?

Broadly speaking, and made easy by hindsight, we were faced by roughly the following choice. In the 1980s, the then rich countries could have opted for a socio-economic development model which combined a consciously modest economic growth with more employment-intensive production patterns. This would have had to be accompanied by a greater transfer of capital to the then Third World.
This would have amounted to a simultaneous approach to getting out of the crisis, and would have given rise to an international division of labour in which the various regions would have been less dependent on each other than was then the case.

Opposed to this was another proposal based on getting the halting economic machinery back into working order, a massive introduction of new technologies, economic restructuring according to our comparative advantages, a solution of the unemployment problem by drastic reduction of working-time, all of which would have to be achieved by first putting our own house in order, i.e. in the industrialised countries. There were many who believed that the poor countries would also benefit from this and would be drawn upwards by the efforts initiated in the rich countries.

We know now that this second choice was ultimately taken. What struck me when glancing through those articles, was that some of them so clearly illustrated the fact that we had reached a crossroads and had to take one choice or the other.

In the early 1980s some of us tried to distil from the available national socio-economic plans, the actual choice as regards international economic relations.

First, we had what I then called the financial-economic orthodoxy, which was then most important. People were obsessed by the size of the financial deficit, and of the public sector, and by the "excesses" of the welfare state. Stimulating the economy was out of the question. It is amusing when you think back: Keynes was seen as little more than a village idiot whose book, published in the 1930s, had then caused somme commotion, but later (i.e. in the 1980s) was considered to be hopelessly beside the point and totally out-of-date. Fortunately, we are now somewhat more balanced in our judgements. In one of my own papers written in 1983, I suggested that the orthodox scenario in the field of international economic relations had a tendency to go protectionist first before returning with increased force to a one-world, global international division of labour approach. In other words, the policy that was then "en vogue" in the industrialised countries was oriented towards a temporary regional self-reliance and a sequential approach towards getting out of the world economic crisis. I warned against that choice.

There was secondly the "synthetic scenario", which I favoured and elaborated upon in an article in an important weekly of those days which since has changed its name to Economy and Leisure Time. There were two differences in comparison with the orthodox scenario. In the first place, an important element of the synthetic scenario was a plan to stimulate international demand. In the second place, it opted for a certain form of work-time reduction which in the present context is very significant, i.e. paid (educational) leave instead of reducing the working-week to 36 or even 25 hours. This proposal called for a simultaneous approach towards getting all countries out of the economic crisis, for perseverance with technological change, and for a well-considered method by which to reduce working-time over an individual's entire lifespan. The latter had to be easily adaptable to the changed circumstances that would prevail early in the 21st century with a quite different labour market situation and a declining working population. This also implied a continuation of the global international division of labour and of the mututal interdependence of regions and countries.

There was yet a third scenario in the 1980s which I used to call "light green". This was conceived by a combination of people belonging to the Green Parties on the one hand and "no-nonsense" economists on the other. Its points of departure were production methods that were ecologically sound and energy-extensive, and adherence to the traditional concept of full employment and thus a more labour-intensive economy. The interesting feature was the explicit orientation towards greater regional - in this case European - collective self-reliance or autonomy. The choice was thus for regional divisions of labour rather than for continuation of the major interdependence inherent in the global international division of labour.

With hindsight, it is clear that during the 1980s our part of the world was governed by people who were charmed by the "new certainties". There are no greater fanatics than those who go from one extreme to another, and this is particularly typical of people who are "bewitched" by new certainties. Europe, and not only Europe, was ruled by such fanatics who were incapable of striking the right balance between alternatives simply because they were not, or no longer, able to see them.

It is now also clear that, under the pressure of circumstances, the policy line adopted in the 1980s was a mixture of the orthodox and the synthetic scenarios, and a poor mixture at that!. This always reminds me of the old joke about George Bernard Shaw and the beautiful actress who said to him: "Imagine I were to have a child by you with your intelligence and my beauty", to which Shaw reacted by saying: "But what if it were the other way around?!"

The choice made was for economic and technological restructuring in the rich countries behind protectionist barriers. A simultaneous world-wide effort to get out of the crisis was rejected as was the proposal for a global Marshall Plan launched by some more far-sighted individuals. The choice was for absurd and irreversible forms of labour-time reduction and against the more effective and adaptable versions of this policy tool. The "light-green" scenario was hardly discussed. Now that I have read the relevant documents again, I remember that I valued some of its points positively and pleaded for the incorporation in whatever scenario would ultimately be chosen by the political decisions-makers. My only real objection to the "light-green" proposal was that it ran completely counter to the comparative advantages of the then developing countries and to continuation of the global international division of labour, which I still supported - wrongly as it has since proved.

Things began to get out of hand around the year 2000, for the rich countries at least, because after the crisis of the 1970s and 1980s Africa and large parts of Asia and Latin America had not been able to link-up to the impetus given by the OECD train, which remained largely empty. Only one-tenth of what was then known as the Third World managed to link-up, i.e. such countries as Brazil, Mexico, and some of the Southeast Asian countries which now belong to the Alpha world. The others were cut adrift without the Northern countries, behind their protectionist walls, even realising what was happening. It must be remembered that we were becoming very self-centered and very worried by what were called the deteriorating East-West relations. Today, now that all East European countries have adopted the classical Hungarian model and an excellent cooperation has been achieved, also in the light of the present crisis, it is difficult to imagine how emotional we were in the 1980s about issues that are now almost forgotten. But at the time the North-South axis of the crucifix was almost entirely sacrificed in favour of the East-West axis.

Some thirty years ago, therefore, it "suddenly" became obvious (again the "new certainties") that we had to make an important choice. With the working population dwindling rapidly and the economy improving, it became necessary either to increase the working-week again or to take refuge in even more advanced technologies. Preference was naturally given to the latter. The impetus was great, and at a given moment the locomotive was, so to speak, behind those countries that had earlier been cut adrift, pushing them instead of pulling. By the year 2010 we had started on another period of aggressive economics, in which it was not so much that the underdeveloped countries tried to re-link as that the Alpha countries tried to re-establish contacts with the Bèta countries. Matters became even more complicated because in the meantime the Bèta countries had

developed a totally different socio-economic and cultural system, but were nevertheless still attracted by the much more varied and colourful lifestyles of the Alpha countries.

The shock that followed was tremendous and degenerated during the 2020s into a situation that led to the serious socio-economic and cultural crisis that we are now experiencing. On the one hand we have the Alpha countries whose people do not know what to do with their leisure time; on the other, milliards of people have to work desperately hard to be able to satisfy their basic needs: an Alpha production pattern that is totally out of line with the needs of the Bèta world. Two worlds that are completely alienated but yet envious of each other - the latter applying particularly to the Bèta world whose populations of over ten milliard are no longer willing to accept their situation. The tragic thing is that the people of the Bèta world would probably have been quite happy if it were not for the exhibitionist and blatant lifestyle of the Alpha world.

My own creative period lies far behind me and I can offer no convincing solution to the present problem. The only things I can do is to think back over the situation of some 50 years ago when we made the wrong choices.

What ought we to have done?

As I wrote earlier in this far too long letter, it is easy to be right in hindsight. In the 1980s, however, the then European Community ought to have initiated a different socio-economic policy because it is well-known that changes can be introduced more easily in bad times than in good - after all, no one wants to change a winning team! The socio-economic policy that should have been introduced in the 1980s should have contained many elements of the "light-green" proposal such as: (i) stimulating the services and the building industry oriented towards the domestic market; (ii) stimulating industrial investment in such areas as environmental technology, energy technology, as well as specific technologies that were needed in the then developing countries; and (iii) restricting the domestic turnover of goods from energy-intensive sectors and stimulating less energy-intensive consumption patterns. We ought to have made a conscious choice for a lower rate of economic growth, with advanced technology but energy-extensive and with a suitable sector-mix that was employment-intensive - not in the international but in the national sectors of our economy. We ought, therefore, to have placed far less emphasis on reducing the working-week. In short, a policy that aimed at far greater autonomy for Europe and for the other regions of the world, but certainly not autarchy. That is why we should have had a Global Marshall Plan, not intended to increase the dependence of the developing countries, but to stimulate their autonomous socio-economic development.

You will undoubtedly protest that all this is about national policies rather than international economic relations. That, my dear boy, is because even now there are no such things as international decisions with the exception of those that are based on a combination of national decision-making processes.

It is now clear that in the 1980s Europe ought to have taken the initiative towards introducing an international division of labour that was based on regional autonomy, i.e. self-reliance. She had a particular interest involved because she was then on the losing side in the world-economic race. This would have put us on the way to achieving a far more evenly balanced world-economic structure and lifestyles, which would not have stifled indigenous cultures, on the contrary, in fact.

It is difficult to know what lessons can be drawn in 2034 from our experiences in the 1980s. I do not even know why I am writing you all this - unless it is to retain some collective memory. Others would say, of course, that this is an example of selective memory. And so the dance will start again, with arguments and counter-arguments, certainties and "new certainties". Now it is your turn to find the right course, to avoid the cliffs, and to reach a safe harbour. Good luck! The challenge has never been greater.

With my best wishes for a prosperous and successful 2035 to you, your wife and little Vera

Yours ever,

Louis Emmerij"

PIONEER PHYSICISTS IN DEVELOPING COUNTRIES: THE CASE OF INDIA

William A. Blanpied

U.S. National Science Foundation.

(21 October 1985)

Introduction

Anyone with the temerity to speak, at Trieste, about the importance of nurturing outstanding leaders of basic scientific research in developing countries must feel himself to be in the unenviable position of the proverbial carrier of coals to Newcastle. For Professor Abdus Salam, more than any other individual in our time, has succeeded in convincing us that, " . . . the supply of towering individuals, the tribal leaders around whom institutes are built [is] first and foremost among the factors that effect advanced scientific research in the developing countries.[1]" During the past quarter century, Professor Salam has also insisted, repeatedly, that:

> . . technology transfers must always be preceeded by science transfers; . . science transfer is affected by and to communities of scientists; these communities need stability, long-term commitment, generous patronage, self-governance and free international contacts to grow.[2]

More than 80 years ago, in 1903, Mahendralal Sircar -- a Bengali physician and visionary who had himself devoted a quarter of a century to realizing his dream of an institution where talented young Indians could conduct genuine scientific research -- articulated the reasons for that dream in words not dissimilar to those of Professor Salam's:

> I have only now to reiterate my conviction that if our country is to advance at all and take rank and share her responsibilities with the civilized nations of the world, it can only be by means of Science, or positive knowledge of God's work.[3]

On an earlier occasion, Sircar had offered his opinion that:

> Educated patriotic gentlemen are wasting their energies in the vain endeavour to promote technical education without even thinking of the absolute necessity of a preliminary scientific education.[4]

But why have Salam, and Sircar, and so many others been so insistent about the importance of supporting high quality basic research in developing countries? For that matter, why should the conduct of basic be assigned a high priority anywhere? Unfortunately, the assertion that basic research often aims at little more than the satisfaction of curiosity or, equivalently, at an increase in knowledge and understanding, is sometimes taken as being tantamount to an admission that basic research is "useless". That intepretation leads in turn to the question: Why expend scarce financial and human resources in pursuit of "useless" research? This challenge is particularly critical for developing countries where it usually takes the form: Can developing countries afford to support basic research?

All of us here today would probably argue, along with Salam and Sircar, that developing countries can ill afford not to support basic research. But why? What contributions can basic research make to any country, developed or developing? Six types of contributions that are often cited are these:

1. Basic research is the first link in a chain running to applied research, development, technological innovation, and adaptation for social or economic benefit. This, of course, is the standard rationale for government support of basic research.

2. Related to this contribution but somewhat more general, basic research activity, rather than being simply the first element in a causal chain leading through development to implementation for some tangible societal benefit, underlies the entire applied research, development, and innnovation sequence. That is, basic research activity supports and maintains a country's entire science and technology infrastructure.

3. Basic research is central to the advancement of understanding in any scientific discipline, regardless of whether such advances lead to specific, tangible applications. More broadly, the directions of basic research inquiry in a discipline defines the discipline itself.

4. Participation in basic research activity provides the best possible training for young scientists and engineers, including both those who intend to devote their careers to basic research and the much larger numbers who intend to devote themselves to applied research, development, or some related career. Since well trained scientists and engineers are a central component of a country's science and technology infrastructure and are also essential to the advancement of a discipline, this contribution can be regarded as a special case of the second and third contributions I have suggested. However, it such an important contribution that it ought to be considered as distinct.

5. Since basic research is pursued in many different countries, it provides an important vehicle for international communication.

6. Basic research activity -- the satisfaction of curiousity about the physical world -- is an essential element in the culture of all societies, and interacts strongly with other cultural elements.

Foundations of Basic Research in India

Today I shall explore the question of which of these contributions, if any, are important to developing countries by examining the successes and failures of six pioneering Indian scientists (or in Professor Salam's words, "tribal leaders"), starting with J.C. Bose, who died in 1937, ten years prior to his country's independence, and ending with Homi Bhabha who, though well regarded among European physicists for his basic research contributions during the late 1930s, is best remembered today for his contributions to the development of the science and technology infrastructure in India in the immediate aftermath of Independence. I shall also consider the work of P.C. Ray, C.V. Raman, S.N. Bose and M.N. Saha whose careers straddle the pre- and post- Independence eras.

Significantly, four of these six pioneer scientists were Benaglis and studied in Calcutta for at least a portion of their undergraduate years. In addition with the exception of Bhabha, all carried out a significant part of their research work in Calcutta. The reasons why Calcutta played such an important role in the early development science in India are not particularly surprising, but are worth noting in any case since they provide some hints about the conditions required to encourage talented young people to think seriously about scientific careers in the first place. In short, Calcutta was, from 1774 to 1905, the seat of the British colonial government in India. Thus, the city provided the best and most sustained opportunities for Indians to be exposed to, and learn something about, modern science, or at least to note and reflect on some of its implications for their society.

Modern science began to emerge in India during the 1870s when a handful of influential Bengalis began to argue that the spirit of modern science was not something exclusively European but, rather, was consistent with India's cultural traditions. During the last quarter of the 19th century and the first quarter of the 20th century, a few visionaries and pioneers -- aided and encouraged by a handful of Europeans -- laid the foundations for India's notable scientific achievements in the post-Independence era. Not only did these people share the conviction that the spirit of modern science is a necessary prerequisite to genuine independence. In addition, they insisted that India had to develop its own scientific institutions in its own way consistent with its own traditions.

The first institution open to Indians that offered some real laboratory science was The Medical College of Bengal, established in 1835 to certify Indians as medical technicians. Higher education was put on a systematic footing in India in 1857 when the Universities of Calcutta, Bombay, and

Madras were established on the model of the University of London. But the curricula of those institutions were heavily weighted toward the liberal arts. By the 1860s and 1870s, some Indians were beginning to participate in scientific activities -- in the geological survey and medical service, for example. But since they served largely in subordinate roles, most Indians continued to view science as a Western import having little to do with their own culture or society.

Throughout the remainder of 19th century and well into the 20th century, even the best of the instruction in science available to Indians was far from the best that Europe had to offer. Still there were, by 1870, at least three institutions in Calcutta that taught the rudiments of modern science. Judging from the subsequent careers at least of J.C. Bose and P.C. Ray -- two of the pioneer scientists I shall introduce presently -- they must have taught it at least well enough to encourage their very best students to think about scientific careers. The first of these institutions was the Medical College of Bengal. The second was Presidency College, also a government institution. Significantly, perhaps, in the late 19th the best scientific instruction in Calcutta and probably in India seems to have been offered at a non-government college -- St. Xavier's, a Jesuit institution. St. Xavier's owed its reputation for excellence in science teaching primarily to Father Eugene La Font, a Belgian who spent more than 40 years as Professor of Physics there, who also became renowned in Calcutta for his public lecture demonstrations.

La Font was a close friend of Mahendralal Sircar, to whom I have already refered. Sircar was the most prominent of the small group of visionary Bengalis who, in the late 19th century, acted on the conviction that India required first rate scientific research institutions if it were to become a self-reliant country. Around 1870 Sircar, a graduate of the Medical College of Bengal and founder-editor of The Indian Journal of Medicine, conceived of the idea of an institution -- The Indian Association for the Cultivation of Science -- where young Indians would have facilities to engage in genuine scientific research. Since, in Sircar's view, this institution was to be a key to genuine independence, he insisted that it be established and supported entirely by the Indian community. He first put forward his idea for the association in 1871 in the pages of his journal, campaigned to raise funds for it, saw the association established in 1876, and fought to expand its scope until his death in 1903.

Sircar's Indian Association for the Cultivation of Science -- the first of two centers of modern science in Calcutta -- was destined to become the laboratory of India's first scientific Nobel Laureate, C.V. Raman, who used the Association's facilities to conduct the research that earned him that distinction. The other center was established through the vision of Ashtoush Mookerjee, a gifted mathematician, lawyer and a younger intimate of Sircar's. Mookerjee became Vice-Chancellor of Calcutta University in 1912, determined to provide adequate opportunities for Indians to study and participate in modern science. To that end he raised funds, principally among his Bengali compatriots, to establish, in 1914, the University College of Science, the first institution in India to offer post-graduate instruction in mathematics and science. Mookerjee also raised funds to endow the first professorial chairs to be reserved for qualified Indian scientists -- among them the Palit Professorships of Chemistry and Physics.

Six "Tribal Leaders" of Science in India

Four of the six pioneers whose careers I shall now highlight took advantage of the opportunity Mookerjee had provided. The first was, however, well advanced in his career by the time the University College was established.

J.C. (Jagadischandra) Bose, born in 1858 in East Bengal -- now Bangladesh -- became the first Indian scientist in modern times to establish an international reputation[5]. He took his B.A. degree from St. Xavier's College in 1879, where he was influenced by Eugene LaFont. Bose traveled to England in 1880 intent on the study of medicine, but decided to pursue pure science instead. He joined Christ College, Cambridge, in January 1881, took the natural science tripos, and received his B.A. degree in 1884. Lord Rayleigh was among his teachers.

Following his return to India in 1884, Bose entered the Imperial Education Service and was appointed Professor of Physics at Presidency College, Calcutta, where he remained until his retirement in 1915. S.N. Bose and M.N. Saha were among his students. Two years after his retirement he became director of the Bose Institute in Calcutta, a research establishment modeled after the Royal Institution, London, which was endowed from the proceeds of Bose's own investments, from private benefactions, and public subscription.

During the first phase of research career -- beginning during his years in England and extending until about 1902 -- Bose was concerned with the generation, reception, and properties of radiowaves in the 1 centimeter wavelength region. He gave a public lecture demonstration of wireless transmission in Calcutta in 1895. In 1896-97 the Government of Bengal sent Bose on a nine month lecture trip to Europe, where he repeated his wireless transmission demonstration at the Royal Institution in London.

