LECTURE 5 19 March 1988

SIENCE IN INDIA

It will be recalled that the simple model of technology- society interactions (Figure 1 of Lecture 1) led on to a view of science-technology interactions (represented in Figure 2 of Lecture 2).

According to this view, the vitality of science in a society depends upon

(1) the challenges thrown up by the innovation chain leading to technology and
(2) its internal momentum arising from the back-log of unresolved problems.

This vitality is also sustained by the supply of instruments, materials and techniques from industry.

But, the simple model of technology-society interactions (Figure 1 of Lecture 1) had to be modified to take into account, on the one hand, the existence in most developing countries of dual societies, and on the other hand, their strong interaction with the industrialized countries. In pursuing this modification, it was found (Figure 1 of Lecture 2) that the coupling with the developed countries leads to the dominance of foreign-collaborating industry based on the import of western technology, and that the dual character of developing societies results in an overwhelmingly elitest thrust of indigenous technology. Further, even these indigenous technological efforts consist almost wholly of the imitation and adaptation of western technology, rather than of innovation.

This almost complete decoupling of science and technology from each other has a profound impact on science in developing countries and produces its first major abnormality. Because of the preponderance of technology imports and of the imitative character of indigenous technology, the initial part of the innovation chain (consisting of research, design and development, and engineering-for-manufacturing) hardly exists in developing countries. As a result, their scientific systems are not subject to the pressure of basic problems emerging from technology. And, without this pressure from technology, indigenous science is deprived of a powerful driving force; if it is to flourish, it must depend solely upon its internal momentum.

This internal momentum of science is the product of the "mass" of scientists and the "velocity" or pace of scientific research. The "mass" depends upon the size of the scientific body (and many developing countries just do not have enough scientists!), but not merely upon the number of scientists. What is required is a <u>community</u> of <u>interacting</u> scientists with the well-established traditions of a peer system. Scientific peers are crucial for discussions, brain-storming and testing out ideas, for acquiring different ways of looking at a problem, for enhancing the quality of seminars, symposia and conferences, for rigorous assessment and constructive criticism of work, for help in improving its quality, for a process of recognition that is appreciated, and so on. In short, without the environment of an actively interacting scientific community, there cannot be the natural selection of scientific ideas and data which only will ensure that the fittest theories and experiments survive.

The tempo of research activity depends upon the existence and maintenance of an atmosphere of excitement which in turn requires a conviction of being "hot on the trail" of important discoveries. Such an atmosphere is facilitated by rapid communication between scientists through personal contacts, seminars, symposia and conferences and through well-referred journals which ensure quick publication. The pace of research is usually set by outstanding scientists who attract a following. The point is that scientists tend "to hunt in packs" behind leaders.

In examining whether science in developing countries can develop and sustain such an internal momentum, it is necessary to recall the strong interaction between the educational and scientific institutions in the industrialized countries and those in the developing countries. In many cases, the latter institutions are direct off-spring of western institutions having been planned, conceived, delivered and nurtured by them. The umbilical bonds are rarely severed, and even when this is achieved, the filial ties remain strong. As a result, scientists in developing countries derive from their counter-parts in the west the emerging areas for research, the trends and fashions and the stream of inspiration. They turn avidly to western scientists for the criteria of excellence, and for assessment, evaluation and recognition.

The whole process is accentuated by the fact that large numbers of developing-country scientists have been trained in the institutions of the western world. If they return to their native countries (and many do not!), they spend the bulk of their remaining professional lives continuing the themes of their foreign researches, look back nostalgically to their halycon days abroad, and above all re-inforce the value system of dependence on western scientists and institutions. This dependence results in two further abnormalities of science in developing countries.