Some of Bose's research may well have anticipated Marconi's. However, he refused to patent any of his discoveries, despite the urging of well wishers, on the grounds that the fruits of scientific research should not belong to any single individual. His work was, in any event, greatly admired by Lord Rayleigh, and earned him a knighthood in 1916 and election to the Royal Society in 1920.

From about 1902 until his retirement from active scientific work thirty years later, Bose's research focused increasingly and then exclusively on studies of the responses of plants to a broad range of stimuli. His stated ambition during this latter phase of his career was to comprehend the lives of plants in their entirety. He pursued these investigations by means of a number of ingenious and highly sensitive instruments of his own design. The delicate measurements he made using these instruments are generally regarded as valid. However, most of his research in this field was not taken seriously by contemporary plant physiologists.

Bose undertook ten scientific missions abroad between 1896 and 1931. He maintained a close and lasting friendship with Rabindranath Tagore, whom he met after the poet had dedicated a poem to him on the occasion of his return from Europe in 1897. He became a leading exponent of Tagore's Bengali renaissance movement and, from 1911 to 1913, served as president of the Bangiya Sahitya Sammilan (Bengali Literary Society).

J.C. Bose's career and many of his public pronouncements suggest that he regarded science as a means for grasping a fundamental unity among all things. He asserted, for example, that his later research was aimed at demonstrating the fundamental unity of plant and animal life, as his earlier work had helped to demonstrate the unity of the electromagnetic spectrum. He also stated on more than one occasion that only his study of science had permitted him to comprehend fully the depths of classical Indian philosophy.

Had J.C. Bose been the only Indian to achieve scientific prominence prior to Independence, he would be interesting primarily as an isolated genius. In fact, one of the most original mathematician of the 20th century -- Srinivas Ramanunjam -- was just such an isolated genuius.[6] Born in 1887 in what is now the South Indian State of Tamil Nadu, Ramanunjam was a true child prodigy in mathematics. He studied for a time at Presidency College, Madras, but lost his scholarship after failing an English language examination. Thereupon he found a civil service post and in his spare time began original research in pure mathematics. Ramanunjam's work might have been lost to the world had he not taken the initiative to send some of his papers to the British mathematician, G.H. Hardy, who recognized his genius and arranged to bring him to Cambridge in 1914. Prior to his premature death in 1920, Ramanunjam was to make an astonish number of original contributions to several fields of pure mathematics, including number theory and functional analysis. Hardy was later to remark that whenever he was forced to put up with dull company, he comforted himself with the realization that he had occasionally able to collaborate with Ramanunjam on more or less equal terms.

One can only speculate about how much talent in mathematics and science went to waste in India during these years because of the absence of encouragment and opportunities for talented young people. Ramanunjam, who had to go to Cambridge for recognition, was not in a position to become the sort of tribal leader who could encourage his younger colleagues in India. But the younger colleagues of J.C. Bose in Calcutta were fortunate in having not just one, but two exemplars.

P.C. (Prafulla Chandra) Ray, born in East Bengal in 1861 three years after J.C. Bose, achieved distinction in both basic and applied research in chemistry and also contributed significantly to the history of science[7]. After two years of study at Metropolitan College, Calcutta, he entered the University of Edinburgh on a Gilchrist scholarship. There he obtained the B.Sc. degree in 1885 and the D.Sc. degree two years later. Ray pursued research in inorganic chemistry at Edinburgh for another year, before returning to India. In 1889 Ray received a teaching appointment at Presidency College, where J.C. Bose was already teaching, and soon became Professor of Chemistry. He remained at that college until 1916, when Mookerjee brought him to his new University College as the first Palit Professor of Chemistry.

By 1894 Ray had managed to raise sufficient funds to establish a new chemistry laboratory at Presidency College, where he focused his initial attention on problems related to food adulteration. During this same period he initiated research to attempt to discover some of the elements missing from the then incomplete periodic table. While analyzing certain rare minerals he found hiterto unobserved crystalline deposits, which turned out to be mercurous nitrate, a compound that had been regarded as unstable. He spent the next several years exploring the properties of this salt and its derivatives, and -- with his students -- published over 100 papers on mercury salts and related compounds.

In 1901 Ray founded the Bengal Chemical and Pharmaceutical Works, Ltd., which began with a handful of workers and modest capital and grew into one of India's major chemical firms. He also established the Bengal Pottery Works, the Calcutta Soap Works, and the Bengal Canning and Condiment Works. Much of the money earned in these industrial ventures was given by Ray to workers, to students as stipends and scholarships, to laboratories, and to scientific organizations. In 1916, he became the first Palit Professor of Chemistry at Mookerjee's newly founded University College of Science, and continued research and teaching in that post for another two decades.

Ray retained a deep attachment to the ideals of traditional Indian culture, having abandoned Western dress and manners from the time he returned to India in 1888. This attachment is reflected by his scholarship in the history of science. The first volume of his History of Hindu Chemistry appeared in 1902 and the second in 1908. He was also an active supporter of the Indian Independence movement, often urging greater participation on the part of his students.

The first scientist to benefit at an early stage in his career from the foundations established by Sircar and Mookerjee was C.V. (Chandrasekhara Venkata) Raman[8]. Raman was born in 1888 in what is now the State of Tamil Nadu. He received his B.A. and M.A. degress at the A.V.C. and the Presidency College, Madras, and published his first scientific paper while a student at the latter institution. After receiving his M.A. degree in 1907, he sought a position where he could make use of his scientific talents. Failing to find one, he joined the Indian finance department and was posted to Calcutta, where he served for ten years. Soon after his arrival, he discovered Sircar's Indian Association for the Cultivation of Science where he began to conduct research before and after his working hours at the finance department. In 1917 he became the first Palit Professor of Physics at Mookerjee's University College of Science, but continued for many years to conduct his research at the Association.

Initially, Raman's research focused on vibrations and sound and on the theory of musical instruments, particularly the violin family and Indian drums. That research was particularly admired by Lord Rayleigh and led to Raman's election to Fellowhip in the Royal Society in 1924. Beginning in the early 1920s, Raman's research interests turned increasingly to optics, a field that continued absorb him in until his death at the age of 82. His early research in this field focused on the scattering of light by gases and liquids. Later he turned his attention to the optical properties of crystals, and -- after 1950 -- particularly the optical properties of gems and minerals. His early investigations of crystal optics also led him to explore new approaches to the dynamics of crystal lattices, explorations that he carried over into his studies of gems.

Raman's research in physical optics also led him to investigations of the physiology of vision, particularly color vision, a field to which he turned much of his attention during the last years of his life. One of his biographers suggests that he may also have been the first to study flowers spectroscopically. While his ideas about the perception of colors are provocative, most of his research in this fields has not been highly regarded by contemporary physiologists.

Raman's best known research contributions were an outgrowth of his discovery (at the Association in collaboration with his younger colleagues K.R. Ramanathan and K.S. Krishnan) that when light is scattered by a gas or liquid, bands of secondary radiation at wavelenths different from that of the incident light are also emitted. This phenomena was later verified for light scattered by crystalline substances. Raman's elucidation and explanation of what is now called Raman scattering or the Raman effect earned him a knighthood in 1929 and the Nobel Prize a year later. Raman scattering was destined to become a powerful tool for exploring molecular structure. However, it only began to be widely used for that purpose in the 1960s when lasers, with their intense, focused, monochromatic beams, became available as sources of incident light.

In 1933 Raman left his professorship in Calcutta for the privately endowed Indian Institute of Science in Bangalore, where he served as president until 1937 and head of the physics department until 1948. Upon retiring from the latter post, he became the first director of the newly established Raman Research Institute in Bangalore.

Raman was noted as a great teacher, once stating that "the principal function of the older generation of scientific men is to discover talent and genius in the yonger generation and to provide ample opportunities for its expression and expansion." He also took pleasure in giving public expositions of science, and gave annual public lectures at the Raman Research Institute on October 2, the birthday of Mahatama Gandhi. Raman traveled extensively during the 1920s, visiting and lecturing at scientific institutions and congresses in the U.K., Western Europe, the U.S.S.R., and the U.S.A. In 1926 he established the Indian Journal of Physics, and in 1934 was among the principal founders the Indian Academy of Sciences. He remained outspoken in his conviction that science had to be central to the achievement of genuine independence in India, stating on one occasion that:

> Unless the real importance of pure science and its fundamental influence in the advancement of all knowledge are realized and acted upon, India cannot make headway in any direction and attain her place among the nations of the world. . . . There is only one solution for India's economic problems and that is science and more science and still more science.[9]

S.N. (Satyendranath) Bose, whose name is linked with Einstein's as co-founder of one of two systems of quantum statistical mechanics, was born in Calcutta in 1894.[11] In 1909 he entered Presidency College, Calcutta, where his teachers included J.C. Bose and P.C. Ray. M.N. Saha was his classmate. Bose received his M.Sc. in Mixed Mathematics in 1915, ranking first in his class with Saha ranking second. In 1916 he and Saha were appointed Lecturers at the University College of Science. Two of Bose's first four papers were co-authored with Saha. In 1919 the Calcutta University press published a volume of Einstein's papers on the Special and General Theories of Relativity, translated into English by Saha and Bose, respectively. This was among the very first collection of those papers to be published in English.

Bose left Calcutta in 1921 to become Reader in Physics at the newly established University of Dacca. Three years later, in July 1924, he sent a short manuscript entitled Planck's Law and the Light Quantum Hypothesis to Einstein for criticism. In this paper, Bose developed a method for deriving the Planck radiation law without any reference to classical electromagnetic assumptions, a problem that had defied the best European physicists for almost 20 years. Einstein was so impressed with Bose's result that he personally translated the paper into German for publication in the Zeitschrift for Physik. He also added a note that "In my opinion Bose's derivation of the Planck formula signifies an important advance. The method used also yields the quantum theory of the ideal gas, as I will work out in detail elsewhere." It is Einstein's generalization of Bose's method that provides the basis for what is now referred to as the Bose-Einstein statistics.

Einstein's enthusiastic endorsement of his work enabled Bose to obtain a two-year paid study leave from Dacca, which he spent in France and Germany. During his year in France he undertook experimental studies and was guided in his efforts by Paul Langevin. He also came into close association with Maurice and Louis de Broglie. Late in 1925 he had a brief and reportedly cordial meeting with Einstein in Berlin. However, although the two years Bose spent in Europe may well have witnessed the most pivotal developments in 20th century theoretical physics, they do not appear to have had any direct influence on Bose's subsequent research.

Bose returned to Dacca as Professor and Head of the Physics Department in 1926, posts he retained until 1945 when he returned to Calcutta as the first Khaira Professor of Physics. Following his retirement from Calcutta University in 1952, he served for three years as Vice-Chancellor of Visva-Bharati, an institution established by Rabindranath Tagore.

The twenty-six original papers that bear Bose's name include contributions to statistical mechanics, the electromagnetic properties of the ionosphere, the theories of x-ray crystallography and thermoluminiscence, and Einstein's unified field theory of Einstein. An extant letter from Einstein to Bose written in October, 1953, comments on a draft paper Bose had sent Einstein on the latter topic. Bose is reputed to have been a devoted and inspiring teacher, and many of his research contribution are -- on the testimony of his students -- reported in papers that bear only the names of those students.

Throughout his life Bose remained deeply attached to, and knowledgable about, the history and culture of India, stating on one occasion that he revered Gautama Buddha above all human beings. He also remained devoted to Tagore's Bengali cultural renaissance movement. Like Tagore, he loved poetry which he read and quoted in Bengali, Sanskrit, English and French. In 1948 he founded the Bangiya Bijnam Parishad, or Science Association of Bengal, as a means for popularizing science in his native language.

M.N. (Meghnad) Saha, the most politically intense of these six pioneer scientists, was born in East Bengal in 1894.[11] Like S.N. Bose, he received his undergraduate training at Presidency College, Calcutta, where he became acquainted with Rajendra Prasad and Subas Chandra Bose. Along with S.N. Bose, he was appointed Lecturer at the University College of Science at Calcutta in 1916. By 1919 he had published eleven papers, most of which applied methods of statistical mechanics to problems in theoretical astrophysics. On the basis of these papers he qualified for the D.Sc. degree from Calcutta. From 1919 to 1921 he pursued his research in theoretical astrophysics at London and Berlin, and in 1922 became Professor of Physics in Allahabd University, a post he retained until his return to Calcutta in 1938 as Palit Professor of Physics. He was elected Fellow of the Royal Society in 1927.

Saha began to become seriously interested in the uses of science for economic development in the early 1930s, recognizing that a prerequisite would have to be the establishment of modern research facilities in India. Beginning in the 1930s he expended a great deal of effort attempting to link the scattered university research centers in the country into a national scientific community and trying to establish first-rate research groups at Allahabad and Calcutta. These efforts were, however, hampered by a chronic lack of funds and a paucity of well-trained scientists.

During this same period, Saha turned his attention to national planning. In 1935 he founded Science and Culture, a journal he was to use until his death as a forum to put forth a range of incisive views on topics such as national planning, public-sector industrialization, and the modernizing role of science and technology. From 1938 he served as a member of the Planning Committee of the Indian National Congress which was chaired by Jawaharlal Nehru. Here he argued forcefully for a large-scale public-sector economy on the Soviet model, and did not hesitate to urge rejection of the Ghandian cottage-industry model on the grounds that it would inhibit modernization of the country. These political and economic ideologies were closely akin to those of Subas Chandra Bose, Saha's old friend from undergraduate days, who in that period was Nehru's principal rival for leadership of the Indian National Congress.

Saha's interest in national planning persisted throughout his life. In 1951 he won election to the Indian Parliament as an independent with leftist backing. He used the parliamentary forum to criticize many of the government's policies for science, technology and planning until his sudden death from a heart attack in 1956.

Saha was noted as an excellent teacher with the ability to provide his students with the breadth and confidence required to branch out into new directions. Many of his students and younger colleagues, such as D.S.

Kothari and B.D. Nag Chaudhuri, went on to play significant national and international roles in their own right.

The concentration of scientific talent and the level of scientific activity in Calcutta between 1916 and 1921 was remarkable. Indeed, with the exception of the great European research centers and a few scattered sites in the United States, no other city in the world boasted an equivalent level of scientific achievement during those few years -- nor would any other city for twenty years or more. In 1917, P.C. Ray, C.V. Raman, S.N. Bose, and M.N. Saha were all active at University College, Calcutta, and J.C. Bose was active at his own research institute. But by 1922, S.N. Bose was in Dacca and Saha in Allahabad. While Ray, Raman and their students continued to carry out excellent research in Calcutta, conditions in British India during the last years of World War I and its immediate aftermath simply were not conducive to allowing the nascent Calcutta school to sustain itself and provide a nucleus for the immediate development of strong basic research capabilities elsewhere in India. Yet the devotion of the Calcutta pioneers was an essential ingredient in laying the foundations for the scientific spirit that later bore fruit in independent India.

My objective in offering these brief biographical cases is to illustrate the persistence of the vision of basic research as essential to genuine self-reliance, rather than to provide a definitive account of the emergence of modern science in India during the pre-independence period. Were I to have attempted such a definitive survey, I could not have ended my biographical notes with M.N. Saha. Nor could I have confined my attention to Calcutta. For example, I would have wanted to trace the careers of some of the better known students of the Calcutta pioneers. I would have wanted to explore the origins, development and influence of scientific institutions in other parts of the country -- for example, the Indian Institute of Science in Bangalore, established in 1906, where Raman served as Director starting in 1933.

The importance of that institution to the development of modern science in India is evident in the career of the last of the six pioneers I want to talk about today. Homi Bhabha, who founded the Tata Institute of Fundamental Research and laid the basis for the Indian Atomic Energy program, was born in Bombay in 1909.[12] He was connected through the marriage of a paternal aunt to the House of Tata, an association that provided him with an early and continuing understanding of business and industry. In 1927 he enrolled in Gonville and Caius College, Cambridge, where he at first studied the mechanical engineering tripos on the expectation that he was bound for an industrial career with the Tata enterprises. However, he prefered mathematics and theoretical physics, and received his B.A. in the latter subject in 1930. Thereupon he was accepted as a research student at the Cavendish Laboratory which was still directed by Ernest Rutherford. His research centered at the Cavendish until 1939, though he also travelled extensively on the continent where he paid extended visits to Enrico Fermi's group in Rome, Wolfgang Pauli's group in Zurich, and Niels Bohr's institute in Copenhagen. He received his PhD from Cambridge in 1935.

Bhabha was in India on leave from Cambridge at the outbreak of World War II. Unable to return to England, he accepted a Readership in Physics at the Indian Institute of Science in Bangalore, where C.V. Raman still headed the department. M.K.G. Menon believes that Bhabha discovered his mission in life during his years at Bangalore, since it was there that he began to understand the unique role he was in a position to play in the development of India's science and technology infrastructure. In March 1944 he proposed to the Tata Trust the establishment of an institution that would be devoted to advanced research and teaching in mathematicss and physics, particularly cosmic ray and nuclear physics. The Tata Institute for Fundamental Research was founded in June 1945 with Bhabha as its first director, and established in temporary quarters in Bombay in December of that same year.

Bhabha conceived of the Tata Institute as both a first-rate center for basic research and as an incubator for new types of industrial enterprises. His vigorous advocacy of a nuclear-powered electrical system for India led to the creation, in 1948, of the Indian Atomic Energy Commission and to Bhabha's appointment as its chairman. Most of the commission's early work in research and development was conducted at the Tata Institute. When the commission was reorganized in 1954 as the Department of Atomic Energy, Bhabha was named as its secretary with cabinet level status and direct responsibility to the prime minister. During that same year Bhabha was appointed Director of the Atomic Energy Research Center whose construction was just getting underway at Trombay, a suburb of Bombay.

Bhabha was a staunch advocate of international cooperation in science and technology, and concluded agreements with the U.K., Canada, France and the United States for assistance in developing the Indian atomic energy program. He was the unanimous choice of the seven-member scientific advisory committee to the Secretary General of the United Nations for the position of President of the First International Conference on Peaceful Uses of Atomic Energy, held in Geneva in 1955. He became a Governor of the International Atomic Energy Agency at Vienna which was established as a result of the Geneva conference, and a member of the Scientific Advisory Committee to its Secretary General. He died in January 1966 when an airplane carrying him to a meeting of that committee crashed on Mount Blanc.

Bhabha continued to publish prolifically in pure physics until he became Secretary of the Department of Atomic Energy, and authored or co-authored more than sixty papers in theoretical physics, cosmic ray physics, and nuclear physics between 1933 and 1954. Although he engaged in formal teaching only during his years in Bangalore, his influence on his contemporaries and younger colleagues at the institutions he established was enormous and lasting. He also had considerable influence with Prime Minister Nehru, who came to rely heavily upon his scientific advice.

Bhabha had a deep aestetic attachment to both music and art. As a boy he had learned to appreciate classical Western music by listening to the extensive record collections of his grandfather and aunt, and he developed that appreciation and knowledge extensively during his years in Europe. However, apparently he only began to immerse himself in the study of classical Indian music during his years in Bangalore. Bhabha also became a

serious artist during his student years in Cambridge, and later was major patron of contemporary art in India, purchasing paintings and sculpture for himself, the Tata Institute, and the Trombay Atomic Research Center. He personally selected the permanant site of the Tata Institute and of the Trombay Center, and worked closely with the architects in designing both complexes. Like the Calcutta pioneers, Bhabha came to conceive of the spirit of modern science as an indispensible foundation for development, once stating that:

> . . the problem of establishing science as a live and vital force in society is an inseparable part of the problem of transforming an industrially underdeveloped to a developed country.[13]

Tangible Contributions of Basic Research

Which of the six possible contributions of basic enumerated earlier in my talk did the careers of these six pioneer scientists make to Indian society? Let me consider each of them in turn.

1. Basic research as a precondition for applied research and development: P.C. Ray and Homi Bhabha enjoyed success both in their own individual basic research activities and in establishing institutions for applied research and development that continue to bring economic benefits to India. A good case can be made that the training and discipline of the basic research careers of both men were significant factors in their later ability in establishing institutions that successfully linked the results of research carried out by their proteges to development and innovation. However, other factors -- possibly more important -- were also involved in their success as institutional innovators and managers. Indeed, it is worth noting that whereas Bhabha made impressive original contributions to basic research in physics for over 20 years, that research was significant primarily in advancing understanding in cosmic ray and nuclear physics rather than in providing any direct basis for useful technological innovations.

The basic research results of two of the remaining four pioneers did lead to technological innovations. Certainly J.C. Bose's research on electromagnetic radiation contributed to the development of radio communication, and, at a minimum, Raman scattering turned out to provide the basis for a powerful analytical tool. However, Indian scientists and engineers were not involved in applying the results of J.C. Bose and Raman to these innovations. Since it is rare for basic research results to find immediate application and not uncommon for others besides the original researcher to understand how those results can be applied, the cases of J.C. Bose and C.V. Raman are more typical than those of P.C. Ray and Homi Bhabha. Still, the fact that Indian society did not reap any direct or at least any appreciable economic benefit from the fundamental research of two of its pioneer scientists has important implications for the question: What areas of fundamental research should be pursued -- or should not be pursued -- in developing countries?

2. Basic research as the foundation of the science and technology infrastructure: The efforts made by these six pioneer scientists in helping develop the science and technology infrastructure in India were no doubt more significant and lasting contributions than were any of the direct applications that derived from their research. The contributions made by P.C. Ray and Homi Bhabha in this regard are the most obvious since both succeed in using laboratories for basic research as springboards for applied research and development. C.V. Raman made a different but no less significant contribution by helping establish national institutions such as the Indian Journal of Physics and the Indian Academy of Sciences. M.N. Saha also understood the connection between basic research and the science and technology infrastructure but was less successful in implementing his ideas -- perhaps because he chose to work through the existing university structure rather than establishing a new institutional framework, perhaps because his views on what science should be able to contribute to India were too ambitions for his times. Yet the ideas he put forward in Science and Culture ultimately had an enormous influence on the development of science policy in Independent India.

In assessing the contributions of J.C. Bose and S.N. Bose to the subsequent development of India's science and technology infrastructure, it is useful to note that the early success of P.C. Ray and C.V. Raman derived in large measure from the existence, in Calcutta, of at least a proto-infrastructure established through the visionary efforts of men like Mahendralal Sircar and Ashtoush Mookerjee. Indeed, P.C. Ray, C.V. Raman, S.N. Bose and M.N. Saha, during the few years when they were all teaching at the University College of Science, actually constituted the core of the fledgling Indian science and technology infrastructure.

J.C. Bose, as a friend and active supporter of the visions of both Sircar and Mookerjee, contributed at least indirectly to the viability of the institutions they had established. However, in retrospect his attempt to add an additional tangible component to the Indian science and technology infrastructure by establishing his own research institute was probably unsuccessful, and perhaps even counterproductive. In part his research interests at that time were simply too much out of the mainstream of world science. In part there were too few human and financial resources available in India to support still another scientific institution.

S.N. Bose, too, failed to make any important direct contributions to the development of the Indian science and technology infrastructure after his departure from Calcutta, quite possibly because he remained isolated in Dacca.

3. Basic research and the advancement of a scientific discipline: The early research work of all six pioneers contributed directly and significantly to the advancement of understanding in their disciplines. It is important to note, however, that in almost all cases the disciplinary advances that resulted their research work were not made in India. The case of S.N. Bose is perhaps the most obvious: Einstein and Einstein alone grasped the full implications of his work and succeed in building on it.

4. Basic research and apprenticeship training: All six of these pioneer scientists, in different ways, became tribal leaders who taught and/or inspired more than one generation of young Indian scientists. Indeed, J.C. Bose and P.C. Ray were among S.N. Bose and M.N. Saha's teachers and mentors at Presidencey College, and the fact that C.V. Raman headed the physics department at the Indian Institute of Science when Bhabha was a reader there is at least worth noting. If, however, the issue is the degree to which this apprenticeship training contributed to Indian society rather than to the individual apprentices, one must ask about the nature of the contributions the apprentices themselves made to Indian society. Viewed from this perspective, the basic research activity of all six pioneers was highly successful in providing student-apprentices with the necessary breadth and confidence to pursue their own course after their apprenticeship was finished.

5. Basic research and international communication: All six of these pioneering scientists came to be well regarded in international scientific circles, and their careers were therefore important in building up the international image of Indian scientific capabilities. The degree to which each of the six succeed in translating his prestige into tangible benefits for Indian society varied, however. J.C. Bose, P.C. Ray, M.N. Saha, Homi Bhabha and -- during the early part of his career -- C.V. Raman were quite successful in this regard, S.N. Bose less so.

6. Basic research and cultural tradition: Finally, all six scientists were concerned throughout their lives with the cultural roots of their own scientific interests and achievements and with gaining a better understanding of the scientific traditions of their own society. P.C. Ray, C.V. Ramam, S.N. Bose, and M.N. Saha were also active in efforts to infuse the spirit and ideas of modern science throughout Indian society, as was J.C. Bose in the first phase of his career. It can and has been argued that J.C. Bose's later unique orientation in the field of plant physiology derived in part from his desire to establish a research program that would be more deeply rooted in Indian cultural traditions than his earlier research on electromagnetic radiation. A similar though less persuasive case can also be made for the latter phases of Raman's work with color perception. It would, however, be presumptuous for any Westerner to attempt to assess the contributions that the late work of J.C. Bose and Raman made to Indian culture, and I do not intend to so.

What generalizable lessons can be drawn from this cursory assessment of the contributions of these six pioneer scientists to Indian society?

> First and most obviously, it is clear that basic research conducted by individual scientists in developing countries can make significant contributions both to worldwide progress in science and technology and to the developing society itself.
>
> Second, the contributions made to international science and technology by research activity in a developing country need not necessarily contribute in any direct or very tangible way to the country itself.

Consider, for example, the cases of J.C. Bose and C.V. Raman, both of whom conducted research that ultimately found fruitful applications -- but primarily outside of India. Does this imply either that Bose and Raman were exploited or that there was necessarily some fundamental flaw in the science and technology infrastructure in India that caused it to fail to recognize the importance of their work? Granted that the infrastructure during those periods was exceedingly fragile, there is no reason to believe that the results would have been a great deal different if it had been far more robust. On the contrary, the fact that the work of J.C. Bose and C.V. Raman was exploited elsewhere, after a considerable lapse of time and in ways neither might have predicted, are simply reflections of the international character of scientific research and the well-documented fact that basic research often yields unexpected benefits long after the research itself has been performed.

For these reasons it is probably futile for a developing country -- or any country -- to attempt to establish capabilities or conditions with the aim of being in a position to exploit all of the basic research results that emerge indigenously. Rather, it has to be recognized that novel results and ideas can originate from many different and unexpected directions, and that developing countries need to establish capabilities to recognize and exploit such ideas regardless of their origins. This is a point that P.C. Ray, M.N. Saha and Homi Bhabha clearly understood and used to considerable advantage for the benefit of their own country. It also suggests -- quite obviously -- that opportunities for free, open and intimate communication among scientists in a developing country and between those scientists and their foreign colleagues is essential if they are to be in a position to recognize important new ideas that emerge in their disciplines.

But of course opportunities for open and frequent communication with foreign colleagues, while pleasant for the individuals concerned, cannot in themselves be a very effective mechanism for exploiting basic research results in the absence of a critical mass or cadre of scientists who are able to grasp and work out the significance of basic research results that emerge in their disciplines. This is another essential point that P.C. Ray, M.N. Saha and Homi Bhabha -- and before them Mahendralal Sircar and Ashtoush Mookerjee -- seem to have understood well. They also understood that appprenticeship training in the conduct of basic research can serve two essential purposes in a developing country. First, it can provide individual students with the capability to recognize and exploit good ideas. Second and slightly less obvious, young scientists who pursue advanced studies in the same or in closely related disciplines can be imbued with a certain disciplinary esprit de corps. If so, they may later constitute -- or become the nucleus of -- the critical mass so essential to the exploitation of research results for the benefit of their society, as for a time P.C. Ray, C.V. Raman, S.N. Bose and M.N. Saha provided such a nucleus at the University College of Science in Calcutta.

What, then, are the conditions under which basic research activity can be an effective mechanism for establishing and strengthening the essential human component of the science and technology infrastructure of a developing country?

First, of course, first rate students need to be attracted to advanced study in basic research in one or more fields. However, attracting and inspiring good students is not enough. For it must be assumed that in a developing country -- as in any country -- many if not most of those who pursue apprenticeship training in basic research with a master scientist will be unable to find positions in their own country where they can pursue basic research in that same sub-discipline throughout their lives. Therefore, students need to be given the breadth and confidence required to be adaptable -- ie., to pursue careers in applied research that build upon their early training in basic research, for example, or to pursue basic research and train a new generation of students in a related discipline. Needless to say, even if there are well trained, highly motivated, and highly adaptable young scientists in a developing country, they will be unlikely to make tangible contributions to their society unless they have opportunities and facilities for fruitful work or, at the very least, encouragement to seek their own opportunities to establish the necessary facilities.

Pioneers in Basic Research in the United States

Lest I appear have denngrated the achievements of these six pioneering Indian scientists, let me compare them with the contributions made by the basic research activities of a handful of scientists in another society during periods when it, too, was underdeveloped scientifically, if not economically. I refer to the United States of America.

The first pioneer American scientists who made significant contributions to scientific knowledge during the latter part of the 18th century was Benjamin Franklin. Franklin qualifies as the first resident of the American colonies to have been recognized internationally for his scientific contributions. However science in Franklin's day was intended as a pursuit for serious amateurs. There simply was no science and technology infrastructure anywhere, nor was there anything approaching a critical mass of gifted amateurs in the American colonies that could have helped build on Franklin's research. Thus while Franklin's research was significant in advancing basic understaanding of electricity, those advances were made in Europe, not the American colonies.

Nevertheless, Franklin's international reputation as a scientist did contribute significantly to his country. In 1776, following the decision by the American colonies to declare their independence from Great Britain, Franklin was dispatched to Paris to plead for recognition of the independent colonies and for material assistance. There is little doubt that his scientific reputation was instrumental in helping him gain access to influential people in Paris with whom he was able to plead successfully for support of the American cause.

By the latter half of the 19th century, US scientists were conducting significant research in a limited number of areas, primarily geology and agriculture. (Significantly, perhaps, geology was also the first field of modern science in which Indians participated -- also in the 19th century.) However, most of the research work in the US was applied rather than basic. The most impressive US achievements in basic research during the late 19th century were A.A. Michelson's measurements of the speed of light and his subsequent work in interferometry. It is worth noting that initial support for his research came from the US military, not from any academic institution, since he conducted his first measurements while an instructor at the US Naval Academy at Annapolis.

Michelson, who in 1907 became the first US Nobel Laureate, was able to build upon his prestige to establish research groups at two academic institutions. The second of these, at the University of Chicago, attracted a number of talented younger experimental physicists, most notably R.A. Millikan whose research included measuring the charge on the electron and verifying Einstein's quantum theory of the photoelectric effect. Millikan went on to help establish the California Institute of Technology, thus building on Michelson's initial contributions to the US infrastructure.

Despite these achievements in experimental physics there was, at the end of the 19th century, almost no support or understanding in the US of the value of basic research in fields such as theoretical physics and mathematics. Consider the career of J. Willard Gibbs, who lived from 1839 to 1903 and taught at Yale University for virtually his entire career. During the course of that career he made highly original and significant contributions to the foundations of thermodynamics which provided the basis for analyzing chemical reactions in thermodynamic terms. But that work was not appreciated in his own country until after his death. In fact, Gibbs value was so little understood that he did not even receive a salary from Yale during the first two or three years in which he taught there! European scientists -- among them James Clerk Maxwell -- did recognize the value of Gibbs' work and built upon it, even as Einstein was to build upon the work of S.N. Bose. But there were, in the US, too few scientists engaged in theoretical physics and chemistry during Gibbs' lifetime to constitute anything approaching the critical mass that might have built upon Gibbs' unique scientific contributions. Nor did Gibbs appear to have had any notable students. In short, his impressive personal achievements did nothing to help develop the U.S. science and technology infrastructure. Perhaps even more than S.N. Bose in Dacca, Gibbs was too isolated to be able to make such contributions.

It was not until the eve of World War II that US theoretical physicists began to gain some recognition and support in their own country. Indeed, even through the US had become highly industrialized by the time Gibbs died in 1903, from the perspective of its basic research capabilities and contributions it was quite underdeveloped. Until the mid-1930s it was a virtual necessity for young Americans who were intent on careers in most basic research fields to pursue their advanced studies in Europe. The emigration of so many leading scientists from Hitler's Europe to the US beginning in the mid-1930s provided a significant impetus that was to help the US become a world leader in basic research within a very few years. But the country's science and technology infrastructure could not have taken full advantage of those European scientists had it not had scientists and institutions who were capable of recognizing their talents and building upon them. Many of those same American scientists had, in fact, been among the young people that had pursued advanced study in Europe a decade or two earlier.

A more detailed comparison of the careers of pioneers in basic research in India and the US could be instructive, particularly in illuminating the question: what are the most appropriate ways in which a scientifically developed country can assist a less developed country to build up its capabilities for basic research? However, I shall not pursue the point here.

Intangible Contributions of Basic Research

Thus far I have been considering only the tangible benefits that can be derived from basic research activity. Of course there are also immense intangible benefits derived by individuals who pursue fundamental research, including intellectual challenge, a sense of community and shared purpose, and the satisfaction of being able to add to the store of human knowledge. But can a developing society derive any intangible benefits from its support of basic research activity?

The conviction that scientific rationality can lead to intellectual liberation and thus convey benefits to a society that are equally important, if not more important than the tangible benefits of science has been central to Western thinking since the 17th century. That conviction is evident, for example, in the career of Benjamin Franklin and is reflected in most of the official documents associated with the establishment of the American Republic. Recent studies by several scholars -- most notably Joseph Needham in his Science and Civilization in China -- indicate that the development of science in other societies has also been deeply rooted in a liberating cultural tradition.[14] If so, then ultimately neither modern science nor any of the tangible benefits that can derive from the pursuit of modern science can thrive in a society unless it can be harmonized with the cultural traditions of that society.

All of the pioneering Indian scientists whose careers I have touched upon seem to have understood this point. All of them in different ways also seem to have grasped intuitively one of the vital points that Needham's scholarship has demonstrated. That is -- in Needham's metaphor -- that modern science is a great river that has received contributions from the separate streams of many different cultural traditions. If so, modern science need not be seen as conflicting in any significant way with other, older scientific traditions, and need not, therefore, do violence to the cultures in which those traditions are rooted. Indeed modern scientific ideas, properly interpreted, should reinforce the liberating cultural traditions of a society.

All six of these pioneer Indian scientists acted in their own ways on the conviction that the ideas of modern science could be infused into Indian culture and that that infusion would liberate the best traditions of that culture. I suspect, though I cannot prove, that those same characteristics that led these six very different men to become successful pioneers in basic research also gave them the deep sense of responsibility they demonstrated for trying to link modern science with both the cultural traditions and the future economic and social needs of their country. Perhaps the connection between what they saw as the value of basic research and the necessity of basing modern science in India on Indian cultural traditions is simply this: at its best basic research aims to satisfy human curiosity. But curiosity is among the most innate and universal of human characteristics. Therefore, the pursuit of curiosity in a systematic, discipline way need do no violence to any culture. On the contrary, it should be in harmony with the best of that culture.

If my supposition has any merit, I suggest that the encouragement of basic research in a developing society is an absolutely necessary precondition for the infusion of of the ideas of modern science into that socity, and thus for the establishment of a stable, deeply rooted, and thriving science and technology infrastructure. Mahendralal Sircar emphasized this point in one of his earliest appeals for support for the Indian Association for the Cultivation of Science:

> We are so constituted that we must either go forward, or be driven backward, we cannot remain stationary. There is an immense difference between the civilized man and the man happening to live in civilized times. Such accidents of birth will never endow us with the privileges of the times in which we live, unless we render ourselves worthy of the same.[15]

Conclusions

The question: What basic research areas should be pursued in a developing country? presupposes that all possible areas of cannot be pursued to advantage. But this same presupposition is applicable to all countries. Priorities need to be established in all countries for the allocation of the scarce financial and human resources that are required to pursue scientific research effectively. The establishment of priorities -- and the identification of criteria for establishing those priorities -- is particularly essential in developing countries where financial and human resources are relatively more scarce.

I do not believe that there are simple answers to the question: What areas of basic research should be pursued? that can be applicable in all developing countries. However, I believe that the careers of pioneering Indian scientists can provide clues or lessons that any country can use to its own advantage in formulating a detailed response to that question.

The first and perhaps clearest lesson is that basic research activity, carried out under appropriate conditions, can make not just one, but several distinct contributions to a developing society. Therefore, the choice of the basic research areas that should be pursued and encouraged should depend upon the priorities a country assigns to those different contributions and on whether the conditions required for basic research to make those contributions can be established and maintained.

Paradoxically, the most commonly stated rationale for encouraging the pursuit of basic research -- ie., that it often leads to practically applicable results -- may not be terribly important to a developing country, particularly if the expectation is that such research results will invariably find application in that country and for its benefit. As I have already noted, it is in the nature of science that the applicability of basic research results is often unpredictable. Therefore, disappointment

with the simplistic assumption that basic research results are easily capturable is almost inevitable. That disappointment can lead, in turn, to a loss of support for basic research activity.