The filial loyalty of native scientists to their western mentors and alma maters inhibits serious interaction with their colleagues. An actively interacting scientific community does not form because these scientists are more reluctant to walk to the next laboratory than to fly across continents and oceans to talk to the scientists of the developed countries. Any recognition and praise received in the course of these foreign contacts is deeply cherished -- "batteries are recharged", it is said -- but this inspiration and stimulation from the west only increases their spiritual distance from their colleagues. Even more vehemently do they feel that their work is too sophisticated and advanced to be appreciated in a backward country and that "there is no one to talk to" at home. Thus, the abnormality is that the peer group which native scientists look up to is abroad in the institutions of the west, and not in their own countries. In the absence of a local peer group of compatriot scientists, rigorous internal assessment and evaluation becomes difficult, refereeing suffers, the quality of journals deteriorates, etc.

In addition, the subservience of native scientists to their "teachers" in the west leads to the following approach to the choice of problems and problem-areas:

Step 1: Become familiar with the output of "western" research.
Step 2: Identify western fashions and frontier areas.
Step 3: Concentrate effort on these fashions and frontier areas.

If the resulting work is noticed in the west, and appreciated there, then the effort is adjudged successful; if it is ignored, the endeavour is construed as a failure. Thus, the criterion of success, viz., recognition from the west, only re-inforces in a positive feed-back sense the whole approach to the selection of research areas and topics.

The result of this approach is that the distribution of indigenous research efforts over the various disciplines and sub- disciplines is very similar to those in the developed countries. But, this distribution is not identical because of the well-known difficulties of doing research in developing countries. These difficulties include poorly-stocked libraries, long delays in receiving journals, extremely limited opportunities of travelling to the west and participating in foreign conferences, badly-equipped laboratories, import restrictions, inadequate laboratory supplies and infra-structure, non-availability of crucial components and materials, bureaucratic interference, etc. As a consequence, the gestation times for "starting up and getting going" are much longer and the tempo of work is much slower. In short, the signals from the advanced countries are received after a delay time and are responded to much later. Even successful competition with western research is not easy, except by the blessed few in abundantly endowed and well-patronized laboratories. And as for pioneering work, it rarely occurs -- there have been very few path-breaking researches from the developing countries.

The similarity between the patterns of research in the developed and developing countries is adjudged an abnormality and a matter of serious concern because it represents an illegitimate driving force which inhibits the autonomous development of an internal dynamic. Most developing-country scientists, however, view this similarity with approval as a confirmation of the international character of science. If the slogan "science is international" means that the laws of nature are invariant with respect to country, there can be no argument. If, however, it means that the pattern of science is not socially and historically conditioned, then there is much to dispute.

The pattern of science is influenced both by the society in which it grows as well by as by its own history. This is why the main preoccupations of science have been different at different periods of its history -- mechanics in the sixteenth and seventeenth centuries, heat in the middle nineteenth century, electricity in the late nineteenth century, and more recently nuclear and solid state physics in the post-World War II period. It appears that there are two circumstances under which a particular aspect of nature becomes the focus of intense scientific activity: firstly, when there is a confluence of the flows of basic problems generated by technology and of relevant background knowledge produced by previous science; and secondly, when there is a torrent of understanding casued by a conceptual or experimental break-through.

This view implies that the foci of scientific activity in several countries will be the same if the problems generated by their emerging technologies are identical[1], their scientific systems share a common history, and their scientists belong to the same peer group. This is the case with the "developed countries" -- they are characterized by the same pattern of social wants, they are involved in the development of the same technologies, their scientific systems have evolved together and share a common history, and their scientists have belonged to, or become part of, the same peer group during the course of several centuries. Science is certainly <u>trans</u>-national amongst the set of industrialized countries.

But, it is difficult to extend these arguments to the developing countries. Because of the almost complete dependence on technology imports and the imitative-adaptive approach to indigenous technology generation, science in these countries is not subject to the pressure of problems thrown up by technology. The scientific systems, in most of these countries, are only a few decades old[2]. And, though their scientists look to the west for their peer group, this view is not reciprocal -- by and large, developing-country scientists can be treated as "camp- followers" who can be ignored because their contributions are peripheral. Thus, most developing countries cannot be included in the set of countries across which science is trans-national. Further, the distribution of their research efforts over the different areas is not the result of autonomous forces, but the natural consequence of following "western" fashions. The similarity of this distribution with that in the industrialized countries is a manifestation of the subservient position of developing country science, and not a proof of the view that it is part of an international effort.