A much more important reason for encouraging the pursuit of basic research is that people who are trained in and engage in that activity are often the most sensitive to the possible applicablity of new ideas and results whatever their source. That is, two important contributions that basic research can make to a developing country are its support of the country's science and technology infrastructure and its teaching function. It follows that an important citerion for selecting basic research areas to be supported in a developing country is this: Which of those areas can provide the necessary foundation for fields of applied science and technology that are judged to be essential to the social and economic development of a particular country, and which provide the best opportunities for broad, adaptable apprenticeshio training?

But the selection of basic research areas to be supported need not and probably should not stop with such practicality criteria. For it is evident from the six careers I have examined that basic research can also convey less tangible benefits. First, since basic research can provide an unparalleled vehicle for apprenticeship training, the particular disciplines in which young scientists are trained may be less important than the adaptability and confidence they acquire as a result of their training. Of course basic research also provides an important vehicle for international communication, and thus for bringing the scientific capabilities of a country to the attention of the international scientific community. Finally and importantly, basic research can make significant cultural contributions and, for reasons I do not completely understand, may provide its practitioners with a special sensitivity to the need for, and possibility of, reconciling modern science with traditional cultural values.

In view of the significant intangible benefits that the pursuit of basic research can confer upon a developing society the question: What research areas of ought to be pursued? may be less important than the question: What areas can be pursued under conditions most likely to yield significant indirect and intangible benefits? If so, the criteria for selecting areas for support should be framed in terms of whether there is or can be a critical mass of well trained and motivated scientists working in that area, whether those scientists have the freedom and means for open communication, whether they are capable of truly excellent research work, and whether they can be provided with the facilities they need to pursue their research with the requisite excellence.

In this talk I have attempted to draw several lessons from the careers of a handful of pioneering scientists in one country during one relatively brief period of time. Some of those lessons may be broadly applicable, others may not be. But one lesson I am convinced is valid is that a deep appreciation of the spirit of modern science, as opposed to a mere recognition of the tangible benefits science can confer, is absolutely essential to the flourishing of science and technology in any country.

The fact that all six of the pioneering Indian scientists I have considered were passionately commited to establishing the spirit of modern science in their country suggests the importance they attached to that spirit as a necessary foundation for genuine independence and self-reliance. Importantly, the conviction of these pioneers that the spirit of modern science is in harmony with the best of India's traditions was to become integral to Independent India's approach to science planning. Following the lead of Prime Minister Jawaharlal Nehru, the Government of India stated, in its 1958 Scientific Policy Recommendation, that:

> It is an inherent obligation of a great country like India with its traditions of scholarship and original thinking and its great cultural heritage, to participate fully in the march of science, which is probably mankind's greatest enterprise today.[16]

Significantly, too, the convictions that drove the visionaries and pioneers whose works I have highlighted still motivates the best of India's scientists, as is evident from the opening words of a January 1982 address by M.G.K. Menon to the Indian National Science Congress:

> The purpose of my address is to point out that there are certain philosophical, cultural and intellectual aspects of basic research that are not well appreciated, but which underpin in an essential manner the very concept of self-reliance.[17]

Earlier in my talk I refered to Joseph Needham's metaphor of modern science as a great river nourished by the streams of many different cultural traditions. Needham coined that metaphor in an attempt to lay to rest the notion that there is something inherently European about modern science. However, in his desire to illustrate the universal character of modern science, Needham has been concerned primarily with the contributions of different cultures in the pre-modern period. Certainly he would agree -- and in fact has agreed -- that traditional Indian science has made important contributions to world science. While the founders of modern science in India appreciated the contributions of their own scientific traditions, they were faced with a different problem from the one Needham has explored. For the great river of modern science, if not properly understood and controlled, can represent a destructive force as well as a source of nourishment. The problem faced by the visionaries and pioneers in the pre-independence period was simply this: how to understand the nature of that river in terms of India's own traditions so that it could be drawn upon for the benefit of India.

While reflecting on the past and future of his country in 1944 while a prisoner at Ahmednager Fortress, Jawaharlal Nehru wrote:

> Science has dominated the Western world and everyone there pays tribute to it, and yet the West is still far from having developed the real temper of science. . . . In India in many obvious ways we have a greater distance to travel. And yet there may be fewer major obstructions on our way, for the essential basis of Indian thought for ages past, though not in its later manifestations, fits in with the scientific temper and approach, as well as with internationalism. It is based on a fearless search for truth, on the solidarity of man, even on the divinity of everything living, and on the free and co-operative development of the individual and the species, ever to greater freedom and higher stages of human growth.[18]

More than three centuries earlier, at the very birth of modern science in Europe, Francis Bacon concluded his Novum Organum with the following admonition:

> Lastly, I would address one general admonition to all; that they consider what are the true ends of knowledge, and that they seek it not either for pleasure of mind, or for contention, or for superiority to others, or for profit, or fame, or power, or any of these inferior things; but for the benefit and use of life; and that they perfect and govern it in charity.[19]

Nehru, at one with the visionaries and pioneers who laid the foundations for modern science in their country, believed that India was particularly well equipped to heed Bacon's admonition to ". . perfect and govern it in charity." In view of the vital importance that science has now assumed throughout the world, the ways in which India struggled and still struggles with that problem is well worth contemplating. The vision of India's scientists and their continuing struggle to realize that vision carries an essential message for all of us here today.

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THE ROLE OF SCIENTIFIC NETWORKS IN THE THIRD WORLD

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(28 November 1985)

TOPICS

1. PROBLEMS FOR THIRD WORLD SCIENTISTS

2. THE CONCEPT OF A SCIENTIFIC NETWORK

3. THE INTERNATIONAL BIOSCIENCE NETWORK

4. THE CURRENT THIRD WORLD SITUATION FOR PHYSICS AND MATHEMATICS

5. A PLAN FOR THE FUTURE

6. ICTP CRITERIA FOR SUPPORT

THE PROBLEMS OF THIRD WORLD SCIENTISTS

- ISOLATION
- LACK OF EQUIPMENT
- LACK OF LITERATURE
- LACK OF RECOGNITION

- INADEQUATE TRAINING FACILITIES

Conventional Wisdom

- Modern technology cannot be dispensed in gift packages;

  It is essential for its really effective application that each community should possess its own indigenous expertise.

- Technology transfer must be preceded by science transfer:

  - to train people

  - to anticipate future trends in technology.

- Research teams need to exceed a certain critical size if their work is to flourish.

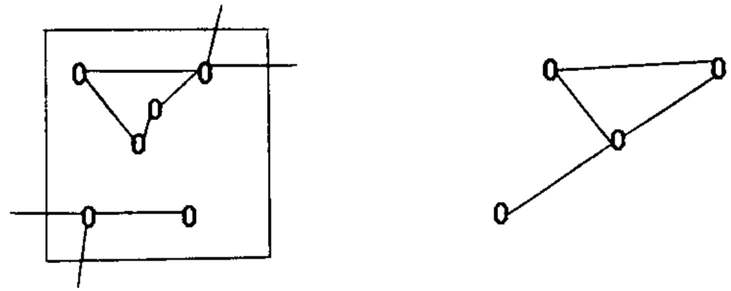
THE CONCEPT OF A SCIENTIFIC NETWORK

- All successful research teams are part of a network

  - communication
  - collaboration
  - joint use of equipment/facilities

- Network

  - in large institutions partly in-house
  - small institutions must rely on other (nearby) institutions



large institution small institutions

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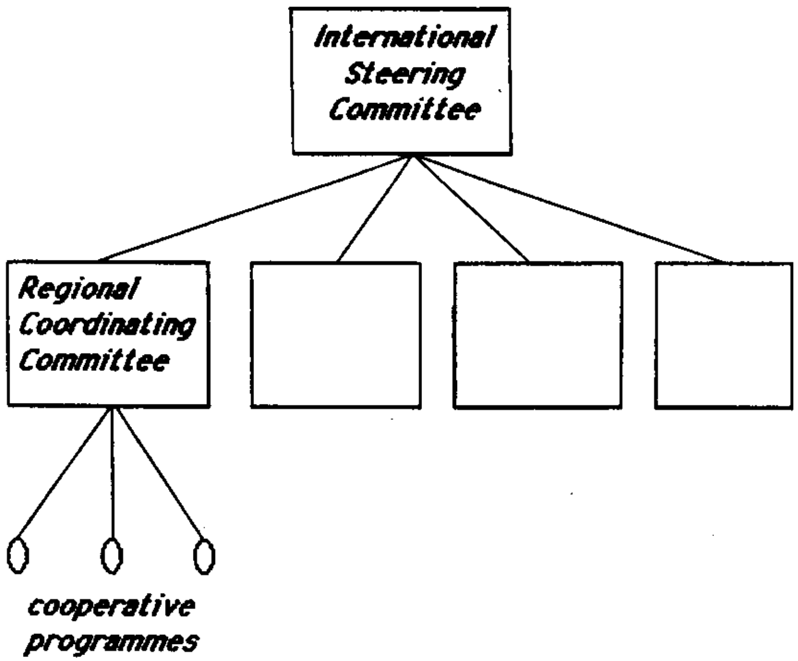
1. Based on existing institutions
2. Regional
3. Initially often formalized - later more flexible
4. "Effective Lobby" — better resources

THE INTERNATIONAL BIOSCIENCE NETWORK

- Created in 1980 by ICSU and UNESCO

- Today active in Africa, Asia, Latin America and the Arab region

- Organizational chart:



International Steering Committee

- 8 members; 4 appointed by ICSU/UNESCO
  4 chairmen of regional IBN networks

  Representatives of Bio-Unions, IUPAC, ICSU Scientific Commissions (COSTED, SCOPE, ...) invited to the meetings.

- Functions:

  - to seek funding for the regional networks

  - to facilitate the exchange of information and communication among networks; clearing house

  - to organize inter- and multiregional activities (Brazil: Interregional Symposium on Savanna Ecosystems)

  - to explore the possibilities of creating new networks or extend participation in existing ones

  - to liaise with scientific unions, etc.

  - to consider and secure rapid flow of knowledge pertaining to specific problems in the Third World

- One meeting per year in conjunction with a scientific meeting.

Regional Coordinating Committees

Main functions:

- to identify existing centres best fitted to serve as nuclei for research in particular areas of biology
- to make an inventory of scientists and technologists in the region trained in the different specialities
- to determine priorities for research and development, taking into account:
    - special problems of the region
    - programmes which may have greatest economic/human impact
    - areas where the prospects of success are greatest
- to organize training courses and other forms of training activities to increase the supply of research workers/technicians with specially needed skills
- to consider the education of biologists at school, university and postgraduate level
- to organize cooperative research programmes
- to liaise with other bodies such as FAO, WHO, UNU, National Aid Organizations, etc.
- to provide liaison with the Biological Unions

"Since official backing is essential, both to secure funds through the IGOs and to obtain local support, and governments must be assured that the objectives of the Networks are properly related to their economic aims, it would be advisable if each Regional Coordinating Committee were composed of delegates representing the governments as well as the scientists of the participating countries, together with representatives appointed by ICSU and UNESCO. Where the number of countries involved would make a single Coordinating Committee unwieldly in size, as for example in Africa, it may be necessary to have Sub-regional Committees, coordinated by a Central Committee."

LATIN AMERICA

Roots: UNDP/UNESCO project for post-graduate training

Programmes:

- training courses/workshops
- one-year fellowships for post-graduate training
- support research projects for training biologists
- support collaborative research projects:
  - -- mechanism of steroid hormones
  - -- the genetics of high altitude Andean populations
  - -- the biochemistry of Trypano-soma cruzi (responsible for Chagas disease)
  - -- the molecular biology of viruses that infect Colombian beans

- national committees; directories of biologists, national projects, training, etc

ASIA

Established by COSTED/UNESCO in 1978

Programmes:

- training activities
- establishment of centres of excellence open for scientists from the region
  - -- Madurai Kamaraj University; photosynthesis
  - -- Chulalongkorn University; Centre for scientific instru-mentation
  - -- Centre for Legume Biology, Malaysia
  - -- Centre for Environmental Biology, Indonesia
  - -- Centre for Waste Recycling, Hong Kong
- publications

1985:

Workshop on: Energy from Biomass
Neurophysiology techniques
Basic techniques in genetic engineering
Urban ecology
Genetic engineering for vaccine strain for cholera

AFRICA

Established 1981

Programmes:

- training activities:

  -- working party on medicinal plants
  -- training course on insect physiology, Ghana
  -- Symposium on sickle-cell anaemia, Abidjan
  -- Workshop on the biology and control of the parasitic weed Striga

- support of research projects:

  -- production of human anti-tetanus globulin, Lagos
  -- parasitic diseases of cattle and their vectors, Senegal
  -- collection of reference data on malaria and bilharzia, Senegal

- support of scientists to attend courses, conferences, etc.

ARAB STATES

Established 1983

Programmes:

- establish research/training needs and priorities

- organize congresses of Arab biologists

- support cooperative research projects

Examples

- International Symposium on crop production in stressful environments, Syria

- Training courses on new frontiers in molecular biology; cell culture and monoclonal antibodies

- Workshop on water microbiology

- Research project on mechanism of drought tolerance and plasticity of desert plants

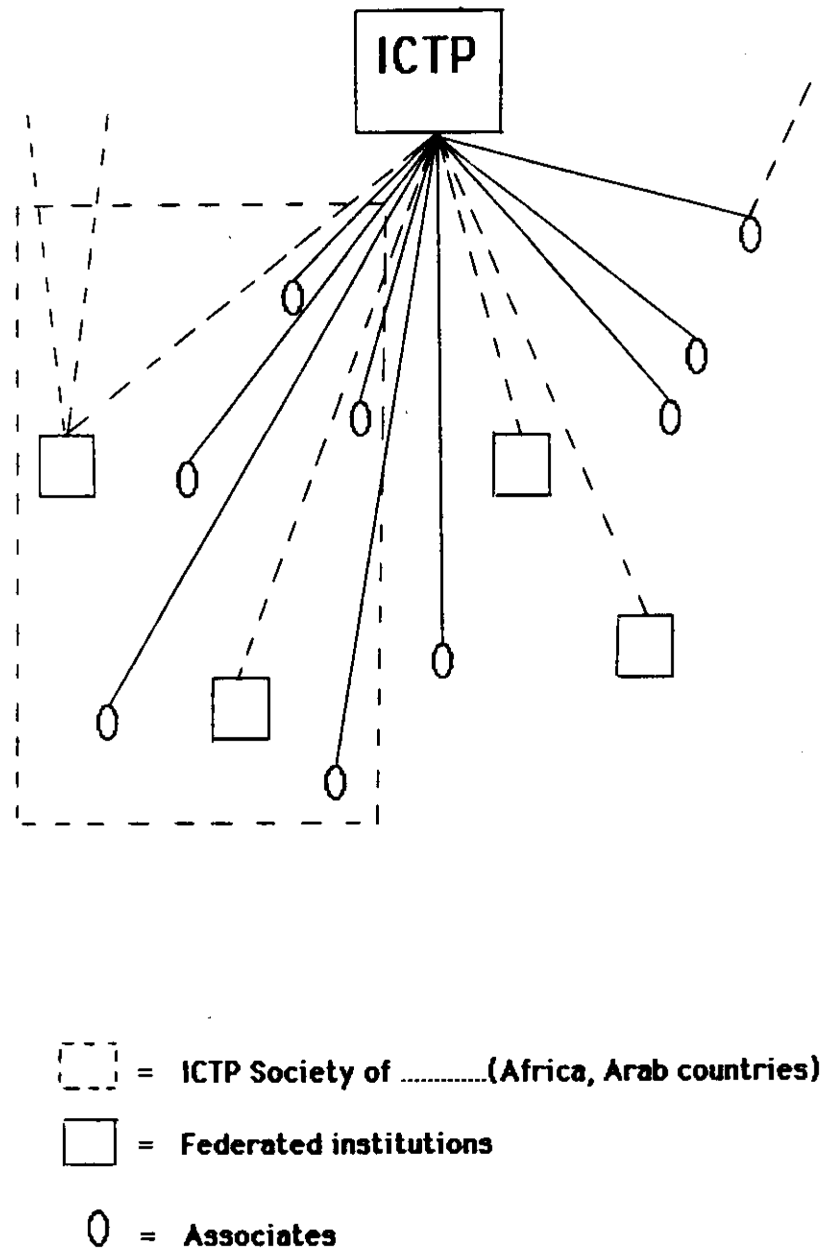
INTER-AND MULTIREGIONAL ACTIVITIES

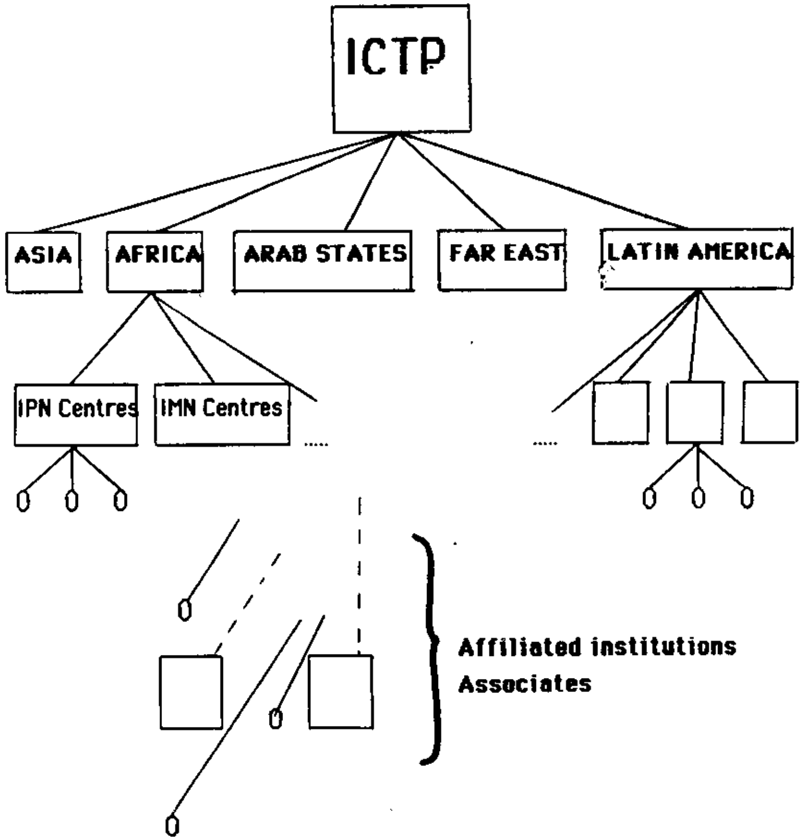
- Symposium on the Savanna and Woodland Ecosystems in Tropical America and Africa, Brasilia, 1983

- Response of Savannas to Stress, Zimbabwe, 1985

- Training courses on non-radioactive labelling of nucleic acids in the diagnosis of viral, bacterial and parasitic diseases and genetic defects.

Will be run in different countries/regions.





<u>Examples</u>

IPN Centre for Material Science
IPN Centre for Tropical Meteorology
IMN Centre for Computer Science
.....
.....

All based on existing centres, but given some preferred status within the ICTP programmes.

IPN:S and IMN:S

- have joint research projects
- share equipment
- collaborate on training activities
- exchange reports (conferences, etc.)

They are linked through:

- exchange of visitors
- correspondence
- joint events
- electronic mail/computer conferences

and through the regional chapters they have contacts with other regions and Scientific Unions, etc.

ICTP POLICY

- So far, the emphasis has been to help build up the physics/mathematics communities by supporting individuals:
  - training activities
  - workshops/conferences
  - associateship programme
  - visits to Italian laboratories

- A gradual shift towards more emphasis on institutions:
  - federation arrangements
  - donation programme - books/journals
  - donation programme - equipment

- Now emphasis will shift to make its activities more directly tuned to regional/national development strategies:
  - activities shall respond to the role science must play in the development process
  - all scientists associated with the Centre are called upon to take an active part in this undertaking

  and this shift in policy is manifested in:

  - shift in emphasis in the scientific programme of the Centre
  - the creation of the Office of External Activities

CRITERIA FOR SUPPORT

A proposal for an external activity will receive ICTP support only if it satisfies one or more of the following criteria:

A. the purpose of the activity is:
- to initiate,
- to stimulate, or
- to make applicable

research and training related to:
- locally available resources, or
- local problems

of specific relevance for the development of the region;

B. the aim of the activity is to form and strengthen national/regional communities by establishing institutions or national societies for physicists and mathematicians at all levels, including college and school teachers;

C. the aim is to improve physics and mathematics teaching at the secondary, polytechnical, college or the university level.

SOCIAL OBSTACLES IN THE PATH OF TECHNICAL SOLUTIONS

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In an earlier study (1) we studied the state of science in the developing countries from a macroscopic point of view. In the present study possible reasons for the underdevelopment of science in the developing countries will be explored. The plan of the essay is as follows. First, relevant statistics about population, gross national products, economy and trade will be presented so as to put the position of developing countries in a world perspective. Secondly, some common characteristics which most developing countries share will be presented. Thirdly, possible reasons for the existing state of affairs in developing countries will be presented. Lastly, some measures to overcome and transcend the existing state of affairs will be suggested. In conclusion, it is found that technical solutions to most problems of underdevelopment already exist, but prevailing social economic, political and cultural environment create obstacles in their acceptance and execution.

Population

According to United Nations (UN) estimates for the year 1980, of the total world population of 4432 millions about 650 million (14.7 percent) were living in countries with developed market economies *, while 375 million (8.5 percent) lived in countries with developed planned economies **, about 1250 million (28.2 percent) living in developing planned economies + (2). The rest, about fifty percent lived in the so called developing market economies.

* Developed Market Economies comprise all the developed capitalist countries which are members of OECD.

** Developed Planned Economies comprise all those countries which follow socialist path to development. The countries include U.S.S.R. and countries of Eastern Europe.

+ Developing Planned economies comprise developing socialist countries, China, Cuba, Korea, Vietnam and other members of COMECON.

The last mentioned countries variousely termed as underdeveloped or developing will be under detailed discussion in the following.

These countries vary greatly as regards their populations. The most populous among them is India with over 660 million inhabitants, After India there are twelve other countries having populations in excess of forty million each, with a combined population of 780 million. Next in order of population size are a group of twenty six countries with populations varying from around ten million to forty million. Their combined population is over five hundred million. Lastly, there are ninty countries with a combined population of about three hundred million, but with individual population sizes ranging from around one hundred thousand to about ten million.(3)

Wealth of nations

During the year 1980, developing countries with about half of world population contributed only 14.9 percent of the world gross domestic product(gdp), while the developed market economies with only 8.5 percent of world population contributed 65.7 percent.(4)

While the average per capita gross national product (gnp) of developing countries is about 800 U.S.$ in 1980, it hides great variations. With Bhutan in South Asia having a per capita gnp of 80 U.S.$ to a per capita gnp of 24,660 U.S.$ for United Arab Emirates in the gulf in the Middle East. The largest group of over a billion

people live in thirty one countries (India, Pakistan, Bangladesh besides others) with per capita gnp of less than 360 US$. The next group termed as that of lower middle income group has a combined population of about 396 million and per capita gnp varying from 360 to 829 US $. The more numerous group of around 655 million people of middle income have per capita gnp from 830 to 3,539 US$. Compared to above per capita gnp in developed market economies vary from the lowest of 5,230 US$ in Ireland to the highest of 17,430 US$ in Switzerland. The average per capita gnp for the 719.6 million people in these countries comes to about eleven thousand US dollars in the year 1981.(5)

World Trade

In the year 1980, the value of total world export and import trade was over 4.08 trillion US dollars in current prices. Of this the share of the developing countries was only 24.83 percent. Exports from developing countries were 27.87 percent of the world total, while imports by them were only 21.88 percent of the world total. It is to be noted that the share of developing countries in world exports was 30.8 percent in the year 1950, decreasing to 17.9 percent in 1970 and rising to 26.9 in 1974 and then to 28.0 percent in 1980.(6) The situation of developing countries without oil for export is especially disappointing, their share in world export declined to 10.1 percent in 1975 from a high significant 23.6 percent in 1950. Since 1970 their share has remained around eleven percent of the world exports. Since 1980 the situation has worsened greatly,exports have stagnated in 1981 and declined by an estimated 2.0 percent in 1982.(7)

Composition of the export/import trade of the developing countries:

Over 80 percent of exports from developing countries consist of primary commodities,agricultural raw materials,minerals,ores fuels and food items.Manufactured items contribute slightly over 19 percent.As opposed to this exports from the developed countries are overwhelmingly of manufactured products.In 1979, share of manufactured items in their exports was over 67 percent. MAnufactured products form 58 percent of the imports by the developing countries, in 1979,declining from 61.6 percent in 1970.(8)

Another notable feature of the world trade is the fact that while overwhelming percentage (50-75 percent) of trade of developing countries is with the developed countries,the same is not true for the developed countries whose greater part of the trade is (65 percent in 1981) is among themselves.Thus although the developing countries are dependent largly on the developed countries for their imports and exports,the developed countries do not provide easy access to the manufactures from developing countries. Another feature of the world trade is the fact that a very significant part of it is among the subsidiaries and affiliates of the multinational companies which belong almost entirely to the developed countries.

Some Common Characteristics shared by by most Developing Countries

Despite great variations as regards population ,geographical area,gross national products,standards of living,health,nutrition, education,science and technology, most developing countries share certain common characteristics,which will be detailed below.

1. Their economies are predominantly agrarian,although the share of agriculture in the gross domestic product is steadily declining.Still, agriculture provides employement to over fifty percent of the labour force. The average percentage of the total labour force in agriculture for the low income developing countries is 73.For India it is 69.Of the thirthythree countries in this group,the percentage is higher than 80 for fifteen.In the thirty nine member group of the lower middle income developing countries the average percentage is 55; and higher than 65 in ten .Among the upper middle income group of twenty countries this percentage is still thirty;although for Malaysia it is as high as 50. Industry is able to provide employement to only 11 percent of the labour force in the low-income developing countries on the average,although the percentage is higher for India (13) ,Pakistan (20) and Ghana (20).For the lower middle income group the average percentage rises to 17,although it is less than 10 for nine of the countries in this group.For the upper-middle income group the average percentage of labour force employed by industries rises to 28.For Chile,Panama and Malaysia it is still less than 20.(9)

2. Most developing countries have become dependent on the production of primary commodities, agricultural and mineral,mostly for export.Somalia derives 87.73 percent of its export income from live animals, Chad and Upper Volta over 35 percent from the same source;Martinique and Guadeloupe over 55 percent from fresh fruits,and dry fruit nuts: Uganda and Brundi over 85 percent from Coffee,SriLanka over 64 percent from tea and rubber: Niger 89 percent from Uranium,Thorium ores and live animals; Madagascar over 70 percent from coffee and spices,Ivory Coast 75 percent from cocoa,coffee and rough wood;Ethopia over 85 percent from coffee and undressed hides and skins,Cuba over 85 percent from sugar;Colombia over 65 percent from coffee and Bolivia over 70 percent from no-ferrous ores,tin,gas crude petroleum, silver and platinum ores.Similar examples can be given for almost every one of the developing countries. Needless to point out that the oil exporters like Saudi Arabia, Kuwait,Libya,Iraq,Iran,Nigeria,Venezuala and UAE derive almost ninty percent of their export income from petroleum and related products.(10)

Dependence of their economies on the production of primary commodities has made the developing countries extremely vulnerable to the vagaries of often fluctuating but steadily decreasing prices.According to the World Bank World Development Report for 1983,"commodity prices were lower in 1982 than at

any time since world war II", ..." non-food agricultural commodities fell by 24 percent, while metal and mineral prices declined by 17 percent. The worst affected commodities were sugar (down 71 percent), cocoa (down 33 percent), rice (down 39 percent). Overall, the prices of the primary commodities have declined continuously to less than what they were in the late fiftees. As a result ,there is now a "real possibility" that the per capita income of low-income countries in Africa "will be lower by the end of 1980's than it was in 1960."(11) The difficulties for the developing countries are compounded by the fact that international trade in the majority of commodities is under the control of transnational corporations.They market the following percentage of the exports of the developing countries:between 70 and 75 percent of bananas,rice,rubber and crude petroleum;between 75 and 80 percent of tin,between 85 and 90 percent of cocoa, tobacco,wheat,cotton;jute,forestry products and copper;between 90 and 95 percent of iron ore and bauxite.The producing country receives a low percentage of earning out of the sale price charged in the consuming countries.Thus,in the period from 1967-1972, the export price as a percentage of the final sale price awas 53 percent for tea,15 percent for cocoa(both as percentage of the United Kingdom price),48 percent for peanut oil,30 percent for citric juices,20 percent for bananas, 14 percent for coffee,32 percent for jute,55 percent for copper concentrate,75 percent for refined tin (in these seven cases as a percentage of the price in France),and 10 percent for iron ore (Fedral Republic of Germany prices)[12].Since the export price includes all the local costs,the primary producers earn only a small percentage of the final sales price,while the transnational corporations - through their peculiar purchasing mechanism obtain the biggest share.Another feature of the international trade which is detrimental to the interests of the developing countries is the growing domination of international trade by jiant transnational corporations mostly based in United States of America,U.K, Germany,Holland,Japan.These companies individually control financial resources larger than the total gross domestic products of many developing countries.Since a very large percentage of international trade is between the subsidiaries and the head office,the transnationals are able to make use of their market control to manouver transfer prices,avoid price and exchange controls,evade taxes and transfer profits to the detriment of the developing countries.[13]

3. Almost all developing countries are ruled by governments committed to eradicate hunger,disease,illiteracy,unemployment and general backwardness and to boost production.

4. Still, great income inequalities exist within most developing countries after years of development efforts.United States Agency for International Development Digest of 1971 pointed out that,"five percent of population in Asia receives almost

the same amount of national income as sixty percent of the population"on the lower scale of income ,while in Africa and Latin America, the rich"five percent get one and half times more"of the national income than their counterparts in Asia.[14] More and more studies of this phenomenon tend to confirm the above statement for other developing countries.Even for Mexico which has been one of the developing countries showing very high growth rates till the end of 1970's,the above observation has been confirmed."In, 1977, the poorest ten percent received one percent of the national income and the richest five percent received twentyfive percent"..."among all families thirty-two percent received the minimum income needed to satisfy the most elementary necessities and fourteen and a half percent received less than the minimum"..."even among those in the economoically active population forty percent received less than the minimum"..."in 1979, the population excluded from the benefit of development was larger in absolute terms than it had been in 1940".[15]

The same is also true about India,the most populous of the developing countries,"the present poverty population of India is estimated to be 309 million,or nearly half of the total population".[16] Poor househoIds are counted as those having a per capita monthly consumption of less than the equivalent of about eight US dollars in the rural areas and the equivalent of about nine US dollars in the urban areas .

More in the same vein is McNamara's observation in his foreword to the World Bank's World Development Report for 1978,"eight hundred million individuals continue to be trapped in what I have termed absolute poverty, a condition of life so characterized by malnutrition,illiteracy,disease,squalid surroundings,high infant mortality,and low life expectancy as to be beneath any reasonable definition of human decency".Six years after situations areeven worse as any cursory glance at daily newspapers in the developed countries will reveal.In latin America the gross domestic products have declined or stagnated since 1979.In Africathe situation has been described as critical.A report by the UN Secretary General in April,1984 has declared, that in Africa,"almost half the continent's population is immediately threatened by severe hunger and malnutrition and in some cases by starvation".[17)]

5.With the exception of India,Brazil,Argentina,Mexico and Egypt, developing countries possess insignificant stock of scientists and engineers.They spend far too little on building up the stock of scientific manpowerand on research and development.In an earlier study[(1)] we have detailed the backwardness of science in the developing countries.Most developing countries have either not adopted any policy for science or they have not been able to devise a policy of development based on the use of science. Although vast number of studies by various agencies, of UN, OECD and others are available.

Why,one may ask ,developing countries are in such state of underdevelopment? Many explanations have been put forward. Some attribute it to unfavourable climate.Some blame the apathy and fatalism of the people.Still others ascribe the mastery of science by developed countries to the uniqueness of the European mind.In our opinion, the origin of present backwardness is to be found in history.All the developing countries had,their natural social evolution interupted,as a result of the colonial onslaught by the Europeans beginning in the eighteenth century and reaching its climax in the last decades of the ninteenth century.By then the entire continents of Asia and Africa,Latin Africa,Oceania and islands in the seas in between were either colonized or brought under the political and economic hegemony of the colonizing European powers,British,Dutch,Spanish,Portugees,French,Belgian and late comers like Czarist Russia,Germany,Italy and U.S.A.

It was only the constant struggle of the colonial people,inter-imperialist rivalries,the two world wars and the October revolution in Russia,that finally loosened the hold of colonial powers so that decolonization started first in South Asia and later in Africa. By the 1960's most of the former colonies had become independent.

Results of the Colonization

Before colonization developing countries had self sufficient economies though of low subsistence level.Living standards for the majority of people all over the world till the eighteenth

(18)

century were more or less similar.After that a world economy gradually emerged in which the colonies were integrated as producers of raw materials agricultural and minerals and as markets for the manufactures from the colonial powers.[19] This is the world economy which the developing countries have found themselves enmeshed in at the end their colonial subjugation.

At present developing countries are certainly aware of their dependent role in the international economic order (NIEO) and clamouring for a new international economic order .Since the mid-seventees there have been many international gatherings where the demand for the NIEO has been vigourousely voiced,but the developed countries have refused to institute any changes in the present order.[20]

Despite their clamouring for the new international Economic Order developing countries continue to follow an economic policy based on a stategy for growth based on exports to developed countries.They have thus relied on the development of production of primary commodities: cash crops,minerals and semi-manufactures. Such policies have led to plantation agriculture and industrialization in port enclaves leading to what has been termed 'enclave development'.[21] It has not led to any self-reliant development but has further enmeshed countries where such development policies has been pursued with vigour ,into the existing inequitable world economic order.It has heightened income inequalities within

the countries as well as indebted them to the extent that there does not seem to be any way out for them. The countries which seem to have followed these development policies with vigour are Mexico, Brazil, Argentina, Venezuela, Chile, South Korea, Philippines. The cumulative debts of the first four Latin-American countries stood at the end of 1982 at 239 billion U.S. dollars.[21] Hence each one of the 235 million inhabitants of these aforementioned countries owed more than one thousand dollars of external debt. The situation is not much better for most of other developing countries. For most developing countries debt service takes away more than half of their export earnings. For the developing countries as a whole the total external debt at the end of 1983 stood at 595.8 billion U.S. dollars, on which the developing countries as a whole were paying interest equivalent to 20.5 percent of their export earnings [22].

Another result of the development strategy followed by the developing countries with its emphasis on cash crops for exports has turned them from a net exporter of food grains in 1930's to a net importer in the 1970's. The developing countries exported 12 million tons of grains in the period 1934-38 but imported 88 million tons in 1980.[23]

At the end of the colonial period most of the developing countries have entered into an era of neo-colonialism.The rule of the foreigner has given way to the rule of local elites,coalition of large landowners, businessmen, and civil and military bureaucrates.[24] They imitate the consumption pattern of their counterparts in the developed countries, spend far too much of the national wealth on arms and military establishment and relegate expenditure on socially useful sectors like health,education to secondary consideration. Thus south Korea spends thirty times more on arms and military than on education and health.,Indonesia spends fifteen times more on armaments than on education and health.Developing countries account for twenty percent of the 550 billion dollars expenditure on military in 1980.The biggest military spenders are ,on the whole,poor achievers in a test of socio-economic performance.Thus Saudi-Arabia with a population of less than ten million in 1980, had spent 93 billion dollars during the 1960-1981 period, thus gaining a ranking of seven as military spender.But in economic social standing it ranked at number 54.Similary Iran ranking as a military spender was tenth, while the ranking lowered down to seventyfirst on economic social standing.[25]

Among twenty countries with the largest foreign debts, arm imports between 1976 and 1980 were equivalent to 20 percent of the increase in debt. In four of the twenty the value of arm imports was equal to 40 percent or more of the rise in their debts in the period [26]. 56 of the developing countries are under military control. They all share some common features. Most have suffered military coups at least once. Most have long records of military rule; the average is 16 years out of the past 23 [27] (in 1983). In relation to their populations, they have more men under arms than other developing countries and double the arm imports. The human rights record of these governments is far from satisfactory; they are much more prone to extreme forms of violence against their citizens than are other developing countries [28]. Another legacy of colonialism has been the arbitrarily drawn national borders which having been drawn during the colonial period for administrative convenience have been constant source of tension among the newly emergent nations. These tensions have been frequently responsible for armed conflicts which, since 1945, have killed more than sixteen million [29] people in the developing countries, and destroyed invaluable material and human resources, which could have been better utilized.

What could be done?

Despite the depressing picture which has been painted of the Developing Countries above, there are some positive features on which the future progress can be planned. During 1950-80 the post-independence period for most of the developing countries, following positive features about the economic and social performance can be noted:

1. The population has increased by 1.8 times, mostly by a reduction in the death rate as a result of better control of disease. The fertility rate has also started to show a significant decline in recent years.
2. The national output has increased in real terms nearly four and a half times in thirty years. The annual growth rate has been five percent - more than ever achieved during the industrialization of the developed countries.
3. Average per capita income in the developing countries today is 2.2 times higher than in 1950. Even in the heydays of the growth of the developed countries in the past, such a doubling usually took more than forty years.
4. The industrial output of the developing countries including China is now seven times higher than in 1950. This is around four to five times the total industrial output of the whole world in 1900.