These abnormalities of indigenous science are aggravated by the lack of a strong instrument ndustries in developing countries. These countries are almost totally dependent on instrument imports. It is well-known, however, that when a new type of instrument arrives on the scientific scene, there is an initial rush to exploit it but this rush is followed by a leveling off in its use after the most significant applications are achieved. Thereafter, and that is when developing countries succeed in importing the instrument, only the residual applications are left for exploitation. But, the instrument has by this time become such a prized and prestigious acquisition that it assumes a dominating

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[1] And according to the technology-society scheme (Figure 1 of Lecture 1), this implies similarity in the social wants in the societies of these countries.
[2] The Indian scientific system is an exception in that its history goes back to more than a century.

position. Problems are chosen for the sake of the instrument, rather than the instrument being selected to suit the problems. And, in this way, western instrument industry (which is linked with western technology and science) has a determining effect on the pattern of science in developing countries.

A viewpoint has been presented of how society shapes science in developing countries. It provides quite an accurate description of science in India, but there are some peculiarities in the Indian case which merit mention.

Indian science is not a post-independence phenomenon; it has a history of over a century. Being virtually a sub-continent with conditions totally different from those prevailing in the home country of the colonial power, and offering promise of enormous natural resources, a number of scientific survey organizations (Geological Survey of India, Botanical Survey of India, etc.) were established even in the last century. Technical education was also started around that time, and the local intelligentzia took advantage of it. With the establishment of a few universities in the second half of the nineteenth century, science education began to be imparted and many students quickly demonstrated their ability to grasp mathematics and science. With the growth of native business activity and of an intellectual community, a movement for national independence began to gather momentum in the first decades of this century.

During the late twenties and early thirties, there was a flowering of science in India. It was during that period that several Indian scientists made outstanding contributions. Raman, Bose, Saha, Sahni and others belonged to this era. They shared several characteristics: they were all educated in India, they were very patriotic, they displayed an intense nationalistic pride, they had firm roots in the local culture. They stormed their way into western science by path-breaking scientific work. But, though they received the highest honours, they remained outside the apparatus of government. Nevertheless, they were the leaders of Indian science, they started its journals, founded its academies and initiated an indigenous peer group system.

And then came political independence in 1947, and the national government's decision to give science the maximum possible support. Funding was escalated rapidly. A large number of agencies and institutions for education, science and technology were hurriedly established. To direct these funds, agencies and institutions, science administrators and technocrats were required, but neither Raman nor Bose nor Saha nor Sahni became government scientists.

In anticipation of the high-level manpower requirements for this increase in technical activity, it was decided to get the manpower trained abroad. The process actually started a year or two before independence, and for several years thousands of Indian students were sent to the universities of Western Europe and North America. It is these foreign-trained scientists and engineers who took over the leadership of institutions when the locally-educated "old guard" retired. The "new breed" brought with them the frontier areas emphasized in their foreign universities. They had not grown in the atmosphere of local laboratories, and had never experienced the days of glory. They returned alienated, and many remained so. The incipient indigenous peer system established by the stalwarts of the thirties began to collapse. But the "old guard" could not stop the process as it had no position in the new government system for funding science and organizing laboratories.

Little distinction was made in the first 2-3 decades after independence between science and technology. And, all the ambitious steps to set up a vast infrastructure for generating technology did not appear to take into account the fact that the bulk of the technology would be imported and that the generation of indigenous technology would be through a process of imitation and adaptation, rather than innovation. Nevertheless, government <u>technological</u> establishments began to play an increasing role in decision-making regarding <u>science</u>. In particular, the heads of these establishments became the leaders of science and the arbiters of science policy even though they were pre-occupied with managing the process of imitating and adapting "western" technology. In terms of funding, personnel, equipment and infrastructure, the support for scientific research became almost two orders of magnitude greater than in the pre-independence era. But, it is a moot point whether Indian science has made the same impact on science as it did during the thirties. It is this phenomenon of vastly increased investments on Indian science producing a diminished impact which has been considered strange, but it only emphasizes the general picture of science in developing countries outlined here.