5. the structure of output has changed significantly. The share of agriculture has been reduced from over 65 percent in 1950 to less than fifty percent in 1980, with important advances in the capital goods and the intermediate goods sector.
6. there has been an explosion of education in the developing countries. The number of students enrolled at universities, colleges and other institutions of higher learning has risen from less than a million in 1950 to around ten million in 1980. These people will be basis for any development planning.

Although there are ninety developing countries with less than ten million people. Their combined population is only 300 million or less than ten percent of the developing countries as a whole. On the other hand there are ten developing countries with population of over fifty million each and with a combined population of 2.4 billion, or over three-fourth of the total [30]. Many of these countries have a considerable industrial base which could serve as an instrument for further expansion.

On the whole one could say that the developing countries despite all their problems and shortcomings have the resources both human and material to become the vehical for future world economic growth. They have already achieved a lot but they can do much better.

Political, social and cultural obstacles.

Experience of development policies pursued over the last thirty years or so brought home the realization that most problems faced by the developing countries can be solved with the known technologies. The reason that these solutions are not adopted is that their adoption calls for modification of existing power relations, which most developing countries rulers resist. Thus Amartya Sen in his seminal work, 'Poverty and Famines: An Essay on Entitlement and Deprivation', [31] has convinvingly shown that problem of hunger is not maily one one of total food production, as usually understood, but more one of entitlement or effective demand. With a very small percentage of landowners controlling the greater majority of cultivable land, the problem of poverty can not be effectively solved without thorough land reforms as has been the case in Japan and Taiwan after the second world war. [32]

Similarly problem of energy can be solved with non-conventional, small sised, decentralized wind, solar and bio-mass based gas producing digestors. But their utility in hierachically organised rural societies will be very limited as borne by contrasting experiences of China and India.

In the field of health and nutrition inexpensive preventive vaccines and medicines coupled with provision of safe water and sanitation could bring down unnecessary deaths considerably. But dependence on market forces and private enterprise for the provision of health facilities produces the prevalent problems. The list could be multiplied.

Practically every government in developing countries has on its agenda, eradication of poverty, illitracy, hunger, malnutrition, disease and unemployment. What is needed is appropriate social, economic and cultural policies to achieve the above. The policies have to move away from their bias for large scale, capital intensive urban favouring projects to low-cost, labour intensive, rural oriented projects to help the great majority of people to overcome, whatever obstacles as percieved by themselves, on their full utilization of their productive potential.

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ILLUSIONS ON NUCLEAR PROLIFERATION *

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There is no disputing the fact that nuclear weapons pose a grave threat to the very survival of mankind. By their very nature, these weapons cause widespread damage, involve non-combatants and have long-run climatic and hereditary effects. This is true even for localised conflicts in which tens of kilotons of explosive power are used; a nuclear exchange between superpowers will precipitate a veritable holocaust. It is therefore of utmost importance and urgency that nuclear proliferation --- in both its vertical and horizontal dimensions --- be prevented or at least contained. Unfortunately, however, discussion on the subject is frequently clouded by certain illusory perceptions which are taken as axiomatic by most of the advanced nuclear states. Some of the more important myths are examined below in the hope that clarification of issues would facilitate objectivity in debate particularly in a forum of scientists and scholars.

Myth No. 1: There is a close connection between nuclear power and nuclear weapons.

The feared link between nuclear power development and nuclear weapons capability is tenuous at best. First, we have the historical record: all the five recognised nuclear weapon states (NWS) had acquired nuclear weapons well before embarking upon the utilisation of nuclear energy for electricity generation. Indeed, one of them even now does not have an operating nuclear power station; and the two superpowers generate less than

* A slightly different version of this paper was contributed to the 35th Pugwash Conference held at Sao Paulo, Brazil, in July 1985.

15% of their electricity with nuclear reactors. On the other hand, this fraction is 51% in Belgium, 41% in Finland and Sweden, 35% in Switzerland and 29% in Bulgaria —— none of which has ever been suspected of any nuclear arms ambition. These figures seem to indicate, if anything, a negative correlation between nuclear power and nuclear weapons.

It is of course true that, if a nation had a nuclear power station and a reprocessing plant, it could in principle reprocess the spent fuel from the reactor to obtain plutonium and then use the plutonium to make bombs. As a practical proposition, however, both the opportunity and the motivation for following this route to acquiring nuclear weapon capability are virtually non-existent. First, only a few of the advanced nations possess the technology for nuclear power production. None of these elite nations would think of offering —— nor would the receipient country consider asking for —— a power reactor without placing it under the safeguards programme of the International Atomic Energy Agency (IAEA) or incorporating it within an equivalent system. With the elaborate measures developed and inspectors trained and equipped to detect diversion of plutonium, it would be almost impossible for a government to obtain plutonium from its nuclear power programme without the rest of the world knowing about it long before the material could be used in bombs. Secondly, in a power reactor, the plutonium recovered is so contaminated that only the most sophisticated nuclear weapon states would be able to build a reliable bomb with it. In order to obtain what is ordinarily regarded as weapons- grade plutonium, the fuel would have to be removed from the reactor core so frequently that the shutdowns thereby necessitated would be unacceptable in a commercial power station besides arousing the suspicions of safeguards inspectors. In short, power reactors do not normally produce plutonium of the desired bomb quality; the diversion of even that material is fraught with extremely high risk of detection.

In view of the above considerations, a nation going in for nuclear weapons would be ill advised to acquire a nuclear power plant for that purpose. In the words of the ANS Special Committee on Nuclear Weapons and peaceful Uses of Nuclear Energy:[1] "in general, for any nation considering alternate routes, the aggregated political, technical, resource, and economic costs associated with diversion from the civilian spent-fuel cycle are most likely to be substantially greater than the costs of a separate dedicated military production program. Therefore, the dedicated military program has been and will probably continue to be the preferred course for a nation seeking a nuclear weapons arsenal".

We would in fact suggest that restrictions on development of safeguarded nuclear power programmes would if anything jeopardise the goal of preventing the spread of nuclear weapons by providing added justification to a determined nation to chart its own nuclear energy course outside any international control. On the other hand, accelerated growth of nuclear power under IAEA safeguards will defuse one of the major triggers for possible nuclear confrontation between the superpowers by providing security of energy supply to industrialized as well as developing countries.

Myth No. 2 Refusal to sign NPT is a sure sign of nuclear weapons ambition.

The Treaty on Non-proliferation of Nuclear Weapons (NPT) has, in the eyes of most advanced countries, attained the status of a touchstone for nuclear proliferation intention. But many Third World countries view the NPT as unequal in principle (because it creates two classes of states, NWS and non-NWS, for which the Treaty applies differently) and unfair in practice (because the non-NWS signatories have in general been denied their rights under the Treaty and have just been saddled with the obligations).

(1) Nuclear News, pp 38-39 (August 1983).

The NPT, as advertised, was supposed to consist of a balance between certain obligations and privileges. The non-NWS signatories agreed to forgo their nuclear weapons option in return for fullest possible exchange of equipment, materials and information for the peaceful uses of nuclear energy, including the use of peaceful applications of nuclear explosions under international control (Articles IV and V). The NWS, on their part, undertook to pursue serious negotiations towards nuclear disarmament and, eventually, general and complete disarmament (Article VI). In actual fact, the NPT has been manipulated to suit the NWS which have not taken any steps toward reduction in their nuclear stockpiles. Instead, there has been an unabated race towards increasing the quantity and quality of the nuclear weapons, leading to the development of new weapons systems with ever greater destructive power, strike accuracy and deployment flexsibility. The major nuclear supplier states also continue to place additional restrictions on the non-NWS regarding acquisition of so-called sensitive technologies, including enrichment and reprocessing, in defiance of Article IV of the Treaty. The transfer of technology has been reserved only for a selected few countries (which like Israel need not even be NPT signatories!) and, as a result, a special group of countries has emerged that is considered entitled to receive the so-called sensitive nuclear technology; the rest are not 'trusted' in spite of their commitment to the NPT.

The repeated violations of the Treaty, in letter and spirit, committed by the NWS and other supplier signatories have ---over the years --- engendered a sense of disenchantment among most of the non-NWS signatories. The obligations are many and real while the benefits are few and illusory. In such an atmosphere, it would be naive to expect that the NPT should be able to attract new adherents, whether these latter have any nuclear weapon ambitions or not. Insistence on ratification of the Treaty as a

pre-condition for transfer of nuclear-related technology can, in present-day reality, only be construed as a subterfuge for outright denial.

Myth No. 3 The Third World cannot be trusted with nuclear technology.

This unarticulated conviction exhibits itself in an obssessive concern, on the part of major NWS and nuclear suppliers, with what is called horizontal proliferation. The very use of the term "proliferation" is a classic example of neo-Nazi misuse of a word until it comes to convey a meaning quite contrary to reality. According to the Oxford Dictionary, "to proliferate" signifies "to increase rapidly in numbers etc". Let us now cast a glance at history. In the first nuclear decade 1945-55, there emerged three NWS, in the second two and, in the twenty years since, only one other country has staged a nuclear explosion and possibly a couple more have attained last-wire capability. Thus, unlike the rapid escalation in the superpowers' nuclear armoury, the lateral spread of nuclear weapons capability has been a slow diffusion - like process; and the use of the term "proliferation" in the latter context can be credibly interpreted as a red herring to divert world attention from the real danger to global peace and security viz. vertical proliferation by the major NWS.

The nuclear arsenals of the superpowers have continued to increase in quantity and improve in quality and accuracy. Taken together these two countries possess the equivalent of over 4 tons of TNT for each inhabitant of earth. Also, with the increase in speed and accuracy, the time available between detection of an impending attack and authorisation of counter-measures has become further reduced. A stage will soon be reached when the authority to launch nuclear-tipped missiles would in effect be delegated to field commanders, each of whom could then have the potential to blow up the world. It is this kind of proliferation that mankind must be on its guard against.

For nuclear weapons have been used —— not by a developing country from the Third World but by a superpower against a small island nation.

On the other hand, developing countries have on the whole shown remarkable restraint in respect of the technologies which they do possess. In conventional wars some codes of conduct have been followed —— except where superpowers have been a party as in Vietnam or Afghanistan. As for the hazard of mercurial, ruthless or irresponsible leaders, the LDCs have yet to produce a Hitler or a Mussolini.

The Third World also happens to embrace most of the cradles of ancient civilization whose humanizing influence is still extant and evident. The heirs to these civilizations could, one feels, be trusted not to precipitate the destruction of their own heritage.

Myth No. 4: It is possible to maintain indefinite monopoly over nuclear technology.

The United States, as the first NWS of the world, suffered most strongly from this illusion. As early as January 1943, the U.S. sent a memorandum to Britain and Canada saying quite bluntly, "since neither the Canadian nor the British governments are in a position to produce the elements 49 and 25 (codes for plutonium and uranium-235 respectively), our interchange has been correspondingly restricted ——" The restriction affected almost all areas except exchange of basic scientific data. In August the same year, at Quebec, Churchill had to concede that, since the burden of producing the atomic bomb would fall upon the United States, she alone would determine the nature and scope of information that could be shared with Britain. After the end of the Second World War, President Truman pursued a policy of complete secrecy in nuclear affairs and regarded it almost a moral responsibility of America to prevent the atomic secret from falling into "irresponsible" hands.

Soon, however, came the grand disillusionment. In 1949, the Soviet Union and, in 1952, Britain joined the Nuclear Club. It was a clear demonstration that the American policy of secrecy had failed. After the initial shock, the US shared a common interest with USSR to keep the Club from enlarging any further. But then France and China also tested their bombs and the nuclear genie was, undeniably and irrevocably, out of the bottle. Finally, in 1974, India exploded the myth that human knowledge —— once created —— could be kept secret by a nation or group of nations for any length of time.

Myth No. 5: There exists a technical solution to the proliferation problem.

The advanced countries even now seem to believe that the goal of nonproliferation will be served by denial of technology. The passage of the Nuclear Nonproliferation Act by the United States is a case in point. The formation of the Nuclear Suppliers Club is another. It is apparently not realised (or conveniently forgotten) that "nuclear technology" does not refer to a single branch of knowledge but encompasses basic sciences, engineering, electronics, metallurgy etc. A comprehensive embargo on all these disciplines will be impractical to implement and —— if at all successfully implemented —— will stifle the overall scientific, technological and economic growth of the prospective recipient country. Most Third World countries view the London Club guidelines in this light; moreover the sweeping nature of these guidelines has caused undercurrents of disstisfaction within the Club itself and the July 1984 meeting of its Western members failed to reach any consensus. The London Club is thus gradually losing its leverage in preventing the diffusion of so-called sensitive technologies.

The Soviet Union has, in its own sphere of influence, followed a similar concept of nuclear assistance in relation to nonproliferation. As a matter of policy, even prior to the NPT, it restricted the flow of so-called sensitive nuclear technology to East European partners and discouraged them from developing their own nuclear fuel cycle programmes. It insisted on the return of fuel irradiated in reactors it had supplied which it agreed to replace by new fuel from the Soviet Union. Since the coming into force of NPT, the Soviet Union has with few exceptions required prior adherence to the Treaty as a condition for concluding bilateral supply agreements concerning nuclear materials and equipment.

There is thus seen to be a common fixation with the superpowers and major nuclear suppliers viz, their preoccupation with the search for a technical solution to a problem which is basically political. The policy of denial of technology has only served to increase tensions and mistrust and must give way to an approach based upon cooperation rather than confrontation. The world as a whole would greatly benefit from a constructive political initiative to help develop an equitable nuclear order which would realistically recognise the historic inequality between the five NWS and the rest of the world, but at the same time seek to reduce the technological disparity in peaceful application of nuclear energy. Such an initiative would most fruitfully come in a regional context because, globally speaking, it is not horizontal but vertical proliferation which ought to be addressed. The political motivation for lateral spread of nuclear weapons arises in

two types of regional situations. One is the emergence of an unnatural state or regime created through alien migrations, such as South Africa or Israel, which wishes to prop itself up with nuclear blackmail; the other is traditional rivalry for regional importance as in Latin America or South Asia. The first type of situation ought to be dealt with by persuading the State concerned to try to temper its intransigence with a measure of good-neighbourliness. In the second type, the rival states ought to be brought round to a position of mutual trust through arrangements like establishment of nuclear weapons free zones, joint declaration of nonproliferation intent, reciprocal inspection of nuclear facilities, etc. The alternative solution, effectively based upon nuclear armed equivalence, is not in consonance with mankind's aspirations and will, we hope, give way to a more rational and less militarized approach so that scarce natural and human resources are channelized into constructive endeavours.

THE ROLE OF MATHEMATICIANS IN DEVELOPING COUNTRIES

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INTRODUCTION

The difference between mathematicians, and indeed all scientists, in developing countries and in developed countries is quantitative, and is inevitably and unfortunately due to the basic characteristic causes of underdevelopment. These are ignorance and poverty, compounded with the confused political, social and economic conditions prevailing in the world in current times. Whereas investments in science produce only long term effects in a country's economy, it is ignorance on this potential which has resulted in almost total neglect of science in many developing countries. Poverty has agravated the situation by making involvement in science an economic venture. It is worth noting that whereas the developed countries spend about 3% of their GNP on science, the developing countries spend only 0.3%.

It is needless to say that the role of scientists in developing countries must include the elimination of underdevelopment over and above anyother role as international scientists. On the other hand it is impossible to play a measurable role in an evironment where science is neglected as in the present day developing countries. This means that an important step to pave a way for future generations of scientists to play their role is to raise the respect and appreciation for science and hence investments in science. A greater part of this talk will be concerned with possible ways to achieve the above objective.

Obviously the first role of any scientist is to perform his duties to the satisfaction of his employer. Most mathematicians in developing countries are employed by training institutions and their main duties include teaching and research, and possibly consultancy work through interaction with industry. There are several problems which are characteristic of developing countries and which must be attended to by the mathematicians if they are to fulfill this role. These include poor libraries and research facilities, isolation and a student audience consisting mainly of sons and daughters of peasant farmers, and therefore studying under difficult economic conditions This calls for the adaptation of appropriate teaching methodologies and special efforts to procure teaching aids such as books.

TRAINING AND RESEARCH IN MATHEMATICS

There is hardly any country which does not acknowledge the importance of mathematics, especially in the pre-university curricula. While addressing the Second National People's Congress of China in 1960, the Vice Premier of the State Council said: "If language and mathematics are properly mastered, it becomes relatively easy to master physics, chemistry, biology, history and geography" (Mathematics Education in China, by Frank Swetz, MIT Press 1974). The role of language in learning is now well known and appreciated by many educators. Indeed one of the factors against mathematics learning in most thirld world countries is the foreign language inherited from colonialism. In Africa, for example, the dominant languages are English, French and Portuguese, depending on the locality. Moreover, the textbooks use examples which are remote from the environment so that even trivial physical concepts in mathematics appear abstract.

The teaching of mathematics has also been gravely affected by lack of motivation which has led to shortages of qualified teachers as well as good students. There are basically three main reasons for this situation. First, the teaching profession has remained comparatively and significantly less lucrative, with the obvious result that good mathematicians opt for non-teaching professions, like engineering and commerce. Secondly, poor planning under conditions of limited financial and human resources led to unmanageable expansions and proliferation of schools, together with poor crash programmes for training the required teachers. Thirdly, ignorance on the role of mathematics in development (on the part of manpower planners and employers), coupled with the inertia to propagate the colonial heritage of depending on foreign experts, limited the career opportunities for mathematicians, with the result that potentially good mathematics students opt for other subjects (such as engineering, law, chemistry, political science and commerce) after the school level. The combination of the crash programmes and poor conditions of service generates a population of teachers with wide variations in abilities especially at the primary and the secondary school levels. It is, however, at these levels that the teacher has to be really good in order not to kill the motivation of students to learn mathematics. The vicious circle whereby future teachers are drawn from the poorest of a class taught by a poor teacher, worsens the situation. The

result is therefore obvious: mathematics is the most unpopular subject in most third world countries. It is more unpopular with the decision- maker who took mathematics only when it was compulsory to do so and yet his decisions are crucial to the advancement of mathematics in the third world.

The training of mathematicians beyond school level suffers from other weaknesses in addition to those inherited from below. At the undergraduate level, the shortage of qualified teachers and textbooks is still a major problem which is aggravated by escalation of prices for foreign books, shortage of hard currency and brain drain. Many mathematics departments in African Universities, for example, still depend on expatriate staff. On the other hand, the quality of expatriates attracted by any country is most often dictated by the conditions and terms of service compared to those prevailing elsewhere. For most poor countries of the third world therefore, and particularly for Africa, the result is once again a staff with wide variations in abilities producing a correspondingly diversified generation of mathematics graduates. The situation is conserved by isolation, low turnover of qualified local replacement of expatriates and lack of a critical number of mathematicians.

Postgraduate training at the level of the Ph.D. in Mathematics has directly or indirectly been foreign for most third world countries. During the colonial times, training abroad, even for an undergraduate degree, was more or less an unwritten law. The generation which was trained in that period is still alive and forms the strength of most institutions in the third world which offer Ph.D. training. The values and characteristics of foreign training cannot be expected to disappear in one generation because of the natural tendency for students to admire the routes of their supervisors.

Foreign training involving the migration of the trainee has two main disadvantages. First the trainee has a limited choice of areas of specialization which are dictated by the training institution's areas of research interest. More often than not the performance of the trainee is gravely affected by the discontinuities resulting from the change from one einvironment to another. Secondly the trainee may suffer permanent cultural deformations. He will most likely continue researching in the same area for the rest of his life, irrespective of how remote this area may be from his environment; publish in foreign journals for which his country may feel too poor to subscribe to, due to being suffocated with a myriad of other more pressing and down to earth problems; demand privileges comparable to those of the foreign country; and consider himself part of the foreign mathematics community. All this is justified within limits, but the fact is that in most cases these limits have been exceeded. It is not surprising that there are three types of brain drain in the third world, and most brains belong to one of them. The first type is through physical migration. The second type is through mental migration whereby the brain, though residing in a third world country, is to all other considerations in a developed country. The third type, known as "brain in the drain", is through academic death whereby the brain is polarized as far as research is concerned, and whatever may have been absorbed in the past decays with time. The "brain in the drain" type of brain drain is an inevitable consequence of salaries which are below subsistence levels. A physicist from one university in Zaire recently informed me that his University Library has virtually stopped ordering journals since 1970, and that instead of doing research he spends almost all his time in business to make up for the deficit necessary to support his family. His monthly take-home

salary is US$ 100 which, according to the cost of living, is enough to feed his family for at most one week. His situation is characteristic of almost all scientists in the third world.

In general, research in any branch of science is done for several reasons which include the following:

(i) satisfaction of intellectual curiosity,

(ii) promotion of individual status,

(iii) solution of application problems to satisfy required need.

By the nature of mathematics, a lot of research in both developed and developing countries is done because of (i) and (ii), although it is rightly argued that what appears abstract today is applicable tomorrow. The application problems referred to in (iii) originate from other disciplines, such as physics, and public and private institutions, such as industry. However, given the poor state of development for the other disciplines in the third world, the fact that most industries are of the import-substitution type, and that development projects are often given to foreign companies which employ their own mathematicians, research motivated by (iii) is not common, especially in the less developed developing countries. This poses an awkward vicious circle problem:

> "The third world administrator and decision-maker does not value mathematics, because the mathematician has not demonstrated his capacity to solve problems of interest, because the problems of interest are contracted to foreign companies, because..."

THE ROLE OF THIRD WORLD MATHEMATICIANS

In a nutshell, the greatest problem facing developing countries is that of deriving the functional equation relating the interactions between "development" in the rich countries and "underdevelopment" in the poor countries, together with the determination of its solution to obtain the optimal path for fastest relative and sustained development of the developing countries. There is no doubt that the solution must involve, among other things, the importation and adaptation of foreign technologies, the creation of indigenous scientific and technological capacity, and optimal development and allocation of resources. The role of mathematicians in the third world must therefore be to contribute effectively towards the solution of this problem which is obviously interdisciplinary.

The third world mathematician, unlike his counterpart in the developed world, has a quadruple role to play. First, he has to strive tirelessly to increase the population and capacity of local mathematicians and related professionals to at least the critical size needed for meaningful effectiveness. Secondly, he has to convince the politicians and decision-makers of the role of science, and mathematics in particular, in economic independence. Thirdly, he has to contribute to the growth of international mathematical knowledge, irrespective of its immediate or direct relevance to his own society, in order to retain his international image as a mathematician. Fourthly, he must tackle problems of immediate relevance to his own society in order to command respect and appreciation for mathematics. He must do all this under difficult economic, cultural, political and environmental conditions, and overcome the temptations to engage in trivial and yet more economically rewarding undertakings. Clearly, he requires to be committed and dedicated to both mathematics and the prosperity of his society.

Apart from qualitative and quantitive differences

among countries, the more common avenues which have been employed to promote mathematics in the third world are:

(i) upgrading courses and seminars for school teachers,
(ii) mathematics contests and publication of mathematics bulletins for schools,
(iii) creation and revision of syllabi and curricula,
(iv) administration of examinations,
(v) prostgraduate training,
(vi) production of textbooks and other publications,
(vii) running journals and societies,
(viii) scientific concourses for mathematics specialists.

Other avenues which are equally important but less common for obvious reasons are:

(ix) interaction with the economic production sector,
(x) the news media and public lectures,
(xi) lucrative and prestigious career opportunities.

With the exception of the more advanced third world countries such as India, China and Brazil, the full execution of any of the eleven activities poses unsurmountable financial and organizational problems in most countries. Lack of foreign exchange to finance regional activities has encouraged national isolation. On the other hand, regional cooperation is indispensable for countries which, individually, lack the necessary critical size for an activity, and there are many, especially in Africa.

The running of journals has been complicated further by conservative attitudes towards foreign journals, as demonstrated by widespread preference to continue publishing in foreign journals after the inauguration of local journals. The apparent neglect of science in most developing countries has generated outward looking scientists with regard to almost everything. In particular, foreign journals are frequently used both as sources of research problems and as depositaries of research findings. In fact, publishing in foreign journals is considered more prestigious. The result is that local journals suffer from two major setbacks. First, good quality production on schedule is prohibited by either poor, overloaded or absence of printing facilities. Secondly, the number of articles received for publication is too small to allow more than one issue per year and even then the size remains too small. For the same reason, specialization in any area of mathematics is not possible. There is then the vicious circle whereby "poor production schedule discourages submission of articles which leads to poor production ...". It is therefore not surprising that the whole continent of Africa has about three journals devoted to mathematics and two devoted to mathematics and physics. Moreover, only two of these are regional. This is an unfortunate situation because the academic climate in Africa is such that any national journal is more foreign to other African countries than European or American journals.

Mathematicians in the third world have the difficult task of overseeing the promotion of mathematics in their region through various avenues, including the eleven mentioned earlier. In particular, they should gather and propagate confidence in their abilities and interact with foreign mathematicians as equals. The growth of local journals, production of books, postgraduate training, mathematics contests and bulletins, and mathematics seminars are some of the activities which are necessary for the creation and growth of a scientific culture. It is often

argued that absence of foreign refereeing for articles may lead to the production of journals of inferior quality. However this is true only if one presupposes the inferiority of the local reviewer and, by implication, of oneself. This is nothing but lack of confidence. But even if the inferiority syndrome were a fact, it definitely must be a transient phenomenon, in which case it is appropriate to ignore it for the sake of creating intellectual, cultural and social dignity and maturity. All developing countries should imitate China by building a strong local capacity to disseminate scientific information. In order to make meaningful achievements, all opportunities must be fully exploited. In particular, young mathematicians should be given special encouragement. Moreover, international institutions such as ICTP, ICPAM and UNESCO should be approached for assistance. Already ICTP has taken the lead by facilitating the formation of mathematics and physics societies in regions of the third world and also by being the mother of the Third World Academy of Sciences, inaugurated on 5th July 1985 by the UN Secretary General. The principle of "Unity is strength" should be adopted by considering a region (rather than individual countries) as the smallest unit of reference with respect to mathematics activities. This is not an easy task, considering the fact that it is extremely difficult for mathematicians from two neighbouring third world countries to meet although meetings for other disciplines in the humanities are very common. It has taken some of us a trip to Trieste to meet fellow mathematicians from across the borders of our own countries.

RECOMMENDATIONS

1. BUILDING SCIENTIFIC COMMUNITIES

There are two factors which make cooperation in scientific research mandatory for any measurable impact. First most of the trivial problems have been solved and the background knowledge necessary to solve any pressing problem today is too enormous for most average brains working in isolation. Secondly, and particularly for developing countries, there is too much scientific isolation. As an example, there is on average only one member of staff in any discipline in mathematics (topology, group theory, etc.) in the only University mathematics department in Tanzania! and this is common in many other developing countries. The nearest other department is about 500 km away and in another country. The only feasible solution within a reasonable time is to build scientific communities consisting of scientists from several countries cooperating in research and other activities. Such communities exist even in the developed countries in various forms: institutionally, nationally and internationally. The common tendency for scientists from developing countries to work in isolation, or in collaboration with scientists from developed countries only, must be modified seriously to include cooperation among scientists in developing countries. This is very important for mathematicians, and the hospitality of institutions such as ICTP should be exploited for initial contacts. Other avenues are formation of mathematical associations/societies and mounting staff/student exchange programmes.

2. APPLY SCIENCE TO LOCAL PROBLEMS

There is a widespread problem of many scientists in developing countries isolating themselves from problems in their societies. In particular, Universities are like ivory towers, concentrating research on problems remote from their environment which has an infinite number of problems (eg. Industry). In order to deserve the appreciation of the tax payers it is inevitable that scientists, and in particular mathematicians, should involve themselves with local problems over and above their abstract research. This will create new career opportunities for mathematicians and hence attract more students and bright ones too who presently prefer other professions.

3. INVOLVEMENT IN INTERDISCIPLINARY ACTIVITIES

Most application problems requiring a mathematicians input are interdisciplinary and therefore require cooperation among scientists in several fields. Cooperation of this type is very common in developed countries but almost absent in developing countries, and yet it is one of the strongest means of raising the appreciation of mathematics. Needless to say, interdisciplinary involvement by mathematicians has often led to new discoveries in mathematics itself - Eg. Quantum mechanics lead to developments in theory of unbounded operators in Hilbert spaces.

4. PROMOTE REGIONAL COOPERATION

(a) Create Centres of Excellence.

(b) Create Central Libraries.

Mathematicians and other scientists should press their governments for the creation of regional Centres of scientific excellence and Central regional Libraries. the roles of such Centres cannot be justifiably questioned since resources are scarce and inadequate when individual countries are considered.

5. ELLIMINATE SCIENTIFIC ILLITERACY

It is extremely important to educate decision makers on the long term role of science in economic development because this has a bearing on investments on, and value for, science. Use can be made of public news media, scientific society news letters and other forums.

6. EXPLOIT HOSPITALITY OF INTERNATIONAL ORGANIZATIONS

These organizations are well placed to act as Catalytic agents for initiating the building up of scientific communities, societies/associations and Centres of excellence, and even regional cooperation. Individual scientists should simultaneously work through their national representatives to these organizations for effectiveness. the hospitality of ICTP should be used partly to initiate ideas for cooperation since it is at present the only unique place where scientists from all developing countries meet.

7. CONDUCT PURE RESEARCH

In addition to applied research, mathematicians and other scientists in developing countries have a duty of maintaining their position as members of the international scientific community - i.e. contribute to the growth of international science. Fortunately this is being done but to a large extent as a continuation of Ph.D or other postgraduate degree work. If appropriate, efforts should be made to enter new areas because too much specialization in a region with small numbers of scientists may inhibit cooperation and therefore lead to isolation with all its undesirable consequences. The role of local journals with wide circulation should be noted as the only means to expose the potential of Third World countries.

8. POPULARIZE MATHEMATICS IN SCHOOLS

The ivory-tower type of University tends to isolate the schools, forgetting that the raw materials for Universities (students) come from the schools. Moreover, in view of the large numbers involved (school teachers vz. University teachers) the appreciation of mathematics by a society will be more easily achieved through the schools. Mathematical associations drawing memberships from all levels of education should be formed in each country/region for the purpose of promoting the appreciation and value of the subject in development.

SCIENCE AND DEVELOPMENT IN INDIA

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1) INTRODUCTION:

India is the seventh largest country in the world, with an area of 32,87,782 sq. kms, consisting of 22 states and 9 Union territories (which are directly governed by the Central Government). The population according to 1981 census was 684 million, the male-female ratio being 1000 to 935. More than 70% of the population depend on agriculture for living and consequently 78.8% of population live in rural areas, while the urban population accounts for 21.2% (1977 figures). The average population growth rate was 2.48% per year during the 1971-81 period. Any development programme the Government undertakes, has to take into account the rural base of our population. Agriculture provided 40% of the national income in 1978 and the rest came from small scale and heavy industries, natural resources and other sources. The Gross National Product GNP for the year 1979-80 was US $ 118,283 million, while the per capita GNP for 1979 was US $ 159. It is an incredible achievement of the Indian educational planners and academicians that during the course of the developing economy after the independence of the country (in 1947 from the British), the percentage of literacy could be increased from 16.67% in 1951 to 36.17% in 1981. The population growth is the main factor stifling the development programmes of the country. The main cause ofor the increase in population is the fall of death rate due to better health conditions, effective control of epidemics, efficient handling of famine conditions and intensive economic development. India has also a large network of railways, roadways and waterways, consequently transportation system is very efficient. Coupled with this is the efficient communication network, which is vital for a developing country, aspiring to improve the quality of life of its citizens.

Focusing on the education side, India had, in 1980-81, 112 Universities and 11 institutions deemed to be Universities, consisting a total of 4722 Colleges, with 2.752 million students at the College/University level. As compared to 39,964 teachers in the University colleges/departments, there were 153,377 teachers in the colleges affiliated to Universities (ref. 1)

As regards Physics and Physicists, ref. 2 shows that the number of employed physicists rose from a mere 3000 in 1950 to 35000 in 1975. The number would be much higher now due to the impetus given to physics during the last few years. A 1971 survey showed that 69.5% of the Physics post-graduates were

engaged in teaching, 6.2% in teaching-cum-research and 9.4% in Research and Development (R & D).

2) THE SCIENCE POLICY OF GOVERNMENT OF INDIA:

The Science policy of the Government of India is guided by a resolution adopted by the Parliament on 4 March 1958.

One of the main objectives of this resolution is to secure for the people of the country, the benefits from the acquisition of scientific knowledge and its application.

The resolution also sets out some other aims like encouraging individual initiative for the acquisition and dissemination of knowledge, as well as the discovery of new knowledge, fostering programmes to train scientific and technical personnel to fulfill the needs in the fields of science and education, agriculture, industry and defence and ensuring an adequate supply of scientists and recognising their work.

The following pages would clearly show that India has indeed been successful in implementing its science policy by way of fostering scientific and technical knowledge and related enterprises. Presently, India is the leader amongst the developing countries, in the realm of science and technology, and provides our technical know-how and service to other under-developed/developing countries of the third world for their betterment.

3) ORGANIZATION OF SCIENTIFIC RESEARCH IN INDIA:

India has a very large number of research laboratories, covering a wide range of scientific disciplines. The research activities of the country are organized under 4 sectors viz. i) Central Government ii) State Governments iii) Universities and Institutes of technology and iv) private and public sector industries. A brief account is given here.

i) Central Government Sector:-

The following agencies carry out the bulk research activities of the country under the auspices of the Central Government. The number of research labs/institutions controlled by each agency is shown in paranthesis.

a) Department of Atomic Energy DAE (12)
b) Department of Space DOS (5)
c) Department of Science and Technology DST (18)
d) Council of Scientific & Industrial Research CSIR (31)
e) Defence Research & Development Organization DRDO (36)
f) Indian Council of Medical Research ICMR (12)
g) Indian Council of Agricultural Research ICAR (38)
h) Department of Electronics DOE (3)

Each of these agencies employ a large number of scientists in their R & D activities and also award research fellowships to research workers at the University and College levels. As an example, the data concerning CSIR as on 1-4-1980 show (ref. 3):

National laboratories/Institutes	31
Industrial Research Associations	2
Extension centres/Field stations	71
Scientists	3,048
Other scientific and technical staff	8,111
Research schemes in progress	554
Pool scientists	386
Research fellowships	3,628
Research committees	12

Thus the vastness of this agency is by itself an indicator of the organized way in which the Central Government promotes scientific persuits in this country.

ii) The State Governments Sector:-

The State Governments have their own research institutions in many areas of science and technology inclusive of agriculture, animal husbandry, fisheries, public health, road transport and housing etc.

iii) Universities and Institutes of Technology:-

Research and development activities are undertaken in the 123 Universities (comprising of 17 agricultural Universities also) and 5 Indian Institutes of Technology (at Delhi, Kanpur, Kharagpur, Bombay and Madras). Almost all the IITs have foreign collaboration in various areas of science and technology.

iv) Private and Public Industries Sector:-

By the end of 1979, 450 establishments in the private sector had set up in-house R & D units, which usually undertake research work connected to their production activities. These units of industry are registered with the Government's Department of Science and Technology, which offer liberal subsidies and tax incentives to the private sector industries.

There are about 60 public sector undertakings, attached to various ministries, which carry out research work connected with their production.

4) EXPENDITURE ON SCIENCE AND TECHNOLOGY:

The budget allocation for science and technology during the different five year plans are as follows:-
(Source: ref. 4, INR = Indian rupees)

PLAN PERIOD	ALLOCATION (10^7 INR)*
I (1951-56)	20
II (1956-61)	67
III (1961-66)	144
IV (1969-74)	373
V (1974-78)	1,017
VI (1980-85)	3,365

* Note: Figures are given in Indian rupees INR in this article. Since the exchange rate of rupee with US $ varies from year to year, readers are requested to refer to "Statistical year book for Asia and Pacific"- United Nations 1978, its later publications and such other sources for the summary of year wise rupee-dollar exchange rates.

The allocation for science and technology has steadily increased, in order to keep pace with the level of S & T persuits undertaken in the advanced countries.

4.1) Expenditure on Scientific Research and Development:-

The Sectorwise expenditure on scientific R & D is as follows: (Source: ref. 3, figures in 10^7 INR)

SECTOR	1974-75	1976-77	1978-79	1979-80	1980-81
Central Govt.	258.92	310.49	432.70	497.60	572.23
State Govt.	28.65	32.05	41.47	45.62	50.17
Private Sector	36.46	48.42	72.04	86.45	103.74
Total	324.03	390.96	546.21	629.67	726.14

It is evident that the Central Government spends the lion's share for scientific research & development in this country. The sectorwise expenditure during 1978-79 shows that the central government sector spent 79.4%, the State Governments sector 8.2% and the share of private sector was 12.4%. It is gratifying to note that the percentage of private sector expenditure is slowly increasing over that by the State Governments sector. In many developing countries, a serious drawback observed is the lack of research support from the private sector. But in India, this factor also shows a positive trend. As regards the total expenditure, the 1980-81 figures show an increase of 124% over that of 1974-75.