<u>TOWARDS AN ALTERNATIVE TECHNOLOGY AND SCIENCE FOR INDIA</u>

A detailed diagnosis of technology and science in India has been presented. The situation can be summarized thus:

(1) Technology in developing countries is oriented towards the demands of the elite which are best satisfied by "western" technology.
(2) Science in developing countries is modelled on science in the developed countries; in addition it is bereft of the driving force of indigenous technology which is based on the imitation and innovation of "western" technology, rather than on innovation.

Hence, technology is inconsistent with need-oriented, self- reliant development, and science has neither the driving force of indigenous technology nor an internal momentum. This diagnosis suggests how technology and science in developing countries should be re-oriented. A very brief indication of this re- orientation is presented below.

Technology in developing countries should cease to be elite- oriented, it must become development-oriented. The overwhelming thrust should be towards technologies for the satisfaction of basic needs, starting from the needs of the neediest, and for strengthening self-reliance based on social participation and control. In short, the filter (cf. Figures 1 of Lecture 1 and Figure 1 of Lecture 2) that determined which social wants are transmitted as demands upon technology-generating institutions and which wants are ignored must be made to operate in the interests of the poor. Such a thrust will develop only when the felt needs of the poverty-stricken masses are identified in all their complexity and subtlety, and when the interaction between people and technologies ensures social participation and control and therefore self-reliance. What is required therefore is direct contact between technology-generating institutions and the people, and this contact can be best achieved by the commitment of these institutions to the problems of the people. A wider range of technological options will have to be generated to enable the people to escape from the present Hobson's choice wherein the traditional technologies are inadequate and "western" technologies are inaccessible because of their costs, resource requirements, energy demands, etc. This means that the alien guidelines (Figures 1 of Lecture 1) for the generation of technology currently in use will have to be jettisoned, and new paradigms developed. In other words, the satisfaction of basic needs in developing countries will require the generation of alternative technologies appropriate for development. Such alternative technologies may be so location-, resource- and culture-specific that perhaps they cannot either be imported or generated by a process of imitation and adaptation. Innovation will become imperative, and it is this pressure to innovate which will revitalize the technology-generating institutions by defining for them a purpose and mission.

Since many new technologies will be required to achieve the tasks of development, the innovation chains which must be completed to bring these technologies into being, will inevitably throw up a host of basic problems for scientific research. If the local scientific system responds to this pressure, then it would have acquired one crucial driving force for the development of science. In fact, indigenous technology and indigenous science will become mutually reinforcing.

If science in developing countries becomes preoccupied with the basic problems thrown up by the task of innovating indigenous technology, there will necessarily be an attenuation of the strong influence of western science particularly in the distribution of research efforts. Such an attenuation will promote interaction between local scientists. If this interaction is further stimulated by concerns arising from the environment, then the process of conversion of a body of native scientists into a community of peers will be facilitated. All this corresponds to the development of an internal momentum which is the other crucial driving force for the vitality of science.

When these two driving forces operate on indigenous science, there is no guarantee that the distribution of research efforts in developing countries will remain the same as that in the industrialized world. In fact, it is almost certain that many of the principal foci of research activity will be different in the two sets of countries. The difference will arise mainly over those aspects of science which interface with technology, but these differences will be super-imposed upon an identity of concerns with regard to the fundamental forces of nature, the basic structure of matter, the core of life and the design of the universe. Thus, there is a distinct possibility of developing- country science being different from developed-country science - a diversity which can only be in the interests of world science.

In conclusion, therefore, it appears that whether the objective is the re-vitalizing of science or the re-orientation of technology, the hope lies in a commitment to the local environment. Technology and science will discover their hositorical missions only if they strike roots in the societies which support them. In that situation alone will the poor in developing countries inherit science and technology and therefore the earth.