The science and technology budget of major organizations would give an idea of the thrust towards each agency. The

S & T budgets are as follows (source: ref. 3, figures in 10^7 INR):

AGENCY	1978-79	1979-80	1980-81
DAE	65.34	70.06	80.54
DOS	45.30	48.49	56.93
DST	43.39	48.22	63.41
CSIR	50.03	54.28	60.45
DRDO	67.41	98.46	74.00
ICMR	5.30	6.15	9.19
ICAR	67.91	85.92	96.36
DOE	6.11	8.96	6.30
TOTAL	351.79	420.54	447.18

The above data show that the ICAR budget is considerably higher than the other agencies and next comes the expenditure on defence research. The agriculture based economy of India definitely needs a major push towards agricultural research and the S & T budget is in tune with this reality.

4.2) <u>Expenditure on Science and Technology in relation to GNP:-</u>

The following table depicts the expenditure on S & T as % of GNP from 1958-59 to 1978-79 (Source: ref. 5)

	1958-59	1968-69	1978-79
a) GNP at current prices (10^7 INR)	12,600	30,293	85,655
b) Expenditure on R & D (10^7 INR)	22.93	107.56	520.42
c) (b) as % of GNP	0.18	0.35	0.60
d) Expenditure on R & D and related S & T activities(10^7 INR)	28.81	131.44	546.21
e) (d) as % of GNP	0.23	0.43	0.64

Over two decades, there has been a three fold increase in the expenditure on R & D and related S & T activities, from

0.23% to 0.64% of the GNPs of the period. At this juncture, it is useful to look at some statistical data depicting the selected indicators for research and development of the World and India.

The UNESCO Statistical Yearbook 1982 (ref. 6) shows that during 1974, the total R & D expenditure for the world (data not including U.S.S.R., China, Mangolia, Vietnam and D.P.R. Korea) was US $ 79,191 million and this rose to US $ 123,074 million in 1978. In 1974 and 1978, the advanced countries had incurred 96.9% and 95.6% of the total expenditure respectively, while the total expenditure in the developing countries rose from 3.1% in 1974 to 4.4% in 1978. As regards the R & D expenditure as % of GNP, the advanced countries spent 1.95% during both 1974 and 1978, while the developing countries spent 0.31% in 1974 and 0.43% in 1978. This is a very healthy trend indeed, as far as the developing countries are concerned. The following shows R & D expenditure as % of GNP for selected countries (Source: ref.5)

Greece	0.2 (1976)	U.K.	2.0 (1975)
Mexico	0.2 (1974)	Japan	2.1 (1976)
Pakistan	0.3 (1973)	Netherlands	2.1 (1976)
Spain	0.3 (1973)	W. Germany	2.2 (1975)
India	0.6 (1978-79)	Switzerland	2.3 (1975)
Yugoslavia	0.8 (1977)	U.S.A.	2.6 (1977)
Italy	0.8 (1976)	Poland	2.7 (1975)
D.P.R. Korea	0.9 (1977)	Czechoslovakia	4.1 (1977)
Canada	1.0 (1975)	U.S.S.R.	4.5 (1977)
Finland	1.1 (1977)		
Belgium	1.4 (1973)		
Australia	1.6 (1973)		
Argentina	1.8 (1976)		
France	1.8 (1975)		
Sweden	1.8 (1975)		

One can see that the tremendous progress made in science and technology by the U.S.A., U.S.S.R. and certain rich nations (which have strong economics) of the northern hemisphere, is due to their large scale spending on R & D. A very important point to be noted here is that the Conference on the Application of Science and Technology in the Asian countries (CASTASIA), in 1968 had passed and accepted a resolution by the developing countries, including India, that the R & D funds will be gradually increased to reach the target of 1% of GNP. It is an obvious reality that India has yet to reach that target.

5) RESEARCH AND DEVELOPMENT - MANPOWER GROWTH:

The science policy of the Government of India (1958) aims to "ensure an adequate supply, within the country of research scientists of the highest quality----, to encourage and initiate, with all possible speed, programmes for the training of scientific and technical personnel on a scale adequate to fulfill the country's needs-----". Science based technology is vital for bringing about economic growth. Many developing countries including India, have top level scientific and engineering manpower and consequently growing capabilities for project design and execution. The manpower growth in various sectors over the last few years is an indicator of the achievement of self-sufficiency in our requirement of high quality S & T personnel. The following data show the growth of manpower in research and development over two decades (Source: ref. 7).

SECTOR		1958-59	1968-69	1978-79
a) CENTRAL:				
	CSIR	3,512	8,848	12,079
	DAE	1,067	7,209	16,248
	DRDO	1,500	7,550	10,953
	ICAR	1,500	7,820	7,958
	ICMR	1,001	1,221	1,096
Central Ministries	..	8,344	20,818	29,089
b) STATES SECTOR	..	1,000	10,115	13,431
c) UNIVERSITIES	..	2,600	7,778	10,000
d) PRIVATE SECTOR	..	200	2,825	13,926
TOTAL		20,724	74,184	114,780

There was an overall increase in manpower by 454% from 1958-59 to 1978-79. Reference 5 shows the following highlights on the developmental aspects of S & T towards the end of 1978:

i) Total stock of economically active S & T personnel in India was estimated to be 1.935 million.

ii) About 150.2 thousand personnel were employed in the R & D establishments, of which 56.5 thousand personnel were directly engaged in R & D work.

iii) 2.9% of the total personnel employed in R & D establishments were women.

5.1) Selected indicaters for Scientific and Technical Manpower:

The following data, which are self explanatory, show some selected indicators for S & T manpower (Source: ref. 6):

A) WORLD

1) Distribution of R & D scientists and engineers:-

	1974	1978
Advanced countries	90.6%	88.7%
Developing countries	9.4%	11.3%

2) Number of R & D scientists and engineers/ million population:

	1974	1978
Advanced countries	1942	2214
Developing countries	91	118
Asia	334	399

B) INDIA (1977)

a) Qualified manpower:

1) Potential scientists and engineers/ million population		1115
2) Potential technicians/million population		2606

b) Personnel engaged in R & D:

1) Scientists and engineers/million population		57
2) Technicians/million population		42
3) Number of technicians/scientist or engineer		0.9
4) Scientists and engineers in R & D as % of potential scientists and engineers		4%

c) Expenditure for R & D:

1) As percentage of GNP		0.5%
2) Per capita in national currency	INR	6.6
3) Annual average per R & D scientist or engineer (in national currency)	INR 142,500 (US $ 17,360)	

5.2) Out turn of S & T personnel in India:-

In general, transfer of science and technology from the advanced countries to the developing countries involve several unmanageable hurdles. In the first place, the cost of buying advanced technology is astronomically high and it becomes imperative to employ trained personnel from abroad in India. Secondly, a developing country would have to rely totally on the advanced countries and their manpower, to implement their own development programmes and this reliance would perpetuate. Thus indigenous scientific and technological research must have to be carried out, which necessiates producing highly qualified personnel in various areas for training and eventual employment in key research and other establishments.

a) Out turn of science degree holders:-

India produces a large number of science degree holders and their growth is as follows (ref. 7):

DEGREE	1950	1960	1970	1980(estimated)
B.Sc.	9,628	22,693	83,610	113,000
M.Sc.	1,425	5,382	16,578	20,000
Ph.D.	100	361	1,212	2,000
Total	11,153	28,436	101,400	135,000

Thus from 1950 to 1980, there has been an eleven-fold increase in the out turn of pure science degree holders in India.

b) Comparison of different categories of S & T personnel in India with some leading countries (Source: ref. 7):

Country	Year	Pure Science	Applied Sciences†
U.S.A.	1974	73,254	133,913
India	1974	123,800	35,058
Brazil	1974	13,922	29,163
Japan	1975	9,504	90,077
Canada	1975	5,033	12,105
U.K.	1973	16,200	16,966
France	1972	13,102*	18,132**
Italy	1974	9,059	18,577

†Including agriculture, engineering & medicine

*Including agriculture

**Excluding agriculture

Analysis of the above data shows that India definitely produces more number of personnel in pure sciences than in applied sciences, when compared with other leading countries. The Indian out turn of pure scientists is 69% more than that of U.S.A., 7 times that of U.K., 10 times that of France and 13 times that of Japan. Also, India produces a small proportion of applied science personnel, unlike the other countries mentioned above. This overproduction of pure scientists has very wide ranging repercussions, as discussed below:

6) UNEMPLOYMENT AND BRAIN DRAIN:

Unemployment is the chief malady caused due to the overproduction of qualified S & T personnel in a developing country

like India. This is a very serious problem affecting the dearth of new job vacancies and due to the inability to disburse sufficient unemployment benefits (which is usually the practice followed in the welfare states).

In 1978, among science post-graduates,unemployment rate was 3.9%, for science graduates 15.8% and for medical and veterinary graduates 2%. For engineering graduates, the unemployment rate was 7.4%, while for engineering diploma holders, it was 20.2%. The total number of unemployed S & T personnel in 1978 was 0.258 million. Keeping the same rate of unemployment the projected figures for 1983 for unemployed S & T personnel are 0.34 million, out of a total stock of 2.801 million (data source: ref. 7)

Aspirations for a better standard of living, coupled with unemployment/under-employment back home, cause a massive brain drain from the developing countries to advanced countries. This is a multi-dimensional Sociological and national problem. The impact of brain drain causes a deep vacuum of potential scientists, engineers and other highly qualified personnel, which, as far as a developing country is concerned, is an irreparable loss indeed without compensation. The UNCTAD report (ref: 8) gives the following data for brain drain from the developing countries including India to advanced countries for the period 1964-72.

	U.S.A.	CANADA	U.K.	TOTAL
ASIA	65,020	29,465	23,685	118,170
India	21,253	8,257)		
Pakistan	1,743	1,684)	23,685	56,881
Sri Lanka	-	259)		
AFRICA	4,641	2,251	10,176	17,068
LATIN AMERICA	16,378	1,195	2,723	20,296

Clearly, the brain drain from India is the highest compared to other Asian countries. Creation of new jobs, self employment and education for skill formation are the dependable solutions to tackle this formidable national problem.

7) ENERGY AND IMPACT OF SCIENCE AND DEVELOPMENT IN RURAL INDIA:

One of the most important impact of science and development in India is, along with attaining self sufficiency in meeting the multifaceted scientific and technological needs of the country, generation of power. Energy forms the basic infrastructure in the development of the society. India taps hydroelectric power, coal, oil and gas, tidal energy, geothermal energy, nuclear energy and solar energy. The per capita consumption of energy at the time of independence in 1947 was 13 KWh, which has increased to 119.5 KWh during 1977. The total installed generating capacity, which was only 2300 MW in 1950, has increased to over 31,025 MW in 1979-80 and according to published data available so far, the anticipated addition in 1980-81 is

1856 MW (ref. 3). India consumes more energy than it produces (for e.g., see ref. 9) from conventional sources and hence thrust is given to develop other sources of energy.

At present, a great emphasis is given to the development of nuclear energy, solar energy and non-conventional sources of energy. India has developed the technology for the design, construction and operation of nuclear reactors for generation of power. The Atomic Energy Commission of India, in its annual report for 1981-82 (ref. 10), shows a total installed nuclear capacity of 860 MW and the commission has drawn up plans for installed nuclear power capacity of 10,000 MW by the end of this century. The allocation of finances for the fiscal year 1981-82 shows 71% for nuclear power programmes and 22.2% for research and development.

For a tropical country like India, Solar energy is also an important source of energy. The capital cost of production of solar energy (like the use of solar cells or central power stations using solar collectors) pauses a serious problem. However, a great impetus is being given to develop and tap solar energy these days.

The exploitation of non-conventional sources of energy has been vigorously persued by the Government. This aspect and other science based development of the rural areas have been envisaged in certain new areas of research and development projects set up by the Department of Science and Technology, Government of India. New areas of R & D include development of energy in the rural sector, for e.g. biogas generation, fuel for rural ovens, solar energy for drying, cooking, pumping and communication, wind and other sources of energy and gas from wood and charcoal. To implement these schemes, it has been recommended to set up rural R & D centres; which have objectives of socio-economic plans such as reducing the dimension of poverty, stabilizing production, social justice and urban-rural equalization. These rural R & D programmes ensure movement of R & D personnel in rural areas from their urban bases to provide a new outlook and greater dynamism in the rural society, and to generate new skills, techniques and knowledge. The present programme envisages to create an R & D block each in the 400 districts of India, with each block having an average of 5 scientists and an equal number of ancillary staff.

Thus the out come of science based development in the agricultural and rural areas (where 80% of the population live) would definitely uplift the quality of life of the rural population.

8) PHYSICS RESEARCH IN INDIA:

Research work is carried out both theoretically and experimentally, in all areas of physics, in the national laboratories, IITs, research organizations, Universities and many colleges of India. Our experimental research output is comparable in quality with that from advanced countries, in spite of the lack of very sophisticated experimental set up used by our research groups.

India has earned a Nobel prize in physics (by Dr. C.V. Raman) but brain drain has caused some of the best scientists from India to seek migration and "Scientific asylum" in the advanced western countries, where they have been earning laurels. Reference 2 shows a compilation of 81,352 research papers in physics, published in the world in the year 1973 (from Physics Abstracts, Vol. 76, 1973) of which, the contributions from the advanced and the developing countries were 95.29% and 4.71% respectively, with India sharing 2.84% of the total world output. The survey revealed the following aspects of Indian research in in the physical sciences:

a) Good trends were shown in the fields of Atomic and Molecular Physics, Geophysics, Earth Sciences, Gases and Fluid dynamics, Plasmas, Nuclear Physics and Mathematical Physics.
b) Special thrust was needed in the areas of Material Science and Metallurgy, Astronomy and Astrophysics.
c) As regards the media of research publications, 62% of the Indian contribution was published in foreign journals (majority in U.S. and British journals)
d) In general, the research out put from the Universities were more than that from research laboratories and research organizations.

8.1) Development Programmes in Physics-Thrust Areas of Research:

Quite recently, the Department of Science & Technology, Government of India, has identified the following thrust areas of front line research for which, large scale research grants are awarded to research workers in India. Since the areas of Physics currently being promoted run to a long list of several hundred, only the major heads are given below:

a) APPLIED OPTICS
b) ASTRONOMY & ASTROPHYSICS
c) ATOMIC AND MOLECULAR PHYSICS
d) BIOPHYSICS
e) CONDENSED MATTER
f) CRYOGENICS
g) DEVELOPMENT OF SOPHISTICATED ANALYTICAL AND MEASURING INSTRUMENTS
h) DISORDERED SYSTEMS & APPLICATIONS
i) EARTH's ATMOSPHERE
j) HIGH ENERGY PHYSICS & ELEMENTARY PARTICLE PHYSICS
k) LASER SCIENCE & TECHNOLOGY
l) MATERIAL SCIENCE & TECHNOLOGY
m) NON-LINEAR PHENOMENA
n) NUCLEAR PHYSICS
o) OCEANOGRAPHY
p) PHYSICS OF SEMICONDUCTING DEVICES
q) PLASMA PHYSICS AND PLASMA DIAGNOSTIC TECHNIQUES
r) SOLAR SYSTEM PHYSICS
s) SOLID EARTH
t) SURFACE PHENOMENA AND TAILORING OF SURFACES TO THE REQUIRED SPECIFICATIONS

9) PROMOTION/DEVELOPMENT OF SCIENCE PROGRAMMES:

The scientific programmes and activities of the country are promoted by prestigeous awards, fellowships and research grants offered by various agencies like the Central Government sector organizations mentioned in section 3.1, state governments and the Indian National Science Academy. The University Grants Commission, in addition to granting research projects, Junior and Senior fellowships, Teacher fellowships and Research Associateships, also award National Associateships, Career Awards and National Awards. The last two awards are intended for most distinguished scientists of proven competence in their research fields. Merit awards are also given by private trusts, business houses and various Central ministries. Some of these coveted awards also act as deterrent to the brain drain of scientists and technologists.

9.1) Cultural Exchange Programmes and International Collaboration:

The following gives a summary of the cultural exchange programmes and international collaboration which the Government of India has with foreign countries. The sponsoring agencies of India and of the foreign country are shown in parentheses. These programmes ensure a free flow of scientists from India and abroad to collaborate with each other so that the scientific community of the world as a whole has the constructive advantage of sharing each other's experience, talents and technology.

a) Indo-foreign cultural exchange programme (UGC) for developing bilateral links with the following countries:

U.S.S.R., Iraq, Czechoslovakia, Hungary, F.R.G., France, Romania, Poland and Belgium.

b) Indo- British Universities collaboration programme (UGC + British council) for joint research projects.

c) CSIR - CNRS (France) programme.

d) Indo-U.S. fellowship programme (UGC)

e) Indo-U.S. exchange of scientists programme (CSIR + National Science foundation of U.S.A.)

f) Common-wealth Academic staff scholarships/fellowships (UGC + Common Wealth Association of U.K.)

g) Programme of exchange of visits by younger scientists between India and U.K. (UGC + British Council)

h) Colombo plan (Govt. of India + Common Wealth countries)

i) West German fellowship programme DAAD (UGC + F.R.G.)

j) UNESCO Programmes (Ministry of education/UGC + UNESCO) An example is the ICTP programmes for which travel grants are borne by the UGC and living expenses are met by UNESCO for the visiting guest scientists.

k) UNESCO/UNDP assistance programme to selected University departments. UNESCO made a provision of $ 24,91,575 for a period of 39 months, with effect from 1-10-1979, and nine University Departments have been benefited.

10) CONCLUDING REMARKS:

It is an irony of fate that the advanced western countries having affluent GNPs, do not spare significantly towards the betterment of the post-colonial developing countries, whose teeming population live in utter destitution and economic

deprivation, and with their financial resources approaching depletion as the years pass by. The GNP and GNP per capita of various countries, which are useful indicators of the comparative sizes of various national economies, are compiled in the "Europa year book 1981- a world survey". The compilation shows that India has one of the lowest per capita GNP. In spite of this, post-independence India has emerged triumphant as regards implementation of ambitious scientific and technological programmes, which also include very pioneering Nuclear and Space programmes, and is steadfast attaining the objectives and goals formulated in the Science policy of Government of India.

The impact of science on the multifaceted developmental aspects of India has been amply demonstrated in this article. The continued activities in the various areas of science and technology to meet the growing needs of man, society and the nation with its stock of high potential manpower and concrete industrial infrastructure, provide impetus for an accelerated growth of the country towards an advanced economy, and would create conditions for high living standards of our population in the years to come. Planned science based developmental programmes of this country would hence forth aspire to strengthen the pillars of human progress, promote culture and international understanding, pave the way to assist our fellow-brethren in the lesser developed countries, and contribute to materialize the economist's coveted dream of achieving an ideal "International Economic Order".

